Light & Engineering
Vol. 28, No. 2, pp. 28–37, 2020

https://doi.org/10.33383/2019–052
Svetotekhnika #6, 2019, pp.58–66

USER LIGHTING PREFERENCES BASED ON NAVIGATION AND SPACE QUALITY IN VIRTUAL EXHIBITION ENVIRONMENTS

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ABSTRACT

Just as any other interior environment, lighting of exhibition spaces must be examined to enhance its visual quality and comfort. In this study, user behaviour, perception and impressions are analyzed for more comprehensive understanding by including subjective reasoning. Due to the chaotic progress and contradictory choices in exhibition lighting, daylight is mostly avoided while the role of users and relation between quantitative and qualitative parameters are often neglected. A series of sample exhibition spaces illuminated either artificially or by daylight are modelled virtually in Lumion software to be evaluated in a three-step questionnaire. A total of 90 participants are selected from three different professions (architects, visitors, artists), their reaction like movement, preference and impressions are gathered via questionnaire while moving through the model. The study aims to find out the role of lighting type in exhibition navigation and its relation with non-lighting parameters using statistical analysis methods. Results show that natural light is preferred more in sculpture exhibition while artificial light is preferred in painting exhibition. Movement towards daylight increases in transition areas and towards the end of the exhibition. A significant difference in navigation choices are found between professions, architects preferred to move towards more natural light while artists preferred artificial light.

Keywords: museum and gallery lighting, exhibition, navigation, artificial light, daylight

1. INTRODUCTION

Exhibiting is possible with light. A complex combination of various quantitative and qualitative aspects should be regarded in lighting design for exhibition spaces. Lighting choices heavily influence the whole experience by altering display quality, atmosphere and the perception of displayed objects. Space and object characteristics also have an impact on lighting strategy and perception [1]. This makes every exhibition lighting design a unique work. In addition, importance of lighting factors changes in each work. Due to the uniqueness, a chaotic approach is commonly acknowledged among many galleries and museums' staff [2]. Although, fundamental choices of this approach can be traced by understanding lighting choices of the staff and their relation between mentioned aspects like exhibition type and light source.

Exhibiting is a collaborative process though priorities and intentions of lighting choices may change between different professions. For conservation-based jobs, preservation is the primary concern while indoor space quality is for architects and artistic expression is for the artists [2, 3]. A consensus has to be made to balance these concerns among different professions by following guidelines and principles. Although there are some guidelines, lighting designers or curators set their own principles and style over time by using trial and error method in practice [4,5]. This causes miscommunication which is considered as an impairing problem among associated professions. Even the target, visitor's perception and expectations are also ignored which

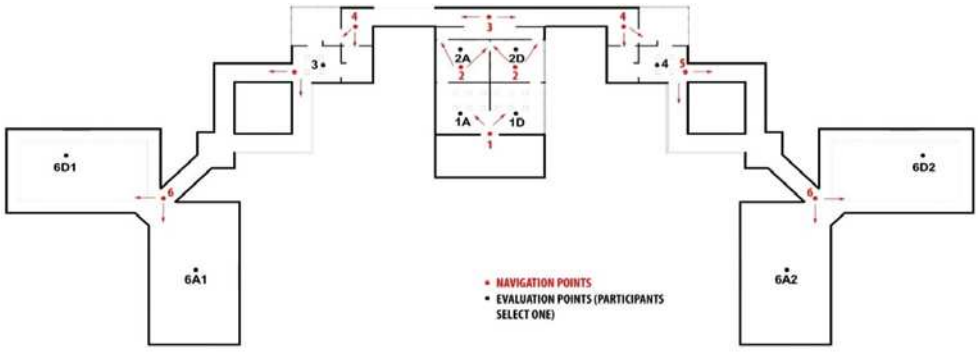

Fig.1. Plan of the exhibition space

can be useful to design more interactive and relatable lighting design. Additionally, the amount of undocumented knowledge increases which are needed for the understanding and the development of lighting design in exhibition [2].

