A semi-immersive virtual environment preference study of four interior architectural geometries

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ABSTRACT: As technology advances, architectural design methodology changes in response. Today's use of advanced computers and digital fabrication often gives rise to non-rectilinear buildings. This pilot study addresses the appropriateness of the resultant architectural forms, and provides a novel process for examining how new forms affect inhabitants' wellbeing.

The present study tested preference levels of four different architectural geometries in an innovative semi-immersive virtual environment ("CAVEtte"), designed and built by the author and a collaborator. All digitally modeled designs were of four built Maggie's Centres: (curved) Southwest Wales by the late Kisho Kurokawa; {mixed} Aberdeen by Snohetta; [rectilinear] Cheltenham by MJP Architects; and <angled> Fife by Zaha Hadid. Rendered walk-through videos of the models were created in Rhinoceros from available plans, sections, elevations, and photographs. Models were generated without textures, and furniture and walls were given the same neutral color throughout.

65 participants (19 females, 46 males) at NewSchool of Architecture + Design participated in Experiment 1, watching four walk-through videos, one of each building, in a randomly selected order. Participants filled out a subjective survey, which helped define "preference" using six pairs of bipolar adjectives of semantic differentials with an added "neutral" between each pair. The word sets were: 1) pleasant, unpleasant; 2) exciting, depressing; 3) relaxing, stressful; 4) friendly, unfriendly; 5) like, dislike; 6) beautiful, ugly. The first word of each set indicated positive preference, while the last word indicated negative preference.

While findings are consistent with previous contour-focused studies, there were some intriguing novel results when the data were parsed demographically by age, gender, education level, designers versus non-designers, and years in the profession, demonstrating that preference was modulated by these factors. Further, the study demonstrates the great potential for architects that a virtual environment can have for judging how designs are perceived by clients and the public.

KEYWORDS: Preference Study, Immersive Virtual Environment

1.0 INTRODUCTION

1.1. Relevance of the Study

In our modern society, studies show we spend a majority of our lives indoors (Juster, Ono, and Stafford, 2004; Klepeis, et al., 2001; Ott, 1989) giving impetus to examine how the built environment affects us. Additionally, architects have been designing buildings to evoke a physiological, spiritual and emotional response without the exacting study of the effect buildings have on the nervous system. As "humans often respond to architectural settings with emotions that are subconscious and sometimes expressed as feelings [they] also may respond to certain settings by changes in behavior" (Eberhard, 2007, p. 68). Neuroscientist Dr. Fred Gage, explained:

> …while the brain controls our behavior and genes control the blueprint for design and structure of the brain, the environment can modulate the function of genes and, ultimately, the structure of our brain. Changes in the environment change the brain, and therefore they change our behavior. In planning the environments in which we live, architectural design changes our brain and our behavior. (Gage, 2003)

Furthermore, brains change due to the enrichment and stimulation of the environment (Van Praag, Kempermann, and Gage, 2000; Rosenzweig, 1979; Renner and Rosenzweig, 1987). Enriched environments are "a combination of complex inanimate and social stimulation" (Rosenzweig, et at, 1978 p.191), and have "been shown to enhance memory function in various learning tasks" (Renner and Rosenweig, 1987). Currently neuroscientists "…are trying to separate the role of visual interactions with an environment from the role of physical interactions" (Tuma, 2006).

Critical and theoretical debate within the architectural and neuroscientific fields show the importance of architectural form as it relates to physical and mental health. “People constantly make snap judgments about objects encountered in the environment. Such rapid judgments must be based on the physical properties of the targets, but the nature of these properties is yet unknown” (Bar and Neta, 2006). Bar and Neta’s 2006 study found higher preference for emotionally neutral objects with curved contours over their sharp-angled counterpart. In 2007, Bar and Neta’s functional magnetic resonance imaging (fMRI) study showed more activation in the amygdala (known to be associated with fear and general arousal) when subjects viewed sharp-angled contour objects over their curved counterpart. While the 2006 and 2007 studies tested emotionally neutral objects, Leder, Tinio and Bar (2011) tested objects with both positive (e.g. cake, chocolate) and negative (e.g. snake, bomb) emotional value. The authors “found that people indeed preferred the curved version of the object to the sharp version of the same object, but only if the objects were neutral or positive in emotional valence.” Their study suggested little preference between emotionally negative curved objects to their angled pairs.

