IMAGERY AS A TOOL TO IMPROVE IDEA DEVELOPMENT

ZAFER BILDA AND JOHN S GERO
Key Centre of Design Computing and Cognition
University of Sydney, Australia

Abstract: This paper shows that use of mental imagery alone during conceptual designing can improve idea development compared to idea development via sketching. We analysed design protocols of six expert architects working on two different design problems on the same site under two different conditions, one in which they were blindfolded and one in which they were sketching. Architects developed design ideas with slightly greater efficiency when they were blindfolded, as opposed to the common view that they would better generate their ideas through sketching. We also tested whether the expert architects were able to improve their idea development when they were engaged in designing on a site they had a previous acquaintance with. In the blindfolded condition, prior familiarity improved architects' satisfaction with how efficiently they used their mental models/representations and improved their idea generation performance. In the sketching condition, it had no effect.

Ferguson (1992) described designing without drawings as the "The artisan's way":

> The product is drawn only in an artisan's mind and worked out directly in suitable materials … First the ideas exist, where the idea could be a clear vision or a glimpse of a possibility. If the idea is in the head of an artisan, he can make the model of the idea directly… or he might make a sketch of an idea on paper in order to keep in mind the shape and the configuration of components (p. 3–4).

This view maintains that the ideas are the basis of conceptual design activity, whether they are drawn as they come into mind or not drawn. Ferguson (1992) considered design as an invention and reported some anecdotal evidence on how creative engineers solved technical problems by using their mental representations. In this literature, the role of the mind's eye was described in terms of the use of tacit knowledge. Tacit knowledge is referred to as the knowledge of how objects would behave in the physical world, our judgments of relative speed, dynamic relationships between objects, knowledge about the use of the right material and so on. Some anecdotes on the use of imagery in Ferguson's book refer to imagery as dynamic scenes wherein objects were animated for resolving a functional problem, while some of the anecdotes refer to a subjective experience of seeing the product or the solution. In the same vein Weisberg (1993) presented anecdotes about scientists in various disciplines who had used their mental imagery for creative inventions. Other examples are often quoted of major architects, such as Frank Lloyd Wright, who could conceive of, and develop a design entirely using imagery with an external representation of the design only being produced at the end of the process (Toker 2003).

Anecdotal views of engineering design, architectural design and of other creative processes put considerable emphasis on the role of imagery. In many of these references imagery has been used in solving design problems or for aiding inventions. The tacit knowledge of the professionals could extend the range of the use of their mental representations which makes it possible for these experts to design buildings or invent structures. Use of imagery alone during conceptual designing can be a tool for idea development for generating thoughts on the fly without the need to settle them on a sketch sheet. It can support a brainstorming process where one is allowed to generate ideas without worrying about the constraints and the implementation of them. This might have the potential to improve idea development.

1. Related Work

In design literature the link between visualisation and engineering design drawing is well established (Hammond et al. 1977, Pare et al. 1987, Ullman et al. 1990, Ferguson 1992). The research of Bertoline and his co-workers (1995) suggests that visualisation ability is central to design, and that imagery provides a bridge between design ideas and their representation in sketching and drawing. It has also been argued that the ability to draw is directly related to the ability to imagine, and that the ability to imagine will feed back into the ability to draw (Laseau 2000).

In design research there are a number of studies which focus on the use of imagery alone during designing. Athavankar (1997) conducted an experiment where an industrial designer was required to design a product in his imagery (with a blindfold on), without having access to sketching and the visual feedback it provides. The results of the study were qualitative, claiming that the designer was able to evolve the shape of the object, manipulate it, evaluate alternative modifications, add details and colour to it. Similar results were obtained in a study with software designers (Petre and Blackwell 1999) where they were required to design using their mental imagery only.

1. SKILLED IMAGERY

Researchers on expert performance agree that expertise in the form of stored knowledge becomes readily available for performing the relevant tasks. Experts can process recall of knowledge interactively with the generation of images in working memory. Related evidence comes from studies of expert and skilled performance of chess players, mnemonists, and skilled readers, as reported in Ericsson and Delaney (1998). The studies with the expert chess players identified a skilled imagery (Simon and Chase 1973, Saarilouma 1998, Ericsson and Kintsch 1995) which shows evidence of the use of imagery for longer periods and with higher cognitive loads. The theory states that the experts develop specific ways for chunking visuo-spatial information that enable them to rapidly retrieve and use it in a new context (Simon and Chase 1973). Visuo-spatial actions in working memory should be associated with LTM and the mechanism is called long-term working memory (LTWM) (Ericsson and Kintsch 1995). Based on this proposal, Ericsson and Delaney (1998) explained that experts have an extended long-term working memory to supplement their short-term working memory.

