An Empirical Inquiry into the Affective Qualities of Virtual Spatial Enclosures in Head Mounted Display driven VR Systems

The Logic at Work behind the Magic of Space

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This research is an inquiry into the correlations between specific formal parameters of virtual spatial enclosures in HMD driven VR systems, and corresponding emotional responses in subjects . The experiments comprised of three sets of formal parameters - size of openings, enclosure volume, and length:width ratio. The emotional attributes tested were Valence and Arousal. Immersive virtual environments depicting enclosures with changing values of these parameters were presented to 50 subjects through a head mounted VR gear. Responses were recorded in the form of affective appraisals using a scaling system based on the Self Assessment Manikin, and were plotted on the Circumplex Model of Affect. The results revealed that the parameter of Arousal strongly correlated with the illumination levels (wall:window ratio) within an enclosure, and did not correlate independently with any other parameter. Peak Valence values corresponded to a wall/window ratio of .03 an enclosure volume of 70 cu.m and a length:width range between 1:1 and 1:1.5. The golden ratio was not rated favorably. Differences in volume between very large enclosures were not perceptible. The appraisal of spaces was also found to be consistently affected by preceding spaces.

Keywords: *spatial enclosures, formal attributes, affective qualities, emotional response, virtual reality, head mounted display*

Spatial enclosures are well known to have a great degree of emotional impact on the individuals inhabiting them. Different spaces affect us in different ways, and elicit a wide variety of emotional and perceptual responses. Some make us feel happy and positive, while others arouse feelings of discomfort or come across as depressing. Small rooms have a different effect on us as compared to very large halls, while dark spaces spark different emotional responses as compared to very bright enclosures.

The affective qualities of specific attributes of enclosures lie within the realm of spatial 'experience', and have long been regarded in the field of architecture as 'intangible' aspects that cannot easily be objectively measured. While the field of environmental psychology has developed multiple models for the objective measurement of affective states, these models have only recently begun to be applied to the realm of spatial enclosures. The basic hypothesis driving such lines of research is that specific attributes of the form of enclosures, such as shape, size, configuration etc. have empirically testable correlations with one's spatial experience and affective response within that space. There has still not been a great deal of focused empirical research on the exact nature of such correlations. For example, while we know that very small enclosures make us feel uncomfortable, we do not know clearly 'how' small an enclosure elicits 'how' uncomfortable a response. Architects usually still rely heavily on their own intuitions while drawing up a design that keeps these experiential aspects in mind, and it is often considered an acquired skill for a designer to deal with these qualities. A study directed specifically towards the effect of specific spatial parameters on emotional response has the potential to open up very valuable lines of enquiry into the correlations between the physical and the emotional realms in spatial enclosures. It will also help to generate a body of empirical data that will provide architects with strong rational grounding for design decisions pertaining to spatial experience, and has the potential to yield mathematical and computational models in the future.

Over the past few decades, the development of immersive, responsive and interactive virtual representations of space, which are capable of generating simulations that can approximate the sensory inputs provided by a real space, has immense potential to develop into a valuable tool for such lines of empirical research. While VR systems in various stages of development have been applied in a few similar studies in the past (Franz et al. 2003) (Shemesh et al. 2015), it is the rapid development in the field of VR in recent years, and the widespread commercial production of head mounted display (HMD) devices that have made the use of such systems for architectural research readily accessible.

EMOTIONAL IMPACT OF SPATIAL ENCLOSURES

There are an incalculable number of factors that determine the way one perceives a space. The way a person 'feels' in a space is also often considered to be a very subjective affair that is dependent on one's own constitution, character, upbringing, and prior experiences. However, the fact that specific attributes of a space do have an impact on one's emotional experience cannot be denied.

Bitner and Schachter identified three primary categories of attributes that influence the experience of individuals inhabiting it, namely:

(i) Formal attributes, (ii) Signs, symbols and artifacts, and (iii) Ambient conditions (Bitner 1992)

This body of research has restricted itself to the first category. In the context of architecture and space, we may describe 'form' as both the 'internal structure and external outline and the principle that gives unity to the whole' (Ching 1996). To put it simply, form refers to both the internal and external attributes of an object or body. The formal attributes are intrinsic, and the primary characteristics that give it a definition. There are a number of primary attributes of form, namely *shape, size, color, texture, position, orientation and visual inertia* (Ching 1996). These pertain solely to the structure that defines the enclosure, and thus encompass all architectural elements and configurations.

