Protocol Analysis in Design Research: a review

Jiang, Hao and Yen, Ching-Chiuan

School of Design and Environment, National University of Singapore
jiangh82@nus.esu.sg; akiyc@nus.edu.sg

Abstract: This paper presents the result of a comprehensive literature review on design protocol studies. A total of 134 papers, including journal and conference papers and PhD dissertations using protocol analysis as research means, as well as the relevant papers which were cited by the abovementioned publications, were reviewed by full paper. The findings depict an overall view of the state of art of design protocol studies, like the taxonomy of protocol types, analysis approaches, current research interests, etc.

Key words: Protocol Analysis, Design Research, Literature Review.

1. Introduction
Protocol analysis is an empirical, observational research method. A protocol is a piece of record of the time path of behaviors [43]. Design protocols are usually in the form of recordings of designer’s overt behaviors, like verbalization, sketches and audio-visual recordings captured by cameras [1]. Since Eastman’s pioneer works of studying interior design in the late 1960s [20, 21], protocol analysis has become one of well-established empirical research tools in the field of design research [9, 15]. However, beside Cross [12] and Eastman [22] have summarized some findings from existing design protocol studies in a small scope, very few comprehensive review has been undertaken to understand its methodological perspectives.

Methodological discussions on generic protocol analysis [24-26, 33] very focused on the issues of verbalization, i.e. the validity and completeness of verbal reports and effects caused by verbal reporting. However, design activities involve many visual and spatial elements which cannot be appropriately reported verbally. Many design theorists not only considered design expertise resides in designers’ visual representations, they also assumed that visual thinking is more crucial than symbolic thinking in designing processes [39, 40, 47]. Schön [46] argued that the “language of designing” is consisted of the tightly connected verbal and non-verbal elements. Akin and Lin [2] proposed a dual mode design thinking, i.e. the coexistence of verbal-conceptual and visual-graphic elements in design activities. The applications of protocol analysis in design research therefore always require incorporating other conventional observing means in order to accommodate non-verbal protocols.

The lack of comprehensive review on design protocol studies and the mixed design research methods which cannot be fully accounted by the principles of original verbal protocol analysis thus demands a systematic literature review with a significant sample size. The purpose of this review is to depict an overall view of the state of art for new researchers how mainstream researchers conduct a design protocol analysis.

2. An Extended Literature Survey for Design Protocol Studies
This literature review was conducted within the library facility of National University of Singapore (NUS). It attempted to access all important publications on design protocol studies accessible within the NUS’s library.
resources. The literature searching was consisted of 2 steps: (1) keywords searching in digital databases for journal papers and PhD dissertations using protocol analysis as primary research means, and (2) manual searching for relevant papers which are cited by the abovementioned papers.

Figure 1: Literature Searching Process

Figure 1 illustrates the literature searching process. The sample pool included six journal databases (Design Studies, Design Issues, Journal of Engineering Design, Environment and Planning B: Planning and Design, and Creativity Research Journal) and three Doctoral Dissertation databases (Australian Digital Theses Database, ProQuest Dissertations and Theses and TU Delft Dissertations). Thereof, 2 journals are ranked in A* level, 2 journals in A level, 1 journal in B level and the other one is a normal ranking journal according to design research journal ranking system [28]. As a result, the selected papers are quite representative in mainstream design research.

3. Result of Literature Survey

3.1 An Overview of the Survey Result

73 cases of design protocol studies published on 134 papers (full paper) were selected and reviewed. They were retrieved from four major sources: (1) design journals, (2) chapters of edited books, (3) design conference proceedings and (4) doctoral dissertations (shown in Figure 2).

Figure 2: Sources of Reviewed Publications

(Except 1 case from monograph, all other 23 publications were chosen from peer-reviewed edited books.)

Figure 2 shows that the exposition of design protocol studies in design journals is very high. A total of 14 design journals have published 78 papers between 1988–2009. Protocol analysis is also a popular topic in design research.

1 Due to the constraints of library resources, some other design journal databases with high impact index and PhD theses databases cannot be accessed.
conferences. Though the literature survey did not explicitly search in proceedings of important design conferences, a substantial portion of results still consisted of conference papers and most identified book sections were also the revised papers based on the publications previously presented in conference or workshops.