Blindfolded chess is played where the players do not see the pieces or the board. Research shows that it is a skill-related activity, and the more skilled a player is, the better s/he normally plays blindfold chess (Saarilouma and Kalakoski, 1997). Skilled imagery research indicated that the memory load can be substantial, and the experts successfully play up to 10 games simultaneously (Saarioluma, 1998). This demonstrated extensive capacity is of interest to researchers for investigating the spatial memory and skilled mental images of expert players. Earlier empirical studies showed that mental transformation plays an important role in their perceptual processes (Chase and Simon, 1973).

Saarilouma et al. (2004) investigated the neural basis of skilled imagery, to understand the resources required to construct such complex images that cannot be represented as a single scene. Saarilouma et al. (2004) compared memory performance, attention and problem solving of highly experienced blindfolded chess players in a brain scanning (PET) investigation. They found that the memory task was performed spatially, such that the storage of information in LTWM involved spatial encoding. Problem solving tasks under imagery conditions involved mental transformation of the pieces, storing information in LTWM and thinking of related activities such as planning and conceptual information processing (demonstrated by increased activity in frontal brain areas). The results maintain the findings of earlier cognitive work on skilled imagery, that skilled visuo-spatial representations are characterized by previously learned visuo-spatial chunks and automated processing habits (Saarilouma et al., 2004). The study concludes that experts' chess-specific images are not necessarily represented in the same way as ordinary mental images.

1.2. BLINDFOLDED DESIGNING

Similar to blindfolded chess players, blindfolded expert architects were able to design during an experimental period of 45 minutes, with complex design outcomes involving residential buildings (Bilda et al., 2006; Bilda and Gero, 2006). Similar to the findings in skilled imagery, architects' imagery processes are assumed to involve image generation and transformation (Kavakli and Gero 2001, Bilda and Gero 2004). Protocol analysis of the blindfolded designing sessions showed that the expert architects constructed visuo-spatial representations through verbalizations rather than a perceptual interaction with their sketches. In an earlier study Bilda and Purcell (2003) characterized this behavior as a meaning-image interaction, through evaluation of forms and concepts, rather than a purely perceptual process. Similarly Saarilouma et al. (2004) found that primary perceptual areas seemed to play a minor role in processing chess-specific images, and they emphasized the relevance of conceptual abstraction and selection of few relevant possibilities among millions of alternatives.

Skilled imagery research supports that blindfolded designing performance can be based on access to and use of previously learned visuo-spatial information and designing skills. The expert architects' blindfolded performance can be related to these factors. Firstly, we tested whether use of imagery alone enhances idea development more than sketching does. The assumption here was that the expert architects have developed a skilled imagery based on designing skills they gained over the years. Secondly, we tested whether familiarity with the site (which is previously learned visuo-spatial information) had an effect on architects' blindfolded performance.

The paper begins with description of the method, including experiment design and how idea development was analysed in the design protocols. In the next section the effect of imagery on idea development is tested by analysing idea links in design protocols. We discuss the influence of site/context familiarity on architects' perception of how well they did during the sessions and on their idea development.

2. Method

The six architects who participated in the study (2 female and 4 male) have each been practicing for more than 15 years. Architects A1 and A2 have been awarded prizes for their designs in Australia; they have been running their own offices and also teaching part-time at the University of Sydney. Architect A3 is a senior designer in a well-known architectural firm and has been teaching part-time at the University of Technology, Sydney.

A4 works for one the Australia's largest architectural company and has been the leader of many residential building projects from small to large scales. He worked in and managed design teams for the last 10 years.

A5 is one of the founders and director of an award wining architectural company. The focus of the company is residential buildings. We approached A5 for his ability to draw quick and neat perspectives during his conceptual design process.

A6 is a very famous residential architect in Sydney and directs his company known by his name with 50 employees. He is the designer of many residential buildings reflecting a unique Australian style, which have received many awards.

2.1. DESIGN OF THE EXPERIMENTS

The first group of the three architects is initially engaged in a design process where they are not allowed to sketch. This phase is called the experiment condition where they receive design brief 01. Design brief 01 requires designing a house for two artists: a painter and a dancer. At least a month after the experiment condition the same three architects were engaged in a design process where they are allowed to sketch. This phase is called the control condition where they receive design brief 02. Design brief 02 requires designing a house on the same site as design brief 01 this time for a couple with 5 children aged from 3 to 17. Both design briefs can be found in Bilda et al (2006).

The second group of the three architects was initially engaged in the sketching (control condition) session, where they received design brief 02. Then after one month they were engaged in the process where they are not allowed to sketch (experiment condition) and were required to work on design brief 01.

