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ANALYSIS OF A BLINDFOLDED ARCHITECT'S DESIGN SESSION

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Abstract: Architects deal with visual/spatial features and organization of larger scale real world elements than other domains. The use of mental imagery in the architectural design process is the key issue to transform and mimic the spatial aspects of the environment. Depending on the focus of the design process, the use of imagery could relate directly to visuo-spatial aspects, or could be about manipulating functions and concepts in an abstract manner since no externalization is involved. The research reported here concerns what types of design tasks are associated with spatial, visual and recall components in imagery. Using protocol analysis we analyzed the design session of an architect wearing a blindfold and concurrently verbalizing her design thoughts about a design brief. At the end of the session she quickly sketched the final design she held in her imagery on paper . This paper presents the analysis of the interactions between visuo-spatial, internal perceptual and recall actions. We found that the involvement level of percepts, recall and visuo-spatial actions differs through the episodes of the session possibly due to the different rates of visuo-spatial processing and due to the different nature of the design tasks at hand.

1. Related Work

Kosslyn (1980) defined mental imagery as "seeing in the absence of the appropriate sensory input". Thus mental images are not directly observable; as such the functions and properties of mental imagery are always inferred. In the cognitive psychology literature most experiments focus on simple mental imagery tasks conducted over a short time span. The cognitive load and the complexity of the tasks were low including short term memory recalls and transforming a basic figure/image over a relatively short time.

In another stream of research, 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. An expert chess player can

play more than 10 concurrent games while blindfolded (Saarilouma 1998). These studies showed that experts with skilled imagery performance can maintain and transform associative connections between the elements in their imagery effectively over an extended time period. Similar to expert chess players, expert architects were found to maintain, inspect and regenerate their internal representations over a relatively long blindfolded design session (Bilda and Purcell 2003). In this paper we analyze the think-aloud imagery activity session of one architect, where the design thinking session is divided into episodes, and each episode is analyzed within categories of internal perceptions, long-term memory recall and visuo-spatial actions.

Use of imagery could be critical in design, because imagery allows one to transform information and to mimic dynamic aspects of the environment (Kosslyn 1980). Considering that a designer needs to initiate some simulations, thoughts and transformations during designing, imagery could be an active design tool. Based on this view, one can ask if imagery alone can be a design tool? Athavankar (1997) conducted an experiment where the subject was required to design a product in his imagery (with an eye mask on), so that the subject had no access to sketching, and the visual feedback it provides. The study claimed that the subject was able to evolve the shape of the object, manipulate it, evaluate alternative modifications, and add details, and colour as well. Those actions could be interpreted as evidence for existence of a virtual model in designer's imagery, which s/he can manipulate. The study concluded that the use of imagery in design, because of its depictive qualities, can potentially be a substitute for sketching.

Similar studies have been conducted at the University of Sydney where architects wear a blindfold and start to design in imagery. When the design is mentally finalized they externalize it with sketching. The architects think aloud while they design blindfolded, and the sessions are videotaped. The content analysis of the three architects' protocols showed that common cognitive actions were used to produce an internal design representation (Bilda and Purcell 2003). These actions (mostly image operations) were observed to be dynamic and linked to each other over the timeline of the design process. This demonstrated that the architects were able to generate, regenerate, inspect, and transform the design images.

Other than empirical studies of imagery in design, research on sketching puts an emphasis on the use of imagery. Imagery is regarded as a source of candidate shapes, objects, or geometries for design (Goldschmidt 1991; 1995). Goldschmidt (1995) defines "interactive imagery" to occur when the designer retrieves images from memory, and externalizes them interactively by sketching. Kavakli, and Gero (2001a) interpreted sketching as a mental imagery process, in other words sketching as a cognitive activity with imagery abilities. Based on a previous study revealing differences between

novice and expert designers, they proposed that the differences can be explained with the rate of the use of imagery processing by designers. Imagery processing was defined in terms of Kosslyn's (1980) five basic image operations. The study provides interpretations on the use of mental imagery within sketching activity.

