Capturing Affect in Architectural Visualization

A Case for integrating 3-dimensional visualization and psychophysiology

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Envisioning architectural experience afforded by a building under design has been difficult due to two reasons. One is simulating the space in full scale, eliminating the need to take a mental leap commonly required of abstract smaller scale representations. Second challenge is in fully capturing the affective experience, which is often subtle in nature. This paper suggests that 3-dimensional visualization - particularly immersive virtual reality can overcome the first challenge. In addition, psychophysiological measures such as facial electromyography (EMG) and electrodermal activity (EDA) can be used to capture the affective component of the architectural experience. We suggest that by taking advantage of these technologies together, one can better simulate and empirically understand the nature of architectural experience.

Keywords: *Architectural visualization; virtual reality; psychophysiology; electrodermal activity (EDA); facial electromyography (EMG)*

Challenges in visualizing architectural space: Capturing scale and psychological experience

Architects and designers make mediating artifacts, which play an important role in simulating the experiences and functionality afforded by the design. As science and technology progressed, these artifacts have evolved from drawings to physical models and more recently to computer simulations including virtual reality. These representations or artifacts start from being highly abstract and take on more definitive qualities as the design progresses. During the design process, the architects' work on an imaginary object conceived in their mind's eye and communicated only through representations (Porter, 1997). Thus the two big challenges faced by the designer still remain - first of simulating the true scale of the space and the other of capturing its psychological effect. The former is due to the fact that with most representational medium, the designer is 'outside' the representation. In other words, the simulation is rarely full scale, limiting the designer's ability to inhabit the space under design. Again, it is common for architects to approach their designs in terms of the emotions they want to evoke. The challenge of capturing the psychological effects of space is perhaps more elusive. Since architectural experience cannot be captured from a mere snap shot in time, continuous assessment is important in capturing the overall experience. Also the psychological experience of an architectural simulation includes both cognitive and affective components and one need to explore both constructs.

Potential of virtual reality

Large screen technologies such as immersive virtual reality technology offer the potential for designers to inhabit the space under design. The concept of *presence*, which is critical to the VR experience, is a psychological state in which even though an individual's current experience results from and is filtered through man-made technology, the individual's perception fails to some extent in acknowledging the role of technology in the experience (Steuer, 1992). Participants who are highly present should experience VR as more engaging reality than the immediate world. Immersion is one of the factors influencing presence (Slater et al., 1994). Additional factors include among others, interactivity, tactile and other sensory feedback. Presence is in essence a psychological experience and as Huang and Alessi (1999) suggest, presence can be reexamined in terms of ones' emotional engagement with their environment. Simulations such as those using immersive virtual reality technologies are the closest we can come to a real world setting to study the psychological impact of spaces while keeping the costs within reasonable limits. These simulations can also improve the experimental rigor by allowing one to control for confounding variables.

Potential of psychophysiological measures

In this paper, we propose to study the experiential aspects of architecture by bringing psychophysiological measures into the realm of 3-dimensional visualization - more specifically, virtual reality. The basic premise is that all psychological states have physiological correlates and by accurately capturing these physiological changes, one can begin to develop an understanding of the psychological impact of an architectural space. Psychophysiology can then be defined in simple terms as the division of psychology that investigates changes in the activity of physiological systems caused by psychological input (Stern, Ray and Davis, 1980). We believe that psychophysiological measurements in combination with one another or other voluntary measures can hopefully provide us with a better understanding of experiential aspects of architecture. We think that this is very important for the study of architecture, since to some extent, the questions one asks are limited by the methods available to explore them. While bringing together psychophysiological measures and virtual reality can be beneficial, one needs to address physiological issues that are unique to virtual reality simulations such as (motion sickness) which may be absent in real world situations as Parsons and Hartig (2001) point out.