Daylight is another ongoing controversial topic. Daylight is avoided, mainly because of preservation concerns such as amount of UV radiation. While the degree of deteriorating effects may vary with the material type, sunlight damages material regardless. As for visual comfort and quality, direct daylight and glare are not approved in any condition. Daylight controlling is considered as too much work and risk due to its dynamic behaviour and amount [6, 7]. On the other hand, avoidance of daylight in exhibition areas isn't a negligible matter since improvements in energy efficiency are expected regardless of building type. Despite the negative and unresponsive attitude in the field, there are many studies on the advantages of daylight in terms of visual quality, visitor satisfaction and sustainability with various proposals of design solutions [8]. Besides, the form of exhibition space and every exhibition type reacts with light differently and strengths of daylight must be detected under different conditions.

Psychological effect of light is needed to be examined especially in exhibition navigation. Illuminated area attracts attention and people tend to move towards it [9]. Most of the time, visitors determine a single direction route to tour exhibition area effectively though light can be used to monitor movement impulsively. Although there is no comprehensive research about it, studies about retail lighting can be referenced [10]. Similar to retail lighting, exhibitions have focus and relief points in order to not exhaust visitors with constant attention. Therefore, lighting shouldn't be monotonous and constantly dense. Dividing exhibition into parts with transition areas like foyers, corridors and circulation areas which lit differently is a common way to achieve it [1, 8]. Daylight can be useful to break the maze effect and to guide the visitor. Characteristics of daylight, visual connection to surroundings and revelation of form can create the in-and-out dynamism [11]. Relation between different light zones should be planned carefully. Mainly focusing on the mentioned aspects above, the aim of this study is to understand lighting choices in exhibitions from multiple points of views. The impact of lighting type and many other exhibition parameters like space and type on user preference are examined.

2. METHOD

2.1. Virtual Model

A series of virtual exhibition rooms are needed to figure out effecting conditions in participant's lighting preference by their orientation in exhibition. A model was prepared in ArchiCAD software (Fig. 1). Exhibition spaces were planned to generate 6 steps of exhibition types (evaluation points in black: 1A, 1D, 2A, 2D, 3, 4, 6A, 6D) and transition zones. Transition areas like corridors were used to locate navigation points (in red: 1, 2, 3, 4, 5, 6), where participants choose one room to continue with. Except the type of the light source, identical exhibition spaces were placed next to each other as a choice to see distinctive results in each step.

After designing process, the model was imported into real-time visualization software Lumion 6.0 to navigate through the model. Sculptures and paintings were added into the model also in this process. Spotlights were mounted to illuminate determined areas (labelled with "A") artificially while clear sunlight was adjusted in daylight areas (labelled with "D"). In exhibition space 6D, ceiling material was illuminated to generate skylight effect. All spot-

Table 1. Classification of the Evaluated Rooms

Exhibition Spaces	Space Dimensions	Exhibition Type	Light Source
1A	Medium	Sculpture	Artificial
1D			Daylight
2A		Painting	Artificial
2D			Daylight
3	Small	Sculpture	Both
4			
6A	Large	Both	Artificial
6D			Daylight

lights had the same colour temperature, brightness and beam angle (Table 1, Fig.2).

2.2. Questionnaire

A three-step questionnaire was prepared. In the first step, participants are navigated regarding which way they would like to continue (Fig.3). On these 6 navigation points, they are asked to move towards either day or artificially lit of the same exhibition area by stating their choice as "right" or "left". After that, the questionnaire data was entered as choices 1 and 2 for artificial and natural light respectively.

In the second step, participants select their favourite exhibition space and answer Likert scale questions based on 11 criteria for this area, giving values between 1 and 5 (Fig. 4). In the first Likert-scale question, recognition of light source is asked to see the visual fidelity of the Lumion software. In the questions between 2 and 9, participants are asked to evaluate both displaying and the space of the exhibition. Since human perception is deceiving when evaluating colour temperature [6], question 10 was put deliberately to find a relation between room and light parameters on colour temperature perception. Question 11 is put to measure the level of preference of evaluated spaces. In the final step, participants asked to pick 3 important questions to assess lighting from the second step (questions 1–11).