The nature of Kosslyn's (1980) and his colleagues' experiments are aimed at testing one image operation at a time, thus the imagery tasks were simple enough to observe the response times (scanning a previously shown map, rotate a figure, etc). Additionally the tasks require retrieval of an existing or previously shown image. However, use of imagery in design has different characteristics:

1. a new image is created which did not exist before,
2. the designing task requires constructing relatively complex associations,
3. the imagery representation changes dynamically over time.

We presume that more than one image operation could occur at the same time. For example image generation could be done in parallel with image inspection. An architect attends to visual and spatial features as well as spatial organization of elements over the period of a design session. This implies that a high rate of visuo-spatial processing must be involved. Recent revisions of visuo-spatial sketch-pad (of working memory) models propose that visual and spatial mechanisms could be separate (Cornoldi and Vecchi, 2003). It is possible that in imagery visual processing or spatial processing could be dominant for the specific tasks involved. Thus one question is whether the type of imagery processing changes due to the visual or spatial requirements of the task. Another question is whether spatial qualities in imagery correlate with image operations and if yes, which image operations frequently occur with spatial qualities/thinking.

In order to explore the above questions we examine the correlations of cognitive actions of an architect engaged in a design process using only her mental imagery. The data coding is based on a constrained protocol study of one architect, thus the results are not general, they could however be insightful for distinguishing between the visual and spatial natures of the tasks in imagery activity. We devised a coding scheme which specifies hypothetical cognitive mechanisms in the imagery activity. The next section describes the methodology and provides the definition of the codes of the imagery coding scheme.

2. Method

We adopted the strategy of having designers engage in the design process without being able to use sketching as part of that process. We used a similar approach to that taken by Athavankar (1997), where we had one architect engaged in the design process while wearing a blindfold and

thinking aloud. The protocol analysis technique was employed to investigate the architect's cognitive actions.

The task for the architect was to design a house for a couple on a particular site. The architect is an expert, and has been practicing for more than 10 years. At the start of the session she was told that she was to engage in a design activity but that she would do it while wearing a blindfold. The aim was to produce an initial design for the house during a 45 minute design session and at the end of the session she was asked to represent the design by drawing it as rapidly as possible and without any changes being permitted. The design session was recorded using a digital video camera. The participant was given a written brief for the design project, asked to read through it and then asked to recite it without reference to the written document. This process was repeated until she could recite the brief without mistakes. The aim of this procedure was to ensure that she would have similar access to the brief as an architect who could consult the written brief during the design process. She was then shown a montage of photographs of the site and allowed to examine them and ask questions if necessary. The participant was also given training in the think aloud method. When this section of the experiment was completed she was asked to put on the blindfold and to start designing. Five minutes before the end of the session the participant was told that this was the amount of time remaining.

The audio files of the concurrent verbalizations were transcribed, and then segmented. The segments were time stamped, and coded with the imagery coding scheme. The protocol was coded twice by the same coder with a one month period between the two coding. Then the codes were arbitrated into a final coding.

The protocol was segmented using the same approach as for segmenting sketching protocols i.e. by inspecting designer's intentions (Suwa and Tversky 1997; Suwa et al. 1998). However for the blindfolded designing case we needed to define how we specify the information shift when a description of an image is involved. The information shift becomes the architect's attention shift to a different part, or the aspect of the image when an image is described in the protocol. The attention shift to a different part /aspect of the image was taken to be the start of a new segment.

2.1. IMAGERY CODING SCHEME

The coding scheme borrows action categories from the sketching studies of Suwa et al (1998). The five action categories include visuo-spatial actions, internal perceptions, functional actions, conceptual actions, and recall actions.

2.1.1. Visuo-Spatial (VS) Actions

Visuo-spatial (VS) actions, Table 1, are based on Kosslyn's (1980) image operations: image generation, image inspection, image scanning, and transformation. We extended the types of image generation and coded a spatial action that refers to the spatial component in mental imagery.

