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Lost in projection – Implicit features experience of 3D architectural forms and their projections

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ABSTRACT

The aim of our study was to investigate whether the experience of objects' implicit features would change if we observe it as a real 3D object or as a photograph or a drawing. In our experiment 46 participants estimated their impression of 10 objects shown in four different presentations. As stimuli, we used 3D objects, their virtual reality models, photographs and drawings from four different viewing directions, created by architecture students. As a measure of implicit features experience we used 12 bipolar adjectives grouped into four factors (attractiveness, regularity, arousal, and calmness) and 3 adjectives forming aesthetic experience factor. Results show significant differences between types of object presentations on four factors of implicit features experience, but not on the aesthetic experience factor. Real 3D objects were experienced as more attractive and calm, while VR presentation showed reduced arousal than other presentation types. On regularity VR and real 3D objects were experienced as same and more regular then drawings and photographs.

1. Introduction

1.1. Drawing, photography and models in architecture

Over time, the methods of representation in architecture have changed. During the Renaissance, perspective studies were considered the most accurate depictions. In the nineteenth century we have geometrization, and in the early twentieth century diagrams became a new way of showing key elements. As a continuation of that continuum of methodologies, which begins in the Renaissance, or maybe few years before the Renaissance (Carbon & Pastukhov, 2018; Kubovy, 1986), modern technologies and virtual reality are increasingly used today.

An architectural drawing is a basic element of architecture, and Fujimoto describes it as an endless process and a dialogue of architects with themselves (Ulrich, 2013). This process represents the expectation of the easy emergence of architecture from, initially, undefined elements into a defined form. Drawing as a way of thinking is also defined by Peter Eisenman, *one of the most significant modern architects and theorists* (Ansari, 2013). For Eisenman, drawing is not a matter of likable presentation, but an incarnation of things. Drawing is not just a tool, but it is inseparable from an architectural object. Therefore, the character of architectural drawing has changed over time, along with styles in architecture, new materials and technologies. Thus, in the previous two centuries we could see changes in line thickness, the impact of printing technology on the character of the drawing, changes in the way of presentation, introduction of color in the drawing, but also new tools with which to draw, the influence of photomontage as a way of presenting ideas, then elements taken from animation, film and video games.

In architecture, photography also occupies an important place. At the beginning of the development of photography, architecture was a very common motif recorded in photography. The practical reason was the staticity that allowed shooting without blur. Today, for the sake of presentation quality, some principles from the field of photography are implemented in architecture. This enabled the technical flourishing of photography, which brought it into the position of an unquestionable resource and in the field of architecture. The role of the photographic medium is multiple, especially in emphasizing photography as an ideal means of imitating "reality" in architectural events (Muñoz Vera, 2005). Kroustallis (2018) believed that photography in architecture balances on the border between a neutral visual experience and an authentic representation of the characteristic values of the photographed form. According to him, in the transmission of information through photography, it is important to leave the focus on the architectural form,

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without the primary role being taken by photography as such.

In addition to drawings, in architecture, the spatial model has long been a basic tool for re-examining the concept by the architect, construction analysis, but also for the presentation of the project. The model is a tool that simulates the spatial relationship between volumes, and considers the constructive system. This type of presentation is very close to the architects and is suitable for testing during the design process, as well as for the final presentation. A significant advantage of the spatial model, in relation to some other types of representation in architecture, is that it very well tolerates the question of scale and level of detail, i.e. the medium is also suitable for rough examination of volume ratios, etc., but also for large-scale displays of details. Apart from the practical application of the physical model, an important issue also refers to the aesthetic framework, and that is the topic that followed the currents and current events in architecture as a discipline (Astbury, 2014).

With the appearance of digital media, the physical model in architecture threatens to become redundant, and its relevance and advantages in relation to digital types of presentation are being questioned. The rapid advancement of technology has led to the shifting of boundaries beyond the physical and static presentation of architecture. Digital models enable a more detailed insight into the project down to the level of detail, and at the same time in all dimensions. In addition, the practical and efficient side of digital models is that changes and updates are possible during the design process. The differences between the physical and digital model are that in the model we remain somewhat trapped by scale, which is not a problem in the digital model. The digital model also offers benefits such as analysis of sunshine, lighting, etc. Perception of the form within the framework of virtual reality enables the eventual observation of some characteristics that would not be observed by other types of observation. However, the possibilities provided by virtual reality do not have to end up being exploited as a presentation tool. Jakob Strømann-Andersen states that the application of virtual reality in architecture is a step forward from attractive architectural visualization, into a new way of shaping the experience of form, i.e. architectural space, which is also interactive and stimulates an authentic experience (Musca, 2017). The use of virtual reality can have an impact on a different perception of a particular form or space, but it also provides a new polygon for rethinking architectural space and its creation.

On the one hand, the experiences and impressions of future users obtained from the introduction to the virtual display of the form can be significant input information in the design process. In addition, the architects themselves have the opportunity to experience the spatial form in a scale of 1: 1, and in that way they can reconsider the project. On the other hand, we come to the question of the potential design of the form in the virtual environment itself, and the influence of these circumstances on the design process and its results. What we can say with certainty is that such a way of determining form would be significantly more interactive and intuitive than conventional methods. Alonso believes that new, digital, technologies have enabled the creation of a new platform for experiencing and thinking about architecture (Owen Moss, 2013). However, he sees this only as another historical moment when there are changes in techniques and methodologies.

