HOW VERBALIZATION INFLUENCES DESIGN COGNITION?

A methodological study

SHU-LING CHEN
Institute of Applied Arts, National Chiao Tung University, Hsinchu, Taiwan 30050

Abstract. The concurrent verbalization would affect not only the normal design behaviors but also the perceptual interactions between designers and their own sketches, while limited by short-term memory, video/audio retrospective protocols may probably induce some selective of memory trace and ambiguous verbal data, resulting in a lower accuracy of reports. This research focuses on examining the validity of video/audio retrospective and think aloud protocols, based on the qualitative comparison of the two methodologies. And we also want to understand the difference of the ability of collecting perceptual information between these two protocols. Moreover the segment and coding scheme for the drawings are primitively developed.

1. Introduction

The study of design thinking develops from the cognitive psychology and the cognitive science, adopting protocol analysis as the major methodology (Eastman, 1970; Akin, 1979; Schon & Wiggins, 1992; Cross, 1997). The design problem differs from other common problems in the solution process and the characteristics because the problems themselves are ill-structured problems larger spatial gestalts, difficulty in systematize the solution process, and dependence on large amount perception. Through the conversation between perception and design representation, the design is revised and continues in the same time. The use of perception is the key to creative design and is the major difference from common problems in the solution (Cross, 1997; Gero, 1990; Robbins, 1994; Suwa and Tversky, 1997).

There are a number of studies on visual cognition in the domain of design thinking, including definition and classification for visual thinking (McKim, 1980), mental imagery and the representation of memory (Downing, 1992), the computer vision (Koutamanis, 1993), the visual attention (Wright, 1998), and so on. However, the most influential issues are the ability of mental imagery and language which is developing over time (Brunner, 1966). In addition to visual
cognition, designers’ linguistic ability is crucial in the processes of design thinking. Creative thinking is not limited to the exploration of visual cognition, especially in the early stage of design processes (Lawson, 1997). Since 1970, there are two concepts about the mapping between mental imagery and language: the first direction approaches the two issues by the same representation, however the second direction argues that they are different (Kosslyn, 1990). These two research directions influence the hypothesis of protocol analysis. Actually, we should put these two directions on the contradictory position, then explore them in the same time.

In most of the discussion of the thinking behavior and knowledge of the design activity, design is viewed as the process of reflection-in-action. Every process differs from each other. Different designer has various solutions corresponding to the situation. Since the 90s, more and more scholars are involved in this field (Cross, 1997; Gero, 1990; Robbins, 1994; Suwa and Tversky, 1997). From this perspective, graphics not only extends the designers’ limited short-term memory, the profound knowledge of which also has much influence on the creative design (Cross, 1997; Gero, 1990). Connecting the graphics with perception activity of design thinking cannot be overlooked. The mutual reflection between perception and graphics is crucial to the distinction from other cognition process (Robbins, 1994; Liu, 1995; Suwa and Tversky, 1997). Verbal data is used to reveal the perception activity of the designers in most of the methodological study to analyze the feature of the design cognition through concurrent or retrospective verbalization of the designer. However, verbalization has to do with the linguistic behavior of the designer, and linguistic behavior is concerned with the individual performance of the designer. Therefore, it is a tough task to obtain the data in collection the verbal data.

Protocol analysis has been the most important methodology in the empirical study in contemporary design thinking. In the stage of data collection, think aloud is the major methodology. In fact, think aloud now is considered as the best way to obtain detailed data. However, the scholar questions if the data can reveal the design cognition of the designer because think aloud asks the subject to have concurrent verbalization (Davis, 1995; Lloyd, Lawson and Scott, 1995). Other studies also show that it difficult for concurrent report to obtain the verbal data corresponding to the design action. On the contrary, it is easy to disturb the normal design behavior also the appearance of the insight or perception. The perception activity might be disturbed by requirement of the concurrent report in the think aloud process so as to affect the actual behavior. Even if the questions about the concurrent report are successively posed such as “not coinciding with the actual design behavior” or “making the cognitive system have extra burden”, this methodology is adopted because it has the advantage of obtaining more and detailed data. The study of protocol analysis focuses on the
verbal data analysis of the concurrent verbalization methodology and has fewer discussion on data collection.