TABLE 1. VS actions

Vgen	Design boundary generation (partial, or global)
Vregen	Regenerate a design image, or state of affairs (SoA)
Vsce	Static or dynamic 3D image generation
Vsyn	Synthesis of parts or boundaries
Sgen	Generate spatial experiences.
Vscan	Scanning a 2D image, or walk-thru in a 3D environment
Vins	Maintain the image in the previous segment, and inspect
Vtrans	Relocate a part/boundary or perform a geometrical/3D operation on a design image

Boundary generation (Vgen) is coded when a designer describes a design boundary for the first time in the protocol eg. "the masonry wall runs along the southern side of the building" or locates a space component eg "kitchen is next to the entry". Boundary generation is an action to develop a space layout which is presumed, here, to be two dimensional.

Scene generation (Vsce) refers to description of 3D physical world-like images. The designer could recall memories of the scenes or combine images from long-term memory to make up a new scene. Prior to previous analysis of three imagery protocols (Bilda and Purcell 2003) scene generation was observed to be utilized by the designers for different purposes:

- to attend to the possible use or mechanics of parts or objects (which usually appear as a dynamic scene generation),
- for assigning material, color or texture as well as evaluating some aesthetical preferences,
- to recall the past cases/experiences,
- to view the surrounding of the imagined design entity (or in the architectural context, to view the site and its environment globally), and
- to refer to the spatial aspects, light, and orientation.

Image regeneration (Vregen) can be considered as a form of image generation since it refers to revisiting the previous design boundaries, scenes, or previous associations between design elements. Regeneration is an essential process in mental imagery because image maintenance time is very short.

The image also can be generated by synthesizing the partial images of boundary/part which has been previously described by Vgen. Use of synthesis is apparent in a strategy where the designer is imagining the sketch design part by part and then bringing the parts together to visualize a region or the global image at some stage. Synthesizing could be used optionally to generate the whole or several parts of the "working design image".

Spatial qualities are assumed to be a part of the tacit knowledge (which is based on real world experiences) and assumed to be simulated by the participant in his/her mental imagery in a similar way to the experiences themselves. Description of spatial experiences (Sgen) could be the slope of the site, height of the other buildings, exposure of a building, experiences of over-looking, over-shadowing, the feeling of far/near distance or height, or sense of the orientation (to the North, West, South or East), etc. Use of hand gestures is also a clue to the participant's spatial experience.

The generated (or regenerated) image should be maintained to be inspected (Vins). The maintenance time is hypothesized to be quite short, so inspection could be carried out in the next couple of segments following the image (re) generation segments.

The theoretical definition for scanning (Vscan) operation is that the attention window moves on the mental image. Scanning a 2D image can be described as sliding the focus of attention incrementally on a sketchpad i.e. when the designer creates the architectural spaces next to each other, one by one, moving along an axis. On the other hand scanning a 3D image is a walk through (or walk around) experience to describe or inspect perceptual features or 3D properties of the design. This type of scanning is very similar to the real world experience of the designer walking through in an architectural space.

Image transformation (Vtrans) occurs when designer re-positions a part/boundary, or performs geometrical/3D operation. Some phrases used are: wrap, peel off, bevel off, triangulate, and lift up. Re-positioning of the observer or rotation of the image plane (change of viewpoint, revolving the object/image) are also image transformations.

2.1.2. Internal Perceptual (IP) Actions

We borrowed some of the perceptual actions from the sketching activity (Suwa et al. 1998) coding scheme. The selected codes, Table 2, are the ones found to be highly correlated with drawing actions during the sketching activity of experts (Kavakli and Gero 2001b).

2.1.3. Functional and Conceptual Actions

The functional actions, Table 3, are coded based on the Suwa et al. (1998) definitions, the same with the sketch coding scheme. Conceptual actions, Table 3, are constituted of 4 types of goals (Kavakli and Gero 2001b).

TABLE 2. Internal perceptual actions

Pfn	Attend to the feature [2D] (geometry/shape/ size), or [3D] (texture/material/color/thickness etc)of a design boundary/part
Prn	Create, or attend to a new relation
Por	Mention, or revisit a relation

TABLE 3. Functional and conceptual actions

Fn	Associate a design image/ boundary/part with a new function
Frei	Reinterpretation of a function
Fnp	Conceiving of a new meaning
Fo	Mention, or revisit a function
Fmt	Attend to metric information about the design boundary/part (numeric)
G1	Goals to set up a new function
G2	Goals to set up a concept/form
G3	Goals to integrate/apply the introduced functions, or arrangements in the current context
G4	Repeated goals from previous segments