1.2. Experience of implicit features of architectural objects

Various representation types in architecture have emerged over time, and an important issue might be whether their expression changed, too. By *expression* we assume spontaneous manifestation of mental states, such as emotions or ideas, through various media (visual, auditory…), and different materials (body, clothes or performance) (Robinson, 2007). In this sense, expression is related to transmitted information in the communication process, while impression relates to received information (Argan & Oliva, 2002). For example, certain body postures or facial expressions can express sorrow, which further leaves an impression of sorrow on the viewer. Besides that, an object can be perceived by the viewer as containing certain expressions, although it does not have any real capacity to express emotions, e.g. rainy day. Collection of such object properties, which enable the viewer to recognize different expressions of that object, is called *expressiveness*. For example, sharp angular lines can have an impression of danger; diagonal lines can induce dynamics; arrangement of elements in a gravitationally stable way induces perceived stability of the composition (Fillinger & Hübner, 2020). Therefore, expressiveness is a wider concept than expression, since it reflects not only spontaneous manifestation of mental states, but all characteristics which can lead to certain impressions in the viewer. In that manner, expressiveness of art products, e.g. paintings or architectural objects, can be found in their composition and color, through which they induce emotional states (Arnheim, 1969, 1980; Gombrich, 1969, 1973; (Graham, 2005); Gooding, 2000; Perry, 2005, Tošković & Marković, 2003, Tošković, 2004). In line with this, many studies do show that even simple visual features, such as colors or shapes, can induce elementary implicit meanings such as dynamics, warmth, relaxation… (Burr, 2000; Gori et al., 2008; Janković & Marković, 2001; Oyama et al., 2008; Palmer & Schloss, 2010). Contrary to that, Fechner argued that aesthetic choices are largely shaped by the observer's learning history and not by an object's formal properties (Ortlieb et al., 2020), and some recent studies indicate that subjective descriptors are better predictors of preference than image properties (Hayn-Leichsenring et al., 2020).

Impression or experience of the object's expressiveness can be considered as a perceptual phenomenon, according to Rudolf Arnheim (Arnheim, 1949, 1969, 1980). He believes that this experience primarily depends on the structure of so called perceptual forces, which act within our visual field. From the neurophysiology side, authors tried to explain impression through activation of mirror neurons (Rizzolatti & Craighero, 2004), denoting it as a special case of so-called "neural empathy" (Freedberg & Gallese, 2007). Studies results have shown that specific cortical and subcortical areas are involved in the visual processing of architectural objects such as buildings (Aguirre et al., 1998; Epstein & Kanwisher, 1998; Ishai et al., 1999; Mecklinger et al., 2014; Oppenheim et al., 2010).

Terzidis dealt with the relation between expressiveness and architectural design by analyzing formal aspects of architectural expressiveness, such as caricatural, hybrid, kinaesthetic, bent, wrapped and algorithmic (Terzidis, 2003). In his opinion, expressiveness denotes essential qualities of architectural form. Similarly to that, Poriau believed that *expressiveness* and *aesthetic value* of an artwork coincide to a great extent (Poriau, 1986).

One of the most frequently used methods to measure impression of certain object expressiveness is Charles Osgood's semantic differential. In this method participants are asked to rate some concepts or objects on bipolar seven-step scales with opposite adjectives, such as pleasant-unpleasant, passive-active…. These opposite adjectives are usually called descriptors. In his study, Osgood asked participants to rate verbally expressed concepts on descriptors, and extracted three factors from descriptors: Evaluation, Potency and Activity. Semantic differential method implies that experience can be defined on two levels: (1) elementary impressions expressed by ratings on the scales; and (2) higher order dimensions (factors), such as Evaluation, Potency and Activity (Osgood et al., 1957; Osgood et al., 1975). This approach was further developed by Berlyne and his collaborators (Berlyne & Ogilvie, 1974; Cupchik, 1974).

Application of semantic differential approach on aesthetic experience showed complex networks of aesthetically related descriptors (Augustin, Carbon, & Wagemans, 2012; Augustin, Wagemans, & Carbon, 2012). Factors lying behind those descriptors refer to certain psychological domains, such as cognitive and emotional (Wolz & Carbon, 2014), perceptual, cognitive and affective (Marković, 2011) or perceptual, cognitive, affective and motivational (Marković, 2014). In a study of Marković and Radonjić, participants were asked to rate their perceptual experience of artistic paintings, on 43 descriptors of implicit and 25 descriptors of explicit features (Marković & Radonjić, 2008).

Implicit features of the paintings are imposed by the observer (pleasantness or interestingness), while explicit features refer to properties which are perceived directly (form, color, depth). Results showed that experience of implicit features of paintings has four factorial structure: Regularity, Relaxation, Hedonic Tone and Arousal. Experience of explicit features also showed four factorial structure, but with different meanings: Form, Color, Space and Complexity. Another study investigated the relation of implicit feature structure and aesthetic experience of paintings (Polovina and Marković, 2006). Aesthetic experience was measured through unipolar descriptor scales (e.g. fascinating, irresistible, unique…) since previous literature suggests that it is hard to denote it's second pole. Results showed weak correlations between aesthetic and implicit features experience, meaning that the aesthetic experience is a relatively independent phenomenon.