Theories and structures of emotion

A number of theories have been proposed to explain the structure of human emotion. One school of thought opines that there are a number of specific and discrete human emotions (Basic Emotion Theories/Discrete Theories). These maintain that there are sets of very basic and discrete human emotions, such as *Joy, Disgust, Surprise, Fear, Anger* and *Distress* (Ekman 1984), which cannot be broken down into simpler parts. These emotions lie within separate domains and are discrete in nature.

More recent schools of thought opine that there is no set of distinct and discrete emotions. All emotions can rather be mapped on dimensional scales such as the circumplex model. The circumplex model consists of a three dimensional emotion-space with Valence (Pleasure-Displeasure) on the x axis and Arousal (Activation-Deactivation) on the y-axis (Russell 2003). (Figure 1) The z-axis of Dominance is also often used. According to this Dimensional Theory, a wide range of possible human emotions can be defined with respect to these dimensions. For example, the quadrant formed between Activation and Pleasure gives us the emotions of Excitement and Elation, while the quadrant formed between Deactivation and Displeasure gives us the emotions of Tiredness and Sadness.

Recording emotional response

In order to systematically study the effects of specific spatial parameters on emotional state, it becomes necessary to adopt an effective framework for objectively recording emotional response.

One approach towards this focuses on recording the physiological and biological responses that accompany emotional response, thus relying on external indicators. These techniques include analysis of visible indicators such as facial expression, or biological indicators such as Electro Dermal Activity (EDA), Skin temperature (SKT), and Electrocardiography (ECG) (Kim et al 2004). Data from biological indicators alone however are not enough to situate a subject's emotional response on the spectrum of human emotions as described by the circumplex model. A variety of emotions may result in very similar sympathetic and parasympathetic responses, and will thus be largely indistinguishable through the analysis of biological parameters alone. Secondly spatial enclosures are environmental stimuli, and are thus expected to induce emotions that are less intense as compared to those induced by more active stimuli such as a threat (fear) or aggression (anger). Variations in the values of the biological indicators thus may not be significant enough to undertake fruitful analyses.

This study thus adopts a second approach, which relies on one's own verbal assessment of his or her emotional response to any given stimulus (known as an 'affective appraisal/report'). The Semantic Differential (Osgood 1952) offers a set of bipolar adjectives (such as good-bad, hot-cold, tense-relaxed etc.) that each serves as rating scales. Bradley and Lang in 1994 developed a language independent scaling method for recording appraisals known as the Self Assessment Manikin, which is now regularly employed in experiments for measuring a range of emotional stimuli. In this method, the two dimensions of human emotion (Valence and Arousal) are represented as pictorial scales (Bradley and Lang 1994). The third dimension of dominance is often omitted because of lack of unanimity regarding its legitimacy as a dimension, and the difficulty of subjects to relate to the scale.

Virtual display systems

Rapid development in virtual interactive display systems has yielded valuable tools for empirical research in the field of space perception. Recent developments in virtual environment simulations include Head Mounted Displays fitted with audio output and a gyroscope. The stereoscopic visual output is done through and inbuilt OLED display and a pair of convex lenses. The gyroscope and accelerometer senses head position and orientation and changes the display scene accordingly. Scene refresh rate is typically 90 Hz. A number of manufacturers such as Oculus and Sony have in recent years introduced a range of wearable HMDs. Scene inputs can be static in the form of 180x360 spherical images, or dynamic such as 3D models adapted for VR display using a display engine. The field of view ranges typically between 100 and 120 degrees with a display resolution of up to 1200p (Mazuryk et al. 2010).

EXPERIMENT METHODOLOGY

Framework for affective appraisal

Since the experiments dealt with absolute emotions aroused within occupants of spatial enclosures, it was necessary to rely upon an existing model of human emotional response and operate within its framework. The circumplex model of affect was chosen for this purpose (Russell and Pratt 1980) (Figure 1).

