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# SPACE AND HUMAN PERCEPTION –

## *Exploring Our Reaction to Different Geometries of Spaces*

AVISHAG SHEMESH[1], MOSHE BAR[2], YASHA JACOB GROBMAN[3]
[1,3] *Faculty of Architecture and Town Planning, Technion – Israel Institute of Technology, Haifa, Israel*
[2] *Brain research center, Bar Ilan University, Ramat-Gan, Israel*
[1]shugi.shemesh@gmail.com, [2]Moshe.Bar@biu.ac.il,
[3]yasha@technion.ac.il

**Abstract.** In the aspiration to design the built environment, architects and designers are continuously trying to create spaces that positively affect users. Both aspects of rational and emotional combined simultaneously with technological advancement are essential to implement in a comprehensive architectural design process. While our ability to create complex architectural forms through computation is in the state of a continuous improvement, our knowledge about their emotional effects over users remain ambiguous. Recent developments in simulation of virtual spaces, along with advancement in neuroscience may enable us to conduct an empirical research on the way we perceive space and the way space affects us emotionally. This paper presents initial results from an ongoing research that examines the connection between human feelings and architectural space. We discuss the first stage of the research in which as we examine the emotional reaction of designers and non-designers to various spatial geometries in an immersive 3D virtual environment inside a visualization laboratory. We then present the methodology for the second stage of the research, in which we repeat the experiment while using Electroencephalography (EEG) device together with a wireless eye tracker and emotional engagement measurements (EEM) system.

**Keywords.** Virtual reality; computational design; human-computer interaction; space perception; Space geometry; Feelings; aesthetic judgment; neuroaesthetics.

## 1. Introduction

Different researches in the fields of psychology, behavioural studies, E-B studies, architecture and other fields have tried to define and explain the emotional impacts space has over a person. These studies show that different spaces evoke different emotions, yet it is still hard to tell exactly how architecture induces them. This research integrates conclusions from several different research fields in order to establish a methodology for exploring the connection between space and human feelings. This may encourage architects and architecture educators to produce more scientific knowledge for the field in the future, using tools of computation and simulations. This may enhance our capabilities to create more pleasant environments- a primary goal for designers, architects and urban planners.

This paper presents initial results from an ongoing research, which aspires to increase the body of knowledge on the connection between geometry of space, visual perception and emotions by visual navigation in a virtual environment, in both qualitative and quantitative methods. The paper starts with a critical review over recent studies, which indicate towards a connection between shapes and feelings. It then discusses a 2-stage experiment, the first part of which examines people's reaction to various spatial conditions in a visualization laboratory. We also present the second stage of the research in which we intend to study the connection between space geometry and emotions by using a wireless EEG device together with a wireless eye tracker and emotional engagement measurements (EEM) system.

## 2. Space Perception and Emotions

Several research fields have meaningful insights which may contribute to our understanding of the way humans perceive different spaces and how the geometry of spaces [1]affects our [2]feelings. Neuroscience and cognitive psychology indicate towards a connection between shapes of objects and feelings. Our preference for objects has been shown to be influenced by many factors including mere exposure, familiarity, symmetry, contrast, complexity, and perceptual fluency (Zajonc, 1968; Winkielman, Schwarz et al., 2002; Hekkert, 2006). "Perceptual fluency", or "high fluency", means that the more fluently perceivers can process an object, the more positive their aesthetic

[1] In psychology, affect refers to a specific kind of influence—something's ability to influence a person's body state (Barrett and Bar, 2009).

[2] Emotions happen in the back of our consciousness. It is not until they register in the foreground as a feeling that we are aware of having an emotional experience. Basically, the difference between an emotion and a feeling depends on the process-emotion emerge as a feeling (Eberhard, 2007).

response. This may explain why people prefer symmetric shapes, as they contain less information than asymmetric shapes (Garner, 1974).