Besides paintings, semantic differential was used in investigating the experience of architecture, too (Canter, 1970; Cass & Hershberger, 1972; Craik, 1968; Kasmar, 1970; for review see Nasar, 1994). For example, Alp (1993) used 26 unipolar scales selected to refer only to "aesthetic dimension" of architectural experience. Franz et al. (2004) used bipolar scales to measure hedonic tone, arousal, aesthetic dimension, cognition, activity, and formal aspects of architectural design, such as spaciousness, brightness and openness. Bishop (2007) specified a priori three categories of attributes: Aesthetic response, Typicality and Formal attributes. The attribute of Aesthetic response consisted out of pleasantness and interestingness (arousal). Rezazadeh (2011) asked his participants to rate streets and buildings in the city of Shiraz (Iran) on a set of scales, and revealed three factors: Organization, Affective dimension, Historical Significance. Using a semantic differential method, Marković and Alfirević asked subjects to rate photographs of buildings. Results revealed four dimensions of experience of expressiveness in architecture: Aggressiveness, Regularity, Color and Aesthetics (Marković & Alfirević, 2015). Cluster analysis of rated building photographs revealed two clusters which authors named as *Phlegmatic* (less aggressive, more regular and less colorful), and *Choleric* (more aggressive, less regular and more colorful). Some authors investigated cultural differences in impression of expressiveness of architectural objects designed in various cultures. Subjects from Serbia and Japan were rating architectural objects from both countries on semantic differential descriptors and three-factorial structure of impression was revealed, Beauty, Firmness and Fullness (Marković et al., 2016). Analysis showed that Serbian (Western) and Japanese (Eastern) participants show general similarity in their experience of implicit features of architectural objects.

2. Purpose and aim of the study

In most of the studies investigating impression of architectural objects, researchers used photographs of those objects as stimuli, since it is easier to show them to participants instead of taking participants in front of the real objects. But, findings show that structure of impression can vary depending on object type, e.g. do we estimate paintings, or photographs of architectural or every-day objects (Marković & Alfirević, 2015; Marković & Radonjić, 2008). Also, recent studies have shown that the experience of paintings changes if they are viewed on a screen or in a simulated gallery in virtual reality setting (Jankovic et al., 2019; Madjarev et al., 2019). According to this, we might ask if results from previous studies show the impression structure of architectural objects or their photographs. Would results from those studies differ if participants were asked to judge real objects instead of their photographs? Accordingly, an important issue would be to investigate if our impression changes depending on the object presentation, e.g. do we judge a drawing, a photograph or a real three-dimensional (3D) object. Also, these presentation modes can be considered as completely different entities, which makes a raised issue even more important, since some previous findings on architectural objects might be attributed to other entities.

From another perspective, some architects consider drawing to be a fundamental means of depicting the essence of architecture, and there are those who assume that new technologies and virtual reality have taken over that role. Hernan Diaz Alonso believes that some new tools, enabled by modern technologies, such as animation, are not just a means of project presentation, but a way of thinking and generating an architectural object (Owen Moss, 2013). Here we come to the question, how can the givens of new technologies redefine the perception of form, but also the ways and processes through which the author determines form?

Having all that in mind, the primary aim of this study was to investigate differences in impression of object expressiveness, or implicit features experience of object, depending on its presentation mode. We decided to compare four different presentation modes, usually used in architecture for modeling: drawing, photograph, virtual reality 3D model, and real physical 3D object.

3. Method

3.1. Participants

In previous studies investigating implicit features experience of various objects, effects between $\eta^2_{partial} = 0.25$ and $\eta^2_{partial} = 0.96$ were obtained. Power analysis (*pwr* package in *R* software) indicated that in order to obtain the lowest previously reported effects in our study with study power of 0.8 and alpha level of 0.05, for comparison of 4 levels (groups) planned we would need a minimum of 44 participants. Therefore, a convenience sample of 46 first-year students (41 female, aged 19) from the University of Belgrade took part in the study. All participants had normal or corrected to normal vision. Informed consent was collected from all subjects prior to their participation in the experiment.

3.2. Stimuli

As stimuli we used *models of imagined architectural objects* designed by students of architecture at the University of Belgrade. During their regular activities, one of the tasks is to design an object made of cardboard, with maximal volume of 800 cm^3, meaning that it cannot exceed borders of imagined box of 20 cm * 20 cm * 20 cm in size. Objects do not have any specified functions and they mainly represent various geometrical shapes in 3D space (Fig. 1). We decided to use abstract geometrical figures in order to control for the effects of familiarity and variability of real architectural objects. Out of all designed shapes, two experienced architects and faculty teachers selected 10 which appeared as most diverse in shape, to be used as a final set of stimuli. At the same time, selected stimuli maintained similar mid-range level of complexity and interestingness, according to independent estimates of twelve experimenters, unfamiliar with the aims of the study.

After creating the above mentioned models, every student had a task to make *drawings* of his object. Instruction for making drawings was that they should be made as two-dimensional (2D) projections of a model viewed from four predefined directions (Fig. 2). Drawings are made as linear isometric projections (30 degrees angles), usually used in engineering professions.

Models were afterwards *photographed* from 4 different angles in order to obtain the same projections of an object as were presented in a drawing. We used HUAWEI camera NEM-L21, F-stop: f/2, Exposure time: 1/100 s. ISO speed: ISO-64, Exposure bias: 0 step, Focal length: 4 mm, Metering mode: Pattern, No flash, 35 mm focal length: 27. During photographing, contrast, exposure program, saturation and sharpness were set to *normal*, brightness to *0*, light source to *daylight*, digital zoom to *1*. In order to equalize colors with those on drawings and 3D models, photographs were done in achromatic mode. What can be seen on Fig. 1 are actually those photographs of real 3D objects. Besides drawings, photographs were used as another two-dimensional stimuli version.

