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A COGNITIVE INVESTIGATION OF INTERIOR EFFECTS OF WINDOW SIZES

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Abstract. In architectural design, window sizes are examined with respect to issues such as energy conservation and sustainability. In this study, unlike the current studies, the effect of different window sizes on the cognitive state of people was examined. Note that, using online eye tracking technique, 32 volunteers participated in the study. The volunteers who participated in the experiment tested three places modelled with differently sized windows using their own computers. After the study, a mini-questionnaire was administered and volunteers were asked in which place they would like to be. In this study, selections made by volunteers depended on the illumination level in the interior, which was brought about by the change in the window size. The window size used in a space can alter the focus of people, because of which the interactions of users with that space can change. Because of the results of this study, the cognitive state of users is recommended to be considered in the window design processes and be used as a supportive factor for improving user experience in environmental design.

Keywords: *architecture, eye tracking, window size, cognitive, design, decision making.*

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1. Introduction

Recently, the impact of cognitive sciences on other disciplines has been particularly evident and contributed to improved understanding of human behavior. Decision-making, which is one of the basic disciplines that combines multidimensional areas of cognitive research techniques, focuses on relationships between mind and human behavior. In (neuro-)cognitive sciences, which investigate how decision-making systems work, the level of abstraction present in people's minds, the role of emotions in decision-making and in deliberate behavior are examined; moreover, behaviors are investigated in multiple fields (from medicine to psychology, engineering sciences, to design decisions). It is considered that there are cognitive influences in all decision-making behaviors of people (Wang & Ruhe, 2007).

In particular, in different studies, visual and cognitive processes have been examined, and the analyses have generally been performed using eye-tracking. Because eye movements are mostly related to cognitive processes, they can be treated as positive behavioral signs in terms of evaluation of visual attention and information acquisition.

In our daily lives, our eye movements are based on tasks (Gidlöf *et al*., 2013). In normal conditions, eye movements are related to the cognitive states of the individual (Wedel & Pieters, 2008), and this affects decision-making. Individuals' eyesight can affect the decision-making mechanism; however, the individuals' eyesight in the decision-making process varies from person to person (Gidlöf *et al.*, 2013). Therefore, to understand decision-making, the study of eye movements is a convenient tool (Watkins & Johnson, 2011; Lai *et al.*, 2013; Zou & Ergan, 2019).

(Neuro-) cognitive studies in the architectural field examine the effects of design and space on people. Studies that combine the discipline of architecture with (neuro-) cognitively assessed different aspects from architectural appreciation (Erkan, 2020a) and perception (Turner & Penn, 1999; Franz & Wiener, 2005) to education (Roberts, 2006; Erkan, 2020b) and from design fiction (Kirsh, 2013) to spatial cognition (Montello, 2014). Furthermore, Emo et al. (2016) addressed the importance of the trilogy of design, space, and behavior; they then stated that the space should be designed after considering behaviors and cognitive differences.

Investigation of in-space fictions will be able to reveal the behavioral states of people in spaces and enable examination of the cognitive effects of space on people. The effect of both interior design and its physical connection to the outdoor space is one of the primary design problems that arise in the early design phase (Erkan, 2020c). In this phase, while interiors are designed, windows are the primary element that combines both the interior and exterior.

One of the two most important features of windows is the view, whereas the other is its providing daylight (Matusiak & Klöckner, 2015). The proper use of daylight directly affects the quality of interior and user comfort. Moreover, disorders can be observed in the cognitive states of individuals in places with insufficient daylight (Celadyn, 2016). At the top of the criteria considered for determining the amount of natural lighting in spaces is wall window ratio. In the literature, the problem of optimizing window sizes in residential buildings has been extensively studied (Alexander, 1977; Matusiak, 2006; Tzempelikos & Athienitis, 2007; Mangkuto *et al.*, 2014; Elghamry & Hassan, 2020). Many studies were conducted over the requirement for reducing the energy spent on heating and cooling (Vanhoutteghem *et al.*, 2013; Kim *et al.*, 2016; Grygierek & Grygierek, 2017). Although there are different aspects investigated in these studies, no study on how window sizes affect the cognitive state of users was reported in the literature.

In this study, the effect of window sizes in residential buildings on spatial preferences of people is examined. Unlike cognitive and eye-tracking studies in architecture, this study examined the relationship between spatial decision-making and eye movements of participants and the effect of interior lighting due to differentiation of window sizes on cognitive interaction.

2. Theoretical Background

The use of tracking eye movements to investigate cognitive processes has been frequently used for four decades (Rayner, 1998). The eye tracking technique is used to measure eye movements in a certain time period and gazing direction (Naspetti *et al.*, 2016). Eye movements generally comprise saccades and fixations. While fixation can be defined as concentration of the eyes directly at some point, saccades are leaps between two fixations. A fixation period can be in the range of 100−500 ms; however, depending on the environment and action, duration of a saccade is in the range of 30−50 ms (Lai *et al.*, 2013). Eye movements are among fixations in the view area when the eye gazing at a stationary scene. In time periods where the eyes are focused are always fixations. Therefore, it is possible to identify the gazed areas on the stage (Weber *et al.*, 2002). Since the close relation between the eye movements and the cognitive processes are known, eye tracking technique has been used in multiple fields such as neurology, psychology, ophthalmology, marketing, and computer science (Duchowski, 2007; Naspetti *et al.*, 2016).