Vartanian et al. (2013) tested three architectural variables (curved versus rectilinear contours, openness, and ceiling height) in an fMRI scanner in two runs (beauty-judgment and approach-avoidance); the results suggested “participants were more likely to judge curvilinear than rectilinear spaces as beautiful” and that “judgment of beauty for curvilinear spaces is underpinned by emotion and reward.” The authors inferred their results to “suggest that in architecture, sharp contour might not serve as an early warning signal for potential danger as it might elsewhere.” Perhaps we are used to angles in architecture, and therefore we do not see them as threatening. In support, “people living in a highly industrialized environments perceive angles and straight edges differently from people who live in environments without square, manufactured structures” (Jansen-Osmann and Heil, 2007; Allport and Pettigrew, 1957). Lastly, Madani Nejad’s 2007 study ranked two modified interior residential views where the “architectural forms gradually changed from fully rectilinear to fully curvilinear” in a card-sorting task. The results “indicate that curvilinear form tends to make observers feel safer and perceive the space as more private,” and “less stressful.”

1.2. Introduction to the Study

Technological advances in architecture impact the design and building process, from computer technology to building materials and digital fabrication, which promote the design of non-rectilinear buildings. It is important that neuroscientists and architects collaborate to understand how both rectilinear and non-rectilinear architectural forms affect us at all levels.

This study tests four different interior architectural contours at a near one-to-one scale in a semi-immersive virtual environment. The architectures studied are of four built “Maggie’s Centres” located around the United Kingdom designed by internationally acclaimed architects who were all given the same architectural brief. The four buildings selected for this study differed in architectural form ranging from curves to a mix of curves and angles to all angles.

Based on previous architectonic and neuroscientific studies showing a statistical significance of preference for, and less amygdala activation of, curved contour objects versus sharp-angled contour objects, this study postulates preference to be higher for curved architectural interior environments over the other geometric architectural interior environments.

2.0. METHODS

2.1. Subject Selection

Studio instructors encouraged at least two of their students to participate voluntarily (with no compensation) in this study. In addition to architecture students, students and faculty from the Construction Management and Interior Design schools participated to assure a range of disciplines to determine if academic training affected preference. All participants signed a release form to participate and filled out a background questionnaire used in data analysis for demographics analysis.

The Primary Investigator (PI) sought out an additional 20 participants for a one-day retest (Experiment 2). The additional participants had not been exposed to the first experiment and consisted of a mix of faculty, staff and students from all departments of the school.

2.2. "CAVEtte" and the testing environment

The semi-immersive virtual environment was designed and built on a limited budget with help from an outside colleague, Kevin Sullivan, M.Arch, based on previous immersive setups found on YouTube (Fig. 1). Testing was conducted at NewSchool of Architecture and Design (NSAD) (Fig. 2).

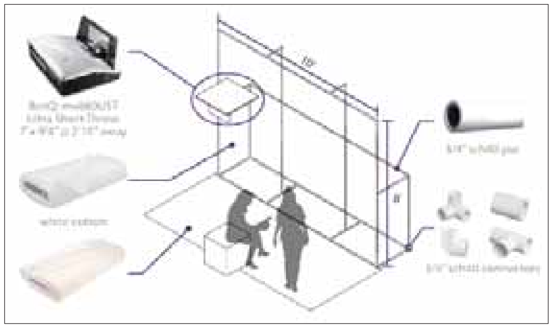

Figure 1: Semi-Immersive virtual environment.