A total of 90 people around Izmir participated in the questionnaire. Three main occupation groups were determined as participants: 30 architects (including architecture students), 30 artists (sculptors, painters and curators) and 30 visitors (other occupations). Participants were divided into these groups to understand priorities and reasoning in lighting preference in each group. Since the progress of questionnaire is highly individual and interactive due to the choices and controlling of the virtual environment; participants joined the questionnaire one-by-one. Questionnaire has been done within 3-month period; lighting conditions of the questionnaire environment are included as variables along with personal information and possible visual im-

Fig.2. Evaluated Exhibition's Spaces

Fig. 3. A view from navigation points

Navigation Points		1	2	3	4	5	6
RIGHT		□	□	□	□	□	□
LEFT		□	□	□	□	□	□
Selected Exhibition Area: ____		1	2	3	4	5	
Lighting Type	1-natural	□	□	□	□	□	artificial
Displaying of the pieces	2-desegregated	□	□	□	□	□	integrated
Quality of the space	3-distinct	□	□	□	□	□	vague
	4-dim	□	□	□	□	□	bright
	5-dull	□	□	□	□	□	catchy
	6-tense	□	□	□	□	□	relax
	7-harsh	□	□	□	□	□	soft
	8-discomfort	□	□	□	□	□	comfort
	9-imbalanced	□	□	□	□	□	uniform
10-How pleasant is colour temperature? (circle the option)		Too warm □	Warm □	Fine □	Cold □	Too Cold □	
11- Overall visual quality of the space?		Very Bad □	Bad □	Fine □	Good □	Very Good □	

Fig.4. Questionnaire step 1 and 2

pairments. 59 women and 31 men participated while 33 % of them are between the ages 17–25, 37 % are between the ages 26–35 and 30 % are between the ages 36 and 75.

2.3. Statistical Analysis

OLS (ordinary least square), ANOVA, T-test and linear regression methods are used to analyze the gathered data (Fig.5). For the first part of the questionnaire, ANOVA is used to find whether there is a meaningful relation between light source type and navigation choices. In the following, the choices of the three occupation groups are analyzed separately.

The second part of the questionnaire is analyzed in two different methods and their results are compared. For T-test, five pairs are formed to simplify the differences of these spaces as one. OLS method is used to figure out the relevance of determined criteria in different exhibition conditions. Each criterion's relevance is analyzed in evaluated rooms (Table 1) excluding the results of exhibition spaces of 3 and 4 in order to use OLS method correctly. The relevance of each criterion is analyzed in dual comparisons of the rooms via T-test. Similar results in other analyses are mentioned in Discussion and Conclusion section.

Table 2. Means and Standard Deviations of Each Step in Exhibition Spaces and ANOVA Result (P-value)

Steps	1		2		3		4		5		6		ANOVA
Choices	M	S	M	S	M	S	M	S	M	S	M	S	P-Value
All groups	1.49	0.50	1.44	0.50	1.64	0.48	1.56	0.50	1.70	0.46	1.57	0.50	0.005*
Architects	1.50	0.51	1.43	0.50	1.67	0.48	1.67	0.48	1.73	0.45	1.57	0.50	0.15
Visitors	1.57	0.50	1.50	0.51	1.70	0.47	1.53	0.51	1.77	0.43	1.57	0.50	0.238
Artists	1.40	0.50	1.40	0.50	1.57	0.50	1.47	0.51	1.60	0.50	1.57	0.50	0.448

3. RESULTS

3.1. Navigation

Difference in navigation choices are observed in each step (Table 2 and Fig. 4). In Fig. 4, four means (all groups, architects, visitors, artists) of navigation choices are shown vertically. Movement towards daylight in means increase upwards while movement towards artificial light increases downwards. In Table 2, if mean value is closer to 1, artificial light tendency is more while from number 1.5 towards 2, natural light tendency increases. Participants preferred to move towards artificial light with 51 %, 56 %, 36 %, 44 %, 30 %, and 43 % respectively in 6 steps. In analysis of variance for all participants, there is a significant difference of light choices in each navigation point (p=0,005). When it's analyzed separately, occupation groups tend to prefer a single lighting type. Except point 2, architects preferred day lit areas. Visitors moved towards daylight in all points. On the contrary, artists moved towards artificial light except point 6 while movement towards daylight in transition areas is also lower in this group.

Although there are differences in preferring light source in exhibitions rooms (steps 1, 2, 4 and 6), participants distinctively preferred daylight in transition areas (3 and 5). Results indicate that, participants are almost divided into half in first steps.