Eye-tracking studies often examined such as Gestalt principles in space (Weber *et al.*, 2002; Sangwon *et al.*, 2015), perception of space (Matusiak, 2006; Hermund *et al.*, 2018), facade design (Mohammadpour *et al.*, 2015; Erkan, 2017) in the disciplines of architecture and design. Also, there are studies on facade perception with 3M-Vas technology that simulates eye tracking technique (Sussman & Ward, 2019; Salingaros & Sussman, 2020).

2.1 Hypothesis

This paper rather is a biometric investigation of how room perception and desirability changes depending on window size and arrangement in day time. Searches for an answer to the ' How window sizes in the interior affect cognitive states in humans?'. Based on the results reported in the studies in the literature on eye tracking, architecture, window sizes and lighting, this study aims to investigate the following hypotheses:

- H.1: The reduction of the window size increases people's focusing on the interior.
- H.2: The level of natural lighting in the interior affects the spatial preferences of people.

3. Method

In this study, unlike conventional eye tracking studies, online eye tracking was conducted to people who were sent randomly over the Internet. Three interior models (only changing window size) suitable for everyday use was presented to participants in a digital environment and eye movements were tracked via a webcam. At the end of the study, a questionnaire was administered asking participants to specify their demographic characteristics and select the place they would like to be in.

3.1 Experimental Design

Three-dimensional (3D) models with three different window sizes were developed to examine the effect of natural lighting on people's spatial preferences through an eye-tracking technique. For interior models, a simple living space, suitable for everyday use, was taken as reference. For stimulants, one sofa, two chairs, one mirror, one glass, one carpet, one canvas, and three different types of coffee tables were installed. The locations were modelled with *SketchUp* and visualized with *Lumion*. Each of the interior models is 22 m^2 (4 m × 5.5m) and 2.7 m high.

In the one-window model, the window area is 1.3 m^2 (1 m × 1.3 m) and the distance to both side walls is 1.5 m.

In the two-window model, the window area is 2.6 m^2 (2 × 1 m × 1.3m), the distance between the two is 1 m and the distance to the side walls is 0.5 m.

In the three-window model, the window area is 3.9 m^2 (3 m × 1.3 m), and the distance to both side walls is 0.5 m.

Figure 1 shows the plans of the designed spaces.

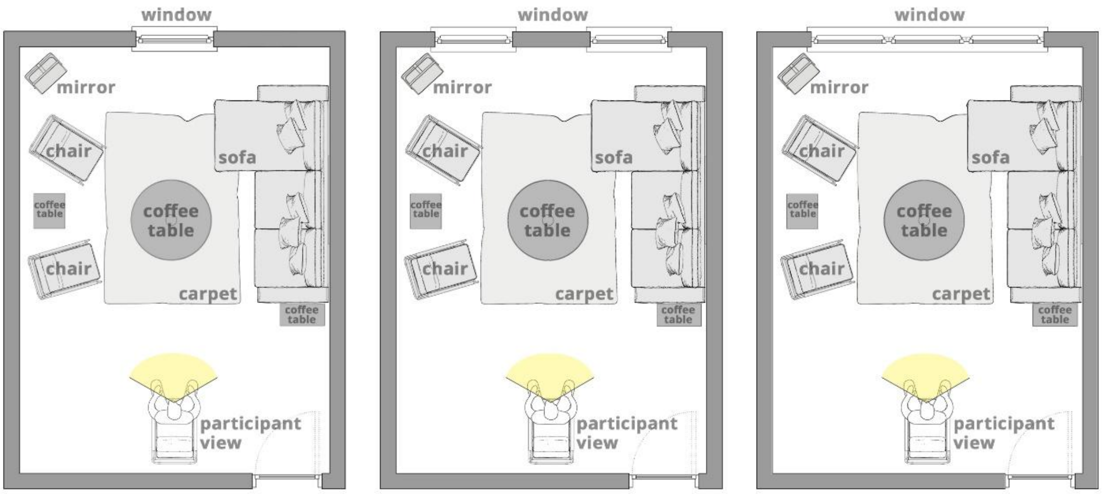

Figure 1. Plans of the spaces designed for the experiment and the location of the subjects (participants) in the space

The height of the windows from the floor in all models is selected as 0.9 m to ensure optimal daylight distribution and minimize the energy load of the building (Vanhoutteghem *et al.*, 2013; Kim *et al.*, 2016).