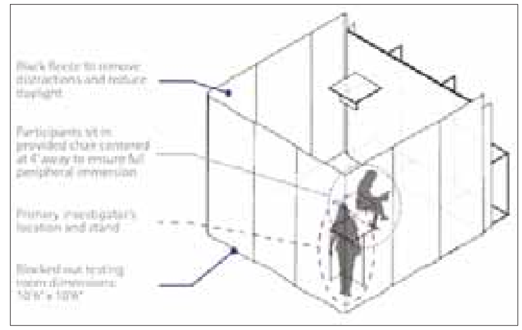

Figure 2:: CAVEtte.

2.3. Maggie's Centres

At the time of the study there were fifteen Maggie's Centres located around the United Kingdom. Each of the Centre's architects applied their own individual approach, resulting in design variations between the centers.

All fifteen centers were analyzed by looking at available drawings, renderings and photographs. The Centres were vetted with author members in a three-stage process to determine contour majority. As four categories emerged (curved, mix of curves and right angles, fully rectilinear, and sharp angled) the selected buildings were decided: (curved) Southwest Wales by the late Kisho Kurokawa; {mixed} Aberdeen by Snohetta; [rectilinear] Cheltenham by MJP Architects; and <angled> Fife by Zaha Hadid**.**

Referencing both the neuroscientific and architectonic studies discussed above, potential irrelevant distractions were eliminated by: 1) removing all extraneous furniture; 2) removing color and materiality from the models, thus creating a similar neutral tone across all modeled buildings; and 3) making slight adjustments to each design to enhance the experience of being in each contour category (Fig. 3).

Figure 3: Selected Maggie's Centres (actual | testing environment).

2.4. Variables

The independent variables in this study were the predesigned rendered walk-through videos of each of the four selected built Maggie's Centres shown in random order and documented. The difference between the first and second immersive experiment was the velocity of the walk-through and thus the duration of each video and session.

The dependent variable was the measure of preference of each interior environment. Preference was defined by using seven sets of bipolar adjectives of semantic differentials with an added “neutral” between each bipolar word. The words chosen for each set were adopted from Hesselgren (1987) as referenced in Madani Nejad’s 2007 Ph.D. study. The word sets were: 1) pleasant, unpleasant; 2) exciting, depressing; 3) relaxing, stressful; 4) friendly, unfriendly; 5) like, dislike; 6) beautiful, ugly; and 7) unique, typical. For sets one through six, positive preference is noted as the first set of words, while negative preference is the last word. Due to time constraints, responses to the seventh set were not used in data analysis.

2.5. Testing methodology

One participant at a time entered the testing room and sat facing the screen in the provided chair. The PI informed each participant of the testing protocol before beginning the experiment. To ensure the order of video sequencing of contours did not bias results, a list of the 24 possible variations was created and subjects were given a random number associated with video sequence file. Video sequence was noted on each subjective survey for data analysis.

3.0 DATA ANALYSIS

3.1. Overview

For Immersive Experiments 1 and 2, the data represents totals calculated from the six word choice preference sets. The words were given a rank of 1 for negative preference, 2 for neutral preference, and 3 for positive preference; the higher the mean, the higher the preference, and vice-versa.

Anova: Single Factor

SUMMARY					
Groups	Count	Sum	Average	Variance	P-value
CurvedPref-Exp1	65	162.5	2.5	0.19618056	0.13349769
CurvedPref-Exp2	20	53.1666667	2.65833333	0.06864035	
SUMMARY					
Groups	Count	Sum	Average	Variance	P-value
MixedPref-Exp1	65	142.5	2.19230769	0.29707532	0.63650068
MixedPref-Exp2	20	45.1666667	2.25833333	0.29378655	
SUMMARY					
Groups	Count	Sum	Average	Variance	P-value
RectilinearPref-Exp1	65	137.6	2.11692308	0.27212233	0.0353237
RectilinearPref-Exp2	20	47.8333333	2.39166667	0.18501462	
SUMMARY					
Groups	Count	Sum	Average	Variance	P-value
AngledPref-Exp1	65	135.466667	2.08410256	0.25472596	0.17427121
AngledPref-Exp2	20	38.1666667	1.90833333	0.24115497	