In addition to the subject of symmetry, there is now evidence that angular hexagons are less pleasing than round circles (Bar and Neta, 2008). Furthermore, people with low expertize in the fields of design prefer curved over angular shapes when they are simple (circles and hexagons), while experts show such curved versus sharp preference bias for the more complex polygons (Silvia and Barona in press, as mentioned by Bar and Neta, 2008). Reber, Schwarz et al. (2004) also discuss the expertise influence, claiming that training in arts gives meaning to complex structures which results in an additional increase in processing ease. Vartanian, Navarrete et al (2013) conducted a functional magnetic resonance imaging study that examines how variation in contour impacts aesthetic judgments and approach-avoidance decisions. Their results demonstrated that participants were more likely to judge curvilinear than rectilinear spaces as beautiful.

Observing visual stimuli regarding spatial perception is a complicated task. These are new methods of observation and a custom-made virtually built setup that may sustain this task. The availability of more realistic representations that involve multiple coordinated sensory modalities offers the possibility of studying spatial cognition using more natural experimental conditions (Bhatt, Hölscher et al., 2011). Edelstein et al. (2008) have shown the ability to reflect a cognitive state of disorientation in a featureless VE (virtual environment) obtained by a Cave-Cad tool and the use of Electroencephalography (EEG). In addition, Dias, Eloy et al. (2014) claimed that by electromyography (EMG) and electrodermal activity (EDA) they were able to objectively discriminate arousal responses related to "positive" or "negative" emotions, from the neutral condition, on users that were confronted with architectural spaces in VR.

## 3. Methodology

In the frame of this research we wish to explore humans' aesthetic judgments and feelings towards spaces characterised by different geometries. There is no doubt that properties of space include colour, light, texture, smell and sound as well, yet in order to simplify the problem and concentrate on a dominant long debated aspect in the field of architecture, we decided to investigate the property of geometry at this stage of our examination.

The research is based on two main preliminary hypotheses. The first states that there is a connection between the properties of space and human emotions. Positive and negative sensations towards different geometries of space can be explored in the setting of VE. The second hypothesis is that thanks to advances in technology it is possible to conduct an empiric measurement of changes happening in our mind in reaction to different spatial conditions.

To verify these hypotheses and examine participants' response to different spatial setups, we have developed a two-staged methodology: The first stage is focused on quantification and analysis of a descriptive response (self-evidence). This stage took place identically over expert and non-expert users. In the next stage we would follow and collect data over physiological response and brain response, as we repeat the experiment. Responses should imply for positive and negative feelings (Barrett and Bar, 2009). By using Electroencephalography (EEG) device, we intend to examine whether possible differences between voltage fluctuations resulting from ionic current flows within brain neurons could be related to the different spatial conditions. In order to achieve lucidity, a wireless eye tracker and emotional engagement measurements (EEM) system would be combined. This system allows us to extract a large variety of physiological features and use them to discriminate the mental and physical loads of user defined exercises (Hintermüller, Edlinger et al., 2012).

The expected results were that experts (designers) would tend to prefer an asymmetric space with sharp edges, as according to previous researchers which indicate their preference towards more complex polygons. In correlation, non-designers were expected to prefer a round symmetric space. We also expected non-experts to feel more pleasant in spaces that were more familiar to them (a square space) in contrast to experts who would likely to show less affection to the familiar.

## 4. Experiment description

### 4.1. THE SETTING

Using the Visualization lab in the architecture faculty, which contains a 3-D immersive theatre consisting of a 2.4 x 7.0 m screen with a 75° field of view, three high-definition projection and motion sensors, participants experienced an inner virtual space, characterized by different forms. A VE setting offers participants a sense of presence in the space (Kieferle and Wössner, 2001). Furthermore, Humans that experience freewill exploration of virtual environments can demonstrate a wide range of behaviours and responses similar to their naturalistic exploration of real world environments, according to Morie, Iyer et al (2005).

## 4.2. THE VIRTUAL SPACES

Planning and deciding over the specific geometry of spaces was complex, as these spaces are not only a platform for the examinee but an integral subject of examination by itself. In order to examine aesthetic judgment towards orthogonal versus curved shapes, and simple symmetrical versus complex unsymmetrical shapes, we chose to build four types of spaces with similar proportions to be the setup of the experiment:
(1) Square symmetrical space (Sq).
(2) Round domed space or half a sphere, symmetrical (Ro).
(3) Sharp edged space, tilted surfaces (walls, ceiling), unsymmetrical (Sh).
(4) Curvy space with rounded smooth surfaces (with no corners), unsymmetrical (Cu).