And finally, we created the same *models in virtual reality*, using Unity

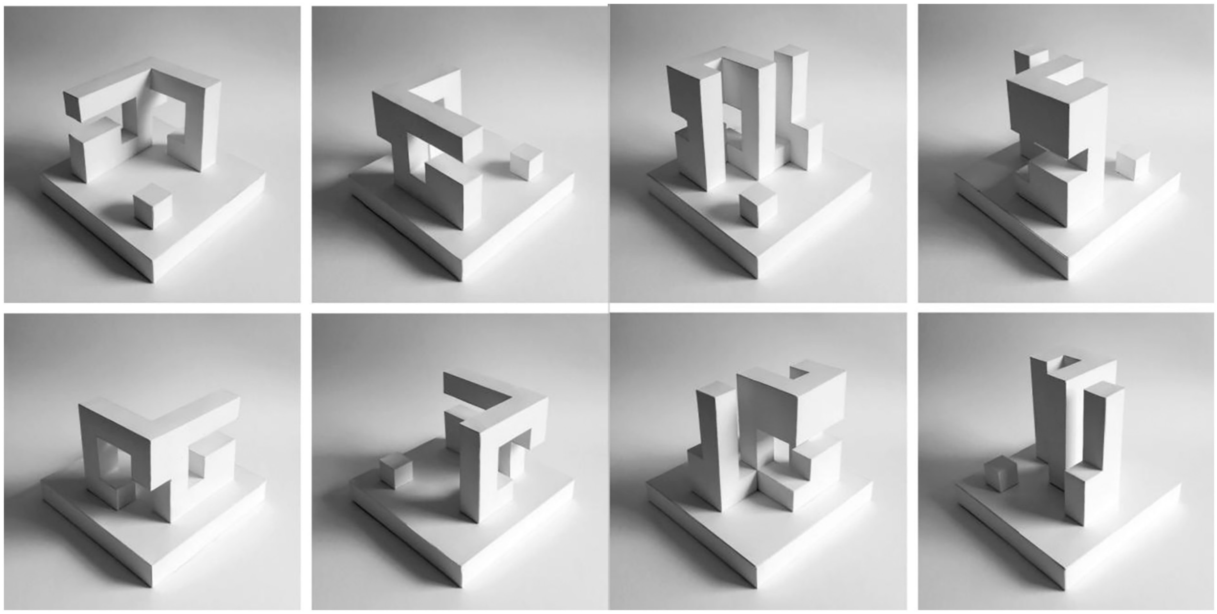

Fig. 1. Example of 2 architectural models used as a stimuli.

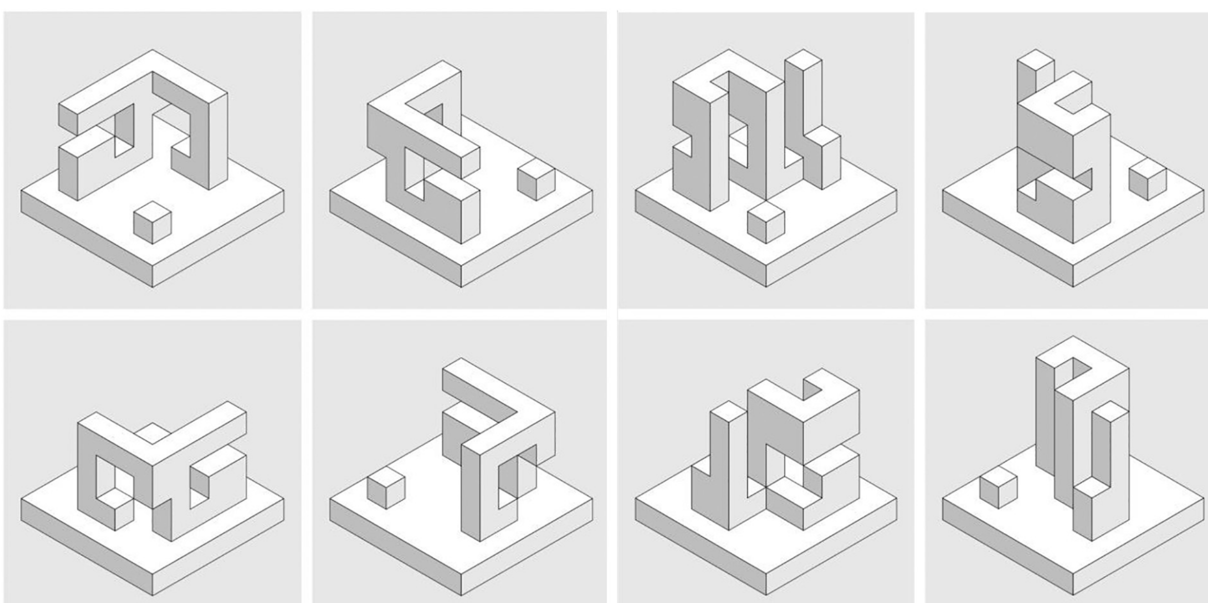

Fig. 2. Example of 2 architectural models drawings, also used as a stimuli.

software. Models were created directly in Unity, as cubes with default material, which were further modified in order to create virtual copies of real 3D objects. We used point light source option without shadows, positioned above each model. No additional effects were used for polishing virtual models, since they were viewed at approximately same virtual distance as other stimuli types, and participants were not allowed to zoom or to virtually approach them. Participants could only rotate virtual objects freely along vertical axes, by using keyboard buttons. These models were presented to participants by VR equipment, Oculus Rift DK2, which shows sufficient characteristics for our stimuli presentation, 960 × 1080 pixels per eye resolution, low-persistence OLED display, 75 Hz refresh rate, with integrated positional tracking. Virtual models looked similar to photographs shown in Fig. 1, but with the use of a VR headset they were observed as three-dimensional objects.