2.1.4. Recall Actions

Long term memory recall actions, Table 4, are of three types:

- Retrieving knowledge about previous cases (Rpc) is related to episodic memory, where the designer remembers his/her previous cases of designing process, a previous layout, the connected problems/issues and the functional solutions. Precedent/previous case knowledge is mostly related to expertise in the area.
- Recalling of previous perceptual experiences (Rperc) is similar to the former but more related to judgment of size, geometry and spatial aspects due to previous percepts. For example "30 sq meters for master bedroom? That is quite big!" is a judgment related to a previous perceptual experience in an architectural context. Similarly the designer recalls aesthetical preferences, considerations and material knowledge.
- Recalling the design brief (Rbf) helps the designer to remember/rehearse the requirements and restructure the design problem.

TABLE 4. Recall Actions

Rpc	Retrieve knowledge about previous cases
Rbf	Retrieve the design brief/requirements
Rperc	Recall percepts of a real environment (tacit knowledge)

3. Results

Coding consistency is measured by the percentage agreement between the first coding and the second coding, between first coding and the arbitrated coding and between second coding and arbitrated coding, Table 5.

TABLE 5. Coding consistency between different coding phases

Agreement Percentages			
Number of segments	Between 1st and 2nd coding	1st coding and arbitrated coding	2nd coding and arbitrated coding
169	76.65%	86.23%	91.62%

The architect's protocol is parsed into 169 segments, and the average length of the segments is 15 seconds. 1244 actions exist in the imagery session and the average number of actions in one segment is 7.5 (with a standard deviation of 4).

3.1. ACTION CORRELATIONS OVER THE EPISODES

The imagery session is divided into episodes, ie smaller and more specific design sub-problems. Tracing the descriptions of the working design image from the verbal protocol we have identified the shifts to different parts of the design. Another way to determine the start and end of a episode is to see if image operations in consecutive segments are connected for a relatively longer periods of time. Then the designer is referring to one design image through that period which defines one episode. Table 6 shows the contents of the eight episodes located in this experiment.

TABLE 6. Episode contents

Episodes	**Content**
E1	Analyze the site and the problem space (global and environmental issues)
E2	Structuring the first outline of the building
E3	Working parts of the building/ main areas and orientations
E4	Parts of the building: Dealing with two studios and observatory
E5	Parts of the building: car-space and sculpture garden
E6	Go over the brief, explore the dance studio as a space
E7	Outline of the building, the roof structure
E8	Material & color selections / aesthetics

In every episode correlations are produced between the actions in VS, IP and Recall categories. Table 7 shows the selected actions in a descending

order that are correlated to 7 (±3) other actions. Table 7 also shows the duration of each episode and the constant actions through each episode. Episode 3 has the highest number and Episode 2 has the lowest number of correlated actions. High numbers of correlated actions are not related to the time length of the episode (see Table 7, E3 and E8, E2 and E6) but to the intensity of the visuo-spatial processing involved in each episode.

