Design Visualization: A Media Effects Approach

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This paper proposes an integrative approach in the evaluative phase of the design process, incorporating concepts, methodologies and measurement strategies that are well established in media psychology. The paper suggests a variable-centered approach for conceptualizing visualization technologies and to evaluate their potential to simulate architectural experience. Psychophysiological measures are introduced to capture the affective component of the architectural experience facilitated by visualization tools such as virtual reality. These are important in order to empirically evaluate the experiential aspects of an architectural space through visualization. Ideas are illustrated with examples drawn from prior and ongoing research collaboration between an architectural visualization lab and a media effects research lab.

1. Introduction

Currently, architects have at their disposal advanced tools for design visualization as well as highly accurate computer aided manufacturing (CAM) tools for physical realization of complex forms. Traditionally, architects have been able to integrate appropriate techniques from domains as diverse as biology (e.g. biomimicry) and electronic sensor technology (e.g. smart spaces) for creating innovative design solutions. If the architectural design process can be broadly seen as a cyclical *propose – evaluate – modify* process, much of the digital innovation and integration has been in the creative phase, i.e. the propose phase of architectural design process. With advances in building information modeling (BIM), there is better communication, co-ordination and conflict resolution in the evaluation stage. However, evaluating experiential aspects of the proposed design is an area that is still lagging behind. The power of architecture ultimately resides in the emotions it evokes, above and beyond fulfillment of functional requirements. This paper suggests an innovative approach to address this shortcoming in the design evaluation stage by integrating simulation techniques from architectural visualization with concepts, methodologies and measurement techniques appropriated from media psychology and psychophysiology. This approach, which forms the foundation for research at our labs, has provided valuable insights into both assessment of architectural experience as well as development of virtual reality technology for simulating architectural experience.

2. Challenges in simulating and evaluating architectural experience

Two significant challenges must be overcome if progress has to be made in simulating and evaluating architectural experience. The first challenge pertains to locating oneself in the design space, i.e., to accurately capture the scale. Architects rarely make buildings directly, but make representations in a number of modalities including physical models and computer simulations that make buildings possible. With most representational media being less than full scale, the designer is 'outside' the representation. Figure 1 shows a common example from a design studio critique. In simulating architectural design, the necessary conversion from that which is inhabitable, experiential, functional, and at times, indescribable to an abstraction in an entirely different media is often an imperfect procedure that centers on its translation rather than the actual design. Thus, it takes a mental leap to locate oneself in the space under design. The second broad challenge has to do with accurately capturing the psychological effects, including both cognitive and affective components of the spatial experience. Architectural design is an iterative visual process that involves thinking and exploration using pictorial or symbolic representations, which can be referred to as the "language" of the architect for communication [1].

◀ Figure 1. A design studio critique session where the designer and reviewers are outside the representation.

When approached from a media psychology point of view, the emphasis of architectural evaluation is shifted from an analytical point of view to one of that of assessing the psychological experience. This implies a recasting of key theoretical concepts underlying architectural visualization as well as choosing methodologies appropriate for empirical evaluation. The remainder of this paper elaborates and illustrates this broad idea. The concept of *spatial presence* is suggested as a key theoretical construct that can bridge architectural visualization and media psychology, with architectural visualization tools seen as *presence* enabling technologies. A variable-centered strategy appropriated from media studies that lends itself to experimental manipulation of technology features and assessment of psychological outcomes is then described. Further, the paper examines issues of measurement, critical for assessment of psychological experience. We conclude by making the case for integrating immersive virtual reality technology and psychophysiological measures as a promising approach for capturing affective experience in architectural visualization. These ideas are illustrated through the prior work in our virtual reality lab.

3. Spatial presence as a key theoretical construct for architectural visualization tools

During the design process, architects use a wide variety of representational media at varying degrees of abstraction to externalize and evaluate design ideas. Two-dimensional orthographic representations are used primarily to evaluate various functional aspects of the design and to identify areas of conflict. Architects use a variety of techniques from hand drawn perspectives to interactive, immersive virtual reality environments to examine the experiential quality of the space under design. In these attempts, irrespective of the modality or the level of realism, an important objective is to locate oneself in the represented space. Given the importance of locating oneself (psychologically, if not with respect to sensory stimulation) for evaluating the spatial experience, the concept of *presence* becomes important. *Presence* can be broadly defined as the subjective experience of "being there" in a mediated environment [2]. With respect to architectural visualization, the narrower concept of *spatial presence* is of interest. Wirth et al. (p. 497) [3] define *spatial presence* as a "binary experience, during which perceived self location and, in most cases, perceived action possibilities are connected to a mediated spatial environment, and mental capacities are bound by the mediated environment instead of reality." This definition is appropriate within the context of architectural visualization since the two main dimensions of spatial presence identified in this definition (spatial self-location and possibilities for action) are critical for evaluating architectural experience using a media simulation. The objective in visualizing any architectural design is to achieve a situational awareness that allows for meaningful criticism of the design.