In the experiment condition, called BF (blindfolded condition), we had the designers engage in the design process while wearing a blindfold. In the control condition, called SK (sketch condition), designers were given paper and pencil and were asked to commence designing. Each participant was given the same instruction before the BF and SK sessions and the experiments were conducted in the same room, where no visual reference was present. The procedures for the experiment and control conditions are outlined in Bilda et al. (2006).

Group 1 architects (who were engaged in the BF condition first) were interviewed after the BF session. Group 2 architects (who were engaged in SK condition first) were also interviewed after the BF session. The interview questions were open ended, and the participants were encouraged to talk about their experience of the blindfolded design process. There was no specified duration for interviews; they varied from 15 minutes to 1 hour.

2.2. ANALYSIS OF IDEA LINKS

Ideas are the basis for conceptual designing. For example an architect may have the idea of a courtyard garden, and eventually design the whole building around this idea. Other ideas come along with initial ones, and may modify, repeat, elaborate or erase the previous ones. Idea development can be defined as this process of establishing a network of ideas which progresses along the timeline of the design thinking.

The linkography technique involves parsing the protocol into design moves, and looking at the design process in terms of relationships created by the links between those moves (Goldschmidt 1990, 1997). Goldschmidt's (1997) notion of the move is smaller than the notion of a segment used in this study. The links are established on the basis of determining where the design ideas occur in the protocol and connecting the related ideas in one or more segments to each other. The process of linking the ideas and related considerations in SK and BF protocols has been discussed in Bilda et al (2006).

During linking the ideas in the sketching protocols, idea connections were coded not only based on verbalization but also on what was drawn on paper. In order to achieve linking of drawn ideas and keeping track of them, the video footage for each segment was visited during the coding of the links in the SK protocols. When the previously drawn elements or geometries recurred, then the current segment was connected to the segment in which the related drawn elements first occurred.

3. Effect of imagery on idea development

We assume that the expert architects in this study have skilled imagery, since they were able end up with reasonable and complex design solutions by using their imagery alone. We test the following hypothesis in this section:

Hypothesis 1: Use of imagery alone enhances idea development more than sketching.

3.1. ANALYSIS OF LINKOGRAPHS

Table 1 shows example linkographs from A1, A3 and A6's BF and SK sessions. The linkographs showed that the architects demonstrated different idea connection patterns in each session. Inspecting the visual structures of the linkographs, it is possible to conjecture about the idea development style in each session; however this is not the aim of this paper. Rather we will define some terms for measurements of linkographs.

Insert Table 1 here

Link Index and Critical Moves (CM)

Link Index is a measure of how connected the design ideas are in a design session. In order to calculate the link index (LI) in the overall session, the total number of links is divided by the total number of moves/segments in the design session.

Critical moves (CM) are the moves that generate a higher number of links (backward or forward). CM^i is defined as a critical move carrying "i" number of links. Goldschmidt (2003) stated "CM identifies design concepts that are deemed "successful" in the sense that the designer values them enough to devote time trying to develop the concepts or at least to promote them at various points in the protocol". Goldschmidt (2003) established a threshold criterion that identified a "critical move" (CM) as a move/segment that typically varies between three and eight links. This criterion is based on an estimate of critical design ideas in a design protocol as a percentage of all ideas that occurred in moves. The threshold value is chosen arbitrarily; however a rule of thumb for setting out a threshold is that the percentage of CMs should not exceed 10 percent of the total number of all moves/segments in the protocol. We have identified the threshold for CM^i by looking at CM percentages with 5 to 8 links in SK sessions, since the linkographs have so far been produced with sketch protocols. CM^5 gave us an average of 9.4% for all SK sessions (Table 2). We had a higher CM^i threshold compared to Goldschmidt (2003)'s study where it was 3. The reason for a higher threshold is based on the size of segments in the current study. Our segments include more information than a "move" includes, thus a segment might have a reference to more than one idea in it. Consequently a critical segment could carry more links, compared to a move. However we maintained the term CM (critical move) to refer to critical segments throughout the paper.

Table 2 shows that CM^5, CM^6, CM^7 and CM^8 percentages are higher under the BF conditions for five architects. A1 is an exception to this, in that A1's SK session has relatively higher percentage of critical moves at 5–8 link levels. In BF sessions 5 out of 6 architects' CM^5 percentage ranged between 12.3 and 17.2, except for A1 who demonstrated a very low CM^5 percentage (1.2). In SK sessions the range of CM^5 percentage was larger (4.2-14.3) producing 9.4% on average.

Insert Table 2 here

Comparing the SK and BF conditions, the link index values in the BF sessions of the five architects were found to be relatively higher than the link index values in their SK condition (Table 2). A1, whose SK condition link index was higher, was an exception. Table 2 also shows that the average link indices in Group 2 architects' (A4, A5, A6) BF and SK sessions were higher than the average link indices in Group 1 architects' (A1, A2, A3) sessions (2.4, and 1.4 in BF sessions; 2.0 and 1.4 in SK sessions).