TABLE 7. Correlated actions in episodes

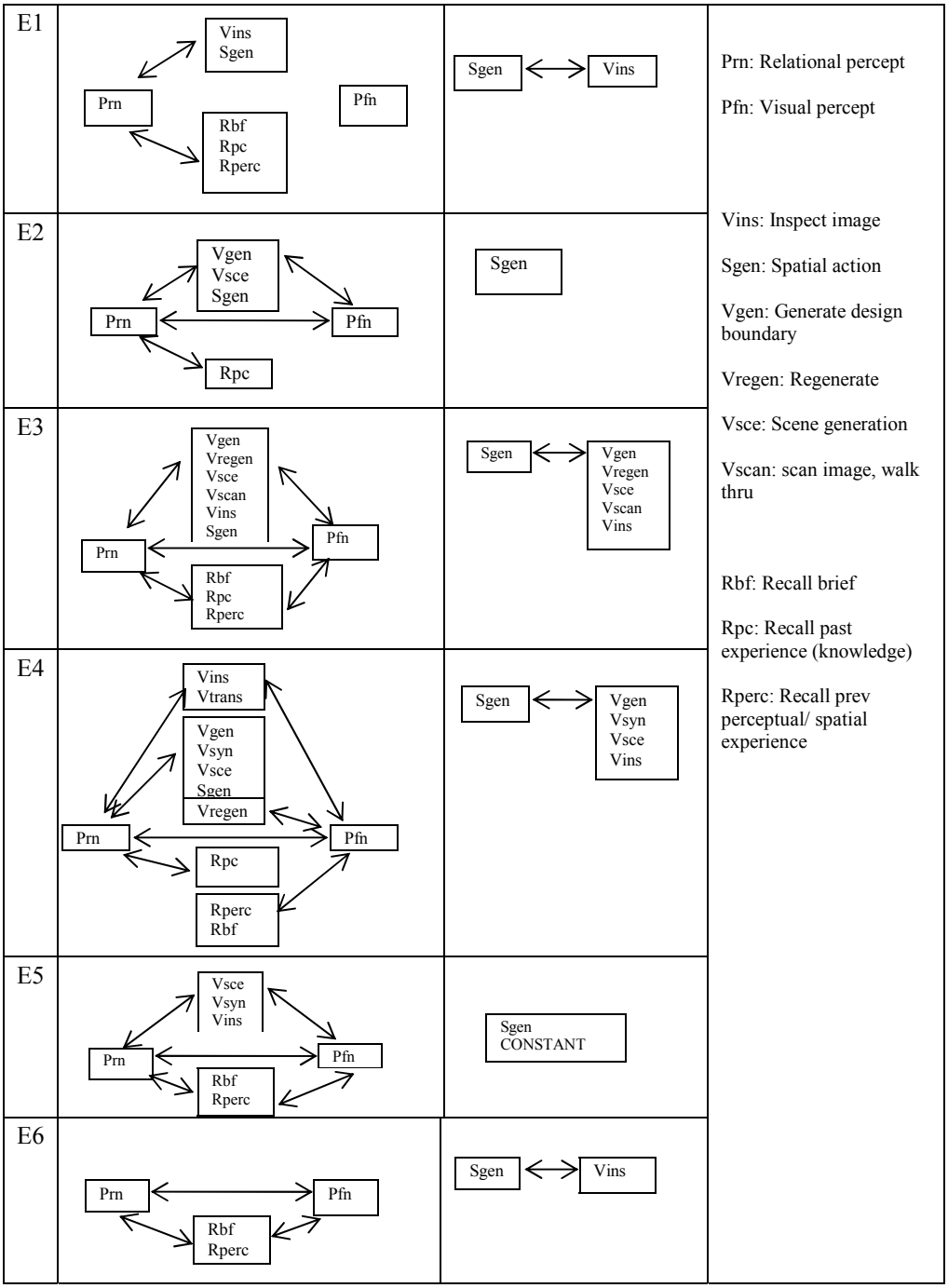
Episodes	Duration (mins)	Actions strongly correlated with 7 (±3)other actions	Constant actions thru the episode
E1	0:01:56	Prn, Sgen, Vins, Por, Rbf, Rperc	Vgen, Vsyn, Vregen, Vscan
E2	0:03:58	Prn, Pfn, Por, Vsce, Vins	Vsyn, Vscan
E3	0:08:36	Pfn, Prn, Vregen, Vsce, Sgen, Vins, Rbf, Rperc, Vgen, Vscan, Rpc, Vtrans	-
E4	0:05:43	Prn, Vsce, Vins, Sgen, Vtrans, Rperc, Rbf	Vscan
E5	0:03:26	Prn, Pfn, Vsyn, Por, Vins, Rperc, Vtrans, Vsce	Vregen, Sgen
E6	0:03:37	Rbf, Vsyn, Sgen, Vins, Prn, Por, Rperc	Vgen, Vsce
E7	0:05:09	Rbf, Por, Pfn, Vsce, Sgen, Vins, Pfn, Prn, Rpc	Vgen, Vscan
E8	0:08:17	Vsce, Vscan, Vins, Por, Pfn, Prn	Vgen, Sgen