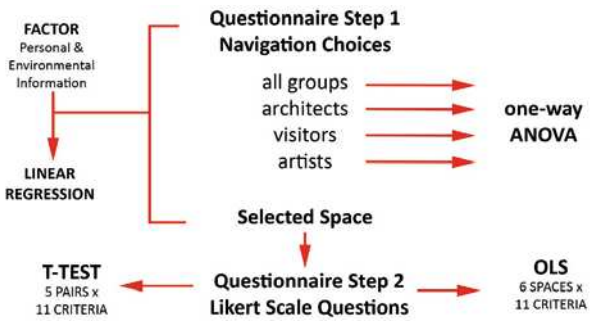

Fig.5. Statistical analysis diagram

Non-lighting factors like space and display positioning should be noted. Additionally, some participants stated that they kept certain orientation (right or left) when touring exhibitions to see everything. Regardless of all these, the tendency to move towards daylight increases when approaching the end of the exhibition. This can be interpreted as the fatigue by focusing exhibited objects or the different opening type in 6D space. Artificial light is mostly used to abstract the space around the displayed object to attract the visitor which consumes the visitor's focus after a while [1,12]. Focusing has to be relieved to keep the attention. When the orientation is examined room by room, results show noticeable differences in exhibition types (Table 2). Participants tend to move towards artificially lit room more when the pieces are paintings rather than sculpture (steps 1 and 2).

3.2. Selected Spaces, Significant Factors and Importance of Questions

Results show that, participant's most selected space is 6D with 29 %, other spaces are shown in Table 1. The main difference of this space from other spaces is that the opening type which is skylight. The second most selected place is 2D which is again another day lit space. This contradicts the relations between daylight – sculpture and artificial light – painting in other results. On the other hand, selection alone isn't enough to understand preference, catchiness must be eliminated. To integrate "selection" and level of "preference", selection percentages are compared with the ratings to questions 11 (Table 4). Even though, its selection percentage is 11 %, 6A is the highest rated space (Fig.7).

Linear regression model is applied to understand the impact of all variables in all selection-based answers like navigation. Personal information and environmental variables are entered as numbers for factors. For example, three age groups are deter-

