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Perceptual Evaluation of 21st Century Architectural Forms by Different Groups

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Abstract
This study aims to analyze how architectural forms recently designed with computational design are perceived by architects and non-architects and to measure the perceptual differences between the groups. For this purpose, an experimental study was designed. In the experimental study, in parallel with the literature, 4th year architecture students were categorized as 'architects' and 4th year civil engineering students were categorized as 'non-architects'. For the survey study, questionnaires were conducted with a total of 84 students, 42 participants from Konya Technical University Department of Architecture 4th year students in the architect category and 42 participants from Konya Technical University Department of Civil Engineering 4th year students in the civil engineer category, and the perceptual differences of the participants towards the architectural forms of computational design products were measured. All the buildings selected within the scope of the field study are iconic forms designed by computational design method in the 21st century. The participants were asked to evaluate each of the building images with the help of a 10-point semantic differential scale (1: positive, 10: negative) in terms of the specified adjective pairs. The data were analyzed, the analyses were interpreted, findings were presented, and recommendations were made.
Keywords: Computational Design, Evolution of Architectural Form, Formal Aesthetics, Perceptual Evaluation, Symbolic Aesthetics

1.INTRODUCTION

The 21st century is a period of significant technological developments, and like many other fields, the field of architecture has also been affected by these developments. The incorporation of computer technologies into the architectural design and production process is a major turning point in the field of architecture. Architectural forms that are difficult to express with techniques such as sketches, models, 2D and 3D drawings used in traditional design method can be easily expressed with digital sketches and digital models used in computational design method. In this way, the computer-aided design method gives the designer more freedom in terms of the production of the architectural form. Architectural form is changing and transforming thanks to the advantages offered by computer technologies, such as the ability to produce alternative forms and quickly experience the difference between these alternatives, and the acceleration and facilitation of the production phase of architectural form.

In the traditional design method, processes that are more independent of each other, such as defining the problem, gathering information, analyzing data, forming an idea and implementation, are intertwined in the computational design process. With computational design, a process defined as digital continuity and expressed as "from file to factory" has emerged. As a result of the ease and speed of communication between people working in different parts of the design and production stages, the design process has become a global process that allows intervention from anywhere, at any time of the day, and continues uninterrupted, independent of time and space (Turan, 2009).

This study aims to analyze how architects and non-architects perceive iconic building forms designed with computational design method in the 21st century. Previous studies have shown that architects perceive the environment differently from non-architects. The main hypothesis of the study is that 'there will be semantic differences between architect and non-architect participants towards architectural forms designed using computational design methods'. A questionnaire study was designed to measure the perceptual differences of the participant groups towards the selected architectural forms using adjective pairs. The study is important in terms of revealing how architects and non-architects perceive the transformation in architectural form with the effect of computer technologies in the 21st century and how computational design product architectural forms are perceived by architects and non-architects.

The main reason why iconic buildings of the 21st century have been chosen as the research area is that digital design tools have entered the field of architecture in this period and have greatly affected the architectural form. As technology and computational design tools evolve, architectural form continues to change and transform.

2. PERCEPTUAL EVALUATION OF ARCHITECTURAL FORMS DESIGNED WITH COMPUTATIONAL DESIGN METHOD IN THE 21ST CENTURY

Design of the Survey

Previous studies were used as a reference when designing the questionnaire form for the field study. Studies aimed at measuring the perceptual differences between different groups of participants towards different classes of buildings were used. (İmamoğlu, 2000; Kılıçoğlu, 2007; Ünal, 2008; Akalın et al., 2009; Yücel, 2011; Vartanian et al., 2017; Serter, 2021).

The survey consists of 2 sections. The first section consists of questions about the demographic characteristics of the survey participants such as name, gender, age and level of education. In the second part, the participants were asked to evaluate the 24 architectural form images presented to them with the help of a 10-point semantic differential scale (1: positive, 10: negative) in terms of the specified adjective pairs.

Within the scope of the study, 11 adjective pairs were determined as 'beautiful/ugly', 'impressive/unimpressive', 'simple/complex', 'fluid/stagnant', 'familiar/unfamiliar', 'cubic form is dominant/amorphous form is dominant', 'there is random behavior on the form/there is no random behavior on the form', 'there is repetition in the design/there is no repetition in the design', 'the form is deformed/the form is not deformed', 'there is structural perfection/there is no structural perfection' and 'there is a direct analogy in form/there is no direct analogy in form' in order to measure the perceptual evaluations of the participant groups about the architectural forms designed with the computational design method in the 21st century.

Table 1 shows the adjective pairs used in the perceptual evaluation of architectural forms in the field study on a 10-point semantic differential scale.

Table 1. Adjective pairs used in the perceptual evaluation of architectural forms and 10-point semantic differential scale

	1	2	3	4	5	6	7	8	9	10	
Beautiful											Ugly
Impressive											Unimpressive
Simple											Complex
Fluid											Stagnant
Familiar											Unfamiliar
Cubic form is dominant											Amorphous form is dominant

There is random behavior on the form											There is no random behavior on the form
There is repetition in the design											There is no repetition in the design
The form is deformed											The form is not deformed
There is structural perfection											There is no structural perfection
There is a direct analogy in form											There is no direct analogy in form

In this study, the adjective pairs constituting the semantic differential scale are the dependent variables of the research. Although there are numerous factors that may affect the perception of the survey participants, in this study, the education of the participants is considered as an independent variable.

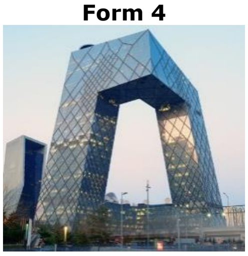
When the studies conducted in the literature are examined, it is determined that 4th-year architecture students are evaluated as architects and 4th-year engineering students are evaluated as engineers with the effect of the education they receive. (Hershberger, 1969; Canter, 1969; Purcell 1995; İmamoğlu, 2000). Based on this, in this study, a survey was conducted with 84 people from two different vocational education groups to reveal the effect of dependent variables, which are adjective pairs, on independent variables, which are different educational groups. The participant groups of the survey are Konya Technical University 4th-year students of architecture department and 4th-year students of engineering department. 42 architecture students and 42 engineering students participated in the study. The images of the architectural forms that constitute the sample of the study were selected to clearly reflect the form of the building. The prepared questionnaires were printed on A4 size papers and distributed to the participant groups.

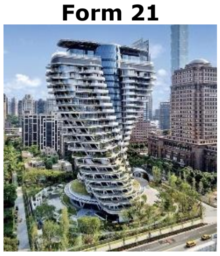
Table 2. shows the educational information of the survey participants. Table 3 shows the visuals and architectural design information of the buildings included in the survey.

Table 2. Education information of survey participants

Architects	42
Non-Architects	42
Total	84

Table 3. The visuals and architectural design information of the buildings included in the survey

Form 1	**Form 2**	**Form 3**
 **Beijing National Aquatics Center** Ptv Architects - Beijing, China 2008 - Sports Centre	 **Opus** Zaha Hadid - Dubai, UAE - 2019 Hotel	 **Museum of Pop Culture (MoPop)** Frank Gehry - Seattle, Washington, ABD - 2000 - Museum
Form 4	**Form 5**	**Form 6**
		

CCTV Headquarters OMA - Beijing, China - 2012 Office	**Wave** Henning Larsen - Vejle, Denmark 2018 - Apartments	**Emporia** Gert Wingardh - Malmö, Sweden 2012 - Shopping Centre
Form 7  **Valley** Mvrdv - Amsterdam, Netherlands 2022 – Apartments	**Form 8**  **Soumaya Museum** Fernando Romero Enterprise Mexico City, Mexico – 2011 Museum	**Form 9**  **KAFD Metro Station** Zaha Hadid - Riyadh, Saudi Arabia 2023 - Metro Station
Form 10  **Harbin Opera House** Mad Architects - Harbin, China 2015 - Opera House	**Form 11**  **Zhuhai Opera House** Long Ma - Beijing, China - 2017 Opera House	**Form 12**  **Turning Torso** Santiago Calatrava - Malmö, Sweden - 2005 - Apartments, Office
Form 13  **The Seminole Hard Rock Hotel** DCL - Los Angeles, California, ABD - 2019 – Hotel	**Form 14**  **AstraZeneca Discovery Centre** Herzog & de Meuron - Cambridge, United Kingdom 2021 – Discovery Centre	**Form 15**  **Foundation Louis Vuitton** Frank Gehry - Paris, France 2014 - Museum, Culture Centre
Form 16  **Shenzhen Universiade Sports Centre - Bao'an Stadium** Gmp Architekten - Shenzhen, China - 2011 - Sports Centre, Stadium	**Form 17**  **Luma Arles** Frank Gehry - Arles, France 2021 – Museum, Art Centre	**Form 18**  **Heydar Aliyev Center** Zaha Hadid - Baku, Azerbaijan 2013 – Culture Centre
Form 19  **Iceberg**	**Form 20**  **Beijing National Stadium**	**Form 21**  **Tao Zhu Yin Yuan**

Cebra, Jds, Louis Paillard Architects Aarhus, Denmark – 2013 - Apartments	Herzog & de Meuron – Beijing – China - 2008 - Sports Centre, Stadium	Vincent Callebaut Architectures Taipei, Taiwan - 2020 - Apartments
Form 22  **Vancouver House** Bjarke Ingels Group Vancouver, Canada - 2020 Apartments	**Form 23**  **Bmw Welt Museum** Coop Himmelblau - Munich, Germany - 2007 - Museum	**Form 24**  **Al Dar Headquarters** MZ Architects - Abu Dhabi, UAE 2010 - Office

3. METHODOLOGY

In the research, the data obtained from the questionnaire study were analyzed by means of the SPSS (Statistical Package for the Social Sciences) statistical analysis program. The reliability of the adjective pairs used in the study was tested using Cronbach's Alpha method. Cronbach's Alpha method, which is one of the most widely used methods to calculate the reliability of a scale, provides information about the consistency of the questions in the research scale with each other. This coefficient takes a value between 0 and 1 and is frequently used in semantic differential scales. (Özdamar, 2002). In the literature, when this value is above 0.70, the scale is considered 'reliable' (Bagozzi and Yi, 1988; Kaplan and Saccuzzo, 2009). Table 4 shows the reliability values of the adjective pairs used in this study.