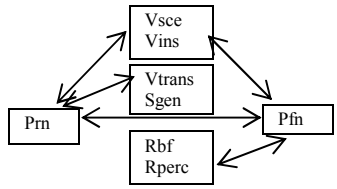
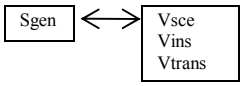
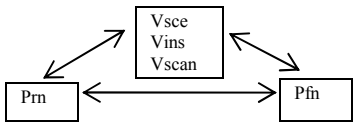
Correlations: Two tailed Pearson coefficient > 0.9

We have observed that a relational percept (Prn) is strongly correlated to 10 other actions in 4 of the 7 episodes. Visual percepts (Pfn) follow the relational percepts in 3 of the 7 episodes. Thus the analysis of each episode is to show correlation relationships between relational and visual percepts and their relationships to VS and Recall actions as well. Table 8 demonstrates the correlation relationships over each episode. For each episode, we also note if spatial action (Sgen) is strongly correlated to any image operation, Table 8. The presence or absence of strong correlations with image operations can demonstrate the spatial qualities of the design tasks in each episode.

Table 8. Correlation relationships over each episode

	Correlated actions with visual and relational percepts	Correlated image operations with spatial action (Sgen)


E1
Vins
Sgen
Prn
Pfn
Rbf
Rpc
Rperc
Sgen
Vins
E2
Vgen
Vsce
Sgen
Prn
Pfn
Rpc
Sgen
E3
Vgen
Vregen
Vsce
Vscan
Vins
Sgen
Prn
Pfn
Rbf
Rpc
Rperc
Sgen
Vgen
Vregen
Vsce
Vscan
Vins
E4
Vins
Vtrans
Vgen
Vsyn
Vsce
Sgen
Vregen
Prn
Pfn
Rpc
Rperc
Rbf
Sgen
Vgen
Vsyn
Vsce
Vins
E5
Vsce
Vsyn
Vins
Prn
Pfn
Rbf
Rperc
Sgen
CONSTANT
E6
Prn
Pfn
Rbf
Rperc
Sgen
Vins
Prn: Relational percept
Pfn: Visual percept
Vins: Inspect image
Sgen: Spatial action
Vgen: Generate design boundary
Vregen: Regenerate
Vsce: Scene generation
Vscan: scan image, walk thru
Rbf: Recall brief
Rpc: Recall past experience (knowledge)
Rperc: Recall prev perceptual/ spatial experience

E7			
E8		Sgen CONSTANT	
Pearson two-tailed correlation > 0.9 ↔			

3.2. ANALYSIS OF THE EPISODES

Episode 1 is about analyzing the site and problem space, thinking about global and environmental issues and setting up a concept for the building. The architect specifically analyzes the proportions of the site, issues related to nature such as breezes, sunlight, views from different parts of the building, how public or private the spaces should be allocated, and how the building should be orientated. Thus Episode 1 is at an abstract level which includes thoughts about the different relations of the building to the site. Spatial action is strongly correlated with image inspection in Episode 1, Table 8, which implies that the spatial experiences were continuously generated through maintenance of a spatial image. Typically the relational percept is correlated with image inspection, spatial action and with all recall actions. The visual percept is not strongly correlated with any actions.

During Episode 2 the architect develops the first outline of the building. She decides on an L-shaped house with an outdoor space. She focuses on the issues like frontage and the boundaries of the building, as well as how boundary walls can be organized inside and outside the building. Episode 2 is twice as long as Episode 1 and not as abstract. This is where the building starts to develop and some basic design decisions are taken. In Episode 2, Table 8, relational and visual percepts are correlated with each other and also correlated with the same VS actions that are boundary generation, scene generation and spatial action. While relational percepts are strongly correlated with recall of past experience, visual percepts are not correlated with any recall action. In Episode 2 spatial action is not strongly correlated with any image operations. Note that this episode is the start of a construction phase and generation of spatial experiences is correlated with visual and relational percepts rather than image operations.

