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COGNITION AND EVALUATION OF ARCHITECTURE ENVIRONMENTS BASED ON GEOMETRIC CONTOUR REFERENCES AND AESTHETIC JUDGEMENTS

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Abstract. This paper presents the outline and the achieved results of an experimental study developed to understand the differences on how close architecture spaces with distinct geometric characteristics at contour level, including rounded, curvilinear and sharp, rectilinear elements, are perceived and evaluated. In order to do so, eighteen virtual reality architecture spaces were evaluated by thirty-two test-subjects according to like/dislike aesthetic judgments. As expected, the tested subjects showed a higher level of preference for spaces with rounded, curvilinear contour elements. On another way, when the level of space curvature was high, considering the whole space surface and not only the contour of plan transitions, the level of preference decreased significantly. These results support the idea that rounded, curvilinear elements are interpreted as being more pleasant and preferred than sharp, rectilinear ones and create new knowledge on the how the levels of such preference are more accurate for moderate rather than radical curvature rates.

Keywords. Geometric contour; Architecture space environment; Curve, rounded, angular and rectilinear; aesthetic judgement; experimental study.

1. Introduction

Automate building technologies gave rise to a whole new era of the discipline of architecture. The facts that: (i) Digital Revolution has been increasingly effecting the architecture field, namely the achieved closeness between prototype and mass production techniques, that; (ii) recent studies have develop work and theories on how curve, rounded and angular, rectilinear contour objects have the ability to trigger specific pleasant or unpleasant cognitive processes on humans and that; (iii) we believe to be of the outmost importance to understand architecture, which are its limits, what it has to offer and how it can better assist our conscious and unconscious needs and feelings; demand an update and clarifying exercise on the potentialities of the architecture of today.

That said, as a field that seeks the knowledge about beauty and taste, aesthetics have been under the scope of thinkers since at least the Greek Classical Period. However, the way we used to examine ”real matter of fact (Hume 1757) would change considerably in the late 19th century when Gustav Fechner tries to understand subjective judgments through methods of extreme ranks. He later introduces the notion of median as a mean of formal analysis of data, jumps into the field of experimental aesthetics and elaborates on the pleasing condition of aesthetic objects (Heidelberg). At this point the study of aesthetics begins to stand apart from subjective reasoning to getting closer to a more objective evaluation.

Future work on the 20th century would perform experimental studies on angularity (Lundholm 1921) and curvature (Poffenberger et al.) and on subjective preferences on lines, forms, colors and shapes (Gordon 1909; Valentine 1962; Silvia et al. 2009).

With the arrival of the Digital Revolution a set of innovative tools would become available to measure beauty at a completely different level. More than ever the study of subjects in general was closer to an objective and quantitative point of view rather than a more subjective, fallible and less accurate one (Hume 1757). Techniques like low and high space frequency (Bar et al. 2007) and biosensing technologies such as hearth beat, electrodermal response and electroencephalography opened a whole new era on the definition, perception and evaluation of pleasantness, beauty and aesthetics.

Among modern researches on angularity and curvature are studies on car interior design (Leder et al. 2005), real objects and meaningless patterns (Bar et al. 2006, 2007), symmetrical and asymmetrical abstract geometric forms (Silvia et al. 2009), level of curvature evolution through time (Carbon 2010), realistic architecture environments with decorative elements (Vartanian et al. 2013) and virtual reality architectural spaces with distinctive high level geometric natures (Shemesh et al. 2015). Balance (Locker et al. 2002), contrast (Specht 2007), color (Polzella et al. 2005) and geometric orientation (Miller 2007) (Silvia et al. 2009) are other studies developed under these new techniques and technologies with the aim to better understand the way that we perceive and evaluate form either in a conscious or unconscious state.