The Sun is the main light source acting on all three models. Since the use of co-source data was intended in the evaluation of results of the study, the solar angle was selected as fixed in Istanbul on December 21. The sun, which is the main light source, gives light to the spaces we designed from the south-east direction. To increase the visibility of interior objects, artificial lighting, along with the sun light, has also been added to the scene.

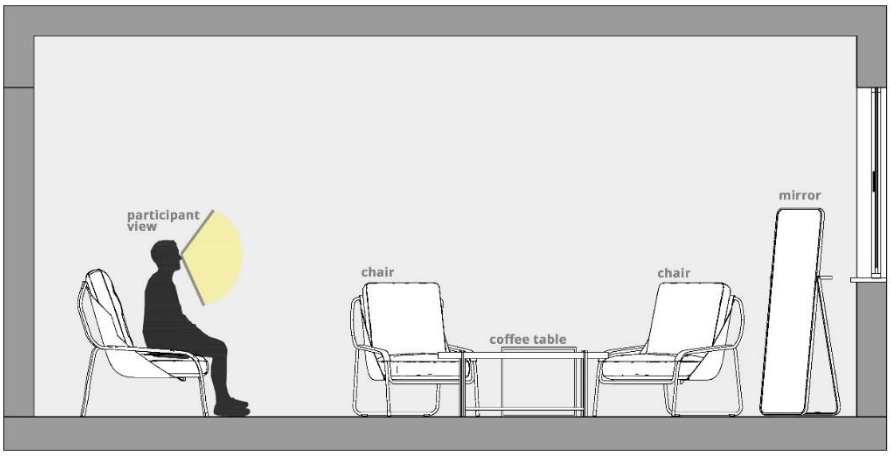

Figure 2. The cross-sectional view of the spaces used in the experiment and the location of the subjects in the space

At the visualization stage of the model, the viewing angle of an imaginary person sitting outside the scene is considered for reference. A scenario in which participants sit in a 40 cm high chair was created, and the view height adjusted to see the whole scene was set at 125 cm (40 cm + 85 cm) height from floor (Erkan, 2020) (Figure 2). The height of the bust is the distance between the surface on which the person sits in a non-stretched seat and the upper point of the head (Mendeş *et al.*, 2016). Güleç *et al.* (2009) reported in their study the average bust height of Turkish men as 88.7 cm and the average bust height of Turkish women as 82 cm. The average bust height for female and male participants was determined to be 85 cm.

3.2 Participants

A total of 32 people, 18 men (56.3%) and 14 women (43.8%), participated in the study. For correct calibration, participants were asked not to use glasses during the experiment and approved by all participants. The demographic characteristics of participants and their educational status are summarized in the table below.

Table 1. Demographic characteristics of people participated in the study

	Character	Number
Gender	Male	18
	Female	14
Age	18-30	4
	31-40	7
	41-50	9
	51-60	11
	61+	1
Profession	High School	0
	University	7
	Master Degree	18
	Phd	7

3.3 Procedure

In the models presented to the participants, it is only the window sizes that differ. Because parameters such as color, material, and size are known to affect cognitive performance (Weber *et al.*, 2002; Yildirim *et al.*, 2007), all other stimuli are the same. Change of the window size in all three models brings about the changes in natural lighting of the interior and in areas receiving direct sunlight. The primary purpose of the study is to examine the impact of this change on the spatial preferences of users.

When preparing a virtual environment, visuals are important to allow subjects to feel verisimilitude. Therefore, the visuals that were considered to be the most realistic among those presented to random users at the preliminary stage were selected for this experiment.

Figure 3 shows the simplified flow of the experiment.

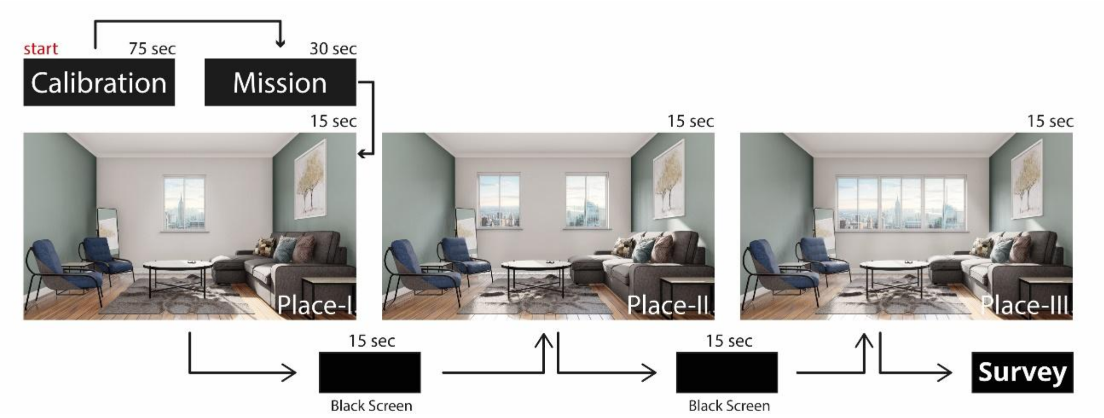

Figure 3. Flow scheme of the experiment

The *app.gazerecorder.com* infrastructure is used for the online study. Participants were given the necessary warnings before starting eye tracking and were asked to come to the appropriate sitting position. Participants were then instructed to provide the necessary lighting for the appearance of their face and, if possible, not to wear glasses.