Figure 3 depicts the distributions of these reviewed papers along time dimension. It clearly shows that, though the pioneer works began in the late 1960s [20, 21], it did not gain much attention until the late 1980s. Since then, in particular after the event of Delft Protocols Workshop held in 1994 [15], protocol studies in design domain have been increasing rapidly. Design research community’s interest on this method continues till now.

![Figure 3: Numbers of Publication Overtime](image)

3.2 Design Disciplines

Design is not a monogenetic activity but contains a large set of sub-disciplines, such as industrial, engineering and architectural design. The review on design protocol studies identified that this method is not only accepted by one or few design disciplines; in fact almost all major design disciplines adopted protocol analysis as a valid research tool.

![Figure 4: Distribution in Design Disciplines](image)

A total of 8 design disciplines were identified to employ protocol analysis during review process. Most publications were published in the fields of industrial design, architecture and engineering design. Except from

---

[20] cannot be accessed by full paper, thus it is not depicted in Figure 3.
the studies of single discipline, this method was also applied to analyze multidisciplinary design collaboration [e.g. 17, 51]. Among that, two exceptional cases were found not belonging to any design discipline but design-related, e.g. the cost estimation in product development [36] or creative drawing [27].

3.3 Taxonomy of Design Protocol Studies

The original protocol analysis employed single-subject thinking-aloud technique to generate verbal protocol data. When this method was introduced to design research, it was soon revised to investigate group design activities conducted by small teams [e.g. 44, 46, 49]. Therefore, a quick way to classify design protocol studies is according to the research participants, i.e. individual designers or design teams. Waldron and Waldron [53], for example, distinguished design protocol studies into “verbal/think-aloud protocols” (for single subjects) and “discussion protocols” (for group subjects). Combined with the distinction of concurrent and retrospective protocols [26, 29], a taxonomy scheme of design protocol studies can be categorized into two dimensions: i.e. research participant type and the time when the verbal protocols are collected (i.e. concurrently report while the task is performing or retrospectively after the completion of task).

Table 1: Taxonomy of Design Protocol Publications

<table>
<thead>
<tr>
<th>Verbalization type</th>
<th>Individual Group</th>
<th>Both Individual &amp; Group</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Concurrent</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Report while task</td>
<td>Think aloud 65</td>
<td>Conversational 37</td>
<td>108</td>
</tr>
<tr>
<td>Report after task</td>
<td>Retrospective 12</td>
<td>0</td>
<td>12</td>
</tr>
<tr>
<td>Introspective 4</td>
<td>0</td>
<td>0</td>
<td>4</td>
</tr>
<tr>
<td>Combined Protocols</td>
<td>6</td>
<td>0</td>
<td>12</td>
</tr>
<tr>
<td>Others 2</td>
<td>2</td>
<td>0</td>
<td>4</td>
</tr>
<tr>
<td>Total</td>
<td>89</td>
<td>39</td>
<td>134</td>
</tr>
</tbody>
</table>

The category of “report after the completion of task” can be further divided into two subcategories: “retrospective” and “introspective”. The former type is defined according to Ericsson and Simon [26], i.e. a description of the activities (ordered in time) retrieved from Long-Term Memory (LTM). Though “introspective” type is also retrieved from LTM, it explicitly includes explanations and post-rationalization. Rigidly speaking, retrospective report cannot be accounted as valid protocol data; however, when authors claimed their works were protocol analysis or design protocols, the papers would be included in this survey but recorded separately.

Exceptional cases were identified in this review. Some publications employed more than one types of protocol data (i.e. combined protocols in Table 1), such as the comparison between think-aloud and retrospective protocols [31, 32] and the employment of post-session interview (i.e. introspective report) to enhance the completeness of think-aloud protocols [6, 50]. Some authors devised some new types of analysis based on the framework of protocol analyses, e.g. Galle and Bela Kovacs [30] proposed replication protocol analyses (i.e. asking participants to give retrospective interpretation on an awarded architecture as s/he was replicating other designer’s design processes) and Waldron and Waldron [53] developed a new form of retrospective report on a long-term team project with the assistant of recorded documents.