2. Goals

The goal of this study is to understand and create knowledge on the hypothesis that humans show a higher preference for curved, rounded elements rather than angular, sharp ones. To identify, in a quantitative level, the way that abstract architecture spaces with different geometric contour natures and distinctive characteristics elements are perceived and the grade of this preference. In order to do so, there will be considered spaces composed by plans, curved surfaces and both elements arranged together. The evaluation of the case studies is to be done according to the basic aesthetic judgment and the approach/avoid decisions that they trigger. This study also aims to verify the existence of a statistical significant correlation between the collected answers on the perceived taste sensation and the attractive judgement on the represented spaces. Ultimately and based on these results, it aims to propose a significant and effective improvement in the process of architecture design.

3. Research Hypothesis and Variables of Study

The primary research question of this study is: Do people find architectural space environments with curved, rounded elements to be more pleasing than architectural space environments with angular, sharp elements?

This study has considered three kinds of variables: Moderating, independent and depended. The (i) moderation variable was gender, divided in male and female; the (ii) independent variables were architectural spaces composed by (1.1) rectilinear surface transitions, (1.2) curvilinear surface transitions, (2.1) non-prominent edges and vertices or derived transitions, (2.2) non-prominent edges and vertices and prominent edges or derived transitions and (2.3) non-prominent edges and vertices and prominent edges and vertices or derived transitions; and finally, the (iii) depended variable was (a) the perceived taste sensation, unfolded by ‘like’ and ‘dislike’ aesthetic judgement towards the presented architectural space-images and (b) the response action time.

4. Description of the Architecture Spaces

In order to investigate this proposition, this study counted with 18 architecture space-images. All space-images are derived from the same base: an orthogonal 3-dimensional virtual space with 20 units of length, 5 of width and 3 of height. The other spaces were found through two main levels of transformations: (i) contour geometric evolution and (ii) comprised element complexity. By turn each of these groups include other revolution stages: 6 in the first case and 3 in the second. Contour and geometric changes embrace low feature transformations, as the name states, at a contour and geometric levels:

- Type 1 (for future notice, ‘sharp-high’) - 90° angle at plan intersection;
- Type 2 (sharp-tight) - 45° angle plan chamfer with a 10cm base radius at plan intersection;
- Type 3 (rounded-tight) - rounded surface with a radius of 10cm at plan intersection;
- Type 4 (sharp-loose) - 45° angle plan chamfer with a 20cm base radius at plan intersection;
- Type 5 (rounded-loose) - rounded surface with a radius of 20cm at plan intersection and finally;
- Type 6 (rounded-high) - a complete transformation from a Euclidian to a non-Euclidian geometric nature at plan intersection. At this level, contour embraces the totality of the space surface.

Element complexity considers high feature transformations:

- Type a (non-prominent) - negative, non-prominent edges or rounded surfaces;
- Type b (rail-prominent) negative, non-prominent and positive, prominent edges or rounded surfaces and;
- Type c (spot-prominent) negative, non-prominent and positive, prominent edges and vertices or rounded surfaces.

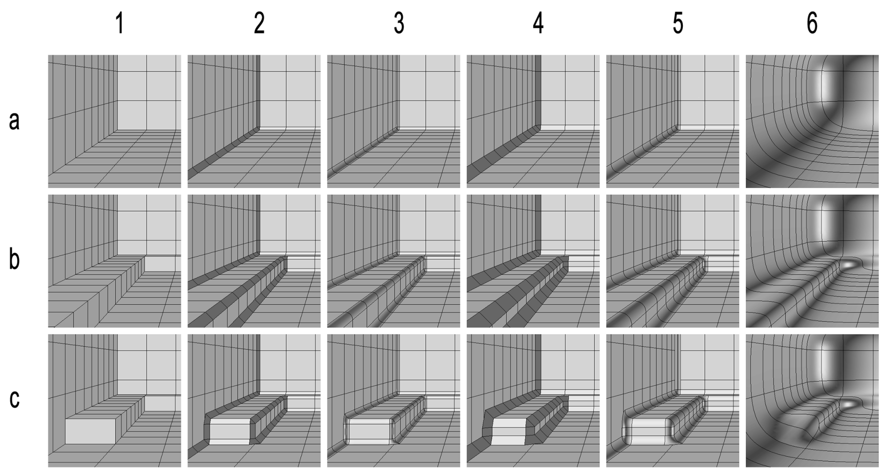

Figure 1. Matrix of the space-images' transformation levels.