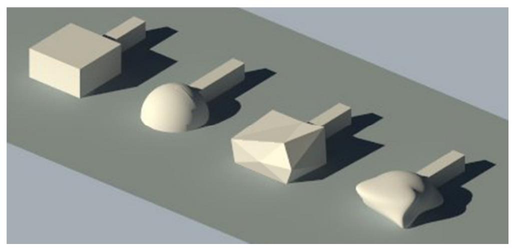


*Figure 1. Four designed VR spaces – external view. First from the left: a Square symmetrical space. Second: a Round domed space. Third: Sharp edged space. Fourth: a curvy space.*

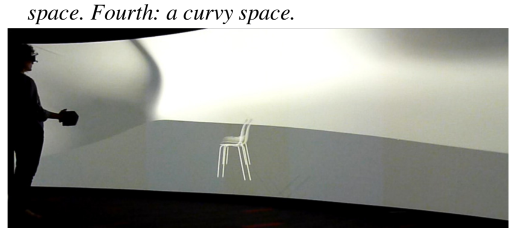


*Figure 2. An internal view of a curvy space from the eye of the participant*

The idea was to examine two pairs of spaces: shape of a square and a shape of a sphere were compared to complex forms with breaks and curves. They also differentiate by their symmetry (two symmetrical forms versus two unsymmetrical forms). Openness and room proportions are matters of relevancy (Franz, von der Heyde et al., 2005) and should be dealt with in another separate experiment. Nevertheless, in order to perform an optimal comparison of geometry impact over user, all designs had to maintain comfortable proportions and a sense of human scale. A space too small might create an automat feeling of suffocation, while a space too large might create discomfort or immediate excitement. As such, all spaces designed to be approximately the same size. Proportions of an average sized auditorium were chosen: a floor of 12 X 12 meters, and ceiling over the height of 6-8 meters. In addition, we had to refer to the difference between an interpersonal objective and perceived distance (Gifford, 1983). In order to do so, we have entered the reference of a chair. Volumes were designed to be colourless (monochromatic), soundless, with no objects (besides a chair).

### 4.3. EXPERIMENT PROCESS

Examinees were asked to practice the 3-D goggles and joystick use in order to gain expertise and a sense of control over the VizTech XL software system. Every participant was asked to wander around an indefinite room which lacks any certain designation and look at famous pictures. This also set participant's mind at ease before starting the experiment.

As the actual experiment begun, the participant entered the space by "walking" through a standard corridor and entering a door. This stage is important, as researchers found that entering a room or walking through doorways can facilitate forgetting or evoke one's memory (Ballard, Hayhoe et al., 1997; Radvansky and Copeland, 2006). Wang and Spelke (2000) found that human navigation through a layout in an unfamiliar environment depends on an updating representation process of targets positioning relative to the self, which occurs during movement. Participants were asked to "walk" towards the chair after entering space, explore the space and leave (through the same door) as they finish. Order of spaces was changed randomly.

### 4.4. PARTICIPANTS

Two groups of 21 people per group participated in the experiment. The first group (Group E) contained students (52.3% women) from the fields of architecture, landscape architecture, interior design and industrial design studies. The second group included 21 people (33.3% women). This group was consisted of non-experts: people who are not connected to design studies (Group NE). Participants were asked to mention where they grew up (type of locality and residence) in order to check possible past experience influence.

## 5. Results and discussion

### 5.1. A PROCESS OF EXPLORATION

Noe (2004) claims that the world makes itself available to the perceiver through physical movement and interaction. We may so look at the process of space perception in VE, as in real life, as an experience. According to Hekkert (2006), we 'experience' when we have a unity of sensuous delight, meaningful interpretation, and emotional involvement. Participants often described a positive experience as a process of exploration and interpretation. Non-interesting spaces were described as responsible for a feeling of impatience and frustration, at most times.

Insufficient data regarding the implications of actual movement in VE is undeniable. An absence of natural movement, poses a problem for the navigator, as idiothetic information that is needed to update egocentric spatial representations is missing (Zhang, Gossmann et al., 2011). Future research combining actual movement is essential for better understanding of the spatial perception process.