The application was conducted in four stages. Participants completed a calibration stage of 75 s on an average at first. In the second stage, to ensure that the participants focus on the visuals, they were instructed to "imagine as though they were sitting in a seat and watching their surrounding" while examining the visuals. In the third stage, the visuals designed with three different window sizes were presented to participants in a random order for a period of 15 s each. Each of the images was in 3840 × 2160 resolution. (The effect of differences in the screen (monitor) size/resolution was ignored as it was shown to random users). A black screen was shown for a period of 15 s to make users aware of the change of visuals and to rest the eyes. In the fourth stage, users were redirected to *Google Survey* for filling out the demographic characteristics and for expressing the space they would like to be in. Eye tracking recorded all data except for the fourth stage. Participants managed to complete the task assigned to them. The entire application, except for the survey stage, took a total of 3 min.

4. Analyses

Heat-map analyses of three different spaces were performed in the study. Figure 4 shows the heat-maps of all three spaces.

The red regions in Figure 4 show a higher number of fixations and the green regions show a lower number of fixations. Heat map analysis calculates the pixel values of the areas occupied by all regions for each screen, i.e., in one-, two- and three-window spaces, red regions that indicate most gazed areas; yellow regions that indicate intermediate gazed areas; and green regions that indicate least gazed areas were identified. As for Figure 5, it shows the areas calculated as per the pixel numbers of three spaces.

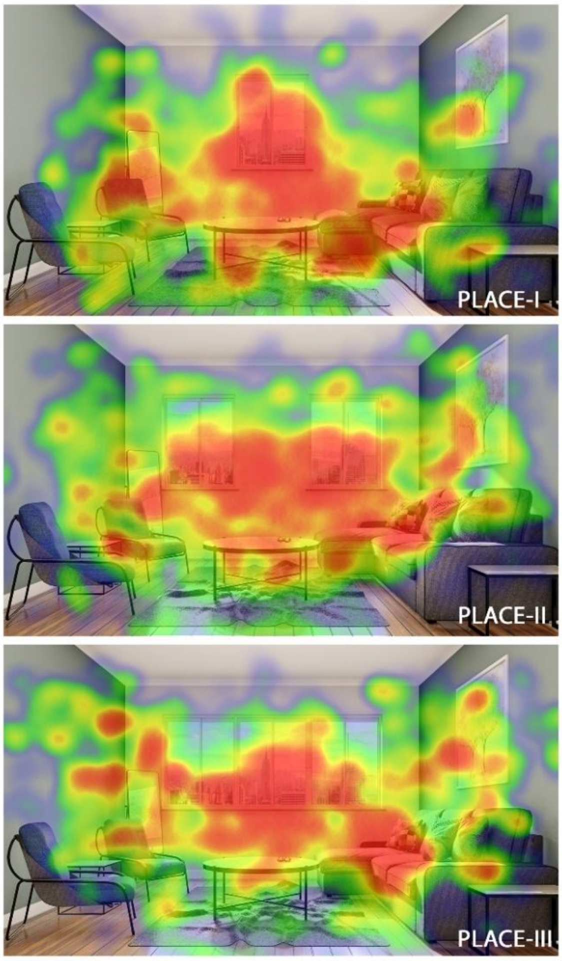

Figure 4. Heat-maps of all participants (created for 3 different spaces)

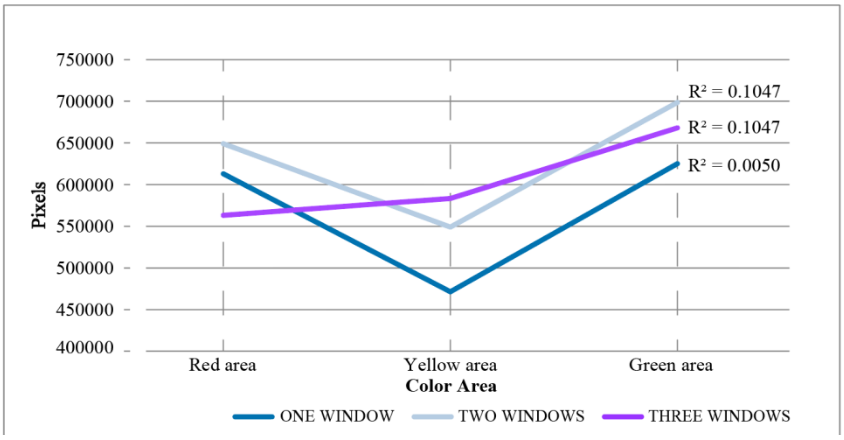

Figure 5. Areas calculated as per the number of pixels for three different spaces

Interestingly, as can be seen from Figure 5, although there is a difference between the color transitions of two- and three-window spaces, the R^2 values are equal. This indicates that pixel areas are very close to each other. Therefore, this suggests that the number of spatial fixations can be equal.