As showed in figure 1, this configuration sets up a matrix of 6x3 space-images where the contour geometric evolution and the comprised complexity elements can be studied and analyzed either in a connected or a separately way.

Within the comprised element complexity level (a, b and c), 'sharp-tight' and 'rounded-tight' space-images (for future notice, SI) share a direct correspondence in the way that they are built upon the same controlled variables, including a plan transition of 10cm base radius. The only difference between them is the geometry nature that is applied at the level of plan intersection. In case of 'sharp-tight', a 45° plan chamfer and in the case of 'rounded-tight', a rounded plan transition with Euclidean and non-Euclidean elements. The same applies to 'sharp-loose' and 'rounded-loose SI with the difference that, instead of a 10cm base radius, it is considered a 20cm base radius (figure 2). Such differentiation is included to understand if a significant change in the transition's scale would interfere with the reported level of preference between the same transformation properties.

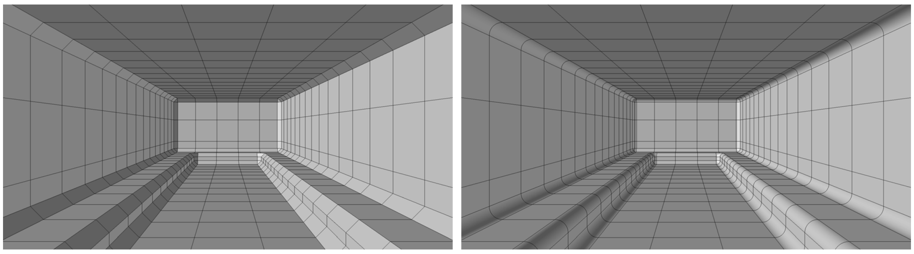

Figure 2. 'sharp-loose' vs 'rounded-loose' space-images.

By another hand, 'sharp-high' and 'rounded-high' SI correspond each other but not in a direct, linear way in the sense that they follow the controlled aforementioned transformation levels but their result is too far apart for a direct correspondence. 'Sharp-high' SI take under consideration 90° plan transitions and are relevant for the study in the way that they are a close analogy to most of the spaces that we build. By doing so, they also tend to fall in the area of the psychological phenomenon of mere-exposure effect (Zajonc 1968). Contrarily, 'rounded-high' space-images represent non-Euclidean geometry spaces, standing apart from most of our built spaces and, by being so "strange" tend to fall in the opposite scope of 'sharp-high'.

The level of information that each space contains was target of deliberately focus attention in order to aim for neutral bias. Despite of the aforementioned elements under examination, all information able to lead to the main object's distraction and sample's infection were abolished. For this reason, all space images appear in tones of gray, without expressive color, texture and additional elements that normally take place in the most simple architecture spaces, such as doors or windows. A simple variation of light was the only parameter that was included due to the fact that it directly interferes with the 3-dimensional perception of the space-images. The observer's height of the space-images was set to 1.675mm, the average height of the Portuguese female and male adult population born between 1971 and 1980 (Garcia 2007), the average born dates of this study´s eligible participant's sample.

5. Experience's Layout

The experience was set upon the group of represented SI to be evaluated by the test-subjects through action-response. In order to assure that each participant went through the same experimental conditions, aiming for a within-subject design, there were constructed 2 sequences of the set of spaces to be presented: a 'regular' sequence, found randomly at www.random.org, and its corresponded inverse order sequence.