Table 4. Reliability analysis results of the dependent variables

Adjective Pairs	Cronbach's Alpha Reliability Coefficient
Beautiful / Ugly	,731
Impressive / Unimpressive	,722
Simple / Complex	,733
Fluid / Stagnant	,737
Familiar / Unfamiliar	,829
Cubic form is dominant / Amorphous form is dominant	,705
There is random behavior on the form / There is no random behavior on the form	,703
There is repetition in the design / There is no repetition in the design	,730
The form is deformed / The form is not deformed	,725
There is structural perfection / There is no structural perfection	,746
There is a direct analogy in form / There is no direct analogy in form	,776

One-way analysis of variance test (One Way Anova) was performed to test whether there were statistically significant differences ($p<0.001$) between the averages of the groups' responses to the adjective pairs and the results were expressed in charts and graphs. Although the Anova test gives very strong results when the number of participants in the groups is equal, the reliability of the test results is negatively affected when the number of participants in the groups is not equal (Wilcox, 2005; Field, 2009). Considering this situation, the participant groups of the questionnaire were kept equal in this study.

4. ANALYSIS OF DATA AND EVALUATION OF FINDINGS

In the questionnaire study, the average values given by the participants to the adjective pairs for the architectural forms designed with the computational design method presented to them are given in Table 5.

Table 5. Mean values given by the participants to adjective pairs for each architectural form

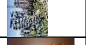
Adjective Pairs	Form No	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	Adjective Pairs
	Form Image																									
Beautiful	Architect	4	1,3	8,3	3,5	7,4	2	6,7	7,4	6,1	1,3	7,6	4,9	7,1	8	8,3	8,6	6,3	3	7,4	2,3	6,1	2,3	4,5	6,7	Ugly
	Non-Architect	1,5	4,2	9,4	4,2	1,5	4,2	6,4	9,1	2,2	5,2	2,2	2,3	1,4	3,4	9,4	2,7	6,1	4,9	2,8	1,4	2,6	1,4	3,2	4,1	
Impressive	Architect	4,1	1,4	8,5	3	8,3	2	6,1	5,9	5	1,5	7	5	8,5	8,4	8,5	9	6,1	2,9	7,5	2,4	6,4	2,4	4,5	7,7	Unimpressive
	Non-Architect	1,4	4	9,6	4	1,4	4	6,4	8,6	2,1	5	2,1	2,2	1,3	3,4	9,6	3,2	7,2	5	2,2	1,6	2,9	1,6	3	4,5	
Simple	Architect	3	3,3	9,6	4	3,4	3,3	9,6	2	7	2	3,1	3,3	5,2	4,5	9,7	3,8	9,7	2,2	4,5	6,7	5,4	3,4	2,3	4,6	Complex
	Non-Architect	1,2	3,4	9,5	4	2	3,4	9,5	3,4	2	3,1	2	2,2	2,5	2,9	9,6	2,9	9,6	1,8	2	2	2,1	2,8	4,1	2,9	
Fluid	Architect	8,7	2,2	2,1	8,1	1,9	4,7	8,8	2,1	2,4	1,9	4,5	4,7	2,9	3,3	1,9	5,7	2,9	3,8	8,3	3,4	3,3	5	3,4	7,1	Stagnant
	Non-Architect	9,3	2,2	2,9	7,1	1,5	3,4	5,7	1,6	1,5	2,3	3	1,5	2,8	3,8	2,7	3,8	3,1	1,5	6,1	2,8	2,9	2,3	1,3	3,4	
Familiar	Architect	1,4	2	1,8	1,9	2	2,1	2,3	3,3	9,2	1,7	2,1	1,4	3,2	4,3	2	6,4	2	1,4	2,1	3	3,2	4,4	1,4	2,4	Unfamiliar
	Non-Architect	2,2	3,9	3,9	2,3	2	5	8,9	9,2	8,8	4,3	1,4	1,5	2,1	9	8,3	8,2	8,3	3,2	2,3	2,4	2,7	2,4	3,3	1,6	
Cubic form is dominant	Architect	2	9	9,7	2,2	7,2	5	3	7,2	9,1	8,3	6,9	8,5	4,1	7,3	9,6	4,4	9,6	8,8	3,2	8,8	4,2	9,1	9,1	7,1	Amorphous form is dominant
	Non-Architect	1,8	8,2	7,9	2,6	7,6	3,9	3,9	7,9	8,7	8,8	7,4	2,2	4,8	5,9	7,6	2,4	4	7,9	2,1	7,9	5,2	3,5	7,5	7,7	
There is random behavior on the form	Architect	9,3	2,9	1,3	2,6	8,6	2,9	3,7	3	3,6	2,5	9	9,3	7	9	1,4	9,2	1,4	3,1	4,6	5,7	9	5,3	1,6	8,6	There is no random behavior on the form
	Non-Architect	9,4	6,9	1,3	6,9	9,6	4,2	4,8	7,3	7,9	5,7	9,6	8,3	8	9,1	1,4	8,8	1,4	4,4	4,4	4,4	8,7	4,5	4,1	7,6	
There is repetition in the design	Architect	5	9,1	8,9	7,9	1,4	7,9	8,8	7,7	1,3	7,7	1,4	2,2	4,9	1,8	9,4	1,7	6,9	6,4	8,8	7,8	1,4	9	9,1	7,8	There is no repetition in the design
	Non-Architect	7,1	9,2	9,6	9,4	1,5	9,4	9,3	8,9	2,8	8	1,5	5,5	9,2	2,1	9,6	2,4	9,4	7,8	9,2	7,1	3	8,1	8,2	8,7	
The form is deformed	Architect	9,1	2	1,5	6,1	5	2	4,9	2,6	8,1	3,2	7,9	2	7,7	4,6	4,9	7	4,9	2	4,3	6	5,8	1,9	1,7	7,3	The form is not deformed
	Non-Architect	9,7	1,7	3,9	4,8	9	2,2	3,9	3,2	9	4,5	9	2,2	8,7	8,6	4	8	4	2,2	5,1	8,5	9,1	4,7	2	8,8	
There is structural perfection	Architect	3,9	1,7	3,2	2,5	4	2,3	3,2	6	2,8	1,4	3,3	2,2	2,5	3,3	3,2	2,5	3,2	2,2	4	1,9	1,7	1,9	1,8	3	There is no structural perfection
	Non-Architect	4,6	2,5	6,1	4,9	3,6	2,1	4,1	5,4	2,4	4,6	2,8	1,8	4,4	4,7	4,2	4,7	4,2	4,3	5	3,8	3,1	1,7	2	5	
There is a direct analogy in form	Architect	1,3	5,2	9	7,2	1,5	5,2	4	7,7	9,6	5,7	2,3	8,4	1,6	9,2	9,5	5,9	9,5	7,1	2,5	2,5	4,6	9	2,2	1,6	There is no direct analogy in form
	Non-Architect	1,8	4,2	8,9	6,1	1,7	4,2	2,3	4,7	9	3	1,2	7,3	1,8	8,7	9,7	2,3	9,7	5,8	1,3	1,7	2,5	7,9	1,3	2	

Figure 1 shows the graphical expression of the mean values for the adjective pairs 'beautiful/ugly' and 'impressive/unimpressive' together. According to the graph, there is a linear relationship between the values given by the groups of architecture and engineering students for the adjective pairs 'beautiful/ugly' and 'impressive/unimpressive'. Participants also found the forms they found beautiful to be impressive, and the forms they found ugly to be unimpressive.

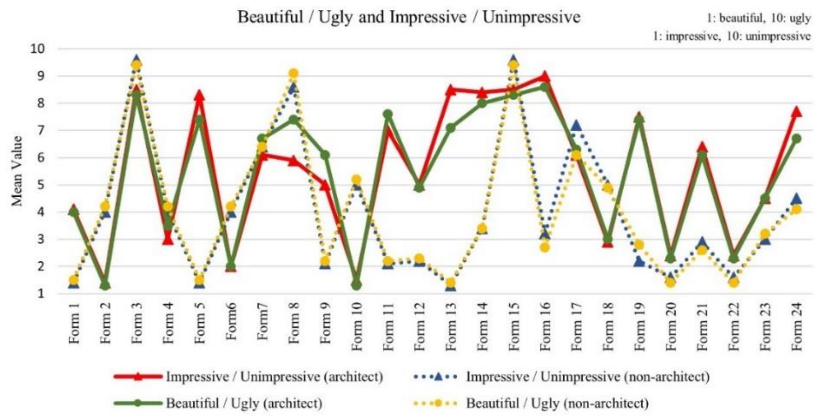


Figure 1. The relationship between liking and impressiveness

In Figure 2, the mean values of 'beautiful/ugly' and 'simple/complex' adjective pairs are given together to determine the relationship between the participant groups' level of liking and complexity according to their education. According to the graph, it is seen that the forms with a moderate level of complexity are considered beautiful, while the forms are evaluated as ugly as the level of complexity increases. 'Opus' number 2, 'Emporia' number 6 and 'Vancouver House' number 22 were found moderately complex and evaluated as beautiful by both groups. The most complex buildings for both groups are 'Pop Culture Museum' number 3, 'Valley' number 7, 'Foundation Louis Vuitton' number 15 and 'Luma Arles' number 17. These 4 buildings were evaluated as ugly by both groups.

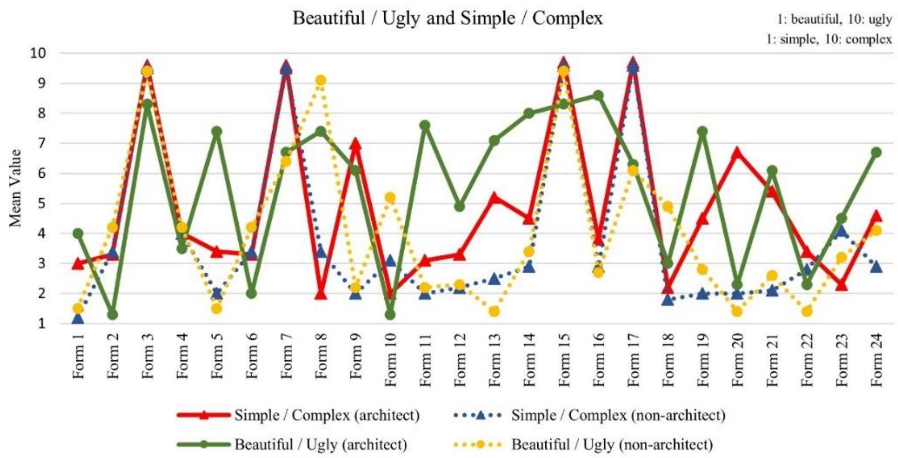


Figure 2. The relationship between liking and complexity

This result supports the studies on the relationship between complexity and liking in the literature. According to the literature, there is an inverted 'U' relationship between complexity and liking. The inverted 'U' relationship system emerged under the leadership of Berlyne's studies. This relationship states that complexity increases liking up to a certain level, but as complexity continues to increase, appreciation decreases (Berlyne, 1974; Wohlwill, 1974; Nasar, 1987; İmamoğlu, 2000; Kılıçoğlu, 2007; Saylan, 2008; Akalın et al., 2009).

