IASDR07 INTERNATIONAL ASSOCIATION OF SOCIETIES OF DESIGN RESEARCH THE HONG KONG POLYTECHNIC UNIVERSITY 12TH TO 15TH NOVEMBER 2007

SKETCHING OR CADDING

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ABSTRACT:

The purpose of this study is to apply the cognitive method by tracking eye movement to analyse the 'mental interaction' whilst reading design drawings, i,e, sketch, 2D rendering and 3D rendering, etc…; in order to establish a logical construction pathway for digital and non-digital presentation for a design. Interviews were conducted in parallel with the record of eye-tracking data, in order to provide more interpretive data resource to offer information on the appropriateness of different presentation modes, as well as other possible affective information. 64 design and non-design students between the ages of 20-25 at the National University of Singapore participated in this experiment. The patterns of participants' eye movements in different presentation modes were recorded and analysed. The visual patterns of designers and non-designers were identified in the study, which can provide as a reference to assist designers in understanding the strengths and weakness of different design presentation methods used in design communication. Recommendations in establishing appropriate principles to enhance design communication in different environments were drawn.

Keywords: eye-tracking, sketch, design presentation

1. BACKGROUND

During visual perception and recognition, the human eyes move and successively fixate at the most informative or eye-catching parts of the image. The eyes actively perform problem-oriented selection and processing of information from the visible world under the control of visual attention. The use of eye trackers can bounce infrared light off a user's eyes and follow the reflections in order to determine where the eyes are focusing at. This makes it useful to collect specific data on user behaviour. In this case, user observation of a design in 3D simulation and the real world can be carried out.

The study of eye movements started more than a hundred years ago. However, most of the established studies have only been conducted from 1980. The eye-tracking studies in the last 20 years can be divided in 3 main directions: (1) physiological characteristics of eye movements in related to eye-tracking (Young and Sheena 1975, Robinson 1968 & Duchowski 2003), (2) application of real time eye tracking to user-machine dialogue, in particular, control of the interface, (3) retrospective analysis to identify the visual cognition and perception (Rayner 1998 & Yarbus 1967).

The application of retrospective analysis has been existent in psychological studies in order to understand the relationship between memory, workload, learning, deployment of attention and eye movement. With the advancement in computer technology, researchers began to investigate how the field of eye tracking could be applied to issues concerning human-computer interaction (HCI). The use of eye tracking in HCI studies has been highly promising for many years, but progress in making good use of eye movements in the study of real world products has been slow to date.

In terms of 3D simulation, most studies were focused on the accuracy of the rendering and the ways in efficiently constructing the model-making. The research in design communication and the differences in user perception of 3D simulation and 3D real world product is also little. Hence, there should be a directive towards a more scientific approach in identifying the psychological effects of design issues.

1. 1. REVIEW OF DESIGN COMMUNICATION

Designing any product will involve representing the design concept in some form of presentation. The easiest way of representing the concept of an object is freehand sketching or computer modelling. Sketching and 3D models are the physical manifestation of visual thinking which provide a language for handling design ideas. In general, sketch drawing is the preferred method, since it is much faster. In addition, the review of available design literature shows a common agreement that sketching is essential for conceptual designing (Bucciarelli 2002, Romer et al., 2001). The activity of drawing design ideas, sometimes called “graphic ideation” or “visual representation”, is important not only as part of the process of producing the design ideas, but also because it is an externalization of the designing which allows for other people to participate (Tovey 1989). Do et al (2000) thus argue that sketches are essential for revising and refining ideas, generating concepts and facilitating problem solving. As drawing is probably the fastest way of representing a design idea, the route to a solution for the design problem can be fairly short and convenient. Design managers, clients, fellow designers and other interested parties can therefore communicate through the drawings and refine accordingly. Despite the extensive literature on the subject, the role of sketching may not have been sufficiently examined or challenged in the digital age, including the opinion that computer-aided design (CAD) is an inappropriate means for conceptualization (Lawson and Loke 1997; Verstijnen et al., 1998).

One of the most influential views is that drawing is a dialogue between the designer and what the drawings suggest (Goldschmidt, 1991; Schon and Wiggins, 1992). Many studies (Schon and Wiggins, 1992; McGown et al., 1998; Verstijnem et al., 1998; Suwa et al., 2000; Dorst and Cross, 2001) suggested that in comparison to normal people, designers are able to see more information in design drawings. Therefore, more visual clues through sketches can be identified from designers’ triggered mental images. Schon and Wiggins (1992) stressed the importance of sketches, and discussed that they may be the essential medium for designers to make a reflective conversation with their own ideas. Although CAD/CAM tools have a great impact on the efficiency of design processes, it is believed that there are still aspects of designing which are uniquely associated with freehand sketches (Suwa, Purcell and Gero 1998). However, little research has been done to empirically examine the perceptions between the designers and their clients in the understanding of design presentations.