Though at a glance, it may seem that our work falls under what can be termed as 'environmental psychophysiology', it is only true in as much as our study also deals with human-environment transactions in a broad sense. Again, as Parsons and Hartig (2000) point out, environmental psychophysiology is not a well-defined field as such. While Parsons and Hartig (2000) under the umbrella of the term 'environmental psychophysiology' have focused on environmental noise, restorative environments and topographic cognition, they cite research in areas relating to other areas such as effects of light, olfactory stimuli and causes of environmental stress such as thermal extremes. Our focus is primarily on architectural space and more specifically on the aesthetic experience, building on the foundation laid by works of Stamps (2000) and others by bringing in psychophysiological approaches to the study of aesthetic experience.

Capturing affect

A quick survey of psychological literature database on affect in general, or a more recent meta-analysis of studies on emotions in environmental perceptions by Stamps (2000) reveals that affect variance is essentially captured by the dimensions of valence, arousal and dominance. Stamps' (2000, p. 81) meta-analysis reveals that the three dimensions of pleasure or valence, arousal and dominance respectively account for 36%, 15% and 9% of the affect variance. These dimensions according to Stamps (2000) also mirror Kant's trilogy of aesthetics, cognition and will. Since valence (the feeling of pleasantness), and arousal (the degree of excitement), account for most of the variance, they are generally used to measure affect. These dimensions of affect are usually captured using self-report measures or psychophysiological measures - both having inherent advantages and disadvantages. Swindells et al. (2006) suggest that self-report measures are preferable when the goal is to capture subtle relative differences between stimuli and biometric techniques are ideally suited for situations where absolute measurements are needed. Ridder et al. (2000) suggest continuous monitoring to capture temporal variations in subjective impressions and psychophysiological measures are ideally suited for this purpose, since they can capture both tonic and phasic information during the course of a given stimuli.

Self-report and psychophysiological measures of affect

Stamps (2000) and Franz (2005) provide an overview of previous attempts to capture affect in an architectural context. Russell (1980) proposed a circumplex model of affect comprising of the two bipolar dimensions of valence and arousal. This model can capture all possible affective states as a combination of the two primary dimensions and have been used widely. Russell et al. (1989) have proposed an affect-grid where the subjects report their affective state by marking an X on a grid, thus capturing the level of valence and arousal in a single response.

A variety of psychophysiological measures such as heart rate variability, electromyography (EMG), electrocardiograph (ECG), electro-oculogram (EOG), electrodermal activity (EDA) and respiration rate among many other measures (Picard, 1997, Cacioppo & Tassinary, 2001, Broek et al., 2006) can be used to capture ones' emotional state. While it is beyond the scope of this paper to go into all of these measures in detail, the potential of facial electromyography (facial EMG) to capture valence as well as that of EDA to capture arousal are discussed. These measures have been used successfully to capture valence and arousal in other contexts. One must keep in mind that EDA and EMG measures are usually used in conjunction with other psychophysiological measure such as heart rate or self-report measures for a deeper understanding of the phenomena under study.

Electrodermal activity (EDA)

Electrodermal activity is perhaps one of the most widely used psychophysiological measure due its relative simplicity and the richness of the collected data. The underlying idea is that, in the presence of external stimuli, the skin becomes a better conductor of electricity. The eccrine sweat glands found in dense concentration on the surface of palms and feet soles are highly sensitive to emotional stimuli and in effect act as a set of variable resistors wired in parallel (Stern, Ray and Davis, 1980). By measuring the skin resistance when a small current is passed through a pair of electrodes attached to skin surface, one can detect variations in responses to different stimuli. Dawson, Schell and Filion (2001) point out that while tonic (background or resting level) EDA is used for measuring arousal, the phasic (short-term) skin conductance responses can be used to explore attentional processes or the ability of a stimulus to elicit an orienting response in the subject. The latter components can be useful to explore information processing mechanisms within the human mind in an architectural context.