Berlyne (1974) proved that there is an inverted 'U' relationship between complexity and satisfaction in his study in which he presented geometric designs and abstract visual textures with planned levels of complexity to participant groups for evaluation. The study also emphasizes that complexity is an important variable of symbolic aesthetics.
Wohlwill (1974), in a study with randomly selected urban images, found that the highest level of appreciation was found in moderately complex images.

Nasar (1987), in his study with images with three different levels of complexity: low complexity, medium complexity and high complexity, stated that the subjects defined medium complexity as the best.

İmamoğlu (2000), in his experimental study with 72 participants (34 architects and 38 non-architects), asked the participants to evaluate 8 traditional and 8 modern residential facades which he ranked as least complex, moderately complex and most complex. The results of the study show that the moderately complex facades are more liked than the least complex and most complex facades.

Kılıçoğlu (2007) carried out a survey study for two different groups of architects and non-architects in his study on detached public housing facades modified by users. He proved once again that there is an inverted 'U' relationship between complexity and level of liking for the architect group, and that the moderately complex is more appreciated than the very complex.

Saylan (2008), in a study conducted with 43 public and 57 senior high school students, selected 7 apartment facades from the Keçiören region of Ankara and developed 3 different scenarios for each facade by modelling in computer environment. A survey study was carried out with these scenarios which are simple, medium complex and most complex. Moderately complex apartment facades were found to be beautiful, modern, elegant and original by the participants, while the most complex ones were interpreted as rude, interesting and ostentatious.
Akalın et al. (2009), in a study conducted with 100 participants (41 architecture and 59 engineering students), analyzed 5 groups of detached public housing facades in Ankara. A total of 15 housing images of different complexity were used for each housing. The existence of an inverted 'U' relationship between complexity and preference was proved.
Yıldız Kuyrukçu and Özdemir Erdoğan (2021) analyzed architect participants' evaluations of modern and postmodern tourism buildings in terms of identity and meaning and found that architects evaluated tourism buildings designed in modern style as simple and had a high level of liking. On the other hand, architects found the tourism buildings designed in postmodern style complex and their level of liking was low.

In Figure 3, the mean values of 'beautiful/ugly' and 'fluid/stagnant' adjective pairs are given together to determine the relationship between liking levels and fluidity according to the education of the participant groups. According to the graph, 'Opus' numbered 2, 'Emporia' numbered 6, 'Harbin Opera House' numbered 10, 'Heydar Aliyev Cultural Centre' numbered 18 and 'Beijing National Stadium' numbered 20 were evaluated as fluid. In this case, it can be stated that architects like fluid forms.

Despite this, it is noticeable that the architect participants have low liking for 'Pop Culture Museum' number 3, 'Wave' number 5 and 'Foundation Louis Vuitton' number 15, which are also considered as fluid.

In the architect group, the liking levels of the forms evaluated as fluid are higher than the buildings evaluated as stagnant.

While the engineer group found the fluid forms ugly, they found the stagnant forms beautiful. In this case, while architecture students like fluid forms more, engineering students like stagnant forms.

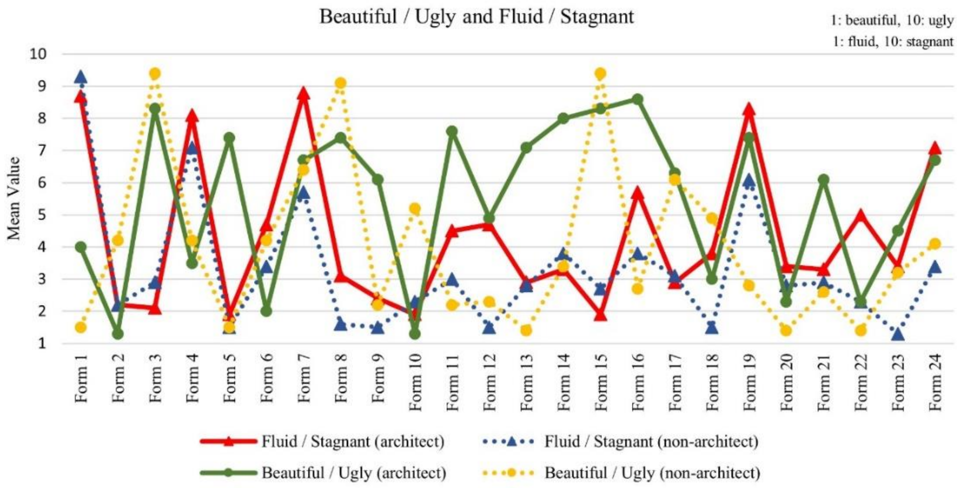


Figure 3. The relationship between liking and fluidity

There are studies in the literature that establish a relationship between complexity and fluidity. In Figure 4, the graphical expression of the mean values for 'simple/complex' and 'fluid/stagnant' adjective pairs are given together. According to the graph, it can be stated that complexity increases when fluidity increases. The forms considered as the most complex are labelled as fluid.

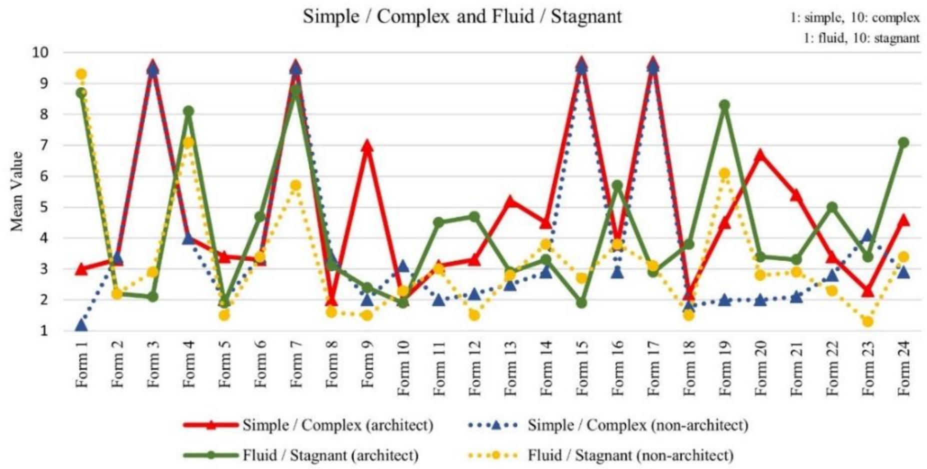


Figure 4. The relationship between complexity and fluidity

The mean values of the adjective pairs of 'beautiful/ugly', 'simple/complex' and 'fluid/stagnant' for the architect group in Figure 5 and for the engineer group in Figure 6 are given together. According to the graphs; the forms that architecture students have the highest liking for are moderately complex and fluid forms. The engineering student group, on the other hand, has a high level of liking for moderately complex and stagnant forms.

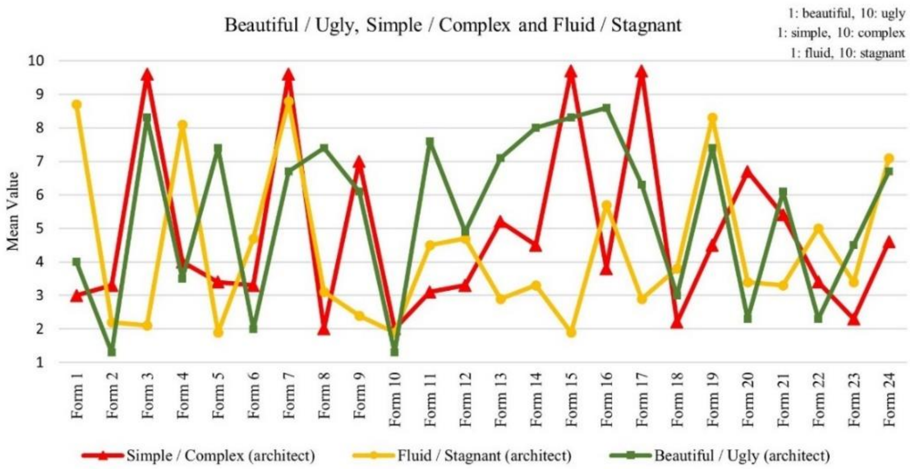


Figure 5. The relationship between liking - complexity – fluidity for architect participants

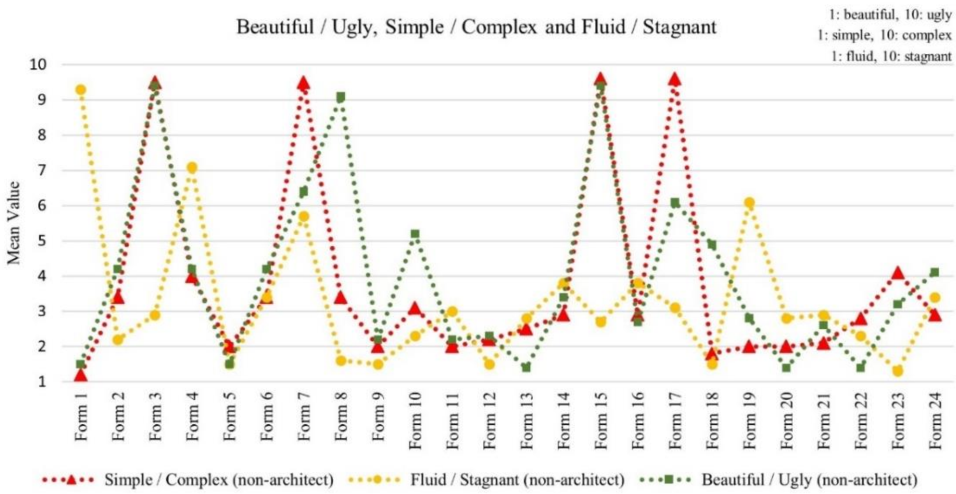


Figure 6. The relationship between liking - complexity – fluidity for non-architect participants

Saatcıoğlu (2011), in his study on the terms simple and complex in architecture, defines facades with low visual data as simple and facades with high visual data as complex. He states that asymmetric, fluid forms far from prime geometry increase complexity. In prime geometric forms, the number of lines and surfaces is less. When the form moves away from prime geometry, complexity begins to increase. Curvilinear and angled surfaces and irregular proportions cause complexity. There is irregularity in complexity. Excessive complexity creates a feeling of discomfort in the user.