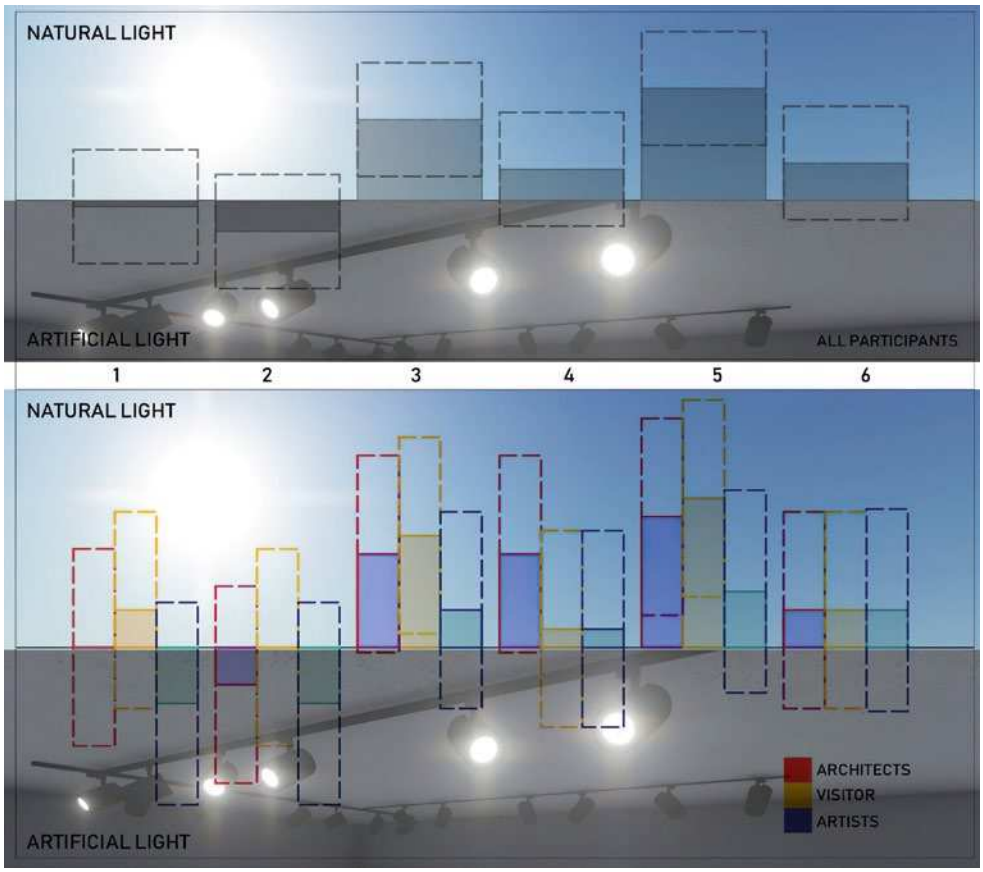

Fig.6. Lighting preference in each navigation point

mined and labelled as 1, 2 and 3. Results show that, age is a determining factor in the first navigation choice, moving towards either 1A or 2A. On the second and third navigation choices, gender is important. As needed, environmental or visual factors don't have significant impact on choices.

At the end of the questionnaire, participants are asked to pick three important criteria/questions to understand their awareness on the role and impact of lighting. As the most important criterion in lighting, the light source type (artificial/natural) (1) was picked 47 times while brightness (4) and colour temperature (10) are picked 35 and 36 times respectively. Relaxing (6), visual quality (11), uniformity (9) and comfort (8) are picked 26, 28, 24 and 20 times respectively. The least picked criteria are listed as integration (2) with 15 times, vagueness (3) with 10 times, catchiness (5) with 14 times and softness (7) with 15 times.

3.3. Dual Comparisons of the Spaces (T-test)

To understand and detect the impact of the space and exhibition factors, dual comparisons are made by using T-test. For analysis, five paired spaces are determined with the responses given to 11 different criteria. These spaces are paired deliberately to have single difference such as light source type or exhibition type, while rest of them stayed identical. Significance values in the Table 3 are analyzed with the mean values in Table 4. For the change in light source, 1A-1D, 2A-2D, 6A and 6D pairs are made while 1A-2A and 1D-2D pairs are made for the change in exhibition type.

In pair 1A-1D, same sculptures are exhibited. In the T-test, four questions showed significant results. In question 1, software's visual fidelity is tested to be successful as the distinction of light source is easily addressed by the participants with significance value of 0.0013. As for the harsh-

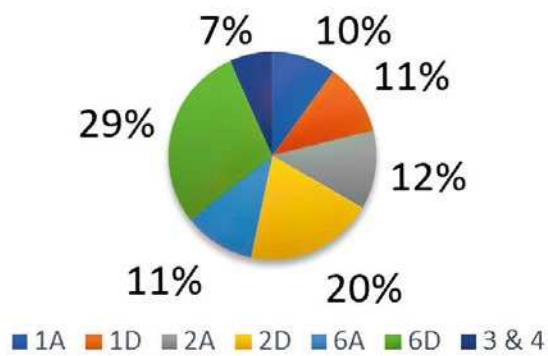

Fig.7. Percentage of Selected Space

Table 3. T-test Results for Pair of Spaces

SPACE PAIRS / CRITERIA	1	2	3	4	5
	1A-1D	2A-2D	1A-2A	1D-2D	6A-6D
1 – Natural / Artificial	0.0013	0.0001	0.1872	0.1375	0.0001
2 – Desegregated / Integrated	0.4841	0.0155	0.2378	**0.0888**	0.0020
3 – Vague / Distinct	0.1518	0.0489	0.4079	0.3305	0.4648
4 – Dim/ Bright	0.4445	0.0925	0.2672	**0.0492**	0.4738
5 – Dull / Catchy	0.3676	0.3484	0.3169	0.3551	0.2660
6 – Tense / Relax	0.1194	0.2781	**0.0170**	0.0391	0.1062
7 – Harsh/ Soft	0.0142	0.4580	0.0019	0.1904	0.3102
8 – Discomfort / Comfort	0.0426	0.3078	0.0040	0.0806	0.1885
9 – Imbalanced / Uniform	0.3488	0.3432	0.0865	0.2246	0.2079
10 – Color of Light	0.1136	0.0555	0.2930	0.3115	0.4907
11 – Visual Quality	0.0398	0.4055	**0.0531**	0.2836	0.1491

ness-softness scale in question 7, day lit exhibition is significantly found softer (p=0.0142). Spotlights create coarser shadows when compared to daylight on 3D objects. Linked to the question 7, day lit exhibition is found visually more comfortable (p=0.0426). Less contrast and soft shadows are perceived more comfortable as found in many other studies. Lastly, day lit sculpture exhibition is rated 0.7 point higher in terms of visual quality, preference (p=0.0398).