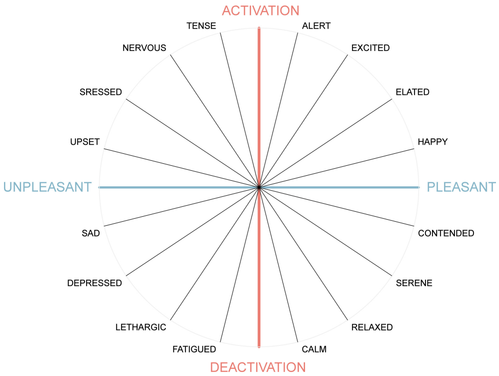

Figure 1
The Circumplex model used for experimentation

The scaling system used for objective recording one's emotional response was derived from Russell's use of the Semantic Differential for unidimensional scaling. It relied on affective appraisals, that is, a subject's own interpretation of his or her affective state. For each spatial variant that was to be tested, subjects' perceived emotional response on the two dimensions of Valence (Pleasant - Unpleasant) and Activation - Deactivation were noted. To do this, the Self Assessment Manikin (SAM) (Bradley and Lang 1994) was employed. The visual scales for Valence and Arousal corresponded to a bipolar scale ranging from -4 to +4. Subjects were asked to respond to each of the spatial configurations being tested by rating the space on each of the two SAM scales. Their responses were then converted into numeric values and plotted on the circumplex model.

Selected spatial parameters for experimentation

There were three sets of parametrically varied spaces that were selected for this stage of experimentation. The spatial parameters chosen were:

(i)Area of Opening (wall area / window area ratio), (ii) Enclosure Volume, and (iii) Enclosure Proportion.

Each of the sets comprised of 6 instances varied according to the parameter being studied. The set varied by size of opening included enclosures with uniformly increasing dimensions of window. Instance 1 thus corresponded to the smallest window, allowing least light to enter, while Instance 6 corresponded to the largest window and thus the brightest enclosure. It may be noted that the area of opening directly defined another parameter, which is the daylight factor (DF), which is described through the following relation:

$$A(glaz) = \frac{DF \cdot 2A_t \cdot (1 - R_{mean})}{T_{vis} \cdot \theta} \quad (1)$$

where DF: Targeted daylight factor in %; A(t): Total area of all interior surfaces; A(glaz): Total glazing area; R(mean): Mean surface reflectance; T(vis): Glazing Transmittance; Θ: Sky angle in degrees; (Brotas and Wilson 2007)

Now since A(total) remains constant for the experiment, all values except DF and A(glazing) are constant. Thus we find that DF is actually directly proportional to A(glazing). In other words, as area of opening increases, the daylight factor also increases proportionately. (Table 1) Thus the correlations that were to be tested between area of opening and affective response could also be described as a function of the correlations between DF and affective response.

Instance	1	2	3_{datum}	4	5	6
$A_{glaz.}$ (sq.m)	.28	.88	1.8	3.04	4.6	6.49
$w_{win}xh_{win}$(m)	.6x.48	.84x.6	1.2x1.5	1.56x1.95	1.92x2.4	2.28x2.85
$A_{glazing}/A_{total}$	.003	.009	.017	.03	.045	.063

Table 1
Instances varied by Area of Opening (Aglazing)

The second set comprised of enclosures where the cardinal dimensions (length, width and height) all increase uniformly, thus increasing the enclosed volume. All other parameters including window size remained the same. Again, from the definition of DF, we see that since A(glazing) is constant, DF becomes inversely proportional to A(total). Thus, as volume increased, so did A(total). , thus proportionately decreasing DF. (Table 2) The effect of volume on affective response could thus be purely due to increase in volume, or due to the decrease in DF. To overcome this apparent confusion, a control experiment was conducted, where A(glazing) increased proportionate to the increase in volume, thus keeping DF constant.

Table 2
Instances varied by Enclosure Volume

Instance	1	2_{datum}	3	4	5	6
Vol. (cu.m)	24.01	70	153.8	286.75	480.19	745.46
LxWxH (m)	2.8x3.5x 2.45	4x5x3.5	5.2x6.5 x4.55	6.4x8x5.6	7.6x9.5x 6.65	8.8x11x7. 7
$A_{glazing}/A_{total}$	.036	.017	.01	.007	.005	.004

The set varied by proportion included enclosures of fixed floor area (20sq.m) where the length/width ratio varies uniformly from 1:1 to 1:2.25, thus changing the geometry of the space from a square to varying configurations of rectangles. (Table 3)

Table 3
Instances varied by Enclosure Proportion

Instance	1	2_{datum}	3	4	5	6
L:W	1:1	1:1.25	1:1.5	1:1.75	1:2	1:2.25
LxWxH(m)	4.47x4.4 7x3.5	4x5x3. 5	3.7x5.5 x3.5	3.38x5.91 x3.5	3.16x6.3 2x3.5	2.98x6.7x 3.5
Area (sq.m)	20	20	20	20	20	20

There were thus a total of 18 spaces (6 instances in 3 sets), apart from the control experiment, that were used for the experiments. There was one space - the datum (4mx5mx3.5m enclosure with a 1mx1.2m window opening) - that was common in all three sets. This space played an important role in the order in which the instances were displayed to subjects. Figure 2 shows the 18 parametrically varied enclosure sets.