There are studies proving that curvilinear and fluid lines in architecture have positive effects on human psychology (Madani Nejad, 2007; Vartanian et al., 2017).
Madani Nejad (2007), in his study investigating the emotional effects of fluid forms in interior spaces, showed 8 different scenarios that gradually curvilinearise for 2 different spaces to architect and non-architect groups and asked them to evaluate the spaces with the help of 9 adjective pairs. The quantitative data obtained from the study show that non-architects have significantly positive reactions to fluid forms.

Vartanian et al. (2017) tested the hypothesis that curvilinear lines and fluid surfaces affect the perception of liking in architecture with a group of architects and designers defined as experts and a group of non-designers defined as non-experts. They concluded that the expert group found fluid surfaces more beautiful than linear surfaces. In the non-expert group, no difference was found in the level of liking for linear and fluid surfaces.

In Figure 7, the graphical expression of the mean values for 'beautiful/ugly' and 'familiar/unfamiliar' adjective pairs are given together to determine the relationship between the participant groups' level of liking and familiarity according to their education. According to the graph, it is seen that the architecture student group's likes for the 'Beijing Aquatics Centre' number 1, 'Turning Torso' number 12, 'Heydar Aliyev Cultural Centre' number 18 and 'Bmw Welt Museum' number 23, which they evaluated as the most familiar, are at medium levels.

It is seen that the engineering student group has a high level of liking for 'Wave' number 5, 'Zhuhai Opera House' number 11, 'Turning Torso' number 12 and 'Al Dar Headquarters' number 24, which are considered as the most familiar buildings.

In this case, while architects have a medium level of liking for the forms, they are familiar with, engineers have a high level of liking for the forms they are familiar with. For architects, appreciation decreases as familiarity increases.

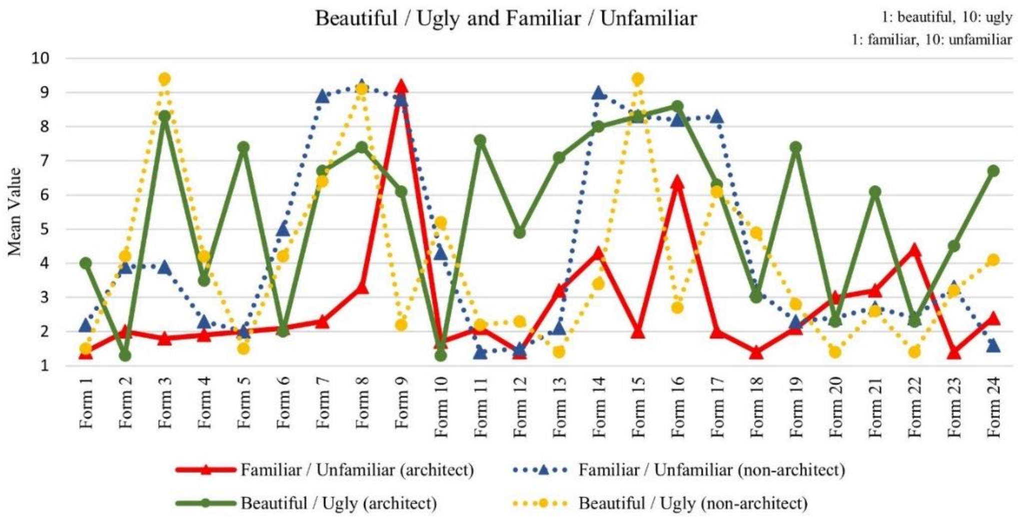


Figure 7. The relationship between liking and familiarity

Ikemi (2005) investigated the effect of unfamiliar, mysterious appearance on the preference of residential façade and concluded that the liking increases in the highly mysterious one. Purcell and Nasar (1992) found that being unlike anything else and being different increases interest.

Yıldız Kuyrukçu and Çınar (2023) measured the level of liking of architect and public participant groups towards historicist city entrance gates and concluded that the architect group found the city entrance gates presented to them more familiar than the engineer group and did not like them. The engineer group, on the other hand, found the city entrance gates familiar and liked them.

Figure 8 shows the mean values of 'beautiful/ugly', 'simple/complex' and 'familiar/unfamiliar' adjective pairs for the architecture student group and Figure 9 for the engineering student group. There are studies in the literature that establish a relationship between familiarity and complexity (Wickelgren, 1979; İmamoğlu, 2000; Ünal, 2008).

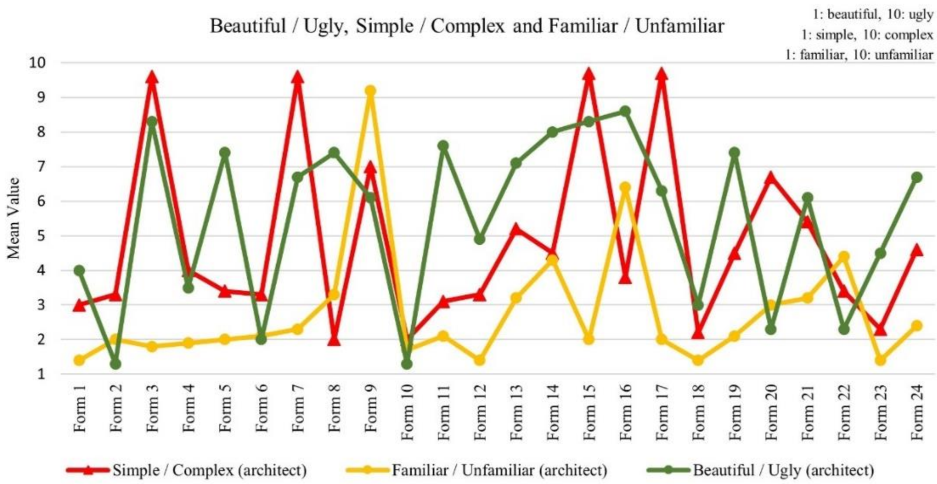


Figure 8. The relationship between liking - complexity - familiarity for architect participants

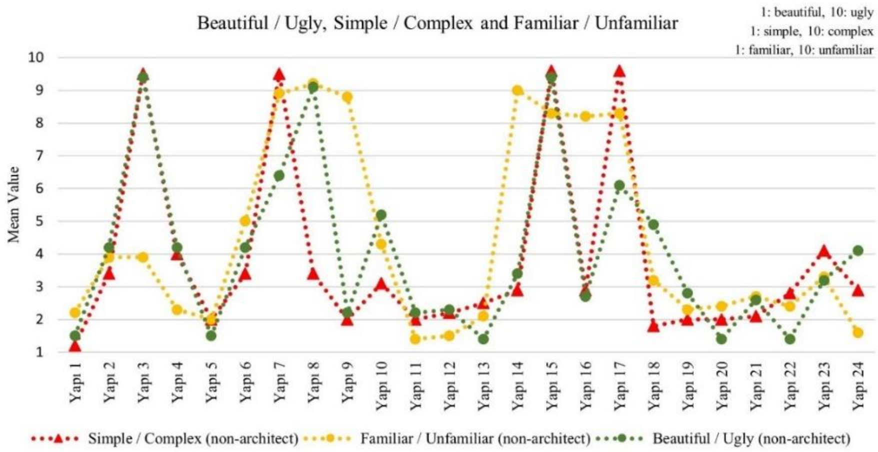


Figure 9. The relationship between liking - complexity - familiarity for non-architect participants

According to Wickelgren (1979), knowing and recognizing an object beforehand means less confusion and more satisfaction (Zajonc, 1968). There is also a contrary finding in the literature.

İmamoğlu (2000) found that there is an opposite relationship between familiarity and complexity and concluded that familiarity decreases in facades with the highest complexity; facades with high familiarity and low complexity are evaluated as more beautiful. In addition, of two different images with equal familiarity, the more complex one is liked more.

Ünal (2008), in his study measuring the perceptual differences of different participant groups towards domestic and foreign residential facades, confirmed the hypothesis that the object will be perceived more easily as a result of increased familiarity and thus the confusion will decrease. The reason for the high preference and liking for unfamiliar foreign facades is explained by the fact that being different is interesting.

In Figure 10, the average values for the adjective pairs 'beautiful/ugly' and 'cubic form is dominant/amorphous form is dominant' are given together according to the education of the participant groups. According to this graph; the buildings that the architecture student group evaluated as the most beautiful are 'Opus' number 2, 'Harbin Opera House' number 10, 'Heydar Aliyev Cultural Centre' number 18, 'Beijing National Stadium' number 20 and 'Vancouver House' number 22. It can be concluded that the architect group has a very high level of liking for the buildings they evaluate as amorphous. In the literature, there are studies suggesting that curvilinear forms arouse a sense of satisfaction in the user compared to square and angular forms.

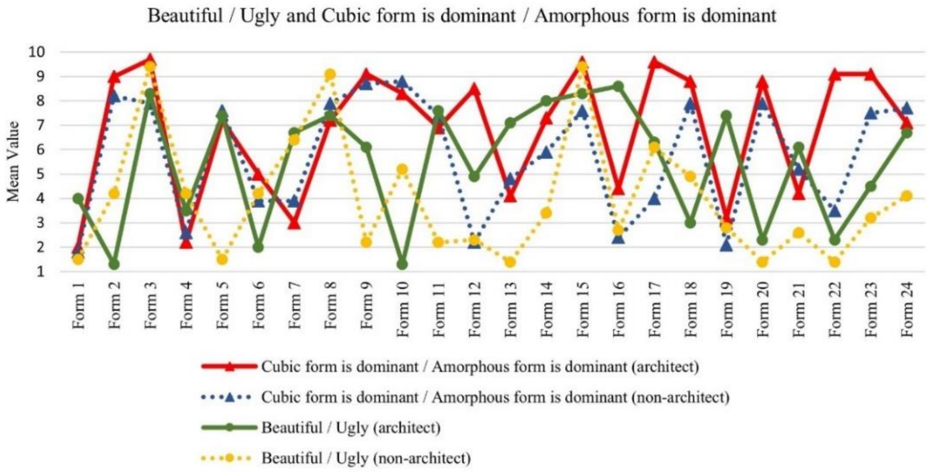


Figure 10. The relationship between liking and 'cubic form dominant/amorphous form dominant'

Figure 11 shows the mean values of the adjective pairs 'beautiful/ugly', 'fluid/stagnant' and 'cubic form dominant/amorphous form dominant' for the architecture student group and Figure 12 for the engineering student group. According to Figure 11, the forms with the highest liking of architecture students are the forms that they evaluate as fluid and amorphous. According to Figure 12, the forms that engineering students consider the ugliest are fluid and amorphous forms.