So, at the end there were 4 different instances of the original object represented in each medium: (1) real 3D objects, (2) their virtual reality copies, (3) their photographs from four angles, and (4) their drawings, also shown from the same four angles. In total we had 40 stimuli, out of which 20 were two-dimensional (photographs and drawings) and 20 were three-dimensional (real and virtual objects). Two-dimensional stimuli were presented on a printed paper to participants, real objects were given to them in hand, and virtual objects were presented through VR headset.

3.3. Instruments

Since structure of impression can vary depending on the object type (Marković & Alfirević, 2015; Marković & Radonjić, 2008), and participants estimated various types of stimuli (from 3D objects to drawings), we decided not to use scales developed specifically for architectural objects such as buildings. Also, many studies show that, although structure can vary, factors do refer to similar psychological domains, such as cognitive and emotional (Wolz & Carbon, 2014), or perceptual, cognitive, affective and motivational (Marković, 2014). Therefore, we used IFE-12 (*Implicit Features Experience 12*) scale, developed by Marković and Radonjić (2008) for measuring experience of stimuli's implicit features, or impression of object expressiveness. This scale contains 12 pairs of opposite adjectives, grouped into four factors: Attractiveness or Hedonic Tone (pleasant, beautiful, and healthy), Regularity (arranged, regular and clear), arousal (unusual, impressible and imaginative) and Calmness or Relaxation (unobtrusive, relaxed and calm). Similar descriptors (adjectives) were used in other studies, including estimation of architectural objects (Marković & Alfirević, 2015). Scale is frequently used for estimation of art-work as well as every-day objects, and for each descriptor estimations range from −3 to +3.

Besides IFE-12 scale, we included three unipolar descriptors (adjectives), in order to measure aesthetic experience per se, as it was previously published by Marković and Polovina (2006). For these descriptors (enchanting, exceptional and irresistible) scale ranged from 1 to 7. Whole instrument can be found in Appendix A.

3.4. Procedure

Experiment was done individually with each participant. After entering the experimental room they were introduced to the research procedure and signed informed consent. The participants' task was to observe each of the stimuli, to estimate their own experience on all scales, and to reply in a spontaneous way. All participants were estimating all 40 stimuli, on all 15 scales, 12 for implicit features experience and 3 for aesthetic experience. Stimuli were presented to each participant in blocks, with each block containing one type of stimuli, drawings, photographs, virtual and real 3D objects. Order of blocks, as well as order of individual stimuli within each block, was randomized between participants. Experiment lasted between 30 and 40 min per one participant.

4. Results

In order to make data from all above mentioned factors comparable, they were first transformed on a numerical scale from 1 to 7. Further on, we calculated scores for all factors of implicit features experience, by averaging estimates from all descriptors constituting a certain factor. Kolmogorov Smirnov test with Lilliefors correction showed that almost all factor scores show normal distribution, except attractiveness ($KS = 0.14$; $df = 146$; $p = .022$) and calmness ($KS = 0.13$; $df = 146$; $p = .043$) in photographs. Since Mauchly's test showed that sphericity condition is satisfied, data were analyzed by analysis of variance, with stimuli type (drawing, photograph, virtual and real 3D object) as a within-subject (repeated) factor. Analysis was performed for each subscale as a separate measure.

Results show significant differences between four types of object presentation on all scales of implicit features experience (impression): attractiveness, arousal, calmness and regularity. But, different presentations of objects did not affect the aesthetic experience of presented stimuli (Table 1). Effect sizes vary between mediate (attractiveness and calmness) to strong (arousal and regularity). Since two factor scores deviate significantly from normal distribution, we also performed by Friedman non-parametric tests and the same results were obtained.

Table 1
significance of differences between various stimuli presentation types on factors of implicit features experience.

	F	*df1*	*df2*	*p*	$\eta^2_{partial}$
Attractiveness	6.95	3	135	<.001	0.13
Arousal	8.76	3	135	<.001	0.16
Calmness	5.21	3	135	.002	0.10
Regularity	12.68	3	135	<.001	0.22
Aesthetic experience	1.78	3	135	*ns*	0.04

Looking at the results of Sidak post hoc test, we can see that real 3D objects were experienced as more attractive and calm from all other presentation types (drawings, photographs, and VR), which were experienced as similar among themselves. VR models showed reduced arousal in comparison to all other presentations. Only on regularity VR and real 3D objects were experienced as the same and more regular than drawings. On an experienced level of regularity, photographs were positioned between drawings on one side and VR and real 3D objects on the other, since they did not show significant differences from either (Appendix B). These findings suggest that presentation type (real or virtual object, photograph, and drawing) does affect and change our impression of objects' expressiveness (Fig. 3).

We also performed factor analysis, with the principal component method and varimax rotation of the principal axis, in order to check the structure of the original scale, IFE-12. Based on the Guttman-Kaiser criterion and Cattell scree plot only three factors can be extracted, which explain 64.24% of the variance in total. According to the component matrix, we can see that only regularity descriptors behave as a separate factor. Attractiveness and calmness descriptors are grouped into one factor, while arousal and aesthetic experience are grouped in the other (Table 2).

After repeating the analysis of variance on these grouped dimensions results remained almost the same. This is expected since gained factors are not a new kind of structure of implicit features experience they just indicate smaller variance between used stimuli in comparison to paintings which are used in previous researches (Marković & Radonjić, 2008). First factor is a combination of attractiveness and calmness and as in previous analysis, real 3D objects had higher scores that all other three presentation types ($F = 8.22$; $df = 3, 135$; $p < .001$; $\eta^2_{partial} = 0.15$). Regularity factor was identical and therefore same results were gained ($F = 12.68$; $df = 3, 135$; $p < .001$; $\eta^2_{partial} = 0.22$). Interesting combination was arousal and aesthetic experience dimension, since in previous analysis significant differences were gained only on the arousal. Combined together these two produced significant differences ($F = 4.04$; $df = 3, 135$; $p < .01$; $\eta^2_{partial} = 0.08$), such that drawing and virtual model had lower scores, while photograph and real 3D model were higher on this dimension. As previously shown, these differences are mainly due to arousal descriptors.