Episode 3 is where the architect details the working parts of the building and develops the relationships between the main areas and the orientations

of them. Tasks include constructing the living areas, bedrooms, conceptualize and decide on the shape of the studios, creating the outdoor space, car space, the boundary walls and the open areas. In this episode the architect builds up most of the areas in the brief (without developing much detail), and goes through an intensive description of the spaces, the relations between them as well as their visual features. Consequently as can bee seen in Table 8 the relational and visual percepts are correlated with each other, with all recall actions, and with most VS actions. In Episode 3 the spatial action (Sgen) is strongly correlated with all basic image operations, which points to occurrences of visual actions and spatial qualities together.

Episode 4 focuses on parts of the building, where the architect deals with the studio for a painter, the studio for a dancer and the observatory. The architect tries to decide where the studios should be in the layout, talks about the possible locations of dance studio, and then starts to set up ideas and concepts for the observatory. The rest of the episode develops like a brainstorming session about what an observatory and its functions might be. The task types vary within this episode between spatial, visuo-spatial and concept formation. In Episode 4 relational and visual percepts are correlated with each other again and with different sets of VS actions instead of common ones, Table 8. This implies involvement of different levels of visuo-spatial processing in this episode. Some VS and Recall actions are correlated with relational percepts while some of them are correlated with visual percepts. Spatial action is correlated with basic image operations which points to involvement of visual-spatial qualities together.

Episode 5 includes revisiting parts of the building, and reconsidering relations between those parts. In terms of design decisions this episode is similar to the third one, where the spaces and the relations are elaborated. In Episode 5 relational percepts are correlated to visual percepts and both percepts correlated to common VS and recall actions, Table 8. Although Episode 5 is similar to Episode 3 in terms of design tasks involved and the correlation patterns, no spatial experiences are involved through the episode, which implies that revisits rarely require exploration of spatial qualities.

Episode 6 starts by going over the brief, remembering the spaces and their relationships in the working design image. This rehearsal of the current state of affairs reminds the architect that the relationship of the dance studio to the building and the site is still pending. The architect again goes through the possible locations for the dance studio and revisits the ideas related to the dance studio. In Episode 6 the spatial action (Sgen) is strongly correlated with image inspection, Table 8, that was also observed in Episode 1. The architect searches for orientation and location of a space in terms of its relationships to the site and environment. This is again similar to the design task in Episode 1. Strong correlations exist between percepts and recall actions while visual and relational percepts are strongly correlated with each

other. In Episode 6 no strong correlations are observed between the percepts and VS actions.

Episode 7 starts with mentioning some aesthetic preferences and material considerations. In the remaining part of the episode the architect considers the roof structure and evaluates how it might look in the neighborhood. At the end of the episode she states: "Again its three dimensional. I'm having some troubles thinking about it. I'd have to start drawing to try to resolve that junction" which implies that the episode included 3D images and evaluations of them. Due to the 3D nature of Episode 7, relational percepts are correlated to spatial experiences, transformation action as well as with 3D image generation and inspection. On the other hand visual percepts occur together with 3D image generation and inspection and with recall actions. This implies that visual and relational percepts work separately again in this episode while spatial experiences are not separable from image operations, Table 8, probably due to involvement of 3D transformations in construction of the roof structure.

In Episode 8, the architect focuses on aesthetic preferences of material, color and how the interiors might look like. These include the type of textures used inside and outside the building, interior details like doors, what the walls are made of, how they are rendered and colored, 3D interior details as well as the budget considerations. In Episode 8 the architect revisits and reconsiders previously built parts, and visually enhances them, however she does not add further spatial qualities. Consequently no spatial experience generation was observed (Sgen is constant, Table 8). Both relational and visual percepts are strongly correlated with the three image operations of scene generation, inspection and 3D type of scanning (walk through). The descriptions of the interiors in the protocol point to possible involvement of visually rich material and presence of an imagery architectural space in this episode. No strong correlations with recall actions are observed since this episode is the end of the design session, and most design issues are almost solved.

4. Discussion

A designer is involved in visual and spatial processing during the use of mental imagery in designing. Analyzing the episodes, it was observed that different levels of visuo-spatial processing were involved for different episodes. The reason for the variations was considered to be the nature of the task involved during the episode. Thus, depending on the type of task at hand, the architect used her mental imagery with a dominant strategy. Table 9 summarizes the type of tasks over the episodes and the dominant imagery processing type associated to it.