For Group 2 architects, the percentages of CM were significantly higher compared to the Group 1, both in the SK and BF sessions. Group 2 architects were more productive in terms of idea generation.

Our findings in this section can be summarized as follows:

LI (link index) was found to be higher in the BF sessions.

LI was significantly higher for the Group 2 architects in the BF sessions.

Group 2 showed significantly higher percentages of CM compared to Group 1, which could indicate more productivity in idea development.

Link density in clusters

A link cluster is formed by links that occur in consecutive segments. Goldschmidt (1995) says "In an ideally structured process, a suggestive move is productive if it is followed by a series of moves that explore issue(s) raised by that initial move or related subjects". This means that clusters indicate the structured units of idea development. Finding the clusters can be useful in analysing the idea development phases; they indicate a continuous development and elaboration of ideas because the links occur in consecutive segments. Each cluster of consecutive links indicates that a designer focused on a connected multiple concepts to form a partial solution. Thus estimating the number of backward or forward clusters and their sizes in a design session would be a useful measure for efficiency of problem-solving: how well integrated the design thoughts are towards a tentative or a partial solution.

Link clusters are determined by visually inspecting the linkographs. For example, in Figure 1, starts of clusters are marked by ellipses. If there are links in more than three consecutive segments, then that group of links defined by those consecutive segments is considered as a cluster. The cluster size refers to "how many segments form a cluster". Visually it is possible to determine at which segment a cluster starts and ends. Figure 1 shows the starting portions of the clusters. The links that extend towards the right hand-side of the graph (that is, forward on the timeline of the design session) are marked as a forward cluster. The links that extend towards the left-hand side of the graph are marked as backward clusters (Figure 1).

Insert Figure 1 here

A link is an intersection point in the linkograph where one segment is connected to the other. The links are shown as black dots on the linkograph (Figure 2). Each link in a cluster is counted. For example, the first move in the (forward) cluster has four links connecting to the latter segments 2, 3, 5 and 9 (circled in Figure 2), the second segment has three links connecting to 3, 4 and 9, and so on. The total number of links in each cluster is divided by the size of the cluster, which gives us the link density in each cluster (in Figure 2, the total number of links is 18, the size of the cluster is 5 and the link density is 18/5 = 3.6).

Insert Figure 2 here

Table 3 shows the total number of forward and backward link clusters, size of clusters, and density of links in the clusters for all participants under BF and SK conditions. The results in Table 3 indicate that the number of backward clusters is higher than the number of forward clusters in all BF sessions. In SK sessions the number of backward and forward clusters are closer to each other.

Insert Table 3 here

Table 3 shows that the fore-link density is relatively higher than back-link density under the BF conditions for all architects except for A1. Note that for A1 the fore-link density in the BF and SK conditions are very close (2.5 and 2.4). If the fore-link density is high in forward clusters, this means that certain design ideas initiated relatively more ideas later on during the design session. Higher fore-link density indicates a richer idea generation, and that the design ideas in the specific cluster were potentially successful.

3.2. DOES IMAGERY ENHANCE IDEA DEVELOPMENT?

Hypothesis 1 stated that use of imagery alone enhances idea development. For five of the six architects, the LI under the BF conditions was higher than the LI under the SK conditions,

Table 2. Hence, BF condition improved the idea development of architects to a greater extent. CM analysis has been used to demonstrate how integrated the idea development was in BF and SK sessions. Higher percentages of CM pointed to a more coherent network of idea generation. Table 2 showed that critical segments with 5 to 8 links had higher percentages in the BF sessions of the five architects compared to their SK sessions. Critical moves with higher numbers of links indicate a more integrated idea generation, and thus the BF condition improved idea development compared to the SK condition. In summary, architects produced more ideas and a more coherent idea network when they were blindfolded as opposed to when they were able to sketch.

A cluster analysis of the links can assist in finding the patterns in the idea generation and density of the fore-links. Inspecting the clusters in the linkographs was mentioned to be useful because they can indicate formulation of tentative/partial solutions to the design problem. A higher density of fore-links in clusters should indicate more idea generation. Table 3 showed that the fore-link density was relatively higher under the BF conditions for all architects except A1.

Hypothesis 1 can be accepted based on the results of five out of six architects; the use of imagery alone enhanced idea generation more than sketching did.

3.3. SUMMARY AND IMPLICATIONS

Analysis of linkographs shows that the density of the idea links, and the percentage of critical moves were higher under BF conditions. Architects generated more ideas and developed a more coherent idea network when they were blindfolded as opposed to when they sketched.