Although we intentionally used abstract geometrical shapes related to architecture, in order to control for various factors such as object complexity, color and familiarity, it would be interesting to compare our stimuli evaluations with real architectural objects. Therefore, we compared our results with estimates gained on similar factors of implicit features experience, for pictures of real architectural objects in a research done by Marković and Alfirević (2015). In their research architectural objects were classified in so called *choleric* and *phlegmatic* types, and we compared average estimates of both types on arousal, regularity and attractiveness factors with our stimuli evaluations. One sample *t*-test showed that our stimuli, in all four presentation types, significantly differ on implicit features experience factors from pictures of both, *choleric* and *phlegmatic* architectural objects (Table 3).

Results indicate that our stimuli, abstract geometrical shapes related to architecture, are estimated as less attractive than both, *choleric* and *phlegmatic* architectural objects, less arousing and more regular than *choleric*, but more arousing and less regular that *phlegmatic* cluster of architectural objects.

5. Discussion

The aim of our study was to investigate whether presentation type can affect our experience of a certain object. Therefore we varied four different presentations of the same set of abstract geometrical shapes,

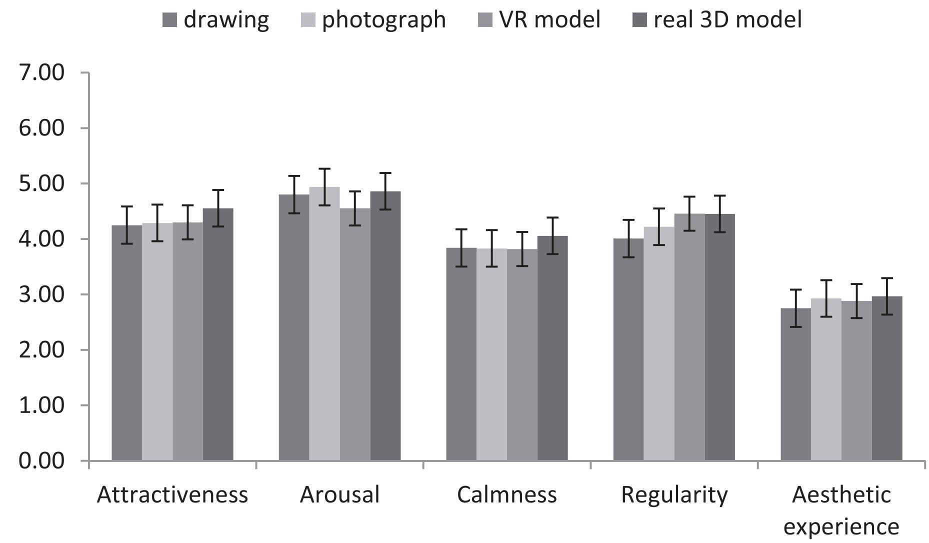

Fig. 3. Average estimates of four stimuli presentation types on five factors of impression.

Table 2
A rotated component matrix for three extracted factors of implicit features experience[a].

	Attractiveness + calmness	Arousal + aesthetic experience	Regularity
Relaxed	**0.79**		0.31
Calm	**0.74**		
Unobtrusive	**0.73**		
Pleasant	**0.70**	0.35	
Healthy	**0.70**		
Beautiful	**0.61**	0.51	
Exceptional		**0.82**	
Enchanting		**0.81**	
Imaginative		**0.74**	
Irresistible	0.38	**0.69**	
Impressible		**0.68**	
Unusual		**0.55**	−0.34
Regular			**0.84**
Arranged	0.37		**0.76**
Clear	0.38		**0.71**

[a] Bold numbers indicate the belongingness of adjectives to certain factors.

imitating architecturally designed objects. Stimuli were presented as real three-dimensional objects, virtual reality copies of them, their photographs, or their drawings made by architecture students. In randomized order, those stimuli were estimated on various descriptors of experience of an object's implicit characteristics (attractiveness, regularity, arousal and calmness) and descriptors of aesthetic experience. Since we did not use real architectural objects, in order to have a better stimuli control, our results can be discussed in terms of experience changes of abstract geometrical forms, but also, in terms of methodological limitations of photographs and drawings usage instead of 3D architectural objects in psychological researches.

The structure of the experience of stimuli implicit features used in this research did not deviate significantly from those gained in previous researches (Marković & Radonjić, 2008; Polovina & Marković, 2006). Of course, since objects used in this research do not vary in appearance as paintings used in previous researches do, the number of factors was lower, but descriptors remained the same positions within those factors. Namely, we got three factors of implicit features experience, but they were just aggregations of existent ones. Regularity remained as a separate dimension, while attractiveness and calmness were aggregated into one dimension, and arousal and aesthetic experience into the other.