Due to the exceptional cases identified during review process, the final classification of the existing publications on design protocol analysis (shown in Table 1) is more complicated than the original 2-dimensional taxonomy scheme. This table illustrates that concurrent protocols were the main choice for most researchers. For single-subject studies, the original thinking-aloud technique was followed. The conversational protocol studies
investigated group activities, which employing the dialogue exchanges between two collaborating participants as protocol data. Figure 3 also shows the publications of both two types were increasing over years.

3.4 The Analyzed Tasks

Various interests were identified during review process. The majority of these studies (N=101) investigated completed design processes which started from the analysis of design problems and ended with design solutions with a certain level of details. Design process can be further divided into two situations: design from scratch (N=92) or development from existing design (i.e. redesign; N=9). A few studies (N=2) studied design process, but only focused on partial episodes rather than the entire process, either analyzing problems or proposing design alternatives. Figure 5 demonstrates that researchers showed their enthusiasm on completed design process, though the analyzed tasks were usually compact versions (protocol analysis is usually applied to a tractable time period of activity, typically from 20 minutes to a few hours).

Design discussion (either between team members or between designers and clients) is another interesting issue reflected in this review (N=17) [e.g. 41, 52]. Except from studying how designers work, protocol analysis was also employed as a means for user study (N=7). Some researchers [e.g. 5, 37] observed how users manipulated artifacts in order to evaluate design solutions or identify design opportunities. The “design-like” category includes a schematic office design game [23], replication of other’s design process [30], production of car styling sketches [6] and describing sketches to other designers [42].

3.5 Analysis Approaches and Analysis Emphasis

Two major approaches for analyzing design activities, i.e. process-oriented and content-oriented analysis [8, 18, 19], were identified. The former emphasizes on the process aspects of design activities and consists of problem solving actions and design strategies which are highly related to design process; while the content-oriented analysis is focused on “what designers look for, see, do, and possibly think” [19] rather than uncovering the underlying structure of design processes.

The majority of publications (n=131, except from 3 papers without detailed analysis) showed a balanced interests on these two approaches (Figure 6). Some studies (N=19) even combined both methods in order to reach a more comprehensive understanding of design activities.
Section 3.4 shows most publications focused on designing tasks. Two kinds of activities could be identified during design process, i.e. design activities and management of designing process. The former refers to the activities directed towards the design problem-solving processes, similar to Goldschmidt’s concept of “design moves” [34]. Meanwhile, the process management refers to the activities towards the organization of the design process. It is the meta-cognition, i.e. reflection about designing processes, rather than designing (i.e. cognition) per se [27]. During this review, most papers discussing the issue of process management occurred in studies which investigate group design activities.

Table 2 depicts how studies investigated group design activities. Almost equal number of researchers applied process-oriented or content-oriented analysis method, but the issue of designing process management received much less attention than design activities. Though works of process management do not directly move the status of design problem solving forward, they are indispensable to maintain design problems manageable. Their importance becomes obvious when design problems are getting complex. The low frequency of existing publications in this category may demonstrate that it is an underexplored area and requires for further studies.

### 3.6 Issues of Research Participants

Protocol analysis is an extremely time-consuming research method, and the ratio of analysis time to sequence time of protocols is usually 10:1 ~ 1000:1, and even more extreme [45]. To make protocol data in a manageable size, researchers usually need to make a compromise between the duration of analyzed task and sample size. Figure 7 shows that most studies restricted their total size of protocols within 1000 minutes.

Some authors [7, 15, 18] suggested that 2-hour duration is an appropriate time period for investigation. The concentration level of most participants could be well maintained in around 2-hour duration. It is also sufficient for most designers to develop a design concept with some details though it is bit of demanding and challenging.
Various types of participants were identified in design protocol studies. As Section 3.4 showed, most design studies concerned with design process, the primary research subjects were either professional designers or design major students, or both.