To every showed SI, subjects were asked to answer to the stand-alone scenario that they have to choose one from the two available answer-options based on a dichotonic pair: 'like' (I like the presented architecture SI) and 'dislike' (I dislike the presented SI). These action-responses were made through the pressing of 2 gray, identical buttons, with a diameter of 5cm, centered over the computer's keyboard and located over the 'd' and 'return' keys. Each of the 18 space-images were presented 5 times for a total of 90 space-images in each sequence and were presented for a maximum span time of 3 seconds. The transition between the space-image parameters was made by a neutral gray image with a centered black ‘X’ and was showed for a variable span time that went from 1.45 to 2.15 seconds.

5.1. STUDY’S SAMPLE

This study has counted with 32 participants. To assure neutral bias in the action-response process participants were divided into 4 groups of 8 test-subjects according to the order that the space-images were presented (first ’regular’, then ’inverted’ and vice-versa) and the location of the action-response buttons (’like’ on the right, ’dislike’ on the left and vice-versa). In order to better assist the test-subjects in their action-responses, it was added a gray horizontal bar with a ’+’ and a ’-’ symbols at the bottom of each space-image. The position of such symbols pointed the side where ’like’ and ’dislike’ action-responses should be made: ’+’ for ’like’ and ’-’ for ’dislike. The sample of participants was divided between 2 geographic areas: a metropolitan city and a peripheral small city.

5.2. PRE-TEST

The experimental stage was preceded by a standard, neutral pre-test. The objective of this pre-test was to prepare the participants for the upcoming decisive phase namely to understand if they were able to follow and control the logic and physical mechanics of the required dichotonic left and right action-responses. In order to do so there were presented 20 parameters for ‘like’/‘dislike’ evaluation, including 3 ‘like’ and 3 ‘dislike’ words to which the participants were asked to answer in accordance.

5.3. TECHNICAL SPECIFICATIONS

For this study it was used a laptop computer for the display and evaluation of the architecture spaces. The specification of this component are: One laptop Computer Intel® Core(TM) i7-4700HQ CPU @ 2.40GHz 2.40GHz processor with 16.0 GB installed memory (RAM), 64-bit Operating System, x64-based processor and an Intel® HD Graphics 4600 and a nVIDIA® GeForce GTX 850M Graphic Card, with a screen resolution of 1920x1080 pixels. Statistical analysis was made through IBM SPSS Statistics, version 22.

5.4. ETHICS PROTOCOL RESEARCH

The Research Protocol of this study has been submitted and approved by the Ethics Committee of ISCTE-IUL.

6. Results

General sample analysis show a preference for rounded over sharp space contour transitions although in small rates due to noise interference. The average of this preference was of 53.98% against 46.02% for ‘rounded-tight’ and ‘sharp-tight’ SI and 54.75% against 45.25% for ‘rounded-loose’ and ‘sharp-loose’ ones, respectively. ANOVA analysis for these transformation levels show statistical significant differences for p-value ≥ 0,064. As expected, there was not found statistical significant correlation between the related 'sharp-high' and 'rounded-high' space-types. This result has probably to do with the aforementioned mere-exposure and strangeness effects. Contrarily to what was expected, there was not found significant differences between the 3 levels of non-prominent and prominent space-types as to the presence of elements with such characteristics. Although it was expected a preference for 'non-prominent' over 'rail-prominent' SI and, by turn, the latter over 'spot-prominent' SI, participants have reported to be more affected by the abstract emptiness of 'non-prominent' SI when in comparison with the more complex composition of the 'rail' and 'spot-prominent' types, declaring a preference of almost identical levels for the last two.

A second analysis was carried considering only the test-subjects that have reported a coherent choice between 'tight' and 'loose' SI either between or among each of the high feature transformation group. The goal of this analysis was to consider only the participants that revealed able to make a distinction between the direct related SI ('sharp/rounded-tight' and 'sharp/rounded-loose'). To be included in this analysis participants had to have reported a preference of at least a 40% variance (a difference of 2 or more 'like' action-responses in the total of 5 times that each SI has been presented) between 2 or more of these groups or at least one preference occurrence equal or over to 60% (difference of 3 or more 'likes'). 13 of the total of 32 test-subjects fulfilled these requirements. A single 40% variance (difference of 2 'likes') and differences of 20% or less (difference of 1 or 0 'likes') in between these groups were considered casual occurrences and led to the participant's exclusion due to the fact that he/she was not able to make a distinction between the direct related space-images and was considered noise. To this last group counted with 19 test-subjects.