Same painting exhibition with different light sources are examined in pair 2A-2D. Five questions show significant results in the T-test. Just like in pair 1, participants addressed the light source successfully (p=0.0001). Artificially lit painting space is perceived more integrated (p= 0.0155). Balanced contrast areas are achieved with spotlights. Equally highlighting paintings abstracts the rest of the space which is perceived as a visual rhythm. Supporting the results of question 3, artificially lit painting space is found more distinct which again can be explained as the spotlights create more focusing points (p=0.0489). Despite of the similar illuminance levels with pair 1, day lit painting space is perceived brighter in pair 2 (p=0.0925). Lastly, artificially lit space is found significantly colder in terms of light colour (p=0.0555).

In the third pairing, sculpture exhibition 1A and painting exhibition 2A which are both illuminated by artificial lighting are compared. Five questions show significant results. The meaningful difference on light source type is not found since both spaces have the same lighting type. Painting exhibition is perceived 1.20 point more relaxing compared to sculpture exhibition (p=0.0170). Same significant difference is found in the comparison (1D and 2D) of same spaces in daylight. Regardless of light type, proportion of exhibited object in a space is the determining factor for this criterion. Paralleling to this, painting exhibition is found softer (p=0.0019) and visually more comfortable (p=0.0040). Shadows in artificially illuminated sculpture exhibition is coarser compared to same day lit space or painting exhibition, just like in the pair 1A and 1D. Additionally, painting exhibition is perceived more balanced (p=0.0865). In these four criteria, painting exhibition is rated "positive" and lastly higher in visual quality (p=0.0531).

In the fourth pairing, sculpture exhibition 1D and painting exhibition 2D which are both illuminated by daylight are compared. Sculpture exhibition is found more integrated (p=0.0888). Different from painting exhibition, shadows in sculpture exhibition form a composition. In question 4, painting exhibition is perceived brighter despite having the same illuminance level (p=0.0492). Painting exhibition enables light to radiate more with less shadow. Related to this, painting exhibition is found

Table 4. Mean and Standard Deviation Values for Spaces of Each Between 1–5 Criterions

SPACES /CRITERIA		1A	1D	2A	2D	3&4	6A	6D
1 –Natural / Artificial	Mean	4.00	1.90	3.45	1.44	2.50	4.10	2.19
	Std. Dev.	1.41	1.10	1.21	0.86	0.84	1.10	1.23
2 –Desegregated / Integrated	Mean	3.78	3.80	4.18	3.22	3.67	4.60	3.46
	Std. Dev.	1.39	0.92	0.98	1.26	1.03	0.70	1.50
3 –Vague / Distinct	Mean	4.67	4.30	4.73	4.11	3.50	4.00	4.04
	Std. Dev.	0.50	0.95	0.65	1.28	1.05	1.15	1.15
4 – Dim/ Bright	Mean	3.67	3.60	3.91	4.33	3.67	3.60	3.58
	Std. Dev.	0.87	1.17	0.83	0.77	1.21	0.84	1.14
5 –Dull / Catchy	Mean	3.56	3.70	3.73	3.83	4.00	4.10	3.85
	Std. Dev.	0.88	0.95	0.65	0.79	0.89	0.99	1.26
6 – Tense / Relax	Mean	2.78	3.50	4.09	4.33	3.00	2.80	2.23
	Std. Dev.	1.30	1.27	1.22	0.69	1.67	1.14	1.31
7 – Harsh/ Soft	Mean	2.11	3.40	3.82	3.78	3.33	2.90	3.08
	Std. Dev.	1.17	1.17	1.08	0.81	1.03	0.74	1.35
8 –Discomfort / Comfort	Mean	3.44	4.20	4.55	4.67	3.17	4.20	3.77
	Std. Dev.	0.88	0.92	0.69	0.49	1.33	1.32	1.14
9 –Imbalanced / Uniform	Mean	3.78	4.00	4.45	4.33	3.17	4.10	3.69
	Std. Dev.	1.20	1.25	0.82	0.69	1.17	1.37	1.12
10 – Colour of Light	Mean	3.22	2.70	3.00	2.56	2.83	3.30	3.31
	Std. Dev.	0.97	0.82	0.77	0.51	0.75	0.95	0.62
11 – Visual Quality	Mean	3.33	4.10	4.00	3.94	3.33	4.20	3.81
	Std. Dev.	1.00	0.74	0.63	0.54	0.82	1.03	0.80

more relaxing (p=0.0391) and visually comfortable (p=0.0806).