Results did show significant differences between four presentation types, on all factors of implicit features experience, but not on the aesthetic experience. This is in line with some recent findings showing differences in evaluation of smart artifacts presented online, in virtual, augmented reality, in laboratory or on site (Voit et al., 2019). Depending on whether we show an object as a drawing, photograph, virtual and real three-dimensional model, it will appear different in attractiveness, regularity, arousal and calmness for the observer. In more details, presenting an object as a drawing, photograph or virtual three-dimensional model will not change its experienced *attractiveness* or *calmness*. But, if someone is observing a real three-dimensional object, it will tend to be more attractive and calm than all previously mentioned presentations of that same object. People will tend to experience a real 3D object as more pleasant, beautiful, healthy, unobtrusive, relaxed and calm than its drawing photograph and virtual model. This finding might be a consequence of higher interactivity with a real object than with all other

Table 3
Differences between our stimuli and pictures of real architectural objects on factors of implicit features experience.

		Arousal *Choleric* = 5.47 *Phlegmatic* = 2.16			Regularity *Choleric* = 3.48 *Phlegmatic* = 6.39			Attractiveness *Choleric* = 5.51 *Phlegmatic* = 5.44		
		t(45)	*p*	Cohen's *d*	*t*(45)	*p*	Cohen's *d*	*t*(45)	*p*	Cohen's *d*
Drawing	*Choleric*	−7.54	<.001	1.11	5.26	<.001	2.15	−13.58	<.001	1.94
	Phlegmatic	29.7	<.001	4.38	−23.76	<.001	2.72	−12.83	<.001	3.32
Photograph	*Choleric*	−5.60	<.001	0.83	7.20	<.001	1.79	−10.79	<.001	1.54
	Phlegmatic	29.11	<.001	4.29	−21.11	<.001	2.96	−10.17	<.001	2.78
VR model	*Choleric*	−8.76	<.001	1.29	7.93	<.001	1.30	−9.20	<.001	1.81
	Phlegmatic	22.79	<.001	3.36	−15.82	<.001	2.93	−8.52	<.001	3.32
Real 3D model	*Choleric*	−5.67	<.001	0.84	8.46	<.001	1.23	−12.71	<.001	1.30
	Phlegmatic	25.11	<.001	3.70	−16.77	<.001	2.76	−11.97	<.001	3.39

presentations. Only real 3D objects allow participants to touch it, feel it through other senses and receive kinesthetic information through interaction with an object. Although participants were able to rotate virtual models by keyboard, which does enable some sort of interaction, it is mediated through the keyboard buttons. Participants cannot touch virtual models, they only touch a keyboard and therefore haptic perception is not informative for experiencing these kinds of objects. Accordingly, some recent findings show that hedonic preference in virtual reality increases when tactile sensations are provided through a haptic device (Etzi et al., 2018), as well as that inconsistent virtual settings alter participants' behaviours (Simeone et al., 2017). With drawings and photographs there is a possibility for participants to touch them, but they usually do not do it, since it is also not informative, it just provides sensations from touching a flat paper. This result might be in line with various empirical and theoretical findings implying the importance of different perceptual modalities in processing of conceptual knowledge (Barsalou, 1999, 2008; Fernandino et al., 2015; Filipović Đurđević et al., 2016; Kiefer et al., 2008; Lynott & Connell, 2010). Also it is shown that objects are judged as having higher valence, or higher attractiveness, if they can be experienced with more senses (Popović Stijačić & Filipović Đurđević, 2018).

Arousal of a certain object will not change if an observer is experiencing it as a real three-dimensional object, or as a drawing or a photograph. Presenting that same object as a virtual 3D model will reduce its arousal, and the object will be experienced as less unusual, impressible and imaginative. This is a bit surprising result, especially having in mind that VR headsets are still not commonly used by our participants. Therefore, we could expect the opposite, that participants will experience virtual models as more unusual, impressionable and imaginative. But it might happen that objects used as stimuli were already quite unusual and imaginative for our participants, since they are abstract forms created by architecture students, and therefore VR appearance couldn't contribute more to their arousal. Also, we can see that arousal is judged as higher than all other factors of implicit features experience, which is in line with previous assumption (Fig. 3). Having in mind that arousal shows higher effect on working memory speed than valence (Yüvrük et al., 2020), we can assume it could lead to a ceiling effect. Nevertheless, the high starting arousal level of our stimuli cannot fully explain its reduction in VR setting, especially having in mind that arousal remained high in drawings and photographs. We can only speculate that it has something to do with computer generated stimulation, since VR experience questionnaires can potentially lead to systematic biases (Putze et al., 2020), or with some confounding factor which we did not notice or measure.

Experienced level of *regularity* will remain the same if an object is presented as real 3D or as a virtual model. Putting an object into a virtual reality setting will not affect the observer's impression on how regular it appears. But, presenting that same object as a drawing will reduce its impression of regularity, and an object will be experienced as less arranged, regular or clear. Since photographs did not appear significantly different from drawings or from virtual and real 3D objects, we can conclude that their regularity is also a bit reduced and it lies between drawings and 3D objects. This purely cognitive dimension is obviously unaffected by changing object setting from real to virtual environment, but it can be affected by reduction of its dimensionality. Projections of 3D objects into 2D planes will probably make them look less arranged, regular and clear.

Lastly, *aesthetic experience* of objects did not vary with presentation type change. Regardless of whether someone is observing a drawing, photograph, virtual or real 3D object, he/she will experience it as enchanting, exceptional and irresistible with the same intensity. This is an important finding for experimental aesthetics since it indicates that aesthetic experience per se might not change if we use different means to present stimuli. It gives us as researchers more freedom in stimuli choice, and it does not limit us to using real objects. For example, if someone is studying aesthetic experience of buildings, using photographs of those stimuli might show the same findings as taking participants in front of real buildings. But, we must have in mind that the obtained result is limited to abstract small size objects, designed by future architects, and we have to be careful with its generalization to real architectural objects. Also this finding is limited to aesthetic experience only, while other dimensions of implicit features experience (attractiveness, arousal, calmness and regularity) are affected by presentation type.