Video/audio retrospective protocols try to improve the weakness of the concurrent verbalization and retrospective verbalization. (Suwa and Tversky, 1997; Suwa and Tversky, 1998). To avoid the side effect of the concurrent verbalization, the data is collected in a retrospective method. Video tapes help the designer remembering the process of design activity to solve the STM problems in the traditional retrospective report. This methodology posed by Suwa and Tversky seems to resolve the dilemma in concurrent report. From the steps of the concurrent report, we can be sure of the two things:

(1) The process of the experiment does not affect perception and other normal design activities

(2) Video tapes help the designer remembering the process in the retrospective report. Therefore, the data is better than that in the traditional retrospective way.

Although we know that the video/retrospective report can solve the weakness of think aloud in the data collection, there is no sufficient study on the validity and data feature of the retrospective report. For example, Suwa and Tversky points out that there is a situation of ambiguous words when designers explain their conceptual actions using the retrospective report methodology. No studies now show the solution to what is the influence of the analysis of perception activity. On the other hand, designers’ decision process and design activity mode is understood by using the graphics data, but the analysis of the detail and mode of design activity relies on the perception data. The perceptual data of the protocol analysis comes from the verbalization data. Therefore, we want to know what is the disadvantage and advantage to the design thinking using the concurrent or retrospective verbalization and what is the difference toward the analysis of the perceptual activity and the mapping of the visual data between the video/audio protocols and think aloud.

2. Methodology and Steps Another First Order Heading

The objective of this research is to compare the validity of the verbal data in the two methodologies of protocol analysis, think aloud and video/audio protocols, and to discuss the advantage and disadvantage of the analysis of perceptual data in these two methodologies, especially some important characteristics in design behavior, including (1) design decisions (2) design activity mode and so on. In addition, the mapping between verbal data and visual data and the analytical methodology is another major issue in this study in order to extend a more effective methodology for qualitative research for the latter researchers.

The perceptual use has deep relationship with the design behavior, especially the study in how and in which stage the novel design decision
generate. The design behavior has to be under overall consideration to be validity study. In protocol analysis verbal data is equally important to visual data. The graphics data often determines the design decision and the segments while the verbal data helps the understanding of the cognitive behavior.

2.1. HYPOTHESIS

According to the previous studies, we found that the think aloud methodology can collect the verbal data exhaustively; the video/audio retrospective methodology can avoid the disadvantage of affecting the cognitive behavior when using the concurrent verbalization. Also, it improves the limitation of short-term memory when using the traditional retrospective methodology. We want to know what is the difference of analytical cognitive behavior using these two different data collection methodologies and what is the different feature in mapping the graphics. This research studies the design decision mode and activity mode of the designer. This empirical study also probes into the two methodologies in the segmentation and coding technique in the visual data and verbal data.

2.2. EXPERIMENTS

2.2.1. Process
The methodologies of collecting data:
(1) think aloud (2) video/audio retrospective report

2.2.2. Environment
Many researchers do not agree that laboratory is the only place to obtain effective data and propose to use the actual working environment as the experiment environment (Lloyd, Lawson and Scott, 1995). This environment in this study is the studio the subjects get used to.

2.2.3. Topics
Because author want the knowledge of dealing with the same type of architecture design to be almost, designers can evade the huge different working load. So author sets the topics as the same types but there are different design programs. Every subject is asked to do the experiment twice. The topic is distributed crossly. There is an interval of one month between the two experiments.

Topic I: a bus station on a specific site; site area: 10m*3m, a front-open near the site and a shade tree, tree-crown is 4m, tree-height is 7m. The tree is irremovable.
Topic II: a bicycle canopy on a specific site; site area: 10m*3m; there is a wall near the site; the road is horizontal to the long side of the site.

2.2.4. Subjects
Two subjects graduate from the department of Architecture in the same school and both have perfect ability of designing.

2.2.5. Time and Minor Aided Notes
(1) Time: The experiment time is within an hour, but the subjects do not have to finish in an hour.
(2) Criteria: Because the topic is fairly simple for the seniors, so it is not necessary to complete specific drawing. The subjects decide when to stop. They are asked to complete the spatial gestalts. Architecture form and material is the basic requirement.

2.3. ANALYSIS
The study uses the visual data and verbal data to analyze the design decision and design activity mode in the early stage of design, the drawing stage. Due to the video tape, visual data is used to determine the design activity mode from the analysis of segmentation and coding; verbal data is used to analyze the feature of perceptual behavior and design decision in the two data collection.