Table 1: ANOVA Single Factor - Immersive Experiments 1 and 2

80 students, faculty and staff from NSAD participated in a multi-week testing of Immersive Experiment 1. The data was reviewed, and concerns regarding validity and limitations of the study led to a second test – Experiment 2 – where an additional 20 students, faculty and staff participated in a one-day retrial. After conducting an Analysis of Variance (ANOVA) there was no statistical difference of preference rating between the first and second experiment for curved, mixed and angled. And while there was a statistical difference between the two immersive experiments for the rectilinear building, overall Immersive Experiment 2 supports data collected from Immersive Experiment 1 and suggests neither speed nor video duration seemed to play a factor in altering data (Table 1). Therefore, the following results are based on Immersive Experiment 1.

15 subject responses were removed from the data analysis from Immersive Experiment 1 due to full or partial knowledge of the study; the following results from Immersive Experiment 1 were based on 65 out of the 80 subjects tested (also reflected in the ANOVA) (Fig. 4).

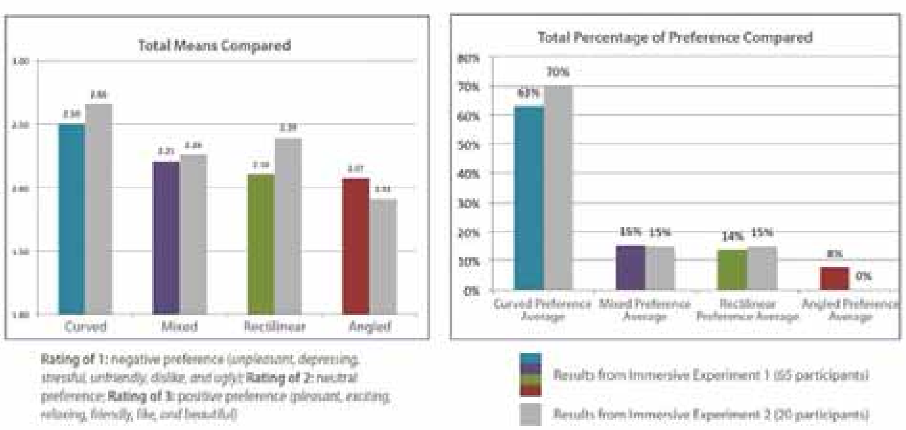

Figure 4: Immersive experiment 1 vs. 2.

3.2. Immersive Experiment 1 by demographics

Gender: While preference ratings differed by gender in this study, with females showing a stronger preference than males for curved geometries, the sample size was too small to draw definitive conclusions, pointing to an area for further study.

Designers vs. Non-Designers. Data shows a similarity between those who have studied (or are currently studying) design, versus those who have not. This information was extracted from the background questionnaire when looking at degree studied (whether previously, or currently). “Designer” was selected when a participant mentioned architecture, interior design, digital media art, art or marketing. “Non-designer” was selected when construction management, counseling, LGBT studies, library science, or education was listed. Additionally, this was matched against years noted of participant’s “studying design.” The thought is to see if design-minded people are more sensitive to the different environments. Note, however, that non-designers in this study work around designers, possibly skewing the results, a potential limitation of the study. Further research is warranted.

The results show higher preference for curved and rectilinear buildings by designers versus non-designers, and a slight negative preference for the mixed and angled building. It is likely that designers are not only more sensitive to buildings (as mentioned above), but they might have been more sensitive to the overall process (and limitations) of the study, thus affecting their experiential results.

Graduates vs. Undergraduates. Participants were placed into two categories, student or faculty/staff; this demographic paring looks at 54 of the 65 participants, current NSAD students who did not know about the study. It shows undergraduate students prefer the more “unconventional” building designs over the rectilinear building the graduate students prefer. This could be due to education level, or excitability level among younger students, responding to novel designs that differ from the norm.