Finally, from the architectural point of view, it is very important to know if various ways of object presentation can redefine the perception of form. Some architecture theorists believe that different tools are not just a means of project presentation, but a way of thinking and generating an architectural object (Owen Moss, 2013). From this perspective, our findings provide important insights, although our stimuli do not represent all possible presentation options of an object. However, we did use presentation modes which are common in architecture, as well as in psychological research. We clearly showed that all other presentation types used in our research, instead of real three-dimensional objects, will reduce its *attractiveness* and *calmness*, and objects will be experienced as less pleasant, beautiful, healthy, unobtrusive, relaxed and calm. Using virtual reality settings to design objects will probably reduce their experienced arousal and they will be experienced as less unusual, impressible and imaginative. Experienced regularity of objects will be conserved in 3D appearances (real and virtual), but it can be reduced in photographs and drawings. People will experience two-dimensional projections of objects as less arranged, regular or clear. Besides all that, an aesthetic experience of designed objects will not be changed significantly. If we follow Musca (2017) claiming that visualization becomes simulation, it is very important for architects and designers to have our study results in mind. Knowing that someone's impression, including designer's or architect's impression, can vary significantly from drawing to real object, and might improve the process of creating new designs, especially during education and training.

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Compliance with ethical standards

Declaration of competing interest

The authors declare that they have no conflict of interest, and no competing financial and/or non-financial interests in relation to the work described.

Ethical approval

All procedures performed on human participants in this study were in accordance with the 1964 Helsinki declaration and its later amendments or comparable ethical standards and with the ethical standards of the institutional research committee. Accordingly, study was approved by Institutional Review Board (IRB) of Department of Psychology, Faculty of Philosophy, University of Belgrade, Serbia, protocol number #2019-036.

Informed consent

Informed consent was obtained from all individual participants included in the study. Also, participants signed informed consent and agreed to publish images from the experiment in an online open-access publication.

Data availability

Datasets analyzed during the current study are available from the corresponding author on reasonable request.

Author contributions

1st author (Oliver Tošković) developed the research questions, experimental design and performed data analysis. 1st and 2nd authors (Vladimir Kovač and Danira Sovilj) designed and developed stimuli. All three authors (Oliver Tošković, Vladimir Kovač and Danira Sovilj) performed and oversaw the experiment and participated in paper writing.

Appendix A. IFE-12 scale for measuring implicit features experience of objects (bipolar adjectives) and 3 scales for aesthetic experience (unipolar adjectives)

Attractiveness (hedonic tone)	Unpleasant	−3	−2	−1	0	1	2	3	Pleasant
	Ugly	−3	−2	−1	0	1	2	3	Beautiful
	Ill	−3	−2	−1	0	1	2	3	Healthy
Arousal	Unimpressive	−3	−2	−1	0	1	2	3	Impressible
	Unimaginative	−3	−2	−1	0	1	2	3	Imaginative
	Usual	−3	−2	−1	0	1	2	3	Unusual
Calmness (relaxation)	Intrusive	−3	−2	−1	0	1	2	3	Unobtrusive
	Tense	−3	−2	−1	0	1	2	3	Relaxed
	Strict	−3	−2	−1	0	1	2	3	Mild
Regularity	Messy	−3	−2	−1	0	1	2	3	Arranged
	Irregular	−3	−2	−1	0	1	2	3	Regular
	Unclear	−3	−2	−1	0	1	2	3	Clear
Aesthetic experience		1	2	3	4	5	6	7	Enchanting
		1	2	3	4	5	6	7	Exceptional
		1	2	3	4	5	6	7	Irresistible

Appendix B. Sidak post hoc tests for significant of differences of impression between four types of object presentation (drawing, photograph, virtual and real 3D object)

Measure	(I)	(J)	Mean difference (I-J)	*SE*	*p*
Attractiveness	Drawing	Photograph	−0.04	0.07	*ns*
		VR 3D	−0.05	0.08	*ns*
		Real 3D	−0.30	0.07	.001
	Photograph	VR 3D	−0.01	0.09	*ns*
		Real 3D	−0.26	0.08	.008
	VR 3D	Real 3D	−0.25	0.07	.002
Arousal	Drawing	Photograph	−0.14	0.07	*ns*
		VR 3D	0.25	0.09	.031
		Real 3D	−0.06	0.08	*ns*
	Photograph	VR 3D	0.39	0.09	.001
		Real 3D	0.08	0.07	*ns*
	VR 3D	Real 3D	−0.31	0.08	.001
Calmness	Drawing	Photograph	0.01	0.07	*ns*
		VR 3D	0.02	0.07	*ns*
		Real 3D	−0.22	0.07	.019
	Photograph	VR 3D	0.01	0.07	*ns*
		Real 3D	−0.23	0.08	.025
	VR 3D	Real 3D	−0.24	0.06	.001
Regularity	Drawing	Photograph	−0.21	0.08	*ns*
		VR 3D	−0.45	0.09	<.001
		Real 3D	−0.44	0.08	<.001
	Photograph	VR 3D	−0.24	0.09	*ns*
		Real 3D	−0.23	0.09	*ns*
	VR 3D	Real 3D	0.01	0.08	*ns*
Aesthetic experience	Drawing	Photograph	−0.18	0.07	*ns*
		VR 3D	−0.13	0.12	*ns*
		Real 3D	−0.22	0.08	*ns*
	Photograph	VR 3D	0.05	0.13	*ns*
		Real 3D	−0.04	0.09	*ns*
	VR 3D	Real 3D	−0.08	0.10	*ns*

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