Table 1. Comparison of 'like' type response-actions.

	Sharp-tight	Rounded-tight		Sharp-loose	Rounded-loose		Sharp-high	Rounded-high
a	18	31		23	35		20	14
	36.73%	63.27%		39.66%	60.34%		58.82%	41.18%
b	31	49		23	49		18	19
	38.75%	61.25%		31.94%	68.06%		48.65	51.35%
c	21	45		22	39		23	18
	31.82%	68.18%		36.07%	63.93%		56.1%	43.9%

In the consistent-response analysis the related preference related between 'sharp/rounded-tight' and 'sharp/rounded-loose' space images was significantly more expressive. ANOVA analysis over these transformations shows a significance level for p-value ≥ 0,0. The average of this preference was 64.1% against 35.9% for 'rounded-tight' and 'sharp-tight' space-images and 64.4% against 35.6% for 'rounded-loose' and 'sharp-loose' types, respectively, being the highest value of reported preference 68.18%, reflecting a level of preference more than 2 times higher for 'rounded-tight' space-images (45 'likes' against 21 for 'sharp-tight') and the lowest, 60.34%, representing a level of preference of 2/3 and 1/3 for 'rounded-loose' and 'sharp-loose' space-images respectively (table 1). There were conducted 3 statistical ANOVA analysis methods: Turkey HSD, Scheffé and Bonferroni. This last was included to attend the relatively low eligible participant's sample of this analysis. All 3 tests show a clear preference for 'rounded-tight' over 'sharp-tight' and 'rounded-loose' over 'sharp-loose' SI with corresponding p-values of 0,002 and 0,002 for Tukey HSD, 0,005 and 0,004 for Scheffé and 0,002 and 0,002 for Bonferroni.

Between 'sharp/rounded-high' related images, significance was less expressive, predominating however a preference for SI that enclosure the mere-exposure effect's hypothesis. Within the high feature transformation SI, the 'non-prominent' type was the less preferred, followed by the 'spot-prominent' and lastly, the 'rail-prominent' types.

Due to the fact that data interpretation aimed to more unconscious over conscious responses, such analyses were made to the first of the two presented sequences. Both sequences point nevertheless to the same reported results. It may also matter to refer that, in the process of data analysis it was observed a high discrepancy between the evaluation answers of participants from the metropolitan and the peripheral city areas. Whereas the former's collected data shows a clear distinction rate on the evaluation of the direct-related SI ('sharp/rounded-tight' and 'sharp/rounded-loose'), pointing to a high level of sensitivity and awareness to close low feature transformations, the latter have reported virtually imperceptible differentiation values. These results are considered to be interesting and should be a target of close attention in a near future.

7. Conclusions

Results show a higher level of preference for architecture space environments with rounded, curvilinear contour elements specially when there were reported significant differences between direct related architecture space-images. On another hand, collected data do not point to a preference for complete non-Euclidean geometry spaces. Such result has probably to do with the fact that participants found these spaces to be "strange", something that may be related with an opposite condition of the well documented mere-exposure effect. Space representations with rounded, curvilinear contour elements were then perceived as being more pleasant and preferred than those with sharp, rectilinear ones particularly when moderate rather than radical curvature levels were considered.

8. Future Work

In the attempt to consolidate the results here obtained, this study will be continued under the same basis considering the enlargement of the participant´s sample. To the strengthening of already achieved outcomes, it will be interesting to include a more clear understanding on the hypothesis that geographic related variables may interfere with the level of perception of test-subjects.

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