2. RESEARCH METHODOLOGY

2. 1. EXPERIMENT DESIGN

The experiment was conducted with a Dell Precision 390 laptop which equips a 17” LCD monitor to display the experiment instrument. Product pictures were shown on the monitor with screen resolution of 1280x1024. A Tobii x50 Eye Tracker is positioned at the base of the monitor to track the participant's gaze. The Tobii ClearView Analysis software is a eye-tracking analysis software developed by Tobii, used for recording and analysing eye-movement and event data. Unlike the traditional eye-tracking equipment, Tobii 50 is a remote eye tracker which allows less intrusive testing without any disruptive equipment attached to a participant. The frame rate is 50 Hz and the accuracy is 0.5 degrees.

A total of 64 undergraduate students between the ages of 20-25 at the National University of Singapore participated in this experiment. Half of the group was from the Department of Architecture while the other half comprised of students from other facilities. 3 participants' eye tracking data were voided due to failure to obtain reliable eye-data. Out of the 61 analyzed participants (for eye tracking data), 32 participants had design education back-ground (16 females and 16 males) and 29 participants had some other education background (13 females and 16 males). The test began with a calibration sequence and subsequently, the test introduction was displayed on screen by the experimenter. When the participant was asked to follow the screen instructions to continue the test, the tracker was already recording. The procedure was explained and the experiment conducted, which took about 20-30 minutes per session. Participants were shown part of the recording of their eye-movements after the experiment. Each participant sat 50 cm from the monitor and went through the calibration process then experiment. Each session involved one student and one operator. The whole session was recording by the eye tracking camera.

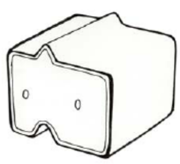
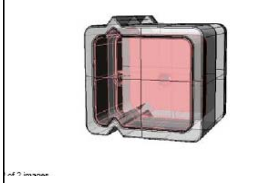
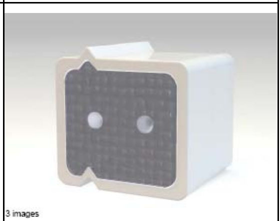
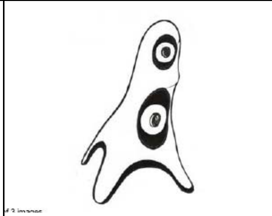
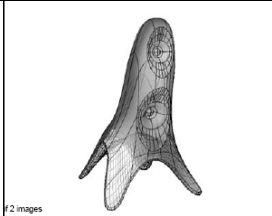
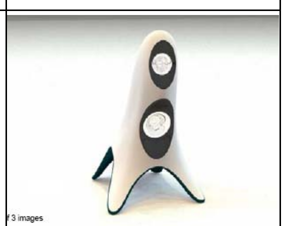
The experiment developed in this study was adapted from the study of Raiha et al. (2006), i.e. studying perception of products by combining (1) eye-tracking and gaze-path analysis, (2) think-aloud protocols in experimental tasks, and (3) comparative controlled studies of products that are manipulated so that they differ only on a given detail. Therefore, the experiment started from free observation on different methods of design presentations and design evaluation with suitability.

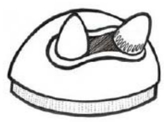
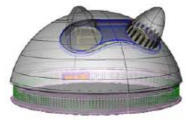
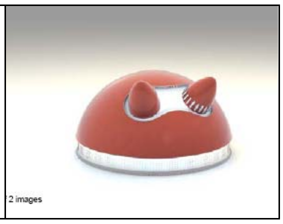
Figure 1: Design Presentation Types (adopted from Raiha et al. 2006).

Four most popular design representation methods were applied in this study, i.e. free hand sketch, 2D rendering, 3D wire frame and 3D rendering (virtual 3D models) (refer to Fig.1). With free observation on different methods of design representation, the perception differences can therefore be recorded, in addition to identify an appropriate design communication method.

3 students' speaker designs were selected for this study. These include designs with a geometric from, an organic form and round shape as shown in Table 1. 3 sets of design presentations were produced by 3 2nd year design students from NUS ID for the test. The images were arranged randomly with some other images inserted in between, in order to reduce memory effects.

Table 1: The Visual Presentations used in the test.