Facial Electromyography (EMG)

Emotions are probably best reflected in our facial expressions and the face is therefore often referred to as a 'window to the soul'. Electromyography is a record of electrical potentials originating in the muscles over time (Stern, Ray, Davis, 2001, p.108). Facial electromyography (facial EMG) is a surface measure designed to examine muscle contractions in the specific facial muscles associated with positive and negative emotions. *Zygomaticus major* , the muscle group which extends from the corner of the mouth , pulling it up while smiling and the *corrugator supercilii*, on the forehead which draws the brows down and closer into a frown are of interest for facial EMG (Tassinary and Cacioppo, 2001). This is based on the

Figure 1
Images from the psychophysiology lab showing EDA measurement to a television stimulus

idea that valence is bipolar in nature ranging from pleasant to unpleasant. Pleasant stimuli will result in greater EMG activity over the zygomaticus major compared to corrugator supercilii and the reverse would be true for unpleasant stimuli. Thus by measuring EDA and facial EMG (in conjunction with additional biometric or self-report measures) in response to an architectural stimuli, one can perhaps get a better understanding affective responses that may be elicited by the same space after construction.

Possible directions for future research and facilities

The paper elaborates how 3-dimensional visualization and psychophysiology can be brought together for the study of architectural experience. The initial phase of research will explore physiological aspects of immersive architectural experiences. Two initial variables of interest would be immersion and flow, i.e. the extent to which one feels part of the virtual environment and the extent of psychological engagement. The preliminary task would be to identify and clearly define the cognitive and affective qualities of architectural experience. This is important since both are multi-dimensional concept and because the models, specifically that of affect are still based on classical behavioral or clinical psychology (Franz, 2005). The latter phase of the research will investigate through controlled experiments, the effect of elements of architectural space – geometry, color, light, shape, movement etc which would further our understanding of the architectural experience. Through a series of experiments we will seek to explore the relative contribution of each of these spatial components on both affective and cognitive aspects of our experiences.

We plan to carry out the idea of bringing together virtual reality and psychophysiology over the next couple of years by combining the strengths of two major research labs at Penn State University - namely the Immersive Environments Lab in the department of architecture and the Media Effects Research Lab under the college of communications. The Media Effects Research Lab is well equipped to undertake psychophysiological research particularly with respect to the psychophysiological measures discussed above. The experimenter has access to psychophysiological observation measures that tap into cardiac, brain, muscular, and ocular activities of participants.

The Immersive Environments Lab (IEL) at the School of Architecture and Landscape Architecture at Penn State University was envisioned as a surround-screen immersive 3-dimensional environment for the personal visualization of architectural models. The IEL started as a single, six-by-eight-foot rear projection display, and in the next phase of development evolved into a two-screen system with the screens at a 120-degree angle to provide a wider field of view. The Immersive Environment Lab display system at the time of this paper, after going through many iterations, is moving into a new facility consisting of a three, large, rear-projection, passive stereo display screens. The screens are joined at an angle of 135 degrees and provide a panoramic view, when used in used in three-screen VR mode.

For the purposes of this research, the distinct locations of the two facilities will not be a problem as the psychophysiological equipment can be easily moved to and set up in the IEL. The research team is inter-disciplinary in nature drawing from faculty and graduate students with expertise in architectural visualization using 3-dimensional media and experience in media effects research using psychophysiology.

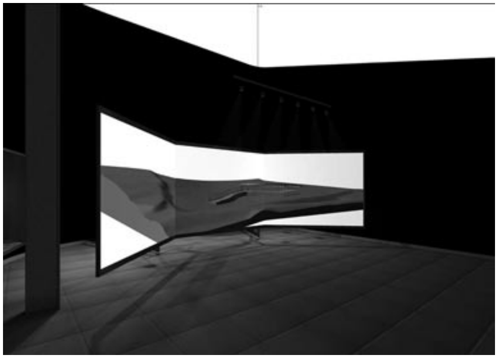

Figure 2
Rendering of the new Immersive Environments lab nearing completion

Conclusion

In this paper we made the case for more empirical studies that would improve our understanding of architectural experience by exploring the possibilities opened up by virtual reality and psychophysiological measures. We hope that our future work and those of others would help us better understand the affective and cognitive components of architectural experience. This could create a foundation for more studies that would help us empirically understand the multiple dimensions of architectural experience and capture its nuances, which are very much a need of our times.

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