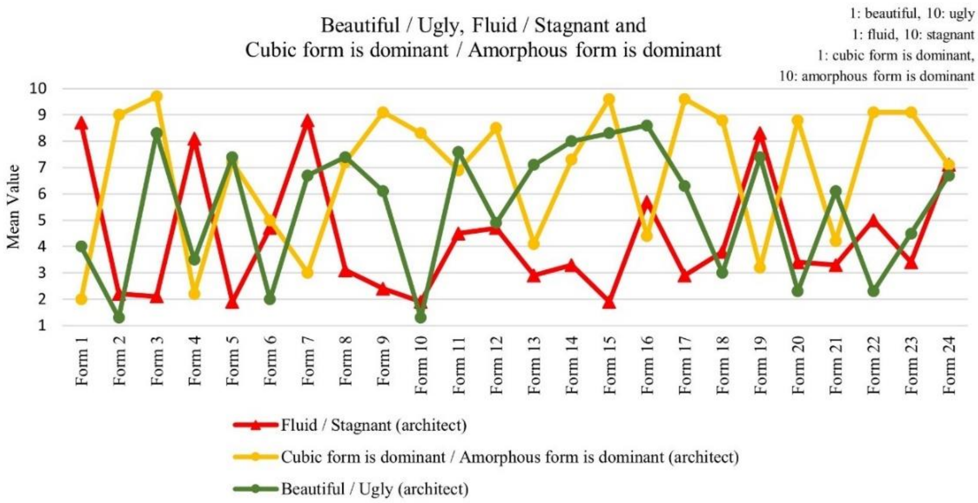


Figure 11. The relationship between liking, fluidity and 'cubic form dominant/amorphous form dominant' for architect participants

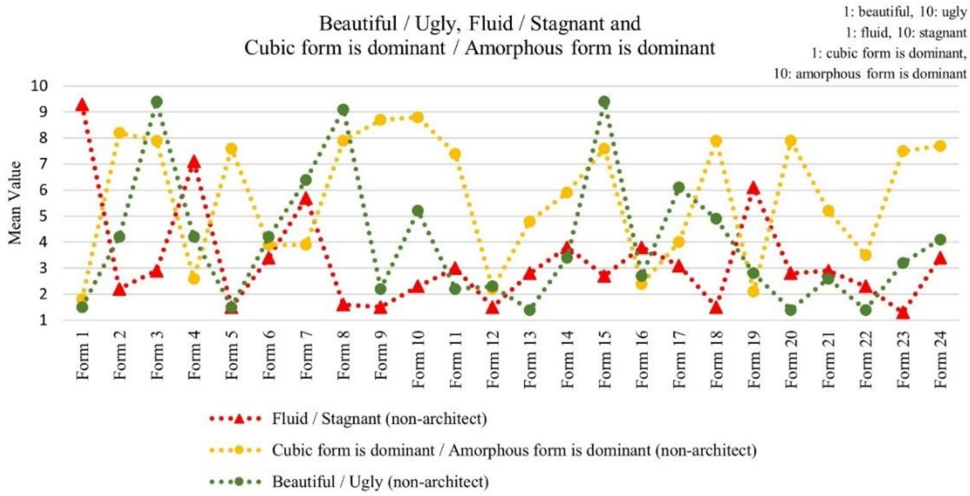


Figure 12. The relationship between liking, fluidity and 'cubic form dominant/amorphous form dominant' for non-architect participants

In Figure 13, the graphical expression of the mean values for the adjective pairs 'beautiful/ugly' and 'there is random behavior on the form/there is no random behavior on the form' are given together. According to the graph, there is a linear relationship between the responses of architect and engineer groups to the adjective pair 'there is random behavior on the form/there is no random behavior on the form'. The forms that the architect group found randomly were also found randomly by the engineer group. In the engineer group, the level of liking for the forms considered as no random behavior is higher than that of the architect group. It is seen that the liking of the engineer group is quite high for the forms numbered 1, 5, 11, 12, 14, 16, 21 and 24, which are evaluated as no random behavior by both groups. In this case, the most favorite forms of the engineer group are the forms evaluated as no random behavior.

According to Figure 13, it is seen that there is an inverted 'U' relationship between the adjective pair 'there is random behavior on the form/there is no random behavior on the form' and the architects' level of liking. The architect group evaluated the forms they liked the most as moderately random. 'Emporia' number 6, 'Harbin Opera House' number 10, 'Beijing National Stadium' number 20 and 'Vancouver House' number 22 were evaluated as moderately random by the architects and were found to be the most beautiful forms. 'The Pop Culture Museum' number 3 and 'Foundation Louis Vuitton' number 15, which were evaluated as the most random, had the lowest level of liking by the architects.

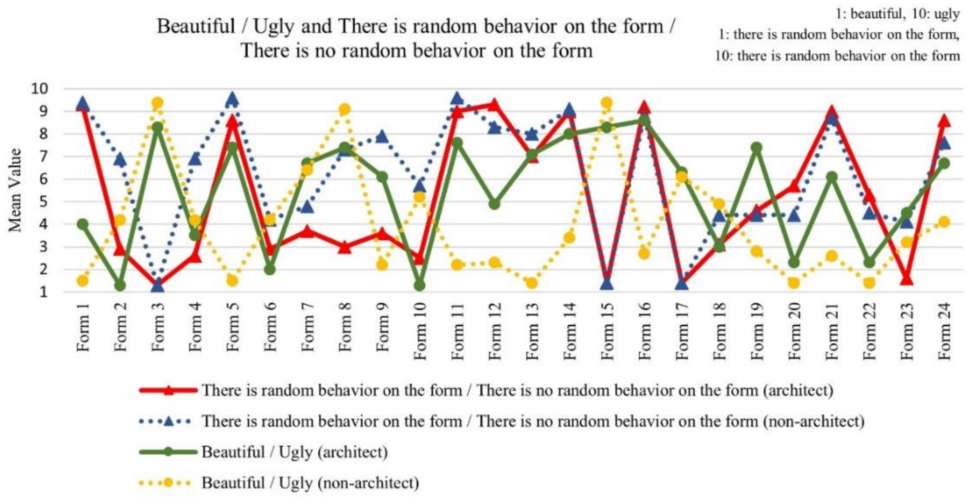


Figure 13. The relationship between liking and 'there is random behavior on the form/there is no random behavior on the form'

Figure 14 shows the graphical expression of the mean values for the adjective pairs 'simple/complex' and 'there is random behavior on the form/there is no random behavior on the form' according to the education of the participant groups. According to the graph, both groups evaluated the forms with the highest random behavior as complex. In this case, random behavior in the form increases complexity.

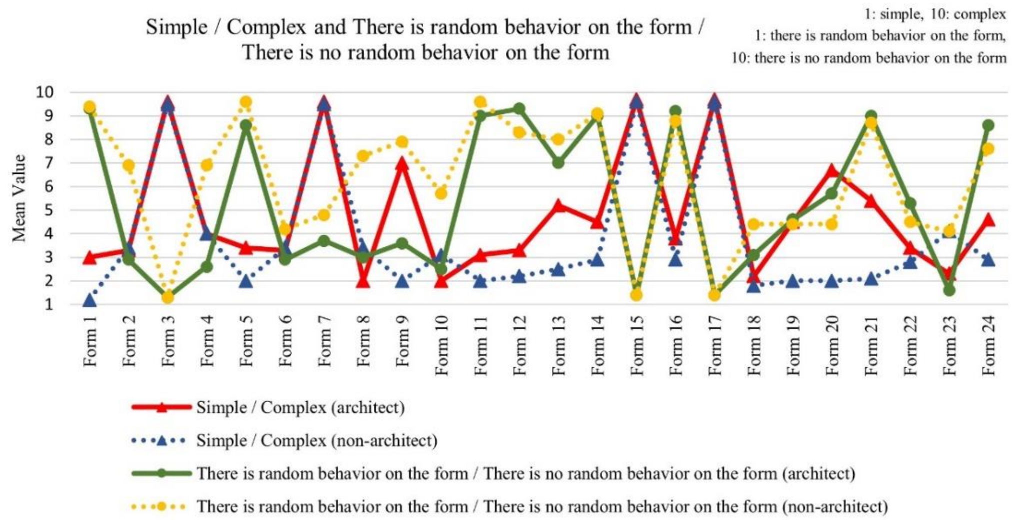


Figure 14. The relationship between complexity and 'there is random behavior on the form/there is no random behavior on the form'

Figure 15 shows the mean values of the adjective pairs 'beautiful/ugly', 'simple/complex' and 'there is random behavior on the form/there is no random behavior on the form' for the architecture student group and Figure 16 for the engineering student group. According to Figure 15, for the architecture student group, complexity and random behavior in form are at medium level, while the level of liking is high. According to Figure 16, it can be stated that the liking of the engineer group is the highest in forms that the complexity is at medium level and the random behavior is the least.