LTWM studies have shown that experts with skilled imagery performance can maintain and transform associative connections between the elements in their imagery effectively over extended time periods of WM (working memory). Similarly, expert architects in the current study could have built this skilled imagery through using and learning the architectural language with the use of sketches. Design education requires an intensive learning process through drawing; students learn the design precedents through drawing and learn how to think with sketches. Thinking with sketches is also associated with the ability to develop design ideas, such as starting with one design proposal and developing it into another one. Students learn how to progress their ideas through sketching. It is assumed that when novices become experts, they might have reached a state where they could progress a design via thinking only, because their repository of experience and design knowledge would allow that. Consequently, when experts are in a situation in which they have to design using their imagery alone, they might be using their experience of conceptually developing a design. This could be an important component of expertise, that is, the ability to simulate how the ideas are developed, and this may be the key to our participants' abilities in blindfolded designing.

Skilled imagery theory states that experts develop specific ways for chunking visuo-spatial information that enable them to rapidly retrieve and use it in a new context (Simon and Chase, 1973). In chess, it is clear how the pieces are initially arranged and the range of final arrangements that could win, therefore the problem and solution spaces are well defined. In architectural design, problem definition is incomplete because the design requirements have to be interpreted to reach an initial problem definition. In the same vein the final solution is never certain because there are many solutions that would satisfy the desired solution state. This shows blindfolded designing to be more complex and unpredictable compared to blindfolded chess play.

According to skilled imagery theory, architects in the current study relied on retrieving and using the visual and spatial information from their LTM. Similar to expert chess players, expert designers could have used pre-existing dynamic bits of visual features or spatial relations encoded with their past experiences. The theory suggests that the previously learned visuo-spatial chunks would be distributed throughout the working memory subsystems which could result in a quick development of solutions through the use of imagery. It is less likely that the architects were using the same pre-existing set of visuo-spatial information as in a chess game where the visuo-spatial chunks do not have to be modified. On the contrary architects often re-represent their problem space for each new design problem or sub-problem and re-interpret the related visuo-spatial information.

4. The influence of site familiarity on imagery performance

Hypothesis 2: Familiarity with the site has a greater effect on blindfolded performance than on a sketching performance.

We have tested whether experts effectively used visuo-spatial information which they previously learned based on the hypothesis that previous practice/experience can make it easier to re-use and process the visuo-spatial information. Therefore in the BF conditions, expert architects may be able to enhance their imagery performance if they are engaged in a familiar design context. The design of the experiments allowed us to test this factor, since Group 2 architects have learned and practiced visuo-spatial information during their sketching design session, before they undertook the blindfolded exercise. Similarly Group 1 architects have learned about the design context when they initially carried out the BF sessions, and this may have an influence on their sketching activity.

The context knowledge seems to be very important in the experts' design process. What is referred to as context knowledge is the private/public and environmental considerations of the problem, thinking about the people who are going to use or give meaning to the spaces and other functional/spatial requirements of the spaces in relation to the context. The following example illustrates the role of context in conceptual designing. During the interview with A6, he stated that he was required to design a church recently, which he never did before. Quoting him: "I feel I am not gonna do a good job, because I need to do all this thinking before I draw, I don't have ideas, you know I don't have a church in the back pocket". It is possible that familiarity with the context might help the architects to be clearer in their thought processes.

Familiarity with the site can make it easier for the architects to develop ideas, concepts and produce quick solutions. The familiarity with the site could be two-fold; first one referring to questions such as 'what is the orientation of the site, what is the surrounding like, where does the sun come from, do they have views' etc. The second type of familiarity could be gained as a result of acquaintance with the geometry of the site. A previous acquaintance with the site might give them the implicit knowledge of what worked on the site before. The second group had the chance to draw and test design alternatives in their first experience with the site, however Group 1 had to do it using their imagery alone. When the Group 2 architects were exposed to the same site with a similar problem in the BF session, it is possible that the design synthesis and evaluation processes might have become easier for them, even without the access to drawing.

4.1. FAMILIARITY EFFECT ON ARCHITECTS' BF SESSIONS

The first three architects' comments reflect the way they see and interpret their experience when they were blindfolded, and that is "frustration" in general. We found no significant differences between the overall qualities of the design outcomes and between the cognitive activities involved when they were blindfolded and when they were sketching (Bilda et al. 2006). Our results and the first three participants' comments are contradictory. The interviews with these architects point to a single conclusion, that "it would not be designing anything if they were not allowed to sketch". The common view was that if they were to put their ideas on paper, they would have seen the problem quickly and that would actually divert their thinking to a different path. In addition, A2 and A3 during their BF sessions reported that they could not hold/maintain the image (the complete geometry of the layout) in their minds. They also reported that synthesizing the parts on the floor layouts was difficult, since they could not retain the parts of the design together at once.