Table 3: Participant Type and Sample Size (Experiments)

<table>
<thead>
<tr>
<th>Sample Size</th>
<th>Participants</th>
<th>1~3</th>
<th>4~6</th>
<th>7~9</th>
<th>10~12</th>
<th>13~15</th>
<th>16~18</th>
<th>19~21</th>
<th>22~24</th>
<th>25~27</th>
<th>28~30</th>
<th>31 &amp; above</th>
<th>NA</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Professional Designers</td>
<td>9</td>
<td>9</td>
<td>2</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>1</td>
<td>22</td>
<td></td>
</tr>
<tr>
<td>Design Students</td>
<td>10</td>
<td>5</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>3</td>
<td>1</td>
<td>-</td>
<td>3</td>
<td>1</td>
<td>2</td>
<td>-</td>
<td>29</td>
<td></td>
</tr>
<tr>
<td>Both P&amp;S w/o comparison</td>
<td>1</td>
<td>3</td>
<td>1</td>
<td>2</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>7</td>
<td></td>
</tr>
<tr>
<td>Both P&amp;S w/ comparison</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>Including non-designers</td>
<td>-</td>
<td>1</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>7</td>
<td></td>
</tr>
<tr>
<td>NA</td>
<td>1</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>2</td>
<td></td>
</tr>
</tbody>
</table>

Compared with professional designers, design students would be more convenient to be recruited. Table 3 confirms that around 40% of design experiments (N=29) enrolled design students as research participants. But studying outstanding designers could yield deeper insights on design activities [13]. A substantial portion of studies (N=22) insisted on investigating professional designers’ work though they may need to make a compromise on sample size (usually less than 10). The number of publications (shown in Table 4) also reflects researchers’ interests on eliciting expertise from design experts.

Table 4: Participant Type and Sample Size (Publications)

<table>
<thead>
<tr>
<th>Sample Size</th>
<th>Participants</th>
<th>1~3</th>
<th>4~6</th>
<th>7~9</th>
<th>10~12</th>
<th>13~15</th>
<th>16~18</th>
<th>19~21</th>
<th>22~24</th>
<th>25~27</th>
<th>28~30</th>
<th>31 &amp; above</th>
<th>NA</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Professional Designers</td>
<td>35</td>
<td>13</td>
<td>5</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>1</td>
<td>2</td>
<td>5</td>
<td>24</td>
<td>1</td>
</tr>
<tr>
<td>Design Students</td>
<td>15</td>
<td>5</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>3</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>2</td>
<td>5</td>
<td>2</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>Both P&amp;S w/o comparison</td>
<td>3</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>-</td>
<td>-</td>
<td>1</td>
<td>-</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>14</td>
</tr>
<tr>
<td>Both P&amp;S w/ comparison</td>
<td>3</td>
<td>1</td>
<td>4</td>
<td>-</td>
<td>-</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>11</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Including non-designers</td>
<td>-</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>2</td>
<td>-</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>10</td>
</tr>
<tr>
<td>NA</td>
<td>1</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>2</td>
</tr>
</tbody>
</table>

However, it is difficult to enroll many professional designers in particular outstanding designers, to participate in research projects. Some studies proposed a mixed set of subjects, including both professional designers and design students. Two situations were identified: some studies [e.g., 38, 48] explicitly compared them as design experts and novice designers, while some other studies [e.g., 19] just employed the mixed set of participants to represent generic designers but without explicit comparison. It should be noted that some
comparative studies between expert and novice designers were also undertaken by comparing junior students with final-year undergraduate [4, 7] or undergraduate and graduate students [35].

Some studies also included non-designers, i.e., people without specific design training, as their research subjects. Most of these studies were user studies, but Crismond [10] also investigated how ordinary people engaged in designing tasks. Archer [3] and Cross [11, 14] argued that design capability not only resided in professional designers, but it is a specific form of general problem-solving capabilities (i.e., every ordinary people can design though their levels are varied). However, it still lacks empirical evidences to support these arguments. It requests further investigation on how ordinary people design and compare it with designers’ design processes.

4. Discussions

Delft protocol workshop argued that “… of all the empirical, observational research methods for the analysis of design activity, protocol analysis is the one that has received the most use and attention in recent years. It has become regarded as the most likely method (perhaps the only method) to bring out into the open the somewhat mysterious cognitive abilities of designers” [16]. This review confirmed this statement. Various types of protocols, study settings and analysis approaches were identified.

However, many design protocol studies took this method for granted. Only one third of publications (N=45) explicitly reflected the pros and cons of the method they employed. Most of these criticisms just repeated the constraints of generic verbal protocol analysis. Few studies considered the distinction between design protocols with original verbal protocol analysis, like the dual mode issue discussed in the introduction section. It demands more methodological reflections to make protocol analysis more fit to the requirements of design research.

5. References


facilitating conversational user interaction. Design Studies, vol. 29, no. 6, pp 556-571.