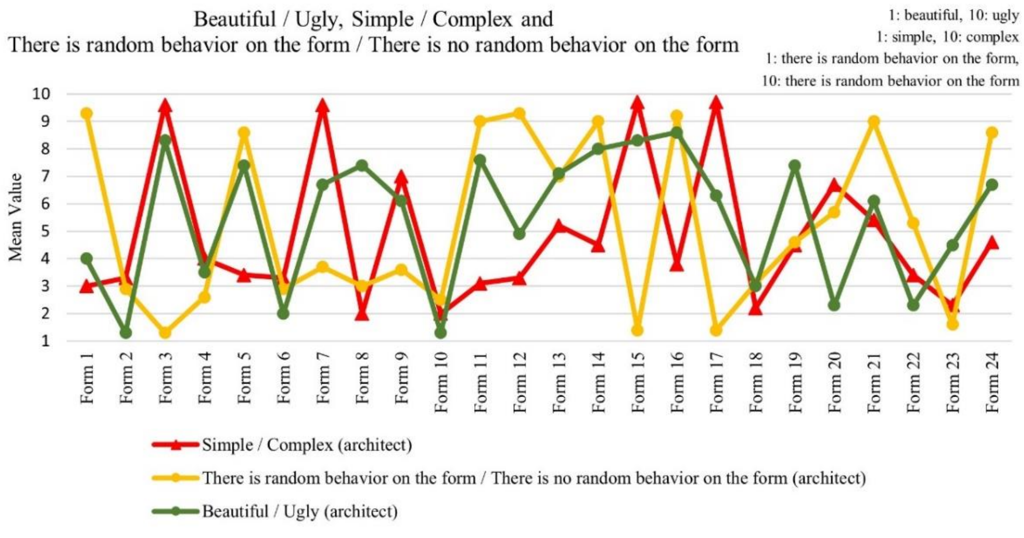


Figure 15. The relationship between liking, complexity and 'there is random behavior on the form/there is no random behavior on the form' for architect participants

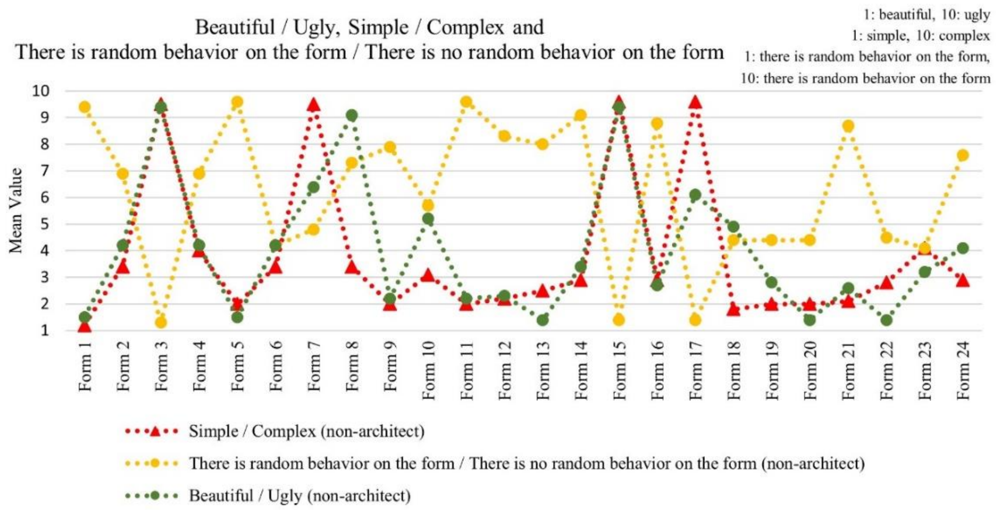


Figure 16. The relationship between liking, complexity and 'there is random behavior on the form/there is no random behavior on the form' for non-architect participants

In Figure 17, the graphical expression of the mean values for the adjective pairs 'beautiful/ugly' and 'there is repetition in the design/there is no repetition in the design' according to the education of the participant groups are given together. According to this graph; architects evaluated the forms numbered 5, 9, 11, 12, 14, 16 and 21 as ugly, which they thought to have the most repetition. On the other hand, it can be stated that the engineering student group's liking for the forms numbered 5, 9, 11, 14 and 16, which they think have the most repetition, is higher than the architectural student group. In this case, the presence of repetitive elements in the form decreases the liking for the architect group, while it increases the liking for the engineer group.

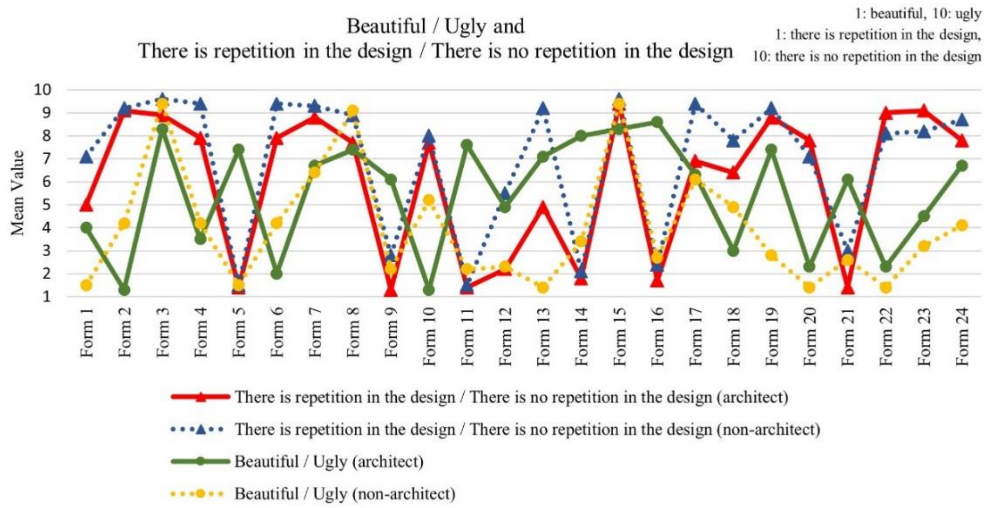


Figure 17. The relationship between liking and 'there is repetition in the design/there is no repetition in the design'

In Figure 18, the graphical expression of the mean values for the adjective pairs 'beautiful/ugly' and 'the form is deformed/the form is not deformed' according to the education of the participant groups are given together. According to this graph; the liking for the forms designed through deformation increased in both groups, and architects found these forms more beautiful compared to engineers.

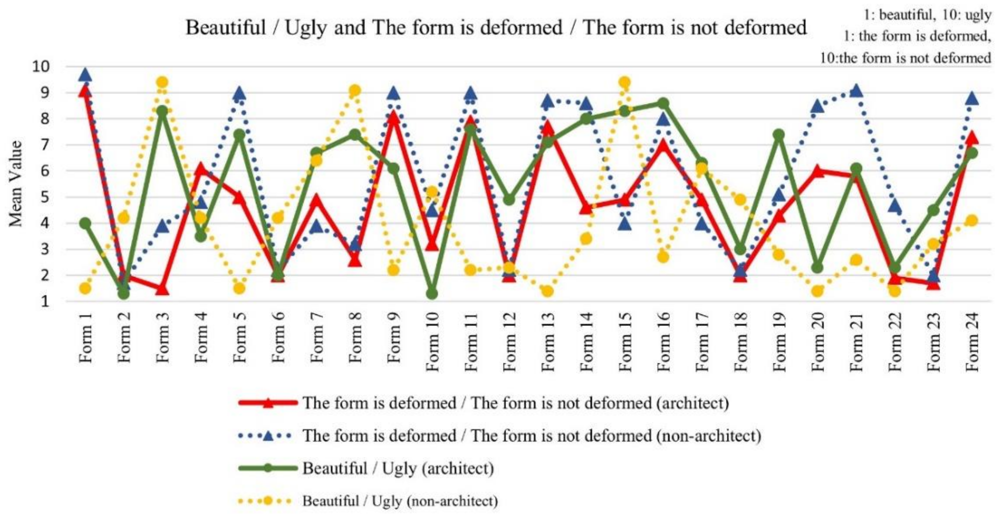


Figure 18. The relationship between liking and 'the form is deformed/the form is not deformed'

Figure 19 shows the mean values of 'beautiful/ugly', 'there is random behavior on the form/there is no random behavior on the form' and 'the form is deformed/the form is not deformed' adjective pairs for the architecture student group and Figure 9 for the engineering student group. According to the graphs; it is seen that deformation and random behavior values are high for 'Opus' number 2, 'Emporia Shopping Centre' number 6 and 'Harbin Opera House' number 10, in which the architects' liking is the highest. In this case, architects have a high liking for forms with random deformation. In the engineer group, the opposite is the case. The engineer group evaluated the forms numbered 1 'Beijing Water Sports Centre', numbered 5 'Wave' and numbered 13 'The Seminole Hard Rock Hotel' as no deformation in form and no random behavior in form. In this case, the engineer group has a high liking for regular and undeformed forms.

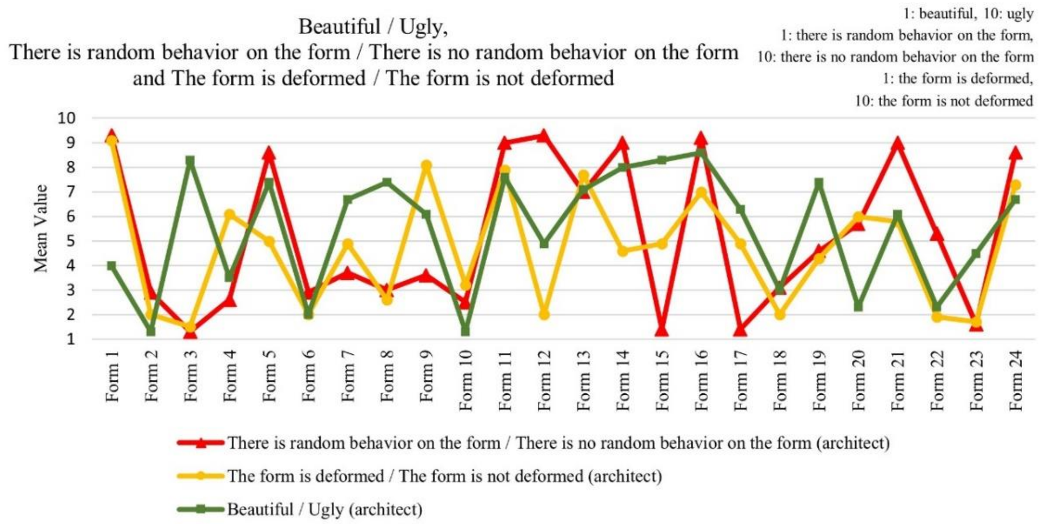


Figure 19. The relationship between liking, 'there is random behavior on the form/there is no random behavior on the form' and 'the form is deformed/the form is not deformed' for architect participants