The comments of the second group of three participants who did the sketching session first and the BF session later were quite different. They were more satisfied with their design solutions and they stated that the blindfolded exercise was another way of designing for them, rather than something that hinders them. For example A4 reported that the blindfolded exercise made him think that there are other ways to do it (designing). His comments about the BF exercise are as follows:

> "One issue you need it in your head first, but secondly you have to test once you've got a vision. …I am heavily relying on my confidence that I can partially visualize that without actually seeing it. It is a skill we (architects) try to develop I believe but something we never trust ourselves on not to rely on what is in the head without the vision".

We asked A5 informally before his BF session, what he thinks he would be doing, when he is allowed to draw. He reported that the BF condition will drive him crazy, he further explained:

> "… you can have ideas, but so much of the process of the drawing is the analysis of the idea and that analysis is about 'is that idea a valid idea?'. Often you can kid yourself on with notions that 'yeah, that will work, that will work', until you actually start to test it".

A5's description of the drawing process is in accord with the views in design research that sketching is like a dialogue to develop ideas and test them (Schon 1983; Goldschmidt 1991), or in other words to synthesize solutions and analyse them (Lawson 1990; Gero and McNeill 1998). However A5's comments were quite different after his BF session, quoting him:

> "It was good. And just an interesting exercise I think to show how rigorously to think about things without sketching. And in many ways it gives you a clearer impression of it by physically not drawing. That was my experience of it".

A6's comments about the BF exercise were similar, he reported that using his imagery and thinking through the design issues without drawing made the process of reaching his design solutions more efficient, quoting him:

> "I have learnt something today. I feel I designed the building better in the second time. …I never think without a drawing. So this time maybe forcing yourself to think through the issues made the drawing go quicker and easier; because I drew that (the outcome) more efficiently than I did last time (sketching session)".

The comments of the second group of architects are quite different from the comments of the first three architects. All experts had more than 15 years of experience, their expertise was residential designing and they all think sketching is essential for their design process. They were good at verbalizing their design process and they worked under the same experimental conditions and design briefs. What we changed was the order of the control and experiment conditions. Because of this change, the second group of architects had a chance to draw their ideas on the site before they did their blindfolded session. This may have influenced their perception positively of how well they did during the BF sessions. As a result Group 2 architects' comments were positive towards the blindfolded designing sessions.

4.2. FAMILIARITY EFFECT ON IDEA LINKS

Table 2 showed that the average number of links in Group 2 BF and SK sessions was higher than the average number of links in Group 1 sessions. While Group 1 architects showed similar link index values under BF and SK conditions, Group 2 architects improved their idea generation under BF conditions, by showing higher link index values. This higher performance in idea generation of Group 2 under BF conditions can be due to the "increased familiarity through prior sketching".

Table 2 showed that the percentages of CM were relatively higher under BF conditions for Group 2 architects compared to all other sessions. In general, Group 2 architects were more productive in terms of idea generation, and further, the CM percentages significantly improved in their BF sessions compared to their SK sessions. This tendency was not observed for Group 1. Thus, Group 2 under the BF conditions demonstrated higher connectedness of ideas, probably due to the "familiarity through sketching" effect.

The link density in forward clusters was found to be significantly higher under BF conditions for Group 2 compared to all other sessions (Table 3). This can be taken as an evidence for the improved idea generation due to the familiarity/learning effect.

4.3. SUMMARY AND IMPLICATIONS

Familiarity with the site had a positive effect on blindfolded activity, and no significant effect on sketching activity. Some possible effects of familiarity on the imagery performance of Group 2 were summarised under two headings: effects on participants' satisfaction with their BF design sessions and effects on their idea development. Group 2 architects' attitude toward the BF exercise changed positively; they thought they achieved good results in terms of design outcome in their BF sessions, when they had increased familiarity with the site.

Group 2 who had familiarity with the site through sketching showed higher link indices and higher percentages of CM compared to Group 1. Our interpretation is that Group 2 under BF conditions performed better in terms of their idea generation and connectedness of ideas. These are considered to be positive effects of familiarity on the imagery performance. On the other hand these positive effects were not observed for the sketching sessions of Group 1. Hypothesis 2 can be accepted, familiarity with the site has a greater effect on blindfolded performance than on a sketching performance.

5. Conclusions

Idea generation is considered to be enhanced by sketching activity, however, the results of this case study showed that idea generation may be enhanced by use of imagery alone. Use of imagery may be a design tool to improve the idea development of expert designers.

The analysis of idea links showed that the architects who carried out the SK condition initially and the BF condition later, performed better in terms of idea development including well connectedness of ideas, and in idea generation. For those architects, the visuo-spatial information previously developed during the SK session might easily be recalled and used later on during the BF session. This may probably be the reason for the improvement in their BF performance. This group of architects' attitude changed positively towards the BF exercise and they thought they performed better during their BF sessions because of their familiarity with the site gained through sketching.