One could expect these repetitive processes to have some sort of an influence over aesthetic judgment. According to adjusted calculation, group E tended to like the first space presented to them the least, while group NE tended to like the second the least. The reason for this difference is unclear to us.

## 5.2. PERFERENCES OF SPACES

Both groups of experts and non-experts preferred asymmetric spaces over symmetric, with one main difference: group E showed a tendency to prefer space Sh (mean of 3.5) while group NE showed a tendency to prefer space Cu (mean of 3.3), (Table 1). Group NE showed a slightly higher standard deviation in symmetric spaces level of preference than group E ($\sigma_{NE, Sq} = 1.7$, $\sigma_{E, Sq} = 1.6$, $\sigma_{NE, Ro} = 1.8$, $\sigma_{E, Ro} = 1.5$). Group E seemed to have a higher standard deviation in asymmetric spaces ($\sigma_{NE, Sh} = 1.8$, $\sigma_{E, Sh} = 1.9$, $\sigma_{NE, Cu} = 1.7$, $\sigma_{E, Cu} = 1.8$). A larger amount of participants is needed in order to achieve a possible significance. Results in the open description part of the questionnaire revealed a preference tendency of group NE towards Cu space (Table 2). NE group may lack skills of space interpretation, which may explain this lower correspondence between classification and open writing data.

Table 1

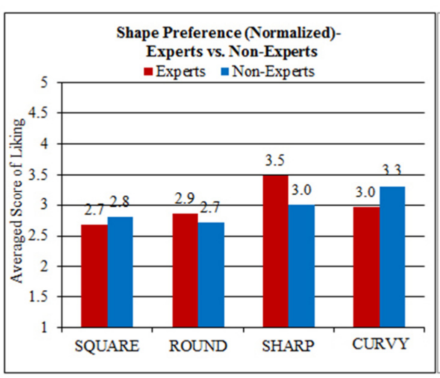
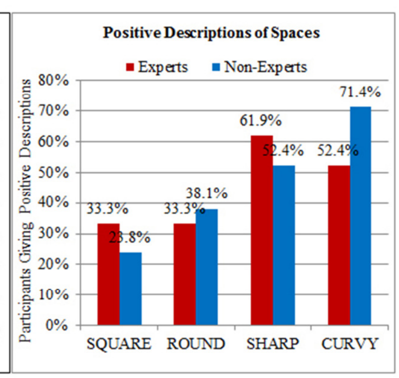



Table 2



## 5.3. THOUGHTS AND FEELINGS TOWARD SPACES

As expected, group NE felt more pleasant in spaces that are more familiar to them. They showed great interest toward the Cu space, as 90.5% of them found this space interesting ($X^2(1)=4.725$, $P<0.05$, Rcrem=0.335, $p<0.5$). They also found this space much prettier than other spaces (and relatively more efficient in contrast to group E). Most participants in group E showed smaller differentiation between categories (Sq space is an exception). Space Ro tented to seem more interesting and pretty to them than to group NE (Table 3,4).

Table 3

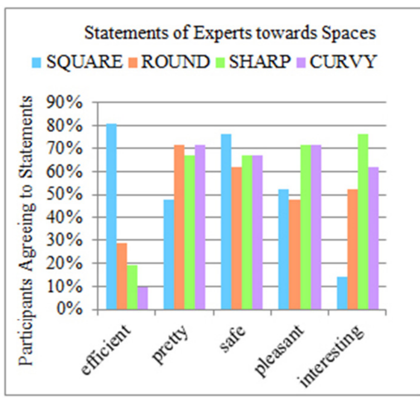
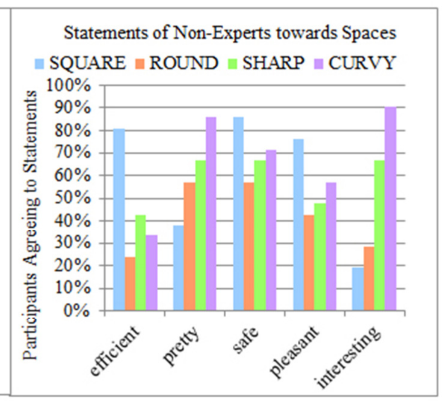