TABLE 9. Visual/spatial processing with task types

	Task Type	**Dominant Strategy**
E1	Explore state of affairs (SoA) in global terms	Spatial processing
E2	Thoughts about geometry/ layout	Visual processing
E3	Creating new parts or elaborating parts	Visuo-spatial processing
E4	Adding new parts or elaborating parts	Visuo-spatial processing
E5	Revisiting previous parts	Visual processing
E6	Explore and revisit state of affairs in local terms	Spatial processing
E7	Create new 3D structure	Visuo-spatial processing
E8	Material/ Color/ 3D looks	Visual processing

The correlation relationships in Table 8 point out to the following:

The strong correlations of visual percepts with relational percepts frequently occur (in 7 of the 8 episodes - except Episode 1 where the global and environmental issues are explored) in imagery processing.

The strong correlations of visual and relational percepts with common VS actions are frequently observed (except Episodes 1 and 6 where dominant strategy is spatial processing). It is reasonable to think that visually richer internal representations are involved in those episodes (E2-5, E7-8).

Some types of imagery tasks can be done through the spatial components (such as spatial action, relational percepts, maintaining/ inspecting the current state of affairs), without intensive involvement of image operations (eg. in E1 and E6 where spatial processing is dominant).

In the first two episodes, where the architect is deciding on the building layout, only relational percepts are connected to recall actions, then in the following episodes, visual precepts are also connected to recall actions. This implies that the architect recalls the information about relations in the beginning of the design and then the recall of visual information follows. In the cognitive science literature, Kosslyn (1980) makes a distinction between a skeletal surface image representation, and a richer representation in which the skeletal image is mapped later with visual features from the deeper representations in long-term memory. Similarly designing with a higher number of correlated actions in one episode is related to the intensity of the visuo-spatial processing involved, not the duration of the episode. Imagery commences with an abstract representation having more spatial qualities, and then develops with added visual percepts into a quasi-pictorial representation.

We observed that spatial action is strongly correlated with more than two image operations in Episodes 3, 4 and 7; where there are new physical parts constructed or added to the design. Thus involvement of spatial experiences to image operations becomes intensive when spaces are developed, otherwise they can be constant where previously parts are revisited

(Episodes 5 and 8), or they can be associated with image maintenance/ inspection where global issues are considered.

The strong correlations of recall actions are first observed with relational percepts during the design concept level and then additionally with visual percepts during the establishment of the building layout. Strong correlations to Recall actions disappear at the end of the session when most design issues are solved.

5. Conclusion

Imagery processing in architectural design is a key issue for understanding visuo-spatial processing, and recall mechanisms in design cognition. In the condition of blindfolded designing, visual and spatial design reasoning is done mentally because the designer does not have the feedback sketches provide. In the absence of externalization a perception-like mechanism is hypothesized to take place internally, interacting with visuo-spatial and recall actions. Coding one architect's blindfolded design session, this paper focused on analyzing: 1) how correlations between visual and relational percepts and their correlations with VS and Recall actions might differ for design tasks of a different nature, and 2) whether generation of spatial experiences is correlated with image operations for design tasks of different nature.

The correlations of percepts, visuo-spatial and recall actions demonstrate different patterns for each episode of different design tasks. Visual and relational percepts are strongly correlated to 9 other actions on average, which implies they are the key actions for designing in imagery. The involvement of percepts with visuo-spatial actions and recall actions are at different levels depending on the dominant levels of spatial, visual, or conceptual qualities of the design tasks. Similarly involvement of the spatial component in the image operations is at different rates depending on the visual/spatial qualities of the design tasks.

The strong correlations of visual and relational percepts with VS actions are observed when the design layout starts to build up. It was observed over the episodes that the architect commences in a spatial dominant mode and then switches to a visual-spatial mode by adding visual features to her design, and can then switch to a spatial dominant mode which requires maintenance of the previous relationships. Visual processing is dominant when the architect thinks about the shape, geometry, materials, and outlook of the design as well as when revisits to previous spaces are involved. Spatial processing is dominant when the design task is more about exploring and revisiting and the state of affairs (in global or local scale). Visuo-spatial processing is involved when new parts are added/ created and when working design image is elaborated.

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