We found that gaining familiarity through sketching had a positive impact on blindfolded design activity; on the other hand gaining familiarity through the use of imagery had no observed effect on sketching activity. We conclude that 1. use of imagery alone can improve idea development and 2. familiarity with the site can increase design performance under no-sketching/ blindfolded conditions.

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Table 1 Linkographs for A1, A3 and A6's BF and SK sessions

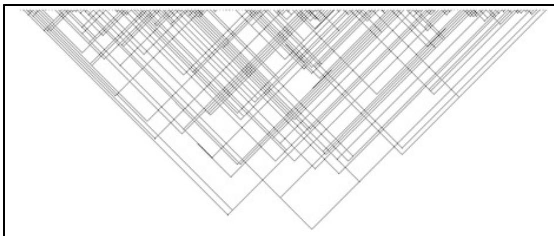
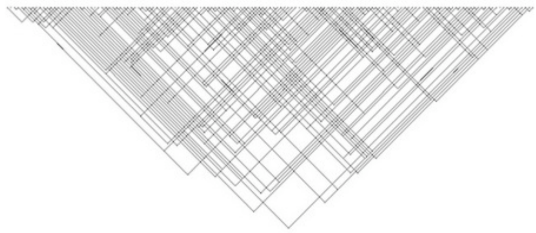
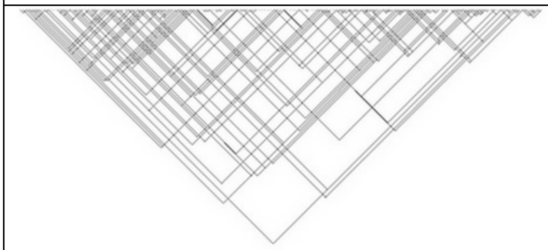
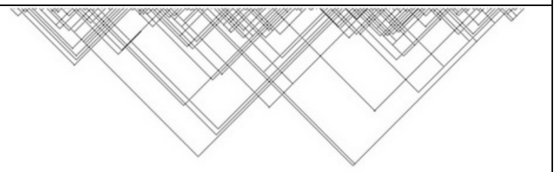
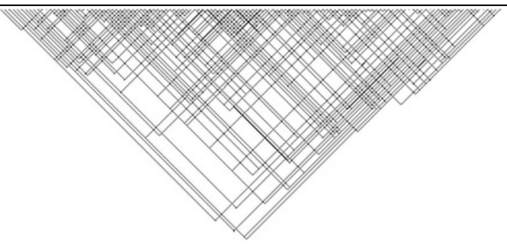
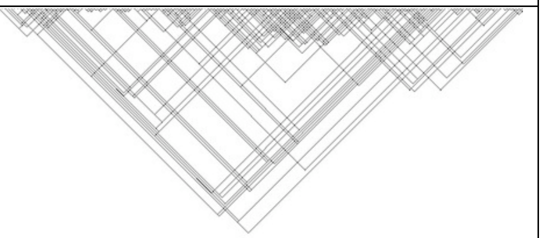
 BF 1	 SK 1
 BF 3	 SK 3
 BF 6	 SK 6

Table 2 Link index and critical moves

	# of links	Link Index	CM^5 %	% CM^6	% CM^7	% CM^8
BF 1	201	1.2	4.8	1.2	1.2	1.2
BF 2	259	1.7	12.3	4.5	3.9	1.3
BF 3	217	1.3	16.0	8.9	4.1	1.2
Av	226	1.4	11.0	4.9	3.1	1.2
BF 4	414	2.5	14.9	9.5	11.3	9.5
BF 5	319	2.2	15.8	13.7	11.6	4.8
BF 6	307	2.5	17.2	8.2	11.5	6.6
Av	347	2.4	16.0	10.5	11.5	7.0
SK 1	205	1.4	11.0	4.8	0.7	2.1
SK 2	272	1.5	7.1	4.3	3.3	2.2
SK 3	171	1.2	4.2	3.5	2.1	0.7
Av	216	1.4	7.4	4.2	2.0	1.7
SK 4	409	2.4	8.3	10.7	7.7	5.9
SK 5	253	1.7	14.3	7.1	4.5	3.2
SK 6	302	1.8	11.6	4.1	7	1.7
Av	321	2.0	11.4	7.3	6.4	3.6
All BF av	*286.2*	*1.9*	*13.5*	*7.7*	*7.3*	*4.1*
All SK av	*268.7*	*1.7*	*9.4*	*5.8*	*4.2*	*2.6*