Finally, identical exhibition spaces 6A and 6D which have different light source are compared. In question 1, visual accuracy of the software is again found successful since the light types are different (p=0.0001). Artificially illuminated space is perceived more integrated (p=0.0020). It can be interpreted with the rhythm formed by focal lighting and the shadows.

3.4. Analysis of Impressions on Spaces (OLS)

Apart from T-test, the relation of exhibition space parameters and criteria/questions are analyzed with OLS (Table 5). Third criterion, vague-distinct, is found significant in artificially illuminated spaces 1A and 2A. In exhibition space 6A, this criterion isn't significant because both exhibition types are included and the space gets bigger. Painting exhibitions 2A and 2D are found significantly relaxing when compared to other spaces. Day lit 2D space is found even more relaxing. There is a significant relation between harshness criteria and exhibition space 1A since the space is both artificially illuminated and sculptures are exhibited which cause coarser shadows. Same criteria are found equally significant in painting exhibition illuminated by both artificial light and daylight (2A and 2D). Except the spaces 1A and 6D, comfort criteria are found relative in all spaces. Paralleling with the relaxing criteria, painting exhibitions 2A and 2D are perceived visually comforting. Daylight is perceived more comforting in sculpture exhibition significantly while in other exhibition spaces too. Uniformity criterion is found significant in painting exhibitions. Artificial light is found more balanced due to focal lighting. Lastly, 6A is significantly rat-

Table 5. OLS Results Showing Significant Dependence between Exhibition Space and Criteria

	1A	1D	2A	2D	6A	6D
2 – Desegregated / Integrated	0.865	0.835	0.413	0.446	0.146	0.714
3 – Vague / Distinct	0.039	0.146	0.025	0.223	0.362	0.263
4 – Dim/ Bright	1.000	0.897	0.631	0.157	0.897	0.842
5 – Dull / Catchy	0.397	0.559	0.589	0.722	0.845	0.732
6 – Tense / Relax	0.726	0.421	0.077	0.021	0.747	0.160
7 – Harsh/ Soft	0.040	0.908	0.391	0.398	0.345	0.611
8 – Discomfort / Comfort	0.592	0.044	0.007	0.002	0.044	0.177
9 – Imbalanced / Uniform	0.283	0.136	0.020	0.024	0.096	0.283
10 – Color of Light	0.317	0.725	0.655	0.424	0.221	0.157
11 – Visual Quality	1.000	0.061	0.097	0.101	0.035	0.184

ed the highest. Following, daylight in sculpture exhibition and artificial light in painting exhibition are significantly found successful.

4. DISCUSSION AND CONCLUSION

In this study, a questionnaire is applied to understand the relation between space, exhibition and user parameters in exhibition lighting. Virtual model is used to find out the effect of light type in navigation. Since exhibiting involves multiple disciplines, participants are selected equally from architects, visitors and artists to see difference in preference. Answers to the questionnaire are analyzed with multiple methods. Similar results are found from different methods.

In navigation, daylight is preferred in transition zones. Similarly, tendency to move towards daylight increases when approaching to the end of exhibition. There are different navigation choices in occupation groups. Architects preferred more daylight while artists preferred artificial light. Day lit exhibition space 6D is the most selected space while 6A is found visually more successful both in T-test and OLS methods. The relation between "preference", "visual quality" and "catchiness" can be examined in the further studies. Additionally, the most important lighting criteria when evaluate lighting is determined as light source by the participants.

Similar results are found in the second step of the questionnaire with the methods T-test and OLS. Firstly, Lumion software is found successful in visual accuracy in every condition. Daylight is perceived softer in T-test, visually more comfortable in both methods. Artificial light is evaluated over spotlights. Since spotlights are usually focused, the composition of bright and dim areas is perceived significantly integrated and balanced. Sculpture exhibition is found more integrated and better. Another difference in exhibition types is the usage of space and the amount of shadows. In both methods, painting exhibition is perceived relaxing, bright, soft and visually comfortable due to less space usage and less shadows. Apart from exhibition and space parameters, a relation is found between visual comfort and uniformity criteria.

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