The drawing of the designer is the important basis of the time stamp in the segmentation. Based on the previous studies (Akin and Lin, 1995), we found that the drawing has been the key to the appearance of the novel design decision. From the analysis and observation of the drawing, we could know more if two different data collection methodology has different influences on the design behavior.

In this study, the author uses five coding schemes (including design decision, design activity mode and perceptual behavior) and proposes methodological suggestion on the mapping of the visual and verbal data: the analytical purposes of the mapping of the drawing and the verbal data is to find out when novel design decision happens, the relationship with the design stage. The visual data discusses the designer’s physical action especially in seeing, drawing (including writing and sketching) and thinking and what is the difference of seeing-as in the two data collection. The verbal data observes the perceptual and thinking behavior of the designer. The coding of the thinking behavior determines the design decision. For example, a design goal is set along with the take place of the important design decision. When setting a goal, the designer defines a crucial design problem at the same time. It is often the key point for the shift of the design decision when the designer decides if the design decision is appropriate.
The sampling of the experiment time is another important issue in the methodological operation: in the observation of the design decision of the drawing, we can adopt all the drawing as the analytical data. When doing the sampling of the visual data and verbal data, the author finds out that in the experiment of the think aloud, the subject is influenced by the way he or she speaks and thinks. In the beginning, the subject says that he is disturbed by this method. Therefore, this stage is excluded in the segmentation and coding of the data in case that it influences the analytical sampling. The last stage is also excluded because the subject concerning the representation of the modeling or the material sometimes forgets to tell the design behavior. Taking the limitation of the think aloud into consideration, the author uses the data in the middle stage of the design to compare the relation between verbal data and visual data.

### TABLE 1. Five Coding Schema

<table>
<thead>
<tr>
<th>Coding Scheme</th>
<th>Clarification</th>
<th>Description</th>
<th>Example</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Drawings</strong></td>
<td>NDD</td>
<td>novel design decision</td>
<td>make the truss roof, this seems to be a big issue...</td>
<td>Akin and Lin (1995)</td>
</tr>
<tr>
<td><strong>Visual Data</strong></td>
<td>S-I-D</td>
<td>S: seeing I: imaging D: drawing</td>
<td></td>
<td>McKim (1980)</td>
</tr>
<tr>
<td><strong>Verbal Data</strong></td>
<td>Perceptual P</td>
<td>attend to visual features of elements</td>
<td>shapes, sizes, textures</td>
<td>Suwa, Purcell and Gero (1998)</td>
</tr>
<tr>
<td></td>
<td>Conceptual E</td>
<td>make preferential and aesthetic evaluations</td>
<td>like-dislike, good-bad, beautiful-ugly</td>
<td></td>
</tr>
<tr>
<td></td>
<td>G</td>
<td>set up goals</td>
<td>I want to make ... (something)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>K</td>
<td>retrieve knowledge</td>
<td>the material should be...</td>
<td></td>
</tr>
</tbody>
</table>

### 3. Novel Design Decisions

According to Akin and Lin (1995), we define the below characteristics of novel design decision:

1. The NDD resolves a problem of bottleneck.
2. The NDD does not follow from previous assumptions
3. The designer identifies the NDD as an important feature of the overall design.

In the four experiments of the two subjects, the appearance of the NDD is shown on Table 2. From the representation, we can see that the amount of visual data and the frequency of the design decision in video/audio retrospective methodology is higher than the think aloud methodology. Under the video/audio retrospective the subject B has more variation on visual and design...
HOW VERBALIZATION INFLUENCES DESIGN COGNITION?  


decision. Under the video/audio retrospective the subject B often overthrows the previous decision and constantly revises the decision in order to show deep design activity. Under the think aloud methodology, the novel design decision is in relation to the relationship of integral design. He is unable to gain insight while he talks and designs in the same time. The subject A indicates that designing while talking reduce the thinking speed but not the depth. He feels much relieved when conducting the video/audio retrospective experiment and he provides more inspiration. He can resolve previously design problem and comes up with more and new decision to complete the design.