From the red, green, and yellow regions mentioned, in terms of how much time the focus was on the objects in the spaces was reported, the following formula is developed for this purpose:

$$Focus\ time = \frac{Pixel\ area(coloured) \times Experiment\ time}{Pixel\ area(total)}$$

In the formula, when calculating the focus time; pixel area is the area of the region for which the focus time is intended to be calculated, time is the total time for elapsed during the experiment, the total pixel area is the pixel area of the entire screen.

Moreover, it is the windows that change in three different spaces. However, gazing points are different for the spaces. These points are new light-receiving areas that come about with the change of window sizes in the spaces, i.e., when the one-window space is transformed into two-window, as a natural consequence, the areas occupied by the incident light beams change. From here, the selection of critical areas and furnishing were made. Therefore, the statistical analyses of the focus time, dwell time, and total regression number for these selected areas, which were determined as per the heat maps and red regions created based on the heat-map, are shown in Table 2. Independent sample t tests were implemented to examine whether there was a significant difference in viewing behaviors in three different locations between participant groups. Should a significant result be identified, Cohen's *d* impact size was calculated.

Table 2. Statistical analysis of different points in spaces

Selected Areas/Furnishing	Eye tracking measurement	Mean	SD	t	P (<0.05)	Cohen's d
Window-1	Focused time (Red)	**6.01**	**3.47**	**1.47**	**0.04**	**1.43**
	Dwell Time	**3.47**	**2.74**	**2.77**	**0.03**	**1.70**
	Total regression number	**8.87**	**7.77**	**2.11**	**0.15**	**-**
Window-2	Focused time (Red)	**6.99**	**3.78**	**1.77**	**0.07**	**1.66**
	Dwell Time	**4.32**	**2.89**	**2.65**	**0.06**	**1.66**
	Total regression number	**9.97**	**8.98**	**1.98**	**0.14**	**-**
Window-3	Focused time (Red)	**9.10**	**7.55**	**1.32**	**0.16**	**1.22**
	Dwell Time	**7.43**	**5.44**	**1.28**	**0.07**	**1.44**
	Total regression number	**10.44**	**8.66**	**1.77**	**1.55**	**1.90**
Sofa	Focused time (Red)	**8.55**	**7.66**	**1.55**	**0.11**	**1.96**
	Dwell Time	**7.77**	**6.77**	**1.11**	**0.06**	**-**
	Total regression number	**11.26**	**9.03**	**2.12**	**0.06**	**-**
Coffee-table	Focused time (Red)	**7.21**	**4.32**	**1.09**	**0.04**	**-**
	Dwell Time	**6.12**	**2.28**	**1.23**	**0.03**	**-**
	Total regression number	**4.12**	**2.14**	**1.20**	**0.05**	**-**
Ground	Focused time (Red)	**3.24**	**4.40**	**1.04**	**0.05**	**1.62**
	Dwell Time	**4.49**	**2.12**	**1.76**	**0.09**	**1.05**
	Total regression number	**6.60**	**3.40**	**1.23**	**1.87**	**-**
Picture	Focused time (Red)	**5.45**	**3.99**	**1.16**	**0.03**	**1.21**
	Dwell Time	**3.33**	**2.88**	**1.22**	**0.06**	**1.60**
	Total regression number	**5.44**	**3.99**	**1.88**	**1.49**	**-**

When examining individual spatial zones, statistically significant differentiation was reported. Note that this significant difference is particularly intensified on three-window space. However, it has been found that the sofa is gazed almost more than two-window and one-window spaces.

Furthermore, multiple comparisons have been made around the boundary line for statistical significance. Data suggest that, with regards to the gazing round the spaces, the participants, particularly by focusing on the three-window and the sofas, tend to pay more attention and make more mental effort to view through the entire space.

The lit areas of the spaces are separately created using *DIALux Evo*. The lighting maps of different parts of all the three spaces were simulated using lux values. For visualizing numerical data, the most lit areas are colored in red and orange, areas lit above average in yellow, areas lit on average are colored in light-green, and areas lit below the average are colored in blue and purple. Figure 6 shows the results of the lighting analysis. Furthermore, the cause for the statistically high regression value of sofa (t = 2.12; d = 1.96) was investigated.