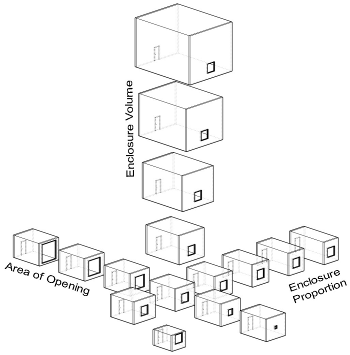

Figure 2
Parameter sets used in preliminary experimentation phase. Area of Opening, Enclosure Volume and Enclosure Proportion

Generating immersive virtual environments

Each of these enclosures was generated using Rhinoceros and Grasshopper3D and rendered using VRay for SketchUp. The images spherical renders of field of view (FOV) 360˚ and resolution 4000x2000 pixels. (Figure 3) Render time for each scene was roughly 30 minutes. All the scenes were rendered with the camera stationed at eye level (1500mm) above the geometric center of the spaces. This allowed the subject to look around and experience the whole space uniformly. AFulldrive VR engine adapted these spherical renders for 360˚ display through the VR gear.

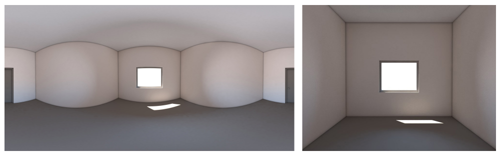

Figure 3
Spherical renders of virtual spaces – FOV 360˚ used in the experiments (left) and FOV 45˚ (right)

Gear

The VR gear comprised of a Head Mounted Device (HMD) comprising of two units - the VR Viewer and the Display Unit. Being a Google Cardboard based setup, the display unit was an android driven mobile device (Lenovo Vibe K5 Note) with a diagonal display dimension of 5.5 inches and a display resolution of 1080 pixels. The head movements of the subject were tracked using the inbuilt gyroscope and the corresponding display was projected. This unit was fitted inside the VR Viewer, which was a Procus One unit with biconvex lenses of focal length 14mm. The interpupillary distance and distance between the display surface and lenses could both be adjusted by the subjects through knob provided on the VR unit.

The setup
The experiment comprised of the subject wearing the HMD. The display that was being shown to the subject at any point of time was streamed live to a laptop (MacBook Pro 8.1) via a steaming engine (Mirror Beta). The immersive spatial environments were displayed through a VR engine (Fulldrive). The observer was seated beside the subject and noted down the SAM Valence and Activation ratings manually.

Sampling
The experiments comprised of a sample of (N = 50) subjects. The control experiment focused towards daylight factor and volume had a sample of (N = 10) subjects. All subjects for all experiments were post-graduate students of CEPT University, Ahmedabad, within the age group 23 - 33, with a bachelor's degree in Architecture.

Experiment Process
The subject was briefed about the experiment process. They were introduced to the two scales of Valence and Arousal, and the rating mechanism (SAM) that they were to employ while giving their responses, and were also given a broad idea of the parameter sets (Opening, Volume and Proportion) that were being studied.

They were then were asked to wear the HMD in a standing position, to ensure coherent interpretation of eye level and freedom of basic movement. and adjust the knobs to ensure that a clear and focused environment was achieved.

The subjects were shown each of the instances for each parameter set. They were given between 15 - 30 seconds to explore each space, and were then asked to rate the space on the SAM scale. The observer translated the SAM rating to a numeric value (between -4 to +4) and recorded it on a data sheet. Qualitative keywords/observations etc were also noted by the observer.

The sample size of 50 was broken into two smaller samples of 25 each. Subjects from the first sample were shown the instances of each parameter set in sequential order i.e. starting from Instance 1 and ending at Instance 6. The order of the three sets themselves was randomized. Subjects from the second sample were shown the instances of each set in random order, but in each case, starting from the datum space(4mx5mx3.5m enclosure with a 1mx1.2m window opening). Thus, the first scene they saw in each set was the same. This was done to ensure perceptual coherence across sets.