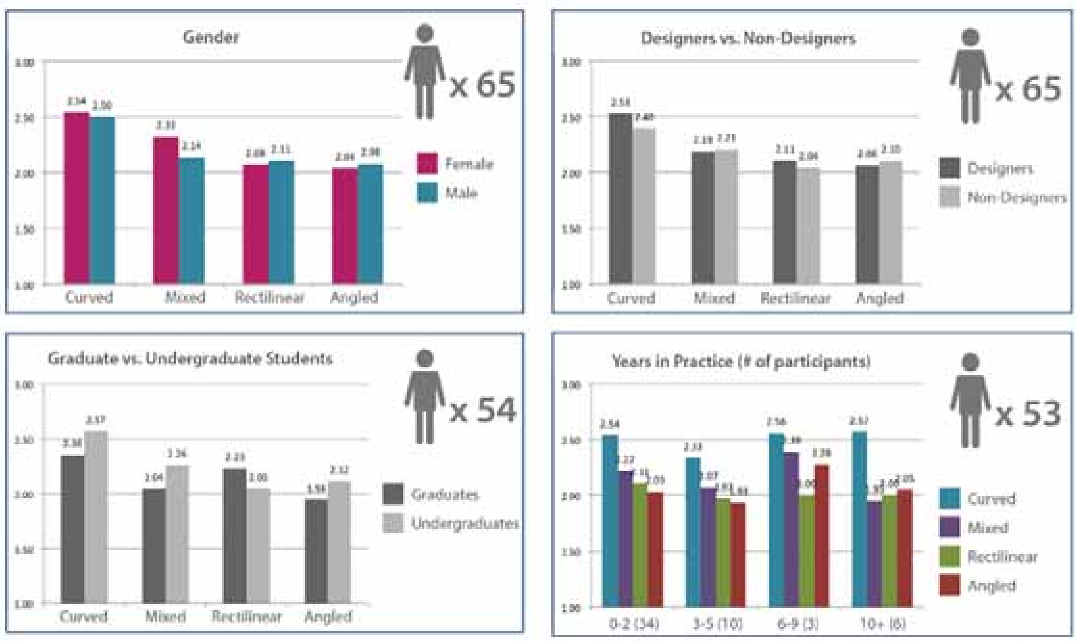

Figure 5: Results by selective demographics

Years in Practice. The term “practice” was intended to imply architecture or the related field (design, interior design, and construction management). Those who marked their years in practice, and practice was not inferred as architecture or the related fields, were given a 0-2 category. 12 subjects did not fill in this information, and were therefore taken out of the analysis.

Preference for the curved building was significantly higher among most participants regardless of years in practice. However, those who marked 6-9 years show a higher preference for the mixed and angled building compared with others. Participants with 10+ years in practice preferred the angled building slightly more than the rectilinear or the mixed.

3.3. Word choice across all shapes

Data analysis compared totals from each word choice per building design to see the overall differences in preference based on the six bipolar adjectives. It is important to see how participants viewed the curved building over the other three buildings. With the exception of “exciting-depressing” and “beautiful-ugly” most ratings were significantly higher, with the latter still showing a higher preference.

In all but the rectilinear building results, a strong positive or negative pull towards “exciting-depressing” is matched by an opposite pull towards “relaxing-stressful.” A potential limitation could be the order of the word choices, for choosing either relaxing, neutral or stressful, each participant could have been biased towards one word or another based on what they chose for the previous word set: “exciting-depressing.”

Curved. The final data, parsed by demographics, showed an overall higher preference for the curved building. Most participants felt the curved building was pleasant, relaxing and friendly. Interestingly, when deciding whether the curved building was either exciting or depressing, overall participants viewed it more closely as neutral – lacking strong positive or negative opinion. Additionally, the “beautiful-ugly” word set tended toward an overall neutral opinion. **Mixed.** While the preference ratings for the mixed design are not as high as the curved buildings, the mixed building preference is still slightly higher than neutral. Note: looking at the word set “relaxing-stressful,” overall participants viewed this building as more stressful – though just below the neutral line. A potential reason could be the limitations in the walk-through video of the unnatural feel of moving up and down the stairs; additionally no other video used stairs. **Rectilinear.** While there is an overall neutral preference towards the rectilinear building, participants rated the rectilinear building slightly more pleasant than unpleasant. Note that none of the word choices drop below a “neutral” rating of 2. **Angled.** Participants viewed the angled building with less preference. While both the overall “pleasant-unpleasant” and “friendly-unfriendly” ratings are slightly below “neutral,” the rating was slightly higher than neutral towards “like” and “beautiful.” Furthermore, the higher response of “exciting” the stronger the response towards “stressful.” Similarly to the mixed building response, the increase in excitability is not always synonymous with pleasant or relaxing.