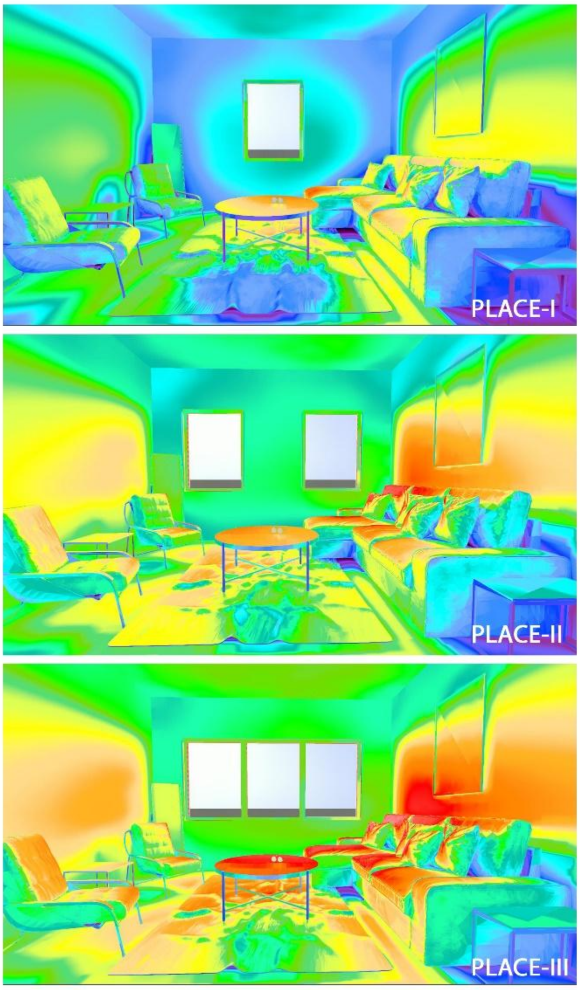

Figure 6. Lighting maps of three different spaces

As shown in Figure 6, the sofa in the image labeled Place-III is the most lit region. The more focus of participants on this most lit area is a result similar to the conclusion that more attraction can be drawn to more illuminated areas, made by Tscharn *et al.* (2016). The fact that the sofa, with a high regression value, being the most lit area and the image labeled Place-III being the most preferred by the participants is the evidence to support the H.2 hypothesis.

Eye tracking techniques can measure visual attention processes in terms of the number or duration of eye fixations on images. Eye tracking was used to measure primary attention to emotional images (Calvo & Lang, 2004) and videos (Teixeira, Wedel & Pieters, 2012).

In this study, the cognitive effects of changes in window sizes in the interior on people were examined using the eye-tracking analysis method. Participants showed more interest in the middle parts of the visuals, and there was no interest in non-stimulant regions. This supports the results of the study by Weber et al. (2002).

Fixation times spent by participants on each image and data from questionnaire were compared. Participants viewed the image Place-I at 55.22%, the image Place-II at 61.28%, and the image Place-III at 58.62%. However, in the space preferences in the questionnaire, Place II was the least preferred space with 3.10%, Place II was second preferred with 40.60%, and Place III was the most preferred with 56.30%. These data bring about two topics of discussion. The first is that image Place I being the least viewed of the spaces rejects the H.1 hypothesis (the reduction of the window size increases people's focusing on the interior). In the H.1 hypothesis, it was thought that as the window opening in the interior decreases, people will focus more on the elements of space." However, the results are that gazing of elements in a space that is not lit enough is decreased. However, by the fact that image Place-II, which has optimal lighting, is the most gazed visual, it can be concluded that the places provided the proper lighting have a positive effect on the cognitive state of people. This conclusion is similar to the conclusion that window size and natural light affect human experience in a designed space, made by Zou & Ergan (2019). The reason image Place III was less gazed than the image Place-II is attributed to the idea that it has slightly more light than the optimum.

The second topic of discussion is that the most viewed image is the second preferred image by participants. This result is similar to the conclusion in the LIGHT ON TWO SIDES OF EVERY ROOM (Pattern #159) Alexander *et al.* (1977) study that 'when given a choice, people tend to choose rooms with light on two side rather than rooms with light on one side'. The reason for this is considered to be the same as the reason expressed on the lighting map. The fact that space Place-III, which ranked second in the participants' gaze data, ranked first according to the questionnaire data, and since Place-III is the most lit space, supports H.2 hypothesis (the level of natural lighting in the interior affects the spatial preferences of people).

5. Result and Conclusion

Descriptive statistical data suggest that all participants spent much of the time focusing on windows and spent relatively more time gazing at areas. Because the images are randomly demonstrated to the participants, the fact that spaces that receive more light were preferred by the participants is amongst the important results of this study. Moreover, the proper design of the interior lighting level is reported to allow users to perceive the space in the best way.

The results of this study may contribute to the improvement of architectural design stages. Although the energy efficiency of a building is prioritized in the building design, the impact of window sizes on user experience should not be ignored. Since the study is sent to random participants, it is believed that the current climatic conditions do not prevent volunteers from choosing more lit spaces. That is, adjusting the window size, hence the amount of natural light in the living area, according to climatic conditions can negatively affect the cognitive states of users. Considering these results, it is proposed that the design of the window size that will provide optimal natural light for particular climatic zone be made at the design stage and parameters that will ensure energy efficiency be developed in different areas of the building. Furthermore, ensuring optimal daylight for the best perception of space can improve the space quality. This study was conducted in a living space suitable for everyday use and it is recommended to be examined in different spaces.