RESULTS
Figures 4, 5 and 6 summarize the data obtained from the three sets of experiments.

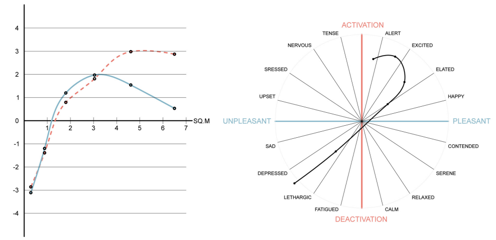

Figure 4
Valence(solid) and Activation(dashed) vs Area of Opening (left) and shift in affective state as plotted on circumplex (right)

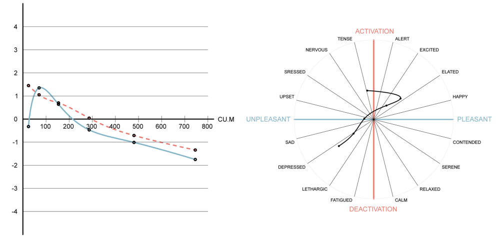

Figure 5
Valence(solid) and Activation(dashed) vs Enclosure Volume (left) and shift in affective state as plotted on circumplex (right)

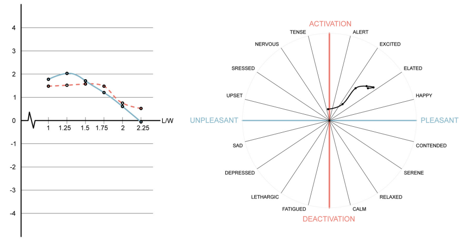

Figure 6
Valence(solid) and Activation(dashed) vs Enclosure Proportion(L/W) (left) and shift in affective state as plotted on circumplex (right)

ANALYSIS AND DISCUSSION

Effect of Sequence

For both sets of subjects (scenes shown in sequence and in random), the nature of the curves for valence and activation were very similar for all three parameter sets, and lay within a very small range of values. (Figure 7), (Figure 8).

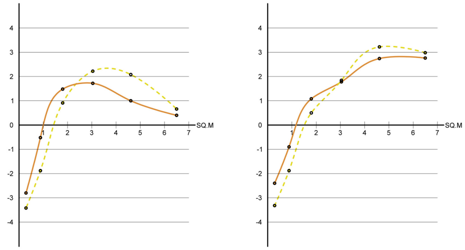

Figure 7
Area of Opening: Ordered(solid) and Random(dashed) sets for Valence (left) and Activation (right)

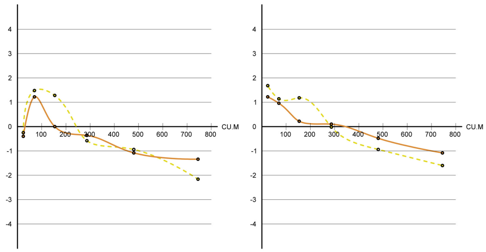

Figure 8
Enclosure Volume: Ordered(solid) and Random(dashed) sets for Valence (left) and Activation (right)

There was, however, a very important point of difference. For both valence and activation, the amplitude (maximum and minimum values) of curves was consistently larger for subjects who were shown scenes in random. This pattern was consistent for all curves for the Opening Size and Enclosure Volume set. (Figure 7), (Figure 8)

This consistent variation in amplitude revealed that the SAM ratings that one would associate to a certain space would be exaggerated if that space followed a contrasting space. For example, a room appeared much brighter to the subject if it was shown immediately after a contrasting dark room and vice versa. This exaggeration of sensory perception was diminished if the spaces were shown in order, i.e. if the bright room followed a room that was marginally less bright. This phenomenon was reflected in both the emotional parameters of valence and activation. In the set where the spaces were shown on random, each space was far more likely to be followed by a contrasting space - something that was never a case in the ordered set.

This inference may be extended to physical spaces too. The entry sequence into a space may well be an important factor in the way we respond emotionally to that space. For example, a large hall may appear larger if entered through a small volume and vice versa.

Peak values of Valence

Peak valence values correspond to architectural configurations where subjects gave the highest ratings on the 'Pleasant - Unpleasant' scale. These configurations thus had the highest degree of 'positive-ness' associated with them.