TABLE 2. Segmentation of Protocol: Subject A (Left: Think Aloud; Right: A/V Protocol)

<table>
<thead>
<tr>
<th>Protocol Segmentation</th>
<th>Designer’s Drawings</th>
<th>Novel Design Decision (NDD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Problem Understanding</td>
<td>Drawing 1</td>
<td>NDD 1</td>
</tr>
<tr>
<td>Conception</td>
<td>Drawing 2, Drawing 3, Drawing 4, Drawing 5</td>
<td>NDD 2, NDD 3</td>
</tr>
<tr>
<td>Design</td>
<td>Drawing 6, Drawing 7, Drawing 8, Drawing 9, Drawing 10</td>
<td>NDD 4, NDD 5, NDD 7, NDD 8</td>
</tr>
<tr>
<td>Representation</td>
<td>Drawing 11</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Protocol Segmentation</th>
<th>Designer’s Drawings</th>
<th>Novel Design Decision (NDD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Problem Understanding</td>
<td>Drawing 1</td>
<td>NDD 1</td>
</tr>
<tr>
<td>Conception</td>
<td>Drawing 2, Drawing 3</td>
<td>NDD 1, NDD 2</td>
</tr>
<tr>
<td>Design</td>
<td>Drawing 1, Drawing 2, Drawing 3, Drawing 4</td>
<td>NDD 1, NDD 2, NDD 3</td>
</tr>
<tr>
<td>Representation</td>
<td>Drawing 13, Drawing 14</td>
<td>NDD 13</td>
</tr>
</tbody>
</table>

TABLE 3. Segmentation of Protocol: Subject B (Left: Think Aloud; Right: A/V Protocol)
4. Design Activity Mode

As cited in the analysis, the author uses the period between 15 minutes and 45 minutes as the comparison data. Due to analytical convenience, the author takes each minute as a unit, and coding the unit. The author decides the unit subjectively in order to compare the design activity mode of the designer. We can deduct that the two subjects under two experiments have something in common.

(1) When conducting the think aloud, the subject spends more time in seeing. When conducting the video/audio retrospective, the subject spends more time in imaging and drawing.

(2) The subject B has more seeing-as in video/audio retrospective methodology while the subject A spends the same amount of time.

(3) Comparing the aspect of seeing-as action, we can see that the subject A or the subject B has more seeing-as in the video-audio retrospective methodology. The subject B even has no seeing-as and drawing, as is shown by the black square in the figure.

(4) Compare the aspect of imaging-seeing-as, we can see that the subject B obviously has more seeing-as in the video/audio retrospective while the subject A spends the same amount of time, as is shown by the gray square in the figure.

(5) From the table of S-I-D coding result, we can find the action-mode is more complex and interactive when the subjects conduct the video/audio protocols.

From this result, we can infer that concurrent verbalization has influence on the drawing behavior, even on the imagining process, but not to the extent of drawing. The subject B indicates that the drawing interferes with the talking when he does these two things together. Some of the words are expressed unconsciously. The drawing becomes a little slower in concurrent verbalization. He can express himself in imaging behavior though it slows down. From the above phenomenon, we can infer when the drawing behavior takes place, the designer also has seeing and imaging behavior. Therefore, concurrent
verbalization complicates the multi-active tripe-mode and deepens the designer’s burden.

When the seeing-as behavior which means the seeing and imaging takes place at the same time, we call it seeing-as. In concurrent verbalization protocol, seeing-as and imagine and drawing cannot take place simultaneously due to the working load of the subject. In the view of the cognitive design we can infer that this fact is limited in the short-term memory, the working memory.

5. Perceptual Activity of Verbalization

When completing only the coding of the verbal data, the author cannot tell the difference between the two cognitive methodologies. There is no obvious
distinction in the essential number. However, when we put the verbal data into
the segmentation of the visual data, we find some interesting phenomenon.
(1) In the think aloud protocol perceptual behavior seems to relate to the
seeing-as behavior. From the representation of the figures, perceptual
behavior almost takes place with the seeing-as simultaneously. Of course,
there are few exceptions. In the video/audio retrospective protocol,
perceptual behavior seems not to relate to the seeing-as behavior.
(2) In the think aloud protocol the subject has the drawing behavior
accompanied by fewer perceptual activity. In the retrospective protocol, the
drawing is often accompanied by the perceptual activity.
(3) Generally speaking, conceptual takes place mostly when the subject has
imaging behavior or seeing behavior. There are few chances that conceptual
behavior emerges as the subject has imaging behavior or seeing behavior.