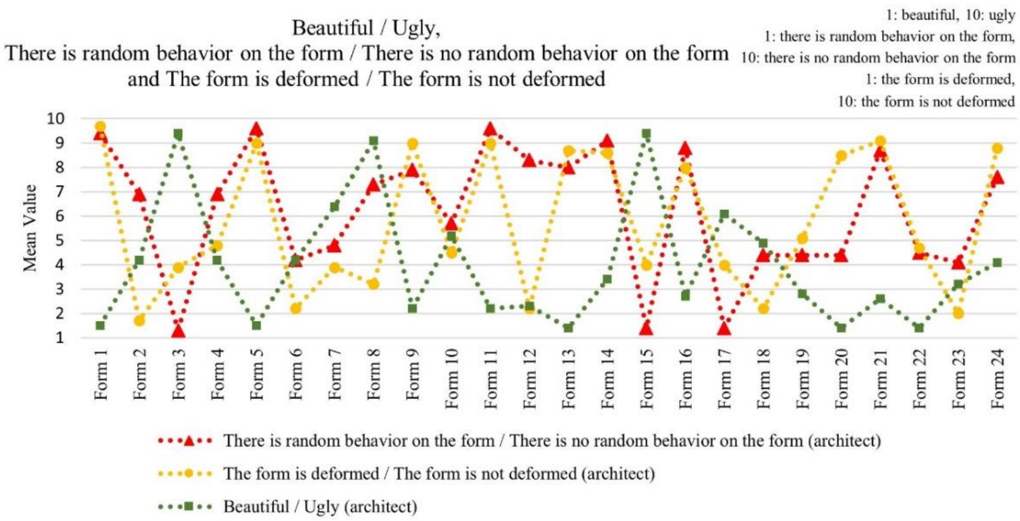


Figure 20. The relationship between liking, 'there is random behavior on the form/there is no random behavior on the form' and 'the form is deformed/the form is not deformed' for non-architect participants

Figure 21 shows the graphical expression of the mean values for the adjective pairs 'beautiful/ugly' and 'there is structural perfection/there is no structural perfection' according to the education of the participant groups are given together. According to this graph; the architecture student group found the forms more structurally perfect than the engineering student group. It can be thought that this situation is related to the fact that the engineer group has better structural knowledge than the architect group. The engineer group approached more critically than the architect group while evaluating the forms presented to them in terms of structure.

It can be stated that there is a linear relationship between the adjective pairs 'beautiful/ugly' and 'there is structural perfection/there is no structural perfection' for both groups. In other words, the participant groups found the forms that they found structurally perfect beautiful. It is noticeable that this situation is more apparent in the engineer group.

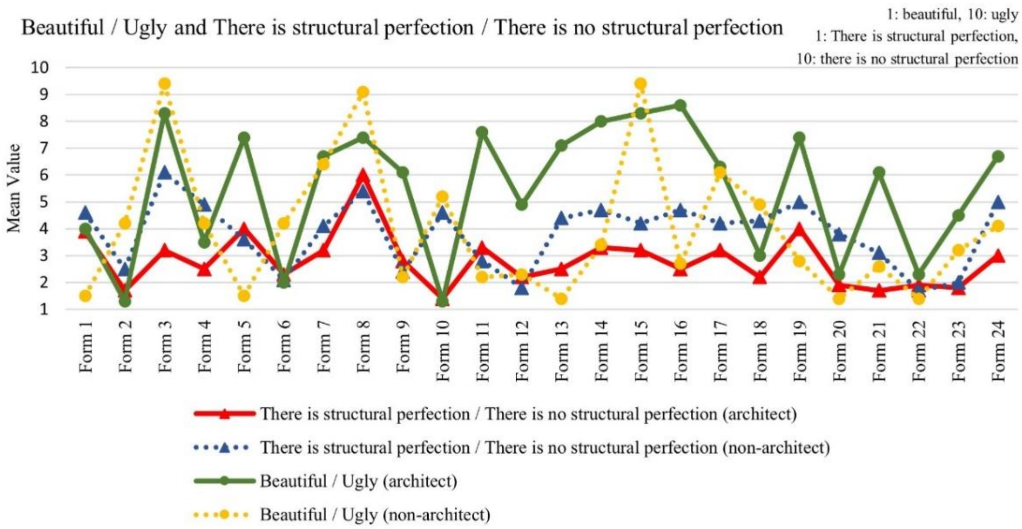


Figure 21. The relationship between liking and 'there is structural perfection/there is no structural perfection'

Figure 22 shows the graphical expression of the mean values for the 'beautiful/ugly', 'fluid/stagnant' and 'there is structural perfection/there is no structural perfection' adjective pairs for the architecture student group and Figure 9 for the engineering student group.

According to Figure 22, it can be stated that the architecture student group has a high level of liking for the forms that they evaluate as fluid and structurally perfect, while according to Figure 23, the engineering student group has a high level of liking for the forms that they evaluate as stagnant and structurally perfect.

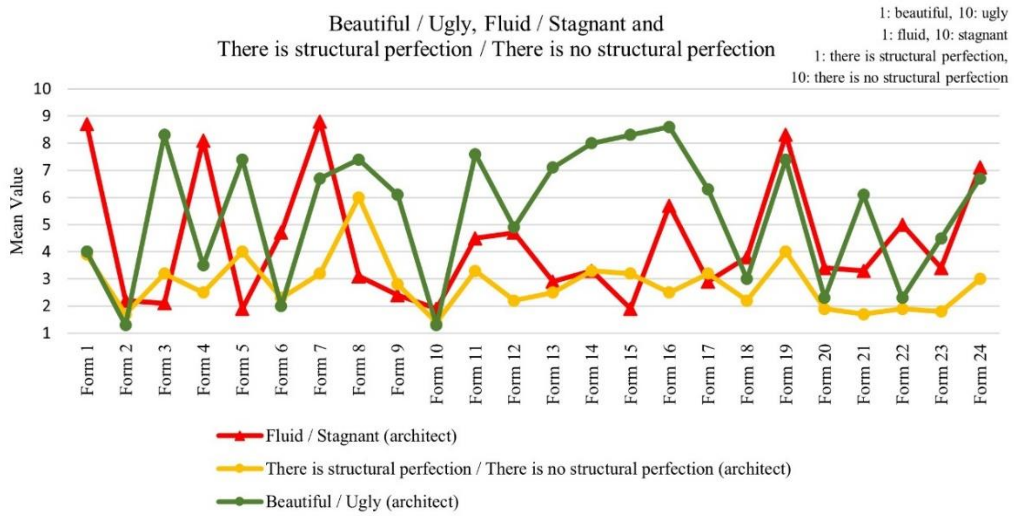


Figure 22. The relationship between liking, fluidity and 'there is structural perfection/there is no structural perfection' for architect participants

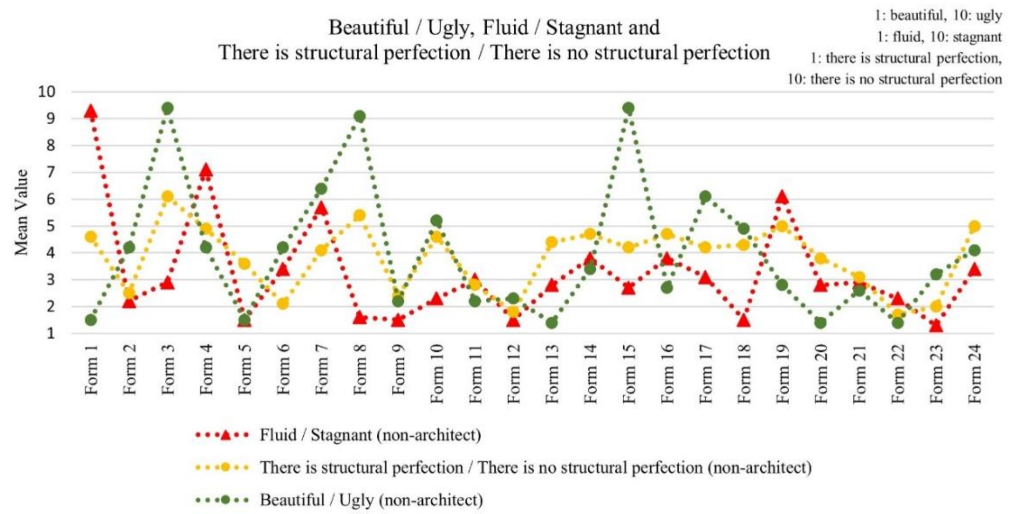


Figure 23. The relationship between liking, fluidity and 'there is structural perfection/there is no structural perfection' for non-architect participants

In Figure 24, the graphical expression of the mean values for the adjective pairs 'beautiful/ugly' and 'there is a direct analogy in form/there is no direct analogy in form' according to the education of the participant groups are given together. According to this graph, there is a linear relationship between the groups. Both groups evaluated whether there is direct analogy in forms with answers close to each other. According to the participants, the liking of forms with high direct analogy decreases. This situation is more apparent in architects.

The architects found 'Wave' number 5, 'Zhuhai Opera House' number 11, 'The Seminole Hard Rock Hotel' number 13, 'Iceberg' number 19, 'Al Dar Headquarters' number 24, which they evaluated as having high direct analogy, ugly. The engineer group found these buildings more beautiful than the architects.

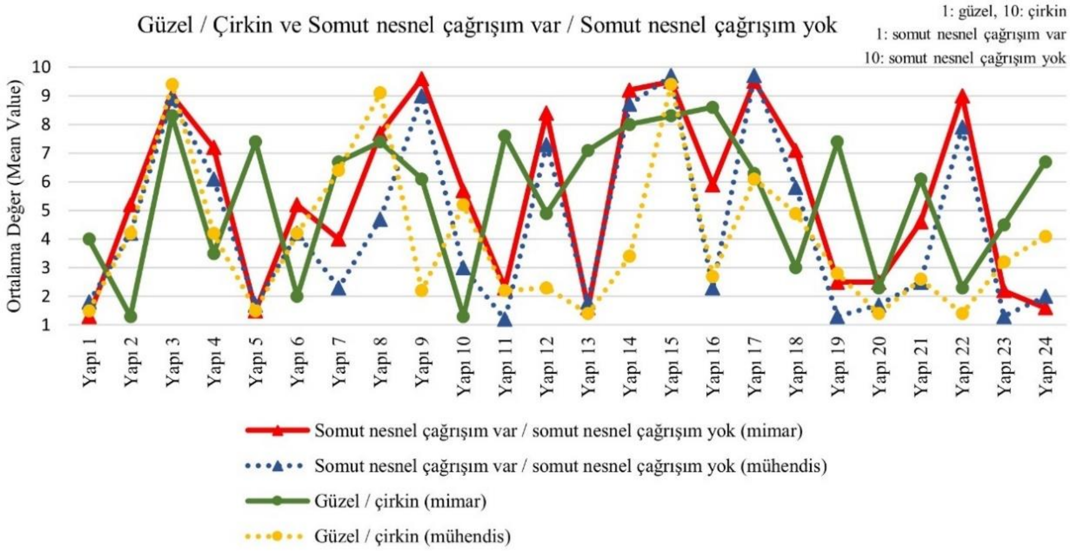


Figure 24. The relationship between liking and 'there is a direct analogy in form/there is no direct analogy in form'

Figure 25 shows the graphical expression of the mean values for the 'beautiful/ugly', 'familiar/unfamiliar' and 'there is a direct analogy in form/there is no direct analogy in form' adjective pairs for the architecture student group and Figure 26 for the engineering student group. According to the graphs; while the architect group found the forms with direct analogy familiar and disliked them, the engineer group found the forms with direct analogy familiar and liked them.