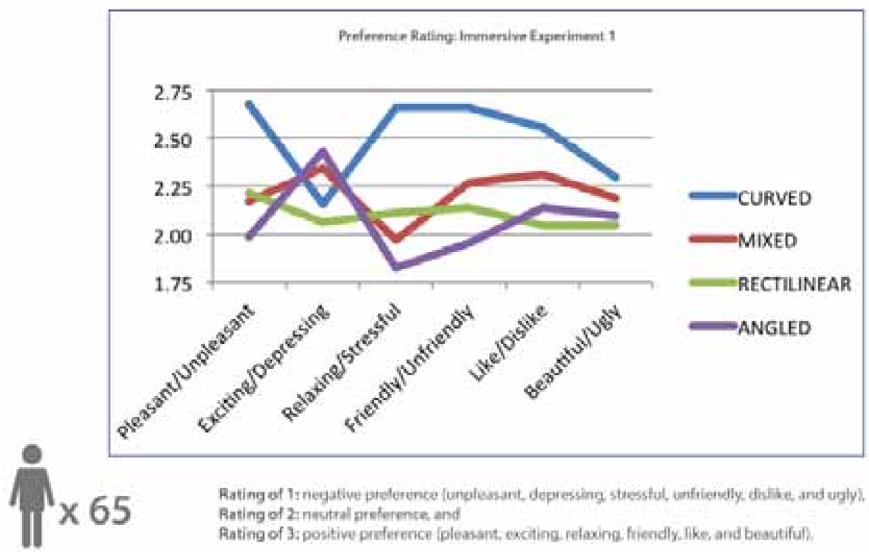

Figure 6: Preference rating: Immersive experiment 1.

4.0 DISCUSSION

4.1. Observations

As findings from this study are consistent with aforementioned studies, key observations and limitations include the following. 1) Preference could have been made on having a shorter path through the building and not experiencing a majority of the building; also alleviating potential inconsistencies across the study. 2) The data presented above shows a neutral preference rating for the rectilinear building across the bipolar word choices. Assuming that in our modern society we are accustomed to rectilinear forms within architecture, we therefore have no strong positive or negative preference towards them, and that right-angled architecture is not always a bad first choice, or default form. 3) Evidence in this study suggests that adding curves into the design might elicit for a more preferred experience, and should be strongly considered by architects within their design.

4.2. Limitations and future studies

Limitations of the study include: conducting an architectural scientific study as a nine-month Master of Architecture thesis; employing the CAVEtte versus a fully immersive environment; velocity of walk-through videos for Immersive Experiment 1; inconsistent lengths of the walk-through paths; and traversing vertically via stairs in only the {mixed} building.

Areas for future studies include: increasing the sample size in a fully immersive environment; controlling for velocity of walk-through videos; and standardizing the length and consistency of the walk-through paths.

4.3. Summary

The findings presented in this study show the overall preference rating was higher for the curved environment in the immersive experiments. Furthermore, as curvature decreased and angles increased, preference drops.

This study was not only about testing preference for curves, mix of curves and 90-degree angles, only 90-degree angles, or acute angles within architecture, but also about testing the validity of utilizing immersive technology in the architectural design process. When comparing the results from this study to the previous neuroscientific and architectonic studies, this study exhibits success and impetus to incorporate immersive technology not only into the architectural design process, but also when researching the effects of architecture. The use of immersive studies have proven to be a powerful means of obtaining feedback on designs and could be used productively by architects before committing their designs to physical construction.

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