CM^i: critical moves with i links

Table 3 Link density in clusters

	Number of clusters in the whole session		Average size of clusters		Link Density in clusters	
	Forward	Backward	Forward	Backward	Fore-link	Back-link
BF1	6	9	5.5	4.6	2.3	1.7
BF2	5	9	6.4	5.2	2.5	2.0
BF3	2	5	5.0	5.2	3.6	2.1
Av	4.3	7.7	5.6	5.0	2.8	1.9
BF4	11	16	5.6	5.8	3.5	2.8
BF5	11	12	5.7	5.8	3.6	2.9
BF6	7	11	8.1	6.1	3.6	3.1
Av	9.7	13.0	6.5	5.9	3.6	2.9
SK1	5	7	7.6	6.4	2.4	2.2
SK2	7	7	5.7	5.4	2.3	2.4
SK 3	3	6	4.7	5.8	2.0	1.6
Av	5.0	6.7	6.0	5.9	2.2	2.1
SK 4	12	10	6.8	7.4	3.2	3.3
SK 5	7	9	7.1	6.6	2.6	2.1
SK 6	6	5	5.4	5.4	2.7	2.7
Av	8.3	8.0	6.4	6.5	2.8	2.7
BF Av	7.0	10.3	6.1	5.5	3.2	2.4
SK Av	6.7	7.3	6.2	6.2	2.5	2.4

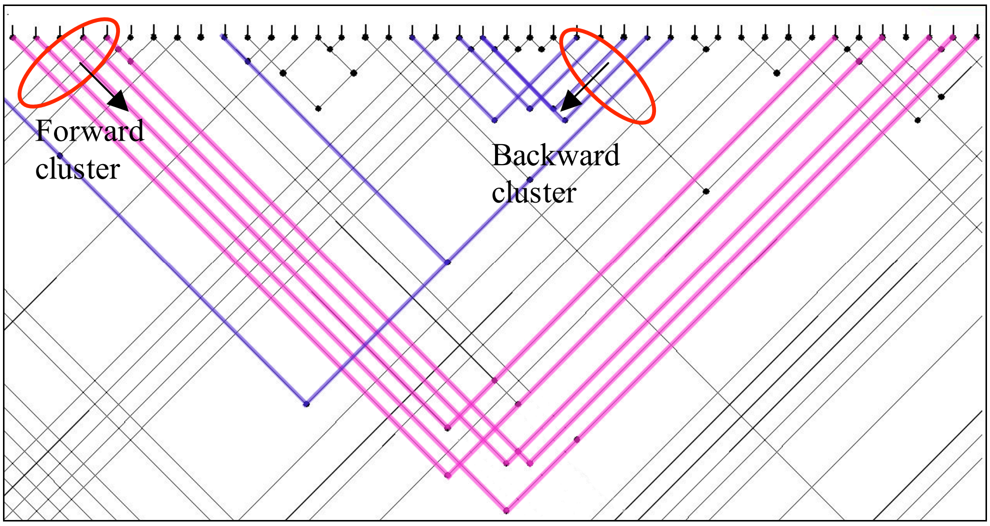


Figure 1 Demonstration of link clusters

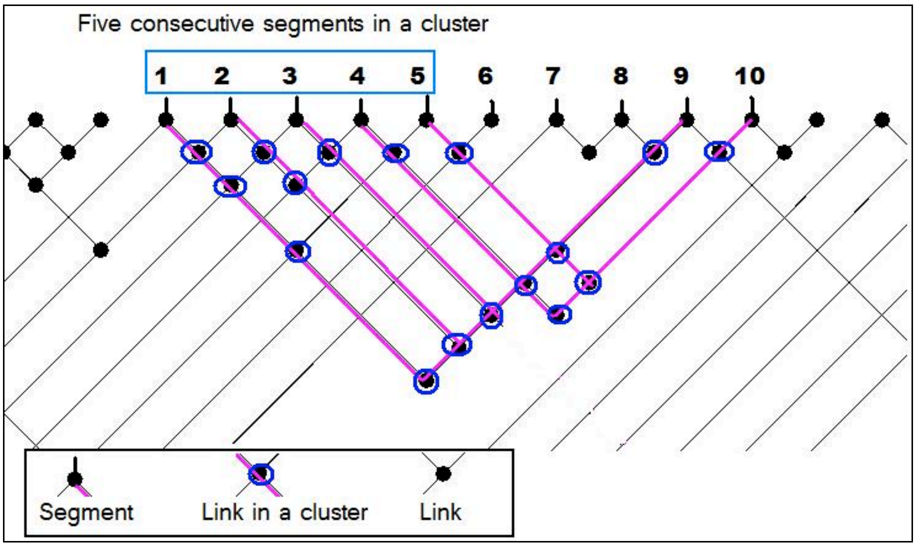


Figure 2 Links in a forward cluster