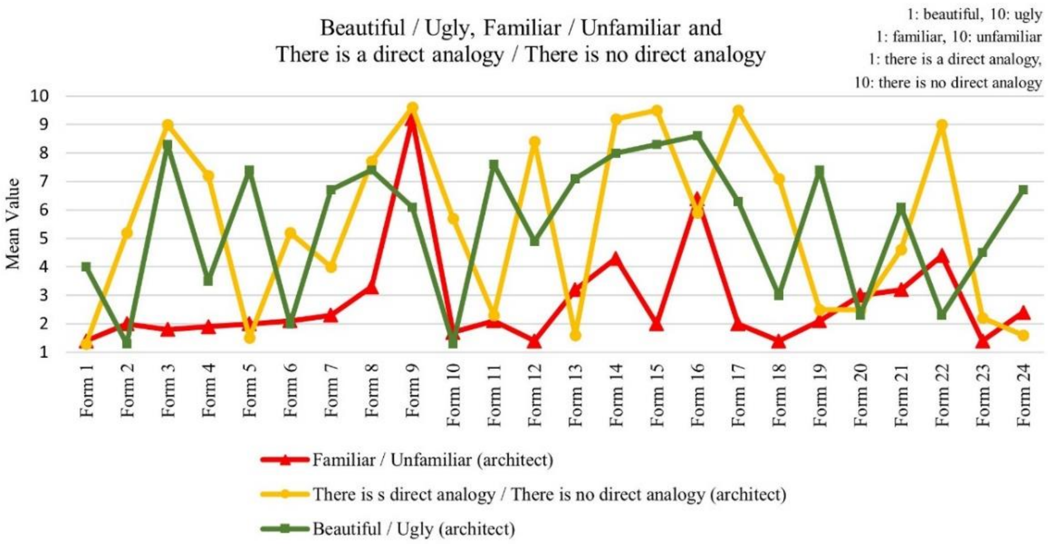


Figure 25. The relationship between liking, familiarity and 'there is a direct analogy in form/there is no direct analogy in form' for architect participants

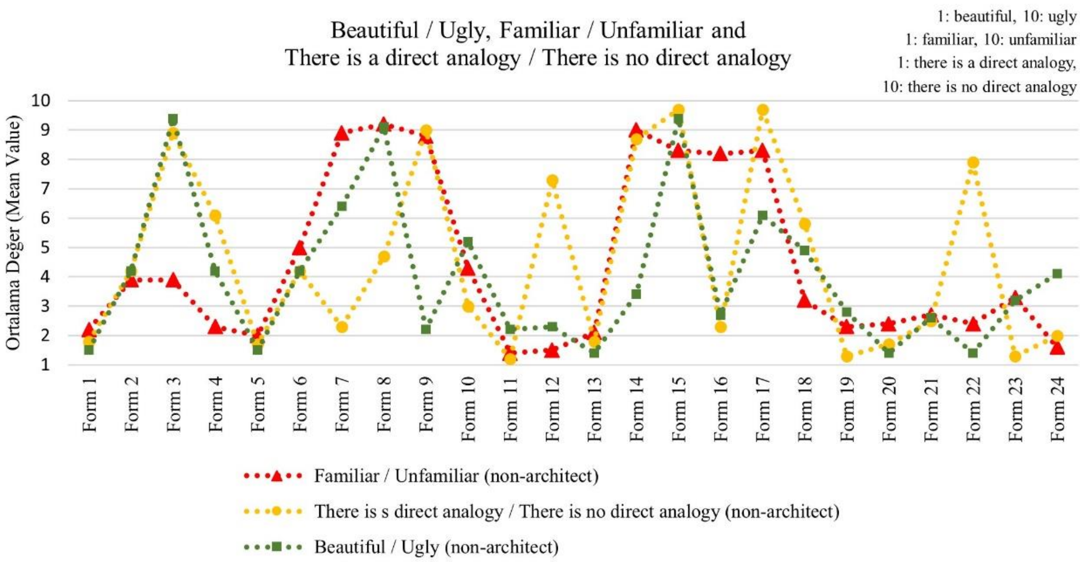


Figure 26. The relationship between liking, familiarity and 'there is a direct analogy in form/there is no direct analogy in form' for non-architect participants

5. CONCLUSION

With the 21st century, the developments in computer technologies have inevitably had an impact on the field of architecture, and the architectural form. In the period when computer technologies had not yet developed and started to be used in the field of architecture, there were traditional design and production methods used in the design and production of architectural form. Computer technologies, which started to develop in the 1950s and have gained an important place in the field of architecture in the 21st century, are now shaping architectural form.

How various building groups are perceived by different users has been addressed by many researchers in different studies. Investigating how respondents perceive various buildings is usually done through empirical methods. In this study, an experimental study was conducted to measure the perceptual differences of the participant groups of 4th year architecture department students, who were evaluated in the category of 'architect', and 4th year civil engineering department students, who were evaluated in the category of 'non-architect', towards the architectural forms designed with the computational design method. The sample of the study consists of 24 iconic, 21st century buildings on a global scale designed with computational design method. As a result of the literature research, 11 adjective pairs were identified for the selected constructs and the hypotheses to be tested. The survey participants were asked to evaluate the 24 building images presented to them on a 10-point semantic differentiation scale with the help of the specified adjective pairs. The main hypothesis of this study is that architecture student and engineering student groups may have different interpretations of computational design product architectural forms. The hypothesis was confirmed by determining that the participant groups gave different responses to the same visuals presented to them.

To summarize the findings of the study;

- There is a linear relationship between 'liking' and 'impressiveness' in the perceptual evaluations of the participant groups towards computational design product architectural forms. Participants also found the forms they found beautiful to be impressive and the forms they considered ugly to be unimpressive. This is true for both groups.

- The inverted 'U' relationship between 'complexity' and 'liking', which is confirmed by many studies in the literature, was also confirmed in this study. The forms that participants rated as moderately complex had the highest level of appreciation. The simplest and most complex forms were rated as ugly by the participants. Thus, the hypothesis in the literature that complexity increases liking up to a certain level and that liking decreases as complexity continues to increase is confirmed. This is true for both groups.

- In support of the finding in the literature that architects liked curvilinear and fluid forms more, the architect group in this study also liked the forms considered as fluid more. The non-architect group, on the other hand, liked stagnant forms more than fluid forms.

- Architecture student participants liked the forms they found most familiar at medium levels. Engineering student participants liked the forms they found most familiar. The studies in the literature, which argue that 'liking' decreases as 'familiarity' increases, were confirmed for the architect group.

- With this study, it was concluded that architect participants liked amorphous forms more than cubic forms in the relationship between 'liking' and the adjective pair 'cubic form dominant/amorphous form dominant'.

- In this study, an inverted 'U' relationship was found between 'liking' and the adjective pair 'there is randomness in form/no randomness in form' for architecture student participants. While the architects found the forms evaluated as the most random and the least random forms ugly, their appreciation levels were quite high for the forms evaluated as moderately random.

- In the relationship between the adjective pair 'complexity' and 'randomness in form/no randomness in form', both groups thought that randomness in form increases complexity. The engineering student group has a high level of appreciation for the forms that they consider to be the most regular. In this case, it was concluded that engineers do not like random behavior in forms.

- Perceptual differences were found between architect and non-architect participants regarding the relationship between 'liking' and 'repetition in form' tested in this study. The presence of repetitive elements in the form decreased the appreciation of architecture student participants, while it increased the appreciation of engineering student participants.

- In this study, when the relationship between the adjective pair 'there is deformation in the form/no deformation in the form' and the level of 'liking' is examined; it is concluded that although the presence of deformation in the form increases liking for both groups, architecture students find deformed forms more beautiful than engineering students.

- When the relationship between the adjective pairs 'random behavior in form/no random behavior in form' and 'deformation in form/no deformation in form' tested in this study and the level of 'liking' is examined, it is seen that there is a contrast between the architect and the engineer group. While the level of appreciation of the architecture student group was high in forms with random deformation, the level of appreciation of the engineering student group was high in forms with regular and undeformed forms.

- When the relationship between the adjective pair 'structural perfection is present/structural perfection is absent' and 'liking' is examined, it is concluded that forms perceived as structurally perfect are found to be beautiful for both groups. The architecture student group found the forms presented to them more structurally perfect than the engineering student group. Engineering students were more critical of the architectural forms presented to them from a structural point of view. This may be related to the structural knowledge of engineers. Engineering students found the forms that they evaluated as structurally perfect more beautiful than architecture students.

- In the relationship between the adjective pair 'there is concrete objective connotation/no concrete objective connotation' and 'liking', it was concluded that the liking of architecture students was quite low in the forms that they thought had high concrete objective connotation, while the liking of engineering students was higher than that of architecture students. When the relationship between the adjective pair 'there is concrete objective connotation/no concrete objective connotation' and 'familiarity' and 'liking' is examined; it is concluded that the engineer group finds the forms with concrete objective connotation familiar and likes them.

In this study, as mentioned in the literature, senior architecture students acted as 'architects' and senior engineering students acted as 'engineers'. In future studies, participant groups can be diversified and perceptual differences between groups can be investigated. In this study, adjective pairs were determined to measure the perceptual differences of the participant groups towards the architectural forms designed with the computational design method. In future studies, various building classes and different architectural forms can be addressed by using the adjective pairs determined in this study. Another study can be conducted by including academic architects in the participant groups.

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