Table 4




## 5.4. SUGGESTED ACTIVITIES

We have divided potential uses of spaces (suggested solely by participants) into seven. Uses refer to suitable activities or a suggested function for the space. Among the results of this part it was most interesting to detect a gap between possible activities offered by experts and non-experts (Table 5,6). These rather different predictions of space use, though may be attributed to different background domains, emphasize the significance of this type of re-

Table 5

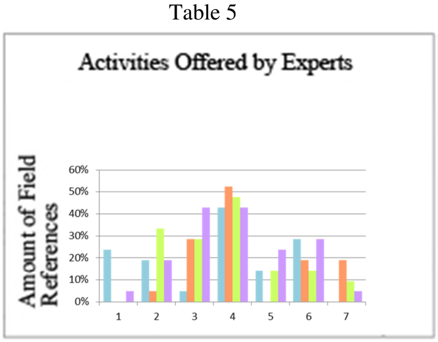
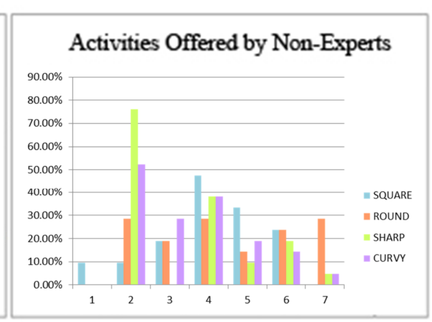



Table 6




*(**1**)Any kind of activity (as mentioned by participants);(**2**)Art/exhibitions/museum (creative context);(**3**)Sport/playing an instrument/children playroom (physical activities);(**4**)Public gathering/working or studying (non-active group activities)(**5**) Solitude (positive)/residence (personal uses);(**6**)Solitude (negative)/storage (unhuman activity);(**7**)Geometry oriented (functions that derive solely from a geometrical prototype, like igloo or planetarium).*

search. By learning these differences and sharpening the reasoning of figural representation (Goldshmidth, 1997), architects may get closer of reaching an effective integration of user knowledge to design (Ozten Anay, 2011), and raise their ability to create custom-built spaces for the potential user.

## 6. Conclusions and future research

The paper presents the results of the first stage of a research that tries to bridge the gap in our understanding of perceptual parameters in architectural design (Grobman, 2011). It also presents a framework for the second stage of the research that will try to validate these initial results using empirical quantitative methods.

Contrary to the initial assumption, in terms of averaged liking score, non-experts showed no preference towards symmetrical spaces. Results show, on the other hand, they were significantly more interested by the Curvy space than the experts, who showed a tendency to prefer the Sharp space. It also showed a difference between these two groups in term of their various thoughts and feelings towards spaces, and their idea on possible uses of the various types of spaces.

Further research is needed in order to fine-tune these results in relation to differences in preference within each category of space in order to determine the relation between the dimensions of the space and human feelings. Another important further examination has to do with the level of complexity of form in the tessellated options and its influence on the results.

## References

Ballard, D.H., Hayhoe, M.M., Pook, P.K. and Rao, R.P: 1997, Deictic codes for the embodiment of cognition. *Behavioral and Brain Sciences*, 20(04), 723-742.

Bar, M. and Neta, M.: 2008, The proactive brain: Using rudimentary information to make predictive judgments. *Journal of Consumer Behaviour,* 7(4-5), 319-330.

Barrett, L. F and Bar, M.: 2009, See it with feeling: affective predictions during object perception. *Philosophical Transactions of the Royal Society B: Biological Sciences,* 364(1521), 1325-1334.

Bhatt, M., Holscher, C. and F. Shipley, T.: 2011, Spatial Cognition for Architectural Design *SCAD conference*, New York, 16–19.

Dias, M.S., Eloy, S., Carreiro, M., Proenca, P., Moural, A., Pedro, T., Freitas, J., Vilar, E., D'alpuim, J. and Azevedo, A.S.: 2014, Designing better spaces for people- Virtual reality and biometric sensing as tools to evaluate space use. *CAADRIA2014,* Hong Kong, 739-748.

Eberhard, J.P., (ed.): 2007, *Architecture and the Brain- A New knowledge base from neuroscience*, Atlanta, GA: Greenway Communications, Ostberg.