Size of Opening

Figure 7 shows that for both the random as well as the ordered sets, subjects rated Instance 4 (3.04 SQM of opening) highest on the valence scale. As per the relation between Area of Opening and Daylight Factor as discussed earlier, this space corresponded to (Aglazing/Atotal) ratio of 0.03. It was still not clear how area of opening affects emotional state independent of levels of illumination. It was established beyond doubt through a control experiment conducted for the volume set (discussed later) that the primary factor behind change in emotional state was not area of opening as an independent entity, but rather the Daylight Factor levels as a function of area of opening.

Enclosure Volume

As we see from Figure 8 the valence curve peaks at a volume of 70 cu.m, which corresponds to a spatial configuration of dimension 4mx5mx3.5m. This was consistent for both ordered and random sets. It is worth noting that this space is in fact the datum space that was common to all the parameter sets. It is also of importance that such a space was of very human scale i.e. of dimensions and proportions commonly found in low occupancy domestic spaces such as bedrooms, studies, etc. This finding may empirically set a volume range that constitutes 'human scale', that is an ideal size of enclosure where occupants feel most pleasant.

Figure 8 also shows that for both the ordered as well as the randomized sets, after reaching peak value, the valence curve descends very gradually. However, the corresponding increase in volume is considerable. It may be noted that while there is a very rapid increase in valence between the 24 - 70 cu.m range, the post peak fall in valence is much more gradual, such as in the (300 - 700 cu.m range). Thus subjects recorded a gradual decrease in valence even when there was a rapid increase in volume.

It is evident from this observation that subjects were more sensitive to changes in volume in enclosures that were of a volume comparable to human scale, whereas the perception of volume decreased drastically as enclosures became very large and were no longer comparable to human scale. This explains the gradually decreasing slope of the descending valence graph. This inference may be directly utilized in design of spaces. Creating very large spaces to instil feelings of wonder and awe may not be effective beyond a certain volume range, and only result in wastage of resources.

It is also evident from the rendered images. (Figure 9) The changes in volume for the two spaces corresponding to Instance 1&2 are instantly perceptible. However, the difference in volume between Instance 5&6 is not easily perceptible, making the spaces look almost identical. It will be interesting to note that the absolute change in volume between Instances 5&6 is much greater then the difference between Instance 1&2.

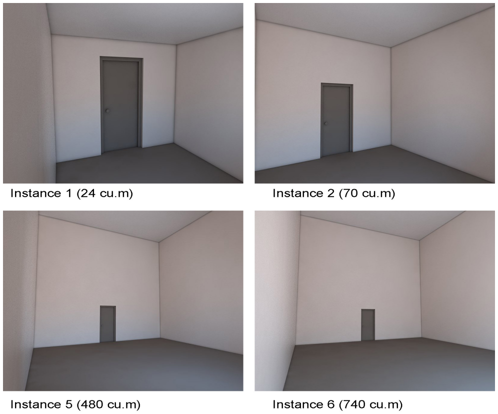

Figure 9
Difference in perceived change in volume in renders for Instance 1&2 (Top) and 5&6 (Bottom). Note how the bottom set appears identical despite having a much larger change in absolute volume

ENCLOSURE PROPORTION

As opposed to the other parameter sets, enclosure proportion did not display a valence peak around a small value range. Figure 6 shows, that even though Instance 2 (length/width = 1.25) corresponded to the maximum value of rated valence, Instance 1 and Instance 3 displayed very similar and high valence values. Thus within the proportion range 1:1 - 1:1.5, rated valence was consistently high. However, there was a sharp drop in the valence curve after 1:1.5. This was clearly evident in the ordered set.

While this tells us that subjects felt most 'positive' within the 1:1 - 1:1.5 proportion range, it also gives us an interesting counter argument to the classical concept of the 'golden ratio' (1:1.61). The data reveals that this ratio was not rated favourably for spaces in plan, where the ratio is not directly visually perceptible. In other words, while the golden ratio may be a very strong 'visual attribute', it may not possess any absolute properties of being perceived independent of the visual realm (such as in elevation).

The emotional parameter of Arousal and Daylight Factor

A study of the Arousal curves of all the parameter sets yields a wide range of very important inferences. A look at Figure 10 tells us that arousal strongly correlates with the area of opening and thus daylight factor. The coefficient of correlation was (r = 0.90). This was consistent for both the ordered and the random sets (r =0.89 and r = 0.91 respectively). For both the sets, rise activation appears to stagnate towards the end (the variant corresponding to the greatest area of opening has an activation value roughly the same as its preceding variant). This reveals that our sensitivity to changes in illumination levels appears to fall significantly for very high range of illumination values.