	Free Hand sketch	2D rendering	3D wireframe	3D virtual model
A				
B				

C				

The procedure begins by briefing the participant on the purpose of the experiment and the instructions was read out to the participant. The experiment began by running a slide show and it was control by the participant. During the test the participant was required to view the slides, and at the intermission, (blank slide) paused to relate comments to the experimenter with regards to how the object in the picture is perceived. The experimenter will record the participant's comments on the worksheet. The participant was asked to comment on the experiment in general at the end. The fixation patterns were recorded and the data collected in the form of fixations and fixation lengths were analyzed.

The verbal data was another focus of this analysis. It was collected from interview notes of the experiments and was composed of 64 descriptions. All sessions and descriptions were analysed separately. Many systems for describing and analysing design protocols have been developed over the recent years (Suwa and Tversky 1997; Suwa et al., 1998; Menezes and Lawson 2006). The method developed in this study was adapted from the analysis methods proposed by Menezes and Lawson (2006). The cognitive actions from the protocol could be further broken down into three sub-categories which are references to feature and reflective descriptions and area of interests (AOIs). In general, feature references are divided in 2 groups (Menezes and Lawson 2006):

- Formal references are related to physical and geometrical characteristics. They include descriptions such as square, oval or line.
- Symbolic references are related to analogies and elements that are not represented in the drawings. They include descriptions such as box, sausage or wall.

In addition to these 2 groups, a new group known as 'Mixed references', was added for those replies related to a mixture of both symbolic and formal references. Reflective references involve judgment such as difficult, easy, hard or simple. AOIs are related to the places that the participants are interested in.

3. RESULTS AND DISCUSSION

3.1 VISUAL ATTENTION

The eye tracker recorded the position of the participant's gaze on the design throughout the experiment. ClearView analysis software was used to calculate the number of fixations that occurred (a fixation is where the eyes rest on part of the stimulus for more than 100 ms, in order to process information), their position, their order, and their average duration. Figure 2 shows the typical samples of hotspot maps which indicate the areas of the product that received the most fixations in different presentations respectively (red = 9 or more fixations, green = 4 or more, grey = 0). Participants tended to fixate on the salient areas when reading the images. The areas with the most fixations also appeared to vary according to the link participants' interests.

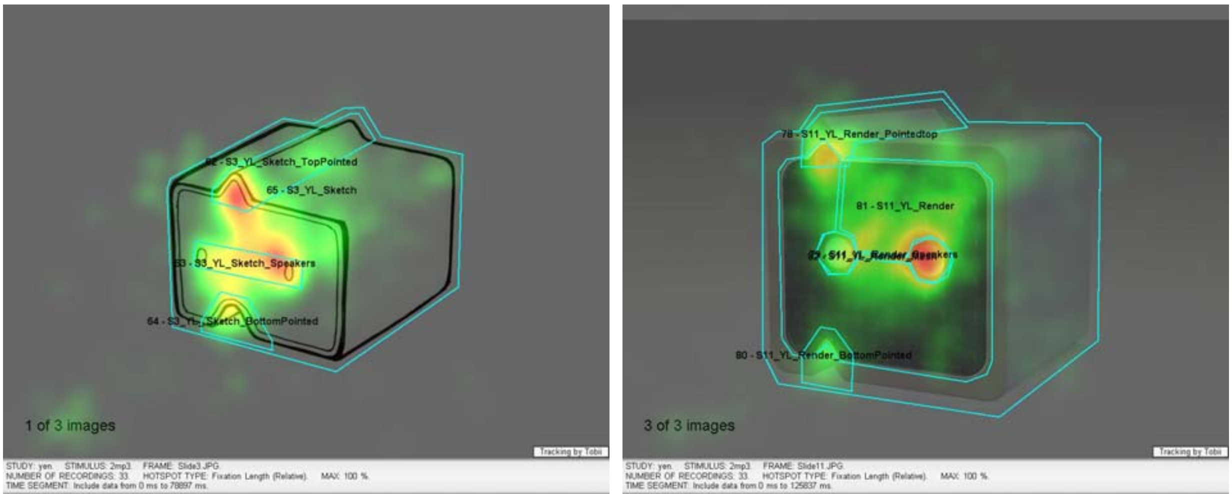


Figure 2: Hotspot Analysis Of Standard Presentation Of The Sketch (A) And 3D Rendering (A).

Table 2 shows the statistical fixation analysis data. The results show that there are no systematic differences between sketch, 2D rendering, wireframe and 3D rendering. The result is similar to the study conducted by Raihi and team which report no systematic differences between drawn sketches and photos (Raihi et al. 2006). To further evaluate the average fixation count for different images, it is found that a simple design could get fewer fixations than a complex one. This finding is consistent with the study by Yarbus (1967) and Raihi et al (2006).

Table 2: Visual Attention With Regard To Different Presentation Methods.