<table>
<thead>
<tr>
<th>TABLE 8. Verbal Data Coding Result (Perceptual and Conceptual): Subject A (Think Aloud)</th>
</tr>
</thead>
<tbody>
<tr>
<td>P 10  C 19</td>
</tr>
<tr>
<td>![Table Image]</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>P 10  C 23</td>
</tr>
<tr>
<td>![Table Image]</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>TABLE 10. Verbal Data Coding Result (Perceptual and Conceptual): Subject B (Think Aloud)</th>
</tr>
</thead>
<tbody>
<tr>
<td>P 8   C 22</td>
</tr>
<tr>
<td>![Table Image]</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>P 9   C 22</td>
</tr>
<tr>
<td>![Table Image]</td>
</tr>
</tbody>
</table>
6. Conclusions, Limitation and Further Research

We found that, using the methodology of protocol analysis, the design of high verbalization will reach a high ratio when designers perform more seeing-as and imaging in the concept generation phase. Moreover, they will spend more time on the seeing and thinking. This result corresponds to the result of Lawson (1997): the words are not only to play the role of memorizing, but also in the design processes, they help designer to create the imagination. Both the verbal actions and the visual data can help memorizing in the analysis of think-aloud. Because of the implication of verbalization behavior, the designer has more activation of perception and concepts in the processes of design. However, we cannot prove it in this study.

The designer has conceptual behavior such as valuation and the objective in the process of design decision. From this study we know that video/audio retrospective protocol helps the drawing speed and the design decision; however, think aloud interferes the design decision.

Concurrent verbalization disturbs the designers’ drawing including imaging and the seeing behavior to block the transformation of the design behavior. The designer has to circulate from the seeing and imaging behavior and then move on to the drawing. In video/audio retrospective protocol we can see more seeing behavior to the drawing behavior or the vice versa.

The representation of the seeing and seeing as behavior is different in these two methodologies. The seeing-as behavior includes the seeing and imaging. Therefore, the coding result shows that the subject cannot bear the burden, when the drawing is involved in concurrent verbalization. We can further infer this is due to the limitation of short-term memory.

From the mapping between the verbal and visual data in concurrent verbalization the author finds that perceptual behavior follows the seeing-as or to say that seeing and seeing-as arise the design perception. The design activity including the spatial valuation, organization, decision on the shape and size, the relation of mass emerges at the same time when seeing-as takes places. In the video/audio retrospective protocol, perceptual behavior might take place in the stage of seeing or seeing-as. The author infers that the subject might have the seeing-as behavior in verbal data collection, but he does not explain later when he retrieves. Also, without the interference of concurrent verbalization, the perceptual activity might be more frequent than it is in retrospective protocol. However, we cannot verify in the coding of the verbal data.

From the above, we see that concurrent does impose extra burden on the subject’s design cognition. We also see that sometimes the subject says something that is irrelevant to the design process in the think aloud protocol. The think-aloud protocol influences the speed of the drawing and the imagining. The author finds that the amount of data obtained from the retrospective
methodology is incomparable to that of the think aloud methodology. This finding causes the author unable to know more from the result of the coding of the perceptual and conceptual data. In the future research, the researcher needs to ask the subject to explain his or her design process more specifically in retrospective analysis.

There is not enough subjects in this study. If we increase the number of the subjects, we might be able to find out more about the relationship between different design activity mode and the contrast of two protocol methodologies. In this paper, we can’t find out more details of designers’ perception, we just record the happening time of the perceptual action. In the future, the further research can be done on this aspect. It is arguable for the author to use one minute as a unit in the segmentation of the design activity mode because according to previous studies each designer’s span of attention differs. Due to the author’s limited knowledge in cognitive psychology and cognitive science, this study is possible to probe into the mutual interval of time of the design activity mode. The further study can clear up this point.

This study fails to have further exploration on the relationship among design decision, design activity mode and perceptual behavior. However, this aspect is an important issue in the domain of design thinking, which is needed to be further studied. Design includes the design behavior and verbal representation of the designer and the communicative skills with the proprietor. These two directions are crucial to good design. The latter researcher can study the different verbal actions to understand more clearly how the verbalization influences design behavior.

Acknowledgments

I have to thank Y. T. Liu’s suggestions of this research. And I am highly appreciative of all the support from my friends in the Institute of Applied Arts of NCTU. Without their care and effort, the project will never succeed.

References

HOW VERBALIZATION INFLUENCES DESIGN COGNITION?