6. Limitations and Future Research

This study was conducted using remote eye-tracking technique. The most important limitation of the study is that the participants participated in the experiment in different environments. Therefore, the study can be improved and conducted in a virtual reality (VR) environment and in an experimental laboratory without different stimuli, in the future. Moreover, it is recommended to examine at different times of the day (night, afternoon) and under the influence of stimuli such as curtains and blinds. Furthermore, the visuals that constitute the foundation of the study were shown to the participants in 2D. It is therefore recommended to repeat the study using VR and 3D space design. The study can be attempted in a virtual reality environment. Thus, both the environment can be clearly perceived in three dimensions and different stimuli will be prevented from changing the cognitive state of subjects. In addition to this study, the physiological measuring equipment such as EEG and pulse measurement can be used, which performs the cognitive investigation of the space using eye-tracking technique. Perceptual situations can be examined by isovist integration analysis. All studies can be ensured to yield more objective results by increasing the number of participants.

References

Alexander, C., Ishikawa, S., Silverstein, M., Jacobson, M., Fiksdahl-King, I. and Angel, S. (1977). *A Pattern Language*, Oxford University Press, New York.

Calvo, M.G., & Lang, P.J. (2004). Gaze patterns when looking at emotional pictures: Motivationally biased attention. *Motivation and Emotion*, *28*(3), 221-243.

Celadyn, M. (2016). Daylighting in sustainable interior design of offices. *Architecture Civil Engineering Environment*, *9*(4), 5-12.

Colaço, C.A., & Acartürk, C. (2018). Visual behaviour during perception of architectural drawings: differences between architects and non-architects. In *International Conference on-Design Computing and Cognitio*n (pp. 381-397). Springer, Cham.

Duchowski, A.T. (2007). Eye tracking methodology. *Theory and Practice*, *328*(614), 2-3.

Elghamry, R., & Hassan, H. (2020). Impact of window parameters on the building envelope on the thermal comfort, energy consumption and cost and environment. *International Journal of Ventilation*, *19*(4), 233-259.

Emo, B., Al-Sayed, K., & Varoudis, T. (2016). Design, cognition & behaviour: usability in the built environment.

Erkan, I. (2017). Effects on the design of transport systems of pedestrian dynamics. *Higway Engineering*, 17-33.

Erkan, İ. (2020a). Cognitive response and how it is affected by changes in temperature. *Building Research & Information*, 1-18.

Erkan, İ. (2020b). A system proposal for rapid detecting of anthropometric data and affecting design strategies. *Journal of Engineering, Design and Technology*.

Erkan, İ. (2020c). Early Design Stage Analysis with Brain Imaging Method. *Interaction Design and Architecture(s) Journal - IxD&A*, 44, 53 – 70.

Ferdyn-Grygierek, J., & Grygierek, K. (2017). Optimization of window size design for detached house using TRNSYS simulations and genetic algorithm. *Archit. Civ. Eng. Environ.*, 10, 133-140.

Franco-Watkins, A.M., & Johnson, J.G. (2011). Decision Moving Window: Using İnteractive Eye Tracking to Examine Decision Processes. *Behavior Research Methods, 43*(3), 853–863.

Franz, G., & Wiener, J. M. (2005, June). Exploring isovist-based correlates of spatial behavior and experience. In *5th International Space Syntax Symposium* (pp. 503-517). Techne Press.

Güleç, E., Galip, A., Sağır, M., Başak, K., Gültekin, T., Bektaş, Y. (2017). Anthropometric Dimensions of Anatolian People: Results of 2005 Turkish Anthropometric Survey. *Ankara Üniversitesi Dil ve Tarih-Coğrafya Fakültesi Dergisi, 49*(2), 187-201 (In Turkish).

Gidlöf, K., Wallin, A., Dewhurst, R., & Holmqvist, K. (2013). Using eye tracking to trace a cognitive process: Gaze behaviour during decision making in a natural environment, *Journal of Eye Movement Research, 6*(1). https://doi.org/10.16910/jemr.6.1.3

Hermund, A., Klint, L., & Bundgård, T. S. (2018). The perception of architectural space in reality, in virtual reality, and through plan and section drawings: a case study of the perception of architectural atmosphere. *Computing for a Better Tomorrow*, 735-744.

Kim, S., Zadeh, P.A., Staub-French, S., Froese, T., & Cavka, B.T. (2016). Assessment of the Impact of Window Size, Position and Orientation on Building Energy Load Using BIM. *Procedia Engineering*, 145, 1424–1431.

Kirsh, D. (2013). Embodied cognition and the magical future of interaction design. *ACM Transactions on Computer-Human Interaction (TOCHI), 20*(1), 1-30.