Edelstein, E.A., Gramann, K., Schulze, J., Shamlo, N.B., Van Erp, E., Vankov, A., Makeig, S., Wolszon, L. and Macango, E.: 2008, Neural Responses during Navigation in the Virtual Aided Design Laboratory: Brain Dynamics of Orientation in Architecturally Ambiguous Space. *Movement and Orientation in Built Environments: Evaluating Design Rationale and User Cognition*, 35.

Franz, G., Von Der Heide, M. and Bulthoff, H.: 2005. An empirical approach to the experience of architectural space in virtual reality—Exploring relations between features and affective appraisals of rectangular indoor spaces. *Automation in Construction,* 14, 165–172.

Garner, W.R.: 1974, *The processing of information and structure*. Lawrence Erlbaum Associates Potomac, MD.

Gifford, R.: 1983. The experience of personal space: Perception of interpersonal distance. *Journal of Nonverbal Behavior*, 7(3), 170-178.

Goldschmidt, G.: 1997, Capturing indeterminism: representation in the design problem space. *Design Studies*, 18(4), 441-455.

Grobman, Y.J.: 2011, *“The Various Dimensions of the Concept of “Performance” in Architecture”. In Performalism – Form and Performance in Digital Architecture. Eds. Routledge Press*. pp. 9-13.

Hekkert, P.: 2006. Design aesthetics: principles of pleasure in design. *Psychology science*, 48(2), 157.

Hintermuller, C., Edlinger, G. and Guger, C.: 2012, Generic Tool for Online Classification of Physical and Mental Workload. *Measuring Behavior* 2012, 206.

Kieferle, J. and Wossner, U.: 2001, Showing the invisible. Seven rules for a new approach of using immersive virtual reality in architecture, *19th eCAADe Conference*, Helsinki, 376-381.

Morie, J.F., Iyer, K., Luigi, D., Williams, J. and Dozois, A.: 2005, Development of a data management tool for investigating multivariate space and free will experiences in virtual reality. *Applied Psychophysiology and Biofeedback*, 30(3), 319-331.

Noe, A.: 2004, *Action in perception*. MIT Press.

Ozten Anay, M.: 2011, Bridging the gap: Designer’s “user concept” as a transformative tool between user knowledge and design. *Anadulo University Journal of Science and Technology–Applied Sciences and Engineering*, 12(2), 111-118.

Radvansky, G.A. and Copeland, D.E.: 2006. Walking through doorways causes forgetting: Situation models and experienced space. *Memory & cognition*, 34(5), 1150-1156.

Reber, R., Schwarz, N. and Winkielman, P.: 2004, Processing fluency and aesthetic pleasure: is beauty in the perceiver's processing experience? *Personality and social psychology review*, 8(4), 364-382.

Silvia, P. and Barona, C.: 2009, Do people prefer curved objects? Angularity, expertise, and aesthetic preference. Empir Stud Arts(27 (1)), 25-42.

Vartanian, O., Navarrete, G., Chatterjee, A., Fich, L.B., Leder, H., Modrono, C. and Skov, M.: 2013, “Impact of Contour on Aesthetic Judgments and Approach-Avoidance Decisions in Architecture.” *Proceedings of the National Academy of Sciences of the United States of America*, 110.Suppl 2 (2013): 10446–10453. PMC. Web. 11 Dec. 2014.

Wang, R.F. and Spelke, E.S., 2000, Updating egocentric representations in human navigation. *Cognition*, 77(3), 215-250.

Winkielman, P., Schwarz, N. and Nowak, A.: 2002, Affect and processing dynamics Perceptual fluency enhances evaluations. *Emotional cognition: From brain to behaviour*, 44, 111.

Zajonc, R.B.: 1968, Attitudinal effects of mere exposure. *Journal of personality and social psychology*, 9(2p2), 1.

Zhang, L., Gossmann, J., Stevenson, C., Chi, M., Cauwenberghs, G., Gramann, K., Schulze, J., Otto, P., Jung, T. and Peterson, R.: 2011, Spatial cognition and architectural design in 4d immersive virtual reality: Testing cognition with a novel audiovisual cave-cad tool. *SCAD conference*, New York, 41-50.