	Fixation count	Average fixation duration	Gaze time
A 3D Rendering	101.2	278.8	28559.3
A 2D rendering	93.2	285.9	26663.4
A Sketch	78.3	292.7	22997.7
A wireframe	73.0	299.4	21871.9
B 2D rendering	113.6	266.0	31108.9

B Sketch	57.7	319.6	18717.2
B wireframe	42.4	322.6	13696.7
B 3D Render	47.6	349.6	16845.9
C Sketch	71.2	282.2	21102.2
C Wireframe	88.7	294.5	25799.1
C 3D rendering	109.0	295.1	32488.6
C 2D rendering	79.0	301.3	23775.6

Therefore, the analysis focused on the areas of interests (AOI), to understand whether the various areas in the drawing received a similar degree of attention in different concept presentations. Table 3 shows the statistical data on AOI. It is revealed that a greater amount of cognitive processing occurred for those AOI indicated during the interview process. This also revealed the consistence between the participants' thinking and eye movement.

Table 3: Visual Attention on Area of Interests (AOI).

	Fixation count	Average fixation Duration	Gaze time
A S3_YL_Sketch_TopPointed	14.0	305.9	4376.2
A S3_YL_Sketch_Speakers	15.9	293.3	4767.0
A S3_YL_ Sketch_BottomPointed	5.7	255.5	1637.0
A S3_YL_Sketch	78.3	292.7	22997.7
B S4_L_Render_Speakers	47.6	349.6	16845.9
B S4_L_Render_NonSpeakerParts	24.4	261.8	6589.1
C S5_SX_Ill_Knobs	47.1	317.3	15199.4
C S5_SX_Ill_Speakers	3.3	162.8	855.7
C S5_SX_Ill	79.0	301.3	23775.6
B S9_L_Sketch_Speakers	57.7	319.6	18717.2
B S9_L_Sketch_FrontBulge	5.0	274.7	1674.0
B S9_L_Sketch_NonSpeaker	34.0	268.0	8972.0
C S10_SX_Wire_knobs	47.1	302.7	14210.2
C S10_SX_Wire_USB	5.9	299.4	1928.6
C S10_SX_Wire_speakers	8.3	246.4	2185.5
C S10_SX_Wire	88.7	294.5	25799.1
A S11_YL_Render_Pointedtop	7.3	256.4	2134.5
A S11_YL_Render_Speakers	17.7	295.6	5583.9
A S11_YL_Render_BottomPointed	4.3	247.4	1151.3
A S11_YL_Render	101.2	278.8	28559.3
A S11_YL_Render_Mesh	62.1	270.8	17022.8
A S15_YL_Ill_Bottompointed	1.1	138.5	304.9
A S15_YL_Ill_Speakers	8.0	272.3	2353.1
A S15_YL_Ill_Pointedtop	16.0	288.6	4774.9
A S15_YL_Ill	93.2	285.9	26663.4

B S16_L_Wire_Speakers	42.4	322.6	13696.7
B S16_L_Wire_NonSpeaker	39.4	290.6	11758.5
C S20_SX_Render_Knobs	65.5	304.2	20191.0
C S20_SX_Render_Speaker	15.7	269.5	4438.0
C S20_SX_Render	109.0	295.1	32488.6
B S25_L_Ill_Bump	2.7	179.5	685.7
B S25_L_Ill_Speakers	24.0	275.1	6724.2
B S25_L_Ill	113.6	266.0	31108.9
C S26_SX_Sketch_Knobs	49.1	298.3	15482.0
C S26_SX_Sketch_Speaker	9.2	265.6	2466.4
C S26_SX_Sketch	71.2	282.2	21102.2
A S21_YL_Wire_Speaker	13.8	318.2	4744.2
A S21_YL_Wire_TopPointed	5.0	262.5	1607.5
A S21_YL_Wire_BottomPointed	8.2	256.7	2341.8
A S21_YL_Wire	73.0	299.4	21871.9

3.2 COMMUNICATION BETWEEN DIFFERENT MODES

Table 4 show the analysis of using the symbolic, formal, and mixture reference during the interview process. It is obvious that participants have used more symbolic references to evaluate the sketches and 2D rendering and formal references to wireframe drawings and 3D renderings. The finding is consistent with the study of Menezes and Lawson (2006) which shows that architecture students use more symbolic references to evaluate the sketches.

For example, participant 32 states that "*Is it a chair? Do not understand why there are 2 dots. Can make quite an interesting garden chair that can respond to weather*….." and participant 54 states that "*Looks like a goggle* ….." Participants had attempted to refer the sketches to a product, an object, an animal, etc, which may create more imaginations during the conceptual process. On the contrary, participants used more formal references to describe the remaining 2 types of rendering images. To better illustrate, participant 30 states "*material looks quite cool, but the centre look very rough dun fit the smooth surrounding…. Part line make it look less thick*" whilst evaluating the 2D rendering and participant 32 states that "*like it rounded, don't know what texture, cannot tell if will like it, think I will need to touch it. Will probably like it if it is reflective, colour will be better*". These sorts of references provide more detailed information in relation to the shape, colour, and materials of the design. This can become useful resource when the design requires more haptic considerations. It is also interesting to note that participants may use more mixture references (mix of symbolic and formal references) to evaluate 2D and 3D renderings.

Table 4: Interview Analysis (Reflective).

	OK (Acceptable)	Relatively better	Relatively worse
A sketch	0	7	6
A 2d render	2	13	18
A wireframe	2	6	20
A 3d rendering	4	22	17
B sketch	1	4	23
B 2D rendering	2	8	16
B 3D wireframe	2	12	10
B 3D rendering	0	18	8
C sketch	7	11	14
C 2d rendering	3	10	13
C wireframe	5	14	14
C rendering	5	32	3

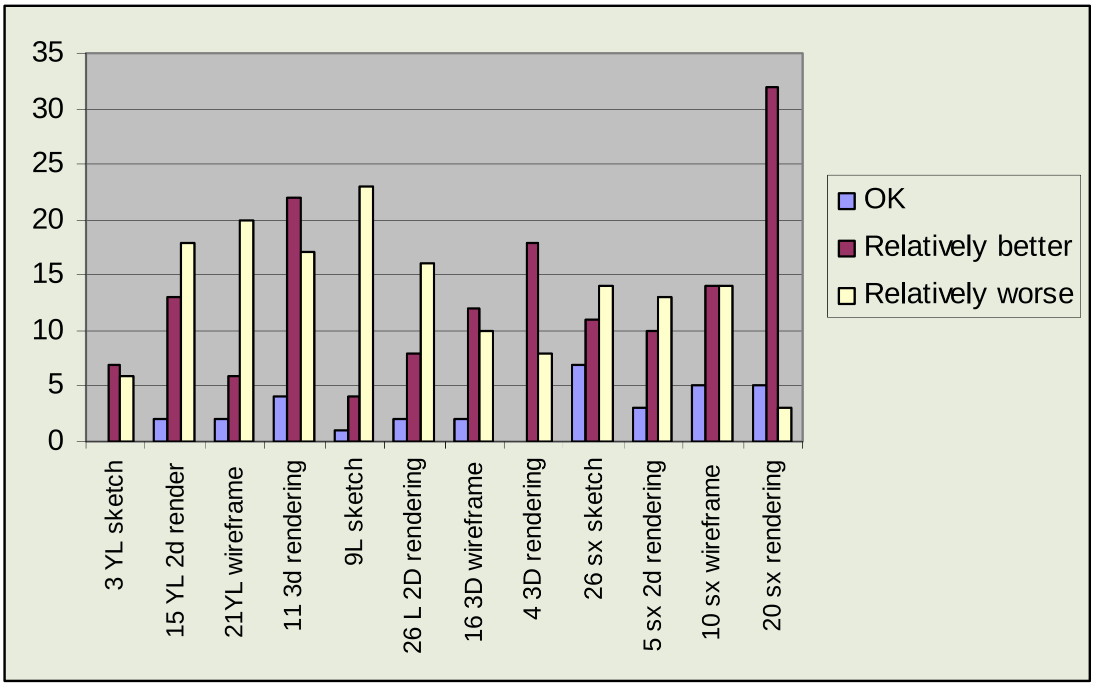


Figure 3: Satisfaction Rate on Different Presentation Methods.

With regards to the reflective analysis of cognition action, Table 4 and Figure 3 show the comparison between the 4 different presentation methods. With the exception of 3D rendering presentation, the rest of 3 presentations modes, i.e. sketch, 2D rendering and wireframe drawing received relatively more negative comments than positive ones; in particular, some participants directly commented that they preferred 3D rendering presentation than the rest as it felt much more real. For instance, participant 3 commented that 3D rendering "*looks better than a drawing. Looks more realistic. With the texture create more character*". Contrasting to this, a number of participants had even mistaken that the wireframe drawings were some kind of architectural or interior drawings. This can be seen from the typical comments like the speaker “*looks like a place to go into. Like a building. Looks complicated…*(Participant 5),” and “*looks architectural, like a sporting dome such as a stadium or an arena, not a product*. (Participant 14)” Obviously, caution should be taken if designers were directly presenting their concept using some 3D wireframe drawings from the computer screen as clients may totally misunderstand the scale of the products.

3.3 DIFFERENT PERCEPTIONS BETWEEN DESIGNERS AND NON-DESIGNERS

Figures 4-6 shows the differences between designers and non-designers in related to their fixation counts, glaze time and average fixation duration. Figure 4 shows that the fixation counts of designers are relatively higher than those of non-designer. Average fixation duration of designers are shorter than those of non-designer (refer to Figure 5) However, there is no significant differences in the gaze time.

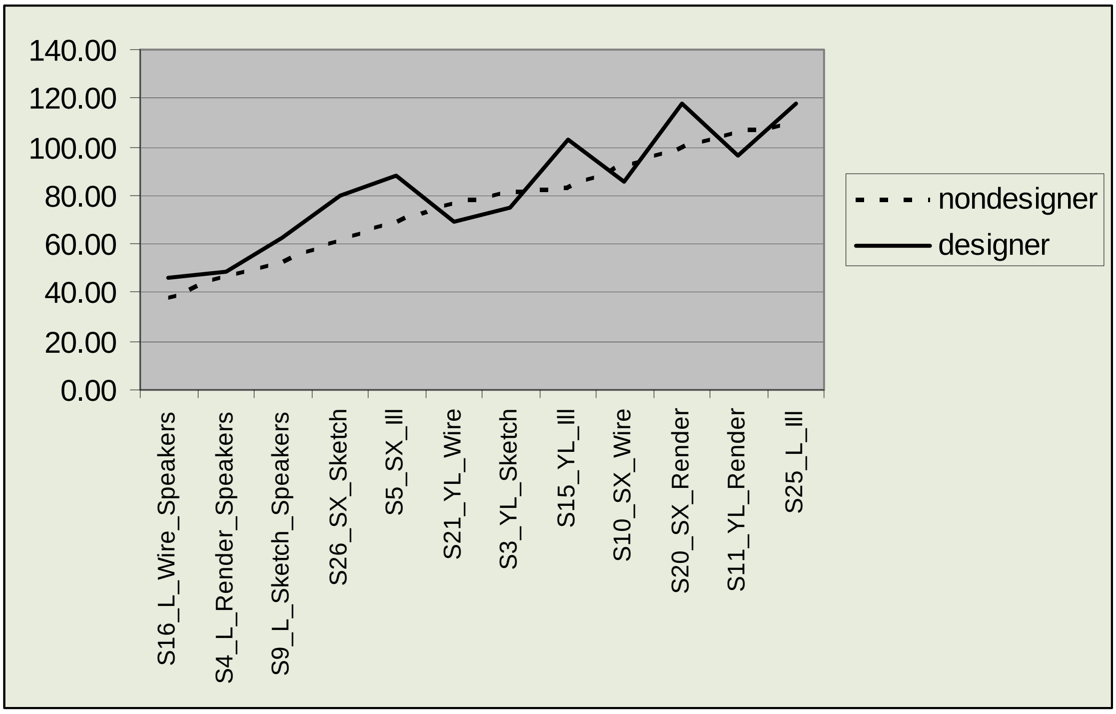


Figure 4: Differences in Fixation Counts.

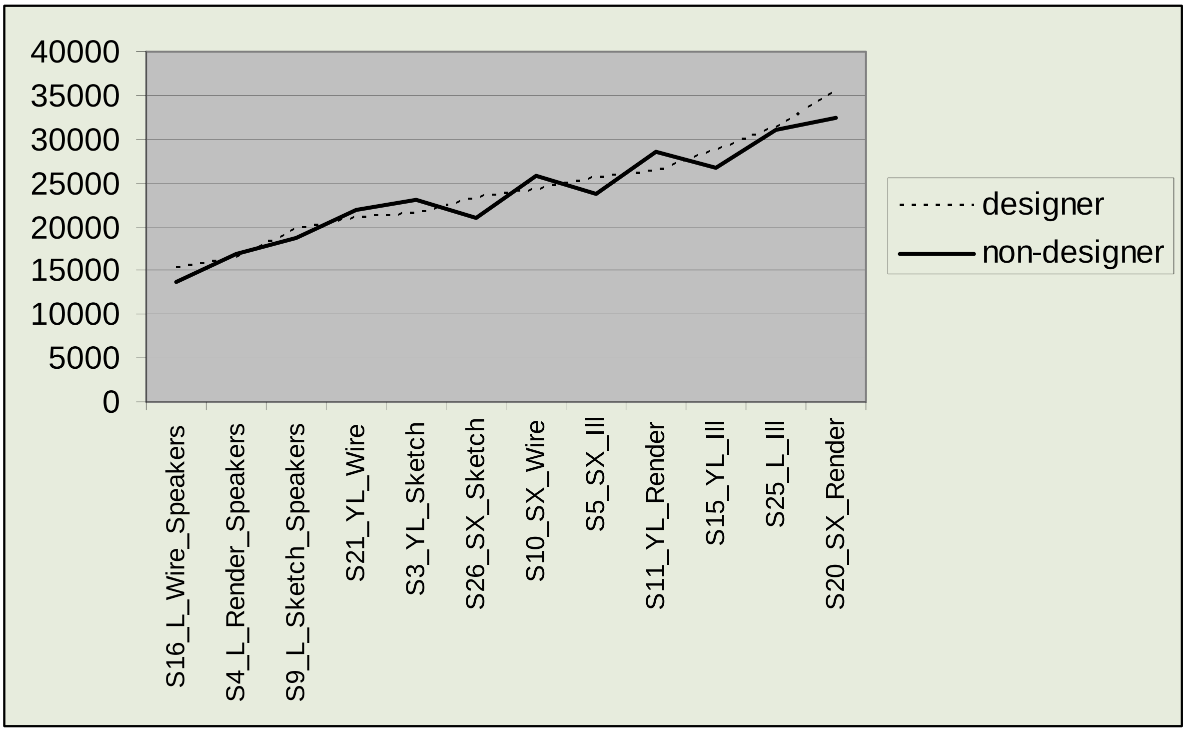


Figure 5: Differences in Gaze Time

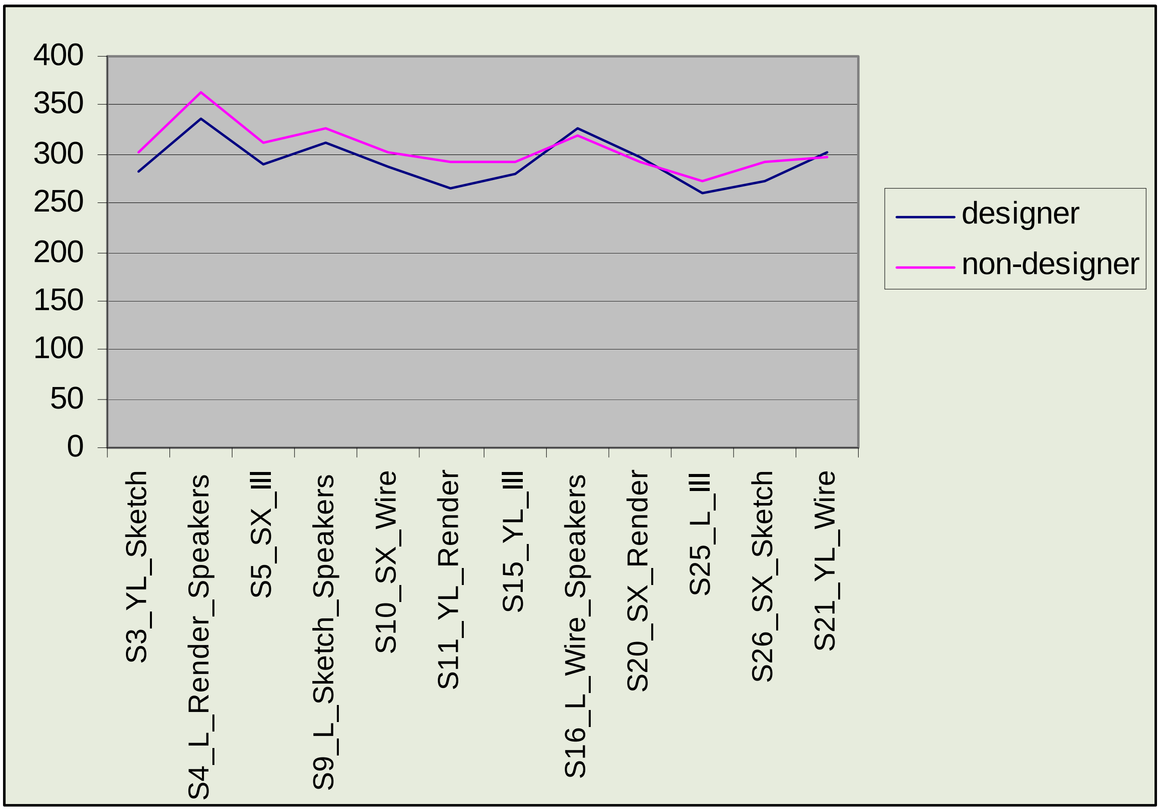


Figure 6: Differences in Average Fixation Duration.

This result is inconsistent with Raiha et al (2006) who found that experts are able to evaluate a situation with fewer fixations. This could be due to the differences between the experiment protocols. A further study is therefore required to evaluate this issue. However, the designers' average duration of fixation is lower than those of non-designer which is also indicated that designers are able to evaluate a drawing with lesser time. The reason for this could be that designers have learnt to look more effectively and differently while practicing drawing. This finding is parallel to an earlier study (Raiha et al. 2006) where it has been found that fixation durations of designers on product evaluation were higher than those of non-designers.

Table 5: Differences in the use of Feature References.

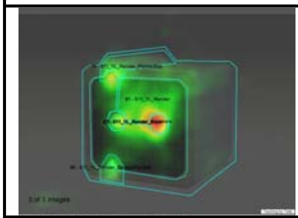
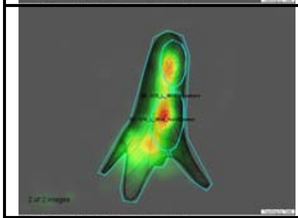
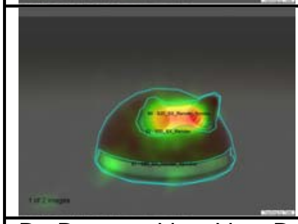
		Symbolic		Formal		Mixture	
		D	NON	D	NON	D	NON
	A sketch	20	22	6	7	2	0
	A 2d render	4	10	19	9	1	3
	A wireframe	1	7	14	6	3	3
	A 3d rendering	7	5	17	9	3	9
	B sketch	10	15	16	10	5	5
	B 2D rendering	9	9	14	15	9	7
	B 3D wireframe	0	7	18	16	8	4
	B 3D rendering	5	5	13	9	13	16
	C sketch	8	9	15	10	5	5
	C rendering	7	13	12	6	10	9
	C wireframe	4	13	14	11	6	5
	C rendering	1	4	18	14	6	10
D= Designer, Non=Non- Designer							

Table 5 shows the different preferences in using feature references from the comments of design presentations. Non-designers used relatively more symbolic references than those of the designers. Non-designers tend to use objects to describe the design, for example, participant 38 states that "*looks like a cartoon drawing, rather cute head of an alien*." The reason for this could be due to the fact that designers tend to critique their peers' works with more professional terminology.

Table 6 illustrates the different preferences in related to different presentations. The results show that designers are more critical than non-designers as they give relatively more negative comments on the presentations. Comparing different types of presentation, 3D renderings received more positive comments and both designers and non-designers replied that the presentation is relatively better than others. It is interesting to note that designer participants indicated that 3D wireframe drawing was the worst presentation modes among 4 different presentations. However, the non-designers indicated that sketch and 2D rendering were relatively worse than the others. The results show that unless the sketch is particularly impressive, the non-designer may not appreciated its presentation. Non-designers tend to prefer something which is presented to be more realistic, even though they may not understand the drawing.

Table 6: Preferences in Different Design Presentations.

	OK (Acceptable)		Relatively better		Relatively worse	
	D	NON	D	NON	D	NON
A sketch	0	0	3	4	4	2
A 2d render	0	2	9	4	10	8
A wireframe	1	1	3	3	14	6
A rendering	0	4	14	8	11	6
B sketch	1	0	2	2	11	12
B 2D rendering	1	1	4	4	11	5
B 3D wireframe	0	2	9	3	5	5
B 3D rendering	0	0	11	7	5	3
C sketch	8	2	6	5	7	7
C 2d rendering	4	1	2	8	9	4
C wireframe	3	1	3	11	12	2
C rendering	1	2	17	15	1	2
D= Designer, Non=Non- Designer						

5 CONCLUSION

The use of eye-tracking technology to understand the design perception is a relatively new approach in the design arena despite its long establishment in other fields. As there is very little research in this domain, the study requires a series of trial and error to establish the methodology for experimentation. The collection of data recorded is also significantly vast as each participant had about a 20-30 minutes video record, i.e. in total more than 36 hours of video capsulation. It is also difficult to find participants for such experiments as many are willing to spend time on a 20-30 minute session without proper incentives. The summary points of this study are:

- A critical review of relevant eye movement study on design recognition has been undertaken. An experiment method adopted from Rantala et al (2006) was modified for the purpose of this study which can apply to any other type of study in design, such as perception of design, selection of product, etc…

- The visual patterns of designers and non-designers have been identified in the study, which can provide as a reference to assist designers in choosing the means of communication during the design process.

- The insight of visual perceptions in relation to different design presentation methods has been recorded, which can provide a brief understanding of the differences between designers and non-designers.

ACKNOWLEDGEMENT

This research is part of Research Project supported by a grant (WBS number: R-295-000-048-112) provided by the School of Design and Environment, National University of Singapore.

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