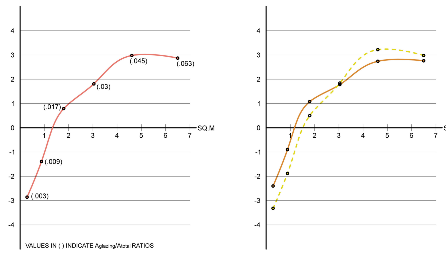

Figure 10
Activation vs Area of Opening: Note the stagnation in slope after Instance 5 for both Ordered(solid) and Random(dashed) sets (right).

In the case of enclosure volume, however, rated activation fell consistently with increase in volume, for both data sets (Figure 11) (r = -0.98). This may mean two things. The first possibility is that activation may actually be inversely related to enclosure volume. This would mean that subjects consistently felt less aroused as the enclosure became larger and larger. The second possibility is that the fall in activation was not due to increase in volume, but actually due to the drop in daylight factor. Since the area of opening was kept constant for all the variants of room volumes, the A(glazing) / A(total) ratio decreased with increasing volume. This may have been the reason for the steady drop in rated arousal. The coefficient of correlation of arousal with A(glazing) / A(total) was high (r = 0.81)

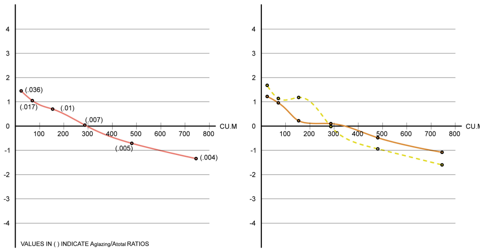

Figure 11
Activation vs Enclosure Volume for combined (left) and Ordered(solid) and Random (dashed) sets (left).

A control experiment was conducted to understand these findings. The experiment was conducted in a smaller sample set of (N=10) subjects. The six spaces used in the volume set remained the same, except that the window opening area was made to increase proportionate to the increase in volume, thus keeping maintaining a constant A(glazing) / A(total) ratio. The valence and activation values were recorded for each of the instances using the same methodology and process as the other experiments. The graphs below (Figure 12) show the Valence and Activation curves derived from the control experiment as compared to the primary experiments.

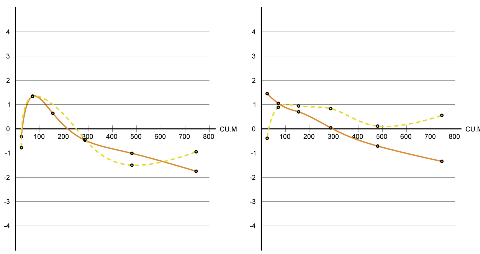

Figure 12
Valence (left) and Activation (right) vs Enclosure volume for Primary(solid) and Control(dashed) Experiments

What was evident from the results of the control experiment was the fact that the nature of the activation curve in the volume set was driven by the level of illumination in the spaces, and not independently by the increase in volume. While the main volume set shows a uniform drop in activation with the increase in volume, the arousal levels in the control experiment (where illumination remained constant) did not correlate with volume (r = 0.06) The Valence parameter behaved in a roughly similar manner for both the primary and the control experiments. (Figure 12)

The strong correlation of the emotional parameter of activation with Aglazing/Atotal in an enclosure gives us valuable insights into the way we respond emotionally to spaces. Activation (or arousal) is a major component of the circumplex model of emotion. From the activation graphs of the three parameter sets, we see that there is little affect of enclosure volume an enclosure proportion on activation, independent of the parameter of illumination. We also know that valence peaks and then drops with increase in illumination.

CONCLUSION

The broad aim of this research was to provide architects with a body of empirically tested scientific knowledge pertaining to specific correlations between specific formal attributes of virtual enclosures and spatial experience in occupants. The inferences derived from this study has the potential to be drawn upon by architects to inform their own design decisions, rather than relying upon intuition alone. More importantly, it is hoped that this work provides direction to future research in this field. There are an infinite number of formal and experiential parameters, and the natural relationships between them are still largely unknown. The HMD driven methodology adopted in this study has the potential to be drawn upon, refined, and applied in similar focused experiments, possibly giving rise to computational models for emotional response in space. This line of inquiry is an attempt to quantify the so-called 'intangible', and to uncover the logic at work behind the magic of space.

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