3.1. Conceptualizing visualization tools as presence enabling technologies

Balakrishnan, Kalisperis and Muramoto [4] examined the concept of spatial presence and its relevance for architectural visualization. Approached through the lens of spatial presence, many commonly used 3D CAD and visualization tools can be re-conceptualized and their emphasis shifted from photorealism aimed at representational isomorphism to one of achieving experiential congruence. A number of factors can contribute to experiencing spatial presence, such as the size of display, stereoscopy and interactivity. Thus, the experience of spatial presence can be enhanced through diverse techniques, each appropriate for the specific modality chosen for architectural visualization. Once visualization tools are conceptualized as spatial presence enabling technologies, we can systematically evaluate, through empirical means, the relative contributions of various structural as well as content factors of visualization tools towards spatial presence. Presence is a multi-dimensional concept and is dependent on a large number of inter-related factors [5]. Variables affecting presence can be broadly grouped into four categories [6]: the extent and fidelity of sensory information such as screen size, resolution and field of view, the match between sensors and display, media content and user characteristics. A more detailed list of technology and user factors that contribute to presence, is given by Lee [7]. Systematic investigations into how these factors affect spatial presence can further improve visualization tools in their ability to simulate spatial experience.

4. A media effects approach for architectural visualization and evaluation

Media effects research within the domain of mass communication studies is broadly concerned with the cognitive, affective and behavioral impact as a function of media consumption and examines the underlying reception processes, inter-media processes and individual differences among other aspects [8]. Media effects research, for most part, takes a quantitative approach, identifying media characteristics as causal variables and cognitive, affective as well as behavioral responses as dependent variables. The media effects approach can complement existing approaches to capturing architectural experience such as reflection-in-action proposed by Schon [9-10] and think aloud protocols (TAP) proposed by Ericsson and Simon [11]. These approaches are still highly relevant for design research, including those pertaining to design visualization and offer rich and nuanced findings. However, findings from these approaches are not easily generalizable which is important for development of tools and strategies for visualization. The media effects approach for architectural visualization has two important characteristics. The first is its variable-centered nature where visualization tools conceptualized in terms of its structural and content variables. The second characteristic is the emphasis on quantitative measurement of the dependent and mediating variables. These two characteristics are discussed in detail below and illustrated with examples drawn from research relevant to architectural visualization in our labs.

4.1. A variable-centered strategy for development and evaluation of architectural visualization tools

Since full-scale physical mock ups are highly expensive, designers rely on virtual environments to evaluate the aesthetic and affective aspects of the architectural experience. Hence the development of presence enhancing environments such as virtual reality is critical to advance our ability to simulate architectural experiences. In the recent past, an important consideration in the development of digital tools for visualization was in benchmarking their performance against traditional representational media based on free-hand drawing techniques. Given the fact that digital media is now commonplace for architectural visualization, it is important to focus our efforts on further developing them beyond achieving efficiency of human-computer interaction and representational isomorphism. While evaluating the efficacy of visualization technologies to simulate architectural experience, it is important to identify what factors impact this experience and assess their relative contributions. To achieve this, one must take a more nuanced approach to evaluating technology rather than treat the technology as a 'black box' (i.e. monolithic entity). Approached from the media effects point of view, attributes of technology can be seen as antecedent or causal variables and the psychological effects as outcome variables. Such an approach will help to predict the impact of various technology variables on spatial presence, building on theories of media psychology. One can then empirically assess these predictions as well as examine the relative impact of different technology attributes. The 'variable-centered' approach towards technology put forth by Nass and Mason [12] suggests breaking down a technology into its component variables and their corresponding values. The advantage of taking a variable-centered approach is that the findings based on a particular variable can be extended to any technology with a corresponding value for that variable [12]. There are a number of ways to partition a visualization technology into component variables. One strategy is to break-down a given technology based on its structural components. For example, screen size, field of view and stereoscopy are all technology variables of virtual reality in a variable-centered approach. These technology variables can then be systematically manipulated and their effects measured.

Illustrations of the variable-centered approach

The ideas described above can be illustrated through two recent studies which utilized a variable-centered approach to assess the potential of virtual reality technology in simulating architectural experience. The first study, by Kalisperis et al. [13] examined the relative contributions of five virtual reality system variables – stereoscopy (stereo/non-stereo), screen size (large screen/ small screen), field of view (wide/ narrow), level of realism (high/ low) and level of detail (high/ low) on spatial comprehension and spatial presence. Here the variable-centered approach took structural and content factors of the virtual reality technology as the starting point. The contributions of these five variables and their two-way interactions are estimated through a 2^{5-1} fractional factorial experiment with 84 subjects. This variable-centered approach yielded many nuanced information about the interactive effect of various structural components on different dimensions of spatial presