A Study on the Comparison of the Visual Attention Characteristics on the Facade Image of a Detached House Due to the Features on Windows

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Abstract

It is necessary to analyze the processes and principles of how building images are formed in an objective way. In this respect, this study intends to find out where people gaze when looking at a building, especially a residential building. This study has aimed to see where people have the most visual attention when glancing at a detached house by using eye movement tracking devices. One method employed in this study was to divide the observed area into two categories, an opening area and a fixed area, in order to find out the different visual interests people have in these two different areas. A second method was to divide the window into a reflected window and a regular window so as to find out how people's visual attention differs depending on the characteristics of windows. Finally, an experiment was carried out to test the different points of view relating to visual attention between two groups with different levels of knowledge in architecture.

The final results are as follows. Firstly, when people see a house, their attention usually goes to opening areas such as windows or doors. The doors and windows are openings that open and close, and they attract a high degree of attention. Secondly, the reflecting window has a larger visual attention than the plain window. Finally, there was no significant difference in visual attention between the two groups.

1. Introduction

The facade of a building plays a very important role in forming a building's image. The facade is like the face of a building, which is most frequently exposed on the outside. Therefore, it is very important to research how facade images of a building are formed in order to research how building images are formed. To establish reasonable and efficient urban and building landscape plans, there is a need for research on landscapes. Secondly, it is necessary to analyze the processes and principles of how building images are formed in an objective way. Therefore, it is necessary to investigate what people gaze at first out of all of the building design elements, in what order they gaze at them, and what areas they gaze at the most or the least.

In this respect, this study intended to find out where people gaze when looking at a building, especially a residential building. Residential buildings are mostly one or two-story buildings and can be divided into two areas, namely an opening and closing area; like doors and windows, and a fixed area; like walls and roofs.

This study attempted to find out the different visual interests people have in these two different areas. In order to do this, the study tried to find out how people's visual attention differs depending on the characteristics of windows by dividing windows into two types, those without visually-inducing elements and those including visually-inducing elements. Furthermore, this study tried to find out whether there was a difference in points of view between two groups of subjects with different levels of knowledge in architecture.

2. Previous Studies

The eye-movement tracking technique is a technique used to trace the location of people's eye movements by precisely detecting their eye movement. Since this technique clearly clarifies humans' visual and cognitive responses toward the environment built around them, it helps researchers analyze data collected by detecting the research subjects' gazes, even when they do not show direct interest in objects.

Previous studies were reviewed to find out how far this eye tracking technique has been researched. Such studies have shown that the fields of architectural and urban studies are largely divided into two sections. One is research on technique establishment and experimental methodology to apply to the field of architectural and urban studies. The other is to establish research topics and apply this technique to the field.

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2.1 The Field of Technique Establishment and Experimental Methodology

This field includes previous studies to extract basic theories and methods which are the foundation of research on utilizing the eye tracking technique. They mostly suggested methods that interpreted digitized data from experiments and investigated gaze frequency and gaze characteristics made by gender, divided area, experiment time, etc.

One study divided an experiment image into 5 areas by gaze frequency and analyzed characteristics appearing in each domain (Kim, J., 2009). The other study was conducted on the characteristics by gender, and it analyzed males and females' gaze frequency and number of gaze occurrences as time went by after dividing an image into 12 different areas for 120 seconds (Kim, J., 2013).

2.2 The Field of Recognition Mode

Previous studies on recognition methods mainly suggested objective materials by digitizing designs that were researched in the field of architectural and urban studies. However, since many of them show a beginning level of application, it is necessary to expand this research by establishing more various hypotheses.

One study analyzed gaze data appearing on the VR image and arranged the characteristics (Kim, J. and Ban, Y., 2013), and another study suggested 20 pictures of the facade of a building and analyzed people's interest in the facade design through area of interest (Yeo, M. and Lee, C., 2014).

There have also been studies conducted on gaze characteristics in natural and built environments. One study tried to monitor the eye movement in different mental tasks to show the differences among preference, prospect and refuge (Su-Hsin L. etc., 2009). Another study tried to specify the space, a constitution element which forms an image of a streetscape by pictures of a sequential streetscape (Kawai, Y. and Zaino, H., 2001). The nature of high gazing elements, the elements of signature, difference of color, and front line elements was made. Another study tried to identify some characteristic patterns in natural landscape observation by different subjects (De Lucio, J. V. etc., 1996). In this paper the patterns of visual exploration of a color landscape photograph were compared.

3. Methodology
3.1 Experimental Image

To examine people's recognition patterns for a building, this study intended to carry out experiments on a detached house, which is regarded as the simplest form out of all the buildings. Housing architecture is one of the most commonly seen buildings around us. It determines urban landscape, while also becoming one of the most important urban components when forming a corresponding one-to-one relationship with the urban environment. A detached house can be seen as the most fundamental form of architecture, and it has all the essential facade elements of architecture, such as a roof, windows, walls and doors. Therefore, a detached house has every design element allocated at a relevant proportion, and was judged to be most suitable for this experiment.

The image selected for this study is shown in Fig.2. It is a two-story building composed of all the basic elements of a building. This study chose a simple and common building because excessive constituents in the experiment image might disturb the experimental subject's focus, resulting in inaccurate comparative research. For this purpose, a simple design was chosen for the house. Table 1. shows basic information about this house.

Table 1. Outline of Experiment House

Project name	House R, Bohinj
Project period	2003 – 2005
Architect	Bevk Perović Arhitekti
Address	Ribčev laz, Bohinj
Photo	Miran Kambič

Since it is a house with a very simple facade, it is quite appropriate for comparing visual attention to each facade component. Specifically, this study sought to compare visual attention to the characteristics of windows, using the original image as seen in Fig.2., and placed a composite image of a tree on the window as seen in Fig.3. It aimed to find out how different visual attention would change when something unusual was seen on the window.

Fig.1. Eye Tracking Device
(Left: Monitor and Supporting Frame, Right: Glasses)

Fig.2. Experiment Image 1
(Source: http://www.bevkperovic.com)

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Fig.3. Experiment Image 2

3.2 Establishment of Experimental Environment

To find out differences in visual attention according to the characteristics of windows in a detached house, this study conducted an experiment by using eye-tracking devices. The table below shows the contents and procedures of this experiment.

Table 2. Experimental Overview

Section	Contents
Date	Mar. 23 to 24 (Mon. to Tues.), 2015
Place	VR Room (Room 426, Building 54) of Architecture Faculty, Changwon University
Device	Viewpoint Eye Tracker, PC-60 Scene camera (Arrington Research)
Subjects	An expert group of 31 people (architecture-related graduates and undergraduates) and a non-expert group of 30 people (students not related to architecture)
Experimental Environment	With the surrounding environment dark, subjects were made to focus on images on the monitor, and the data needed for this experiment was adjusted through another monitor.
Data Record	Data was recorded at [x, y] coordinates, and 30 coordinate data points were created per second.

The experimental procedures were as follows. Subjects were instructed to look at house facade images. They were given a 30-second adaptation time in the darkroom while wearing a visual device. Calibration was conducted to adjust the measurement point and the eye focus when the subjects were gazing at the monitor. They were informed that 20 seconds would be spent for each image. Subjects were then randomly divided into two groups. One group was assigned to look at Image 1 (Fig.2.) and the other group to look at Image 2 (Fig.3.).

3.3 Adjustment of Observation Data

Data created through this experiment were adjusted as seen in Table 3.

3.4 Analysis of Image Areas

As experimental targets, house images were divided into windows, doors, walls and roofs. The element area of each image was evaluated through an analysis program to designate a proper range. The study divided the areas according to foveal vision, which is the visual characteristic of people looking at objects. The images were mutually comprised of each element to divide the areas clearly. Backgrounds were excluded from the experiment targets.

Table 3. Data Adjustment Overview

| Section	Contents
Data Arrangement	The device used for this study can record 60 data points per minute with x and y coordinates and creates 3,600 data points for 1 minute while the subject is looking at three images of a detached house. Since subjects might have afterimages from the previous images, data for the first second was excluded from the record.
Data Compensation	There took place slight differences from actual points seen because of the error of experiment devices. After selecting images with errors and comparing them with an analysis program, this study designated a proper range.
Effective Rate	To reduce the rate of errors when analyzing the experiment data, the authors calculated the rate of effective data (effective rate) against the entire gaze data and excluded the data from subjects whose effective rate was below 90%. During this process, the data from 6 subjects were excluded.
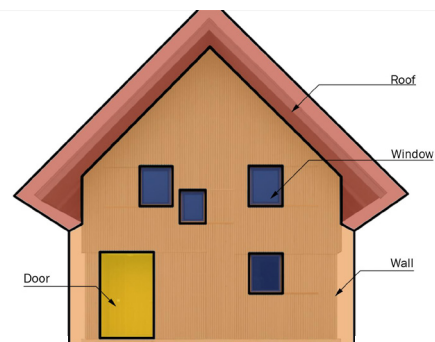
Fig.4. Area Partition

Table 4. Area Partition of the Experimental Image

Area Division	Area Rate (%)
Wall	64.13
Roof	16.13
Window	13.27
Door	6.47
Total	100

3.5 Main Indicators

To analyze the data collected, this study used Gaze Data, Gaze Number and Gaze Frequency as key indicators.

Table 5. Indicators Definition

Indicators	Definition
Gaze Data	Data used for the movement of gaze to analyze the gaze phenomenon in an eye tracking experiment
Gaze Number	Data used for analysis or the number of gazes, which is included in the Gaze Frequency.
Gaze Frequency	When Gaze Data is formed with over 9 gazes consecutively coming into the center and range of the object while a subject is gazing at a building

4. Data Analysis
4.1 Outline of Data Analysis

After carrying out this experiment on a total of 55 subjects (an expert group of 27 people and a non-expert group of 28 people), this study obtained a total of 576.6 valid gaze data. Table 6. shows the mean Gaze Data, Gaze Number and Gaze Frequency. The data from

Image 2 where the image of a tree was seen on the window was a little more than the data from Image 1.

Table 6. Outline of Gaze Data Analysis

Section	Gaze Data	Gaze Number	Gaze Frequency
Mean	576.60	203.05	29.85
Image 1	547.70	188.00	28.33
Image 2	555.03	204.43	29.14

4.2 Research Hypotheses

This research attempted to clarify these three theories.

Hypothesis 1: When people look at a house, they give most of their attention to opening areas, such as windows or doors.

Hypothesis 2: The window with the surrounding image reflected on it has more visual attention than the one without it.

Hypothesis 3: The visual attention between the two groups with different levels of knowledge in architecture is different.

4.3 Visual Attention of Each Area in Image 1 and Image 2

To verify the hypothesis 1, visual attention of each area needs to be analyzed along with the arithmetic average result in Images 1 & 2. It was necessary to exclude the influence from area rates, because the wider the area, the higher the visual attention. To reduce the effect given by the area, this study divided the raw data by the area rate of each area. The main results of this analysis are arranged in Table 7. As can be seen, this table has been divided into two sections. The opening area; which consists of windows and doors, and the fixed area; which consists of walls and roofs.

It was found that with the area rates reflected, the door showed the highest Gaze Data, Gaze Number, and the Gaze Frequency. The window was the second highest. It was discovered that the roof and wall received a lower score than the window and door.

Table 7. Area Rate Reflected Data of Opening and Fixed Areas

Section		Area Rate Reflected Data		
		Gaze Data	Gaze Number	Gaze Frequency
Opening Area	Window	7.04	3.01	0.40
	Door	8.02	3.65	0.42
Fixed Area	Roof	4.97	1.52	0.28
	Wall	4.58	1.56	0.23

All Gaze Data, Gaze Number and Gaze Frequency of 55 subjects were gathered to find out the difference between the two areas. To find out the difference, a T-test was organized. The results of T-test are arranged in Table 8. The results showed that the Gaze Data, Gaze Number, and Gaze Frequency's P-value between two groups was 0.000. In other words, the opening area and fixed areas indeed had a difference, which means when people are looking at a house their visual

attention usually goes to opening areas, rather than the fixed areas. Unlike the other elements, the doors and the windows are openings to open and close, and they attracted the highest degree of attention.

Table 8. Independent T-test Result (Opening Areas/Fixed Areas)

Section		N	Mean	Std. Deviation	Levene's Test for Equality of Variances	
					F	p-value
Gaze Data	Opening	55	7.5307	4.79664	43.063	.000
	Fixed	55	4.7736	1.32628		
Gaze Number	Opening	55	3.3310	3.32907	26.386	.000
	Fixed	55	1.5276	.95736		
Gaze Frequency	Opening	55	.4101	.31540	28.305	.000
	Fixed	55	.2521	.11613		

4.4 Visual Attention of Window between Image 1 and Image 2

Among the total of 55 subjects, Image 1 had 27 subjects while Image 2 had 28. The visual attention of the window between Image 1 and Image 2 was analyzed. The main results of this analysis were arranged in Table 9.

Table 9. Area Rate Reflected Data of Image 1 and Image 2

Section	Image 1			Image 2		
	Gaze Data	Gaze Number	Gaze Frequency	Gaze Data	Gaze Number	Gaze Frequency
Roof	5.01	1.32	0.27	4.93	1.66	0.28
Window	**4.89**	**1.85**	**0.28**	**9.12**	**4.14**	**0.52**
Door	8.16	3.72	0.45	7.89	3.58	0.39
Wall	4.88	1.70	0.24	4.28	1.42	0.22

In Image 1, the door showed the highest Gaze Data, Gaze Number, and Gaze Frequency. In respect of the Gaze frequency, the window was second highest. Interestingly enough, it was found that the data for the window is very similar to the roof. The wall was the smallest in all indicators.

In Image 2, the window showed the highest Gaze Data, Gaze Number, and Gaze Frequency. All indicators of the door were the second highest in the area rate of reflected data. As in Image 1, the wall was the smallest in all indicators too.

The door showed the highest visual attention in Image 1, and the window showed a relatively low one. In Image 2, however, the window showed the highest visual attention, followed by the door. Although the image of the tree was not easily noticeable, it contributed to increasing the visual attention about twice that in Image 1.

The data from 55 subjects used in the T-test were split into two groups, one looking at Image 1 (plain window) and the other looking at Image 2 (tree window). The analyzed results for the Gaze Data, Gaze Number and Gaze Frequency showed that each of their P-values were as follows; 0.014, 0.024 and 0.035. This means there was a significant difference between the two images. In conclusion, this supported hypothesis 2. This can tell us that the reflecting window has a larger visual attention than the plain window.

Table 10. Independent T-test Result (Plain Window/Tree Window)

Section		N	Mean	Std. Deviation	Levene's Test for Equality of Variances	
					F	P-value
Gaze Data	Plain_Win	27	4.8871	4.20909	6.476	.014
	Tree_Win	28	9.1183	6.75185		
Gaze Number	Plain_Win	27	1.8505	2.69587	5.439	.024
	Tree_Win	28	4.1366	4.39391		
Gaze Frequency	Plain_Win	27	.2763	.32108	4.707	.035
	Tree_Win	28	.5221	.47657		

4.5 Difference between Two Groups

The third and final hypothesis was to find out whether the points of view between the two groups with different levels of knowledge in architecture are different or not. In order to verify this hypothesis two groups were formed: an expert group of 31 people consisting of architectural related graduates and undergraduates, and a non-expert group of 30 people consisting of students who weren't in the architectural field. However, to reduce the rate of error, the data of 4 subjects in the expert group and 2 subjects in the non-expert group were excluded. Table 11. shows the information from the experimental subjects.

Table 11. Composition of Subjects

Section	Image 1	Image 2	Total
Expert	12	15	27
Non-expert	15	13	28
Total	27	28	55

The experiment was conducted by using the one-way ANOVA analysis to examine differences between the two groups based on the experimental data derived from the two images. The final results are shown in Table 12. Indicators show that all the P-values were larger than 0.05, meaning that there was not much difference with regard to visual attention among the two groups. Therefore, hypothesis 3, which was a study to see if there was a difference in visual attention between two groups with different levels of knowledge in architecture, was dismissed.

The results indicate that the sample images lacked the architectural complexity needed to activate the expert group's knowledge base. Also, this search only gathered architectural related graduates and undergraduates. Therefore, further experiments are needed to verify whether visual attention between the two groups is different.

5. Conclusion

This study aimed to see where people have the most visual attention when glancing at a detached house by using eye movement tracking devices. One method was to divide the observed area into two categories, an opening area and a fixed area. This study attempted to ascertain the different visual interests people have in these two different areas. A second method was to divide the window into a reflected window and a regular window. The study tried to find out how

Table 12. Result of ANOVA Analysis (Expert Group/Non-Expert Group)

		Sum of Squares	df	Mean Square	F	p-value
Roof Gaze Data	Between Groups	16.253	1	16.253	1.754	.191
	Within Groups	491.018	53	9.264		
	Total	507.271	54			
Roof Gaze Number	Between Groups	8.916	1	8.916	3.795	.057
	Within Groups	124.525	53	2.350		
	Total	133.440	54			
Roof Gaze Frequency	Between Groups	.045	1	.045	.811	.372
	Within Groups	2.959	53	.056		
	Total	3.004	54			
Window Gaze Data	Between Groups	.223	1	.223	.006	.938
	Within Groups	1937.354	53	36.554		
	Total	1937.577	54			
Window Gaze Number	Between Groups	9.172	1	9.172	.629	.431
	Within Groups	772.904	53	14.583		
	Total	782.076	54			
Window Gaze Frequency	Between Groups	.168	1	.168	.940	.337
	Within Groups	9.475	53	.179		
	Total	9.643	54			
Door Gaze Data	Between Groups	25.890	1	25.890	.827	.367
	Within Groups	1659.915	53	31.319		
	Total	1685.806	54			
Door Gaze Number	Between Groups	31.768	1	31.768	1.992	.164
	Within Groups	845.404	53	15.951		
	Total	877.172	54			
Door Gaze Frequency	Between Groups	.399	1	.399	2.675	.108
	Within Groups	7.899	53	.149		
	Total	8.298	54			
Wall Gaze Data	Between Groups	.006	1	.006	.002	.961
	Within Groups	128.493	53	2.424		
	Total	128.499	54			
Wall Gaze Number	Between Groups	.031	1	.031	.017	.895
	Within Groups	94.766	53	1.788		
	Total	94.797	54			
Wall Gaze Frequency	Between Groups	.007	1	.007	.756	.388
	Within Groups	.511	53	.010		
	Total	.519	54			

people's visual attention differs depending on the characteristics of windows. Finally, an experiment was carried out to test the different points of view relating to visual attention between two groups with different levels of knowledge in architecture. The final results are as follows.

Firstly, experiment 1 focused on the difference between the opening and closing area using the T-test. The opening areas consisted of the windows and doors whilst the closing area consisted of the walls and roofs. There were 56 subjects to analyze the data for Gaze Data, Gaze Frequency, and Gaze Number. The final result was that the opening area had greater visual attention than the fixed area. Therefore it has been proven that when people see a house, their attention usually goes to opening areas such as windows or doors.

Secondly, two images were presented for the second hypothesis. Image 1 contains a plain window and image 2 contained a reflected tree window. This information was once again gathered with the T-test.

Fifty-six subjects were gathered and analyzed based on their gaze data, number and frequency. From the results, Images 1 and 2 did correlate with different visual attention patterns. It was found that the reflecting window had a higher visual attention than that of Image 1.

Finally, a one-way ANOVA analysis was applied using the two groups. One was a group which is experienced with architecture, and the other was a group which is not experienced with architecture. This was done by using the experimental data from Images 1 and 2. The final result was that there was no significant difference in visual attention between the two groups.

In conclusion, this study used a very simple model of a detached house. It is felt that further investigation is needed using a wider range of architectural features in order to gain more accurate results. Moreover, this search only gathered architectural related graduates and undergraduates. There may be a need to extend the range of architecture subjects to include more experienced architects or people who have experience in the field.

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