Lai, M.L., Tsai, M.J., Yang, F.Y., Hsu, C.Y., Liu, T.C., Lee, S.W.Y., ... & Tsai, C.C. (2013). A review of using eye-tracking technology in exploring learning from 2000 to 2012. *Educational Research Review*, 10, 90-115.

Lee, S., Cinn, E., Yan, J., & Jung, J. (2015). Using An Eye Tracker To Study Three-Dimensional Environmental Aesthetics: The Impact Of Architectural Elements And Educatıonal Training On Viewers'visual Attention. *Journal of architectural and Planning Research*, *32*(2), 145-167.

Mangkuto, R.A., Wang, S., Aries, M.B.C., Van Loenen, E.J., & Hensen, J.L.M. (2014). Comparison between lighting performance of a virtual natural lighting solutions prototype and a real window based on computer simulation. *Frontiers of Architectural Research*, *3*(4), 398-412.

Matusiak, B. (2006). The Impact of Window Form on the Size Impression of the Room—Full-Scale Studies. *Architectural Science Review*, *49*(1), 43–51.

Matusiak, B.S., & Klöckner, C.A. (2015). How We Evaluate The View Out Through The Window. *Architectural Science Review*, *59*(3), 203–211.

Mendeş, B., Mendeş, E., & Ayhan, T. The Effect of Bust Height on Some Selected Physical and Physiological Parameters in Footballers and Sedentaries. *Gaziantep Üniversitesi Spor Bilimleri Dergisi*, *1*(1), 57-68 (In Turkish).

Montello, D.R. (2014). Spatial cognition and architectural space: Research perspectives. *Architectural Design*, *84*(5), 74-79.

Mohammadpour, A., Karan, E., Asadi, S., & Rothrock, L. (2015). Measuring end-user satisfaction in the design of building projects using eye-tracking technology. In *Computing in Civil Engineering* 2015 (pp. 564-571).

Naspetti, S., Pierdicca, R., Mandolesi, S., Paolanti, M., Frontoni, E., & Zanoli, R. (2016, June). Automatic analysis of eye-tracking data for augmented reality applications: A prospective outlook. In *International Conference on Augmented Reality, Virtual Reality and Computer Graphics* (pp. 217-230). Springer, Cham.

Rayner, K. (1998). Eye movements in reading and information processing: 20 years of research. *Psychological bulletin, 124*(3), 372.

Roberts, A. (2006). Cognitive styles and student progression in architectural design education. *Design Studies, 27*(2), 167-181.

Salingaros, N.A., & Sussman, A. (2020). Biometric Pilot-Studies Reveal the Arrangement and Shape of Windows on a Traditional Façade to be Implicitly "Engaging", Whereas Contemporary Façades are Not. *Urban Science, 4*(2), 26.

Sussman, A., & Ward, J. (2019). EYE-TRACKING Boston City Hall To Better Understand Human Perception And The Architectural Experience. *New Design Ideas, 3*(1), 53-59.

Teixeira, T., Wedel, M., & Pieters, R. (2012). Emotion-induced engagement in internet video advertisements. *Journal of Marketing Research, 49*(2), 144-159.

Turner, A., & Penn, A. (1999, March). Making isovists syntactic: isovist integration analysis. In 2nd International Symposium on Space Syntax, Brasilia.

Tscharn, R., Ly-Tung, N., Löffler, D., & Hurtienne, J. (2016, September). Ambient light as spatial attention guidance in indoor environments. In *Proceedings of the 2016 ACM international joint conference on pervasive and ubiquitous computing*: adjunct (pp. 1627-1630).

Tzempelikos, A., & Athienitis, A. K. (2007). The impact of shading design and control on building cooling and lighting demand. *Solar Energy, 81*(3), 369-382.

Vanhoutteghem, L., Skarning, G. C. J., Hviid, C. A., & Svendsen, S. (2015). Impact of façade window design on energy, daylighting and thermal comfort in nearly zero-energy houses. *Energy and Buildings*, 102, 149–156.

Wang, Y., & Ruhe, G. (2007). The cognitive process of decision making. *International Journal of Cognitive Informatics and Natural Intelligence (IJCINI),* 1(2), 73-85.

Weber, R., Choi, Y., & Stark, L. (2002). The impact of formal properties on eye movement during the perception of architecture. *Journal of Architectural and Planning Research*, 57-69.

Wedel, M., & Pieters, R. (2008). A review of eye-tracking research in marketing. *Review of Marketing Research, 4*(2008), 123-147.

Yildirim, K., Akalin-Baskaya, A., & Hidayetoglu, M.L. (2007). Effects of indoor color on mood and cognitive performance. *Building and Environment, 42*(9), 3233-3240.

Zou, Z., & Ergan, S. (2019). Where do we look? An eye-tracking study of architectural features in building design. In *Advances in Informatics and Computing in Civil and Construction Engineering* (pp. 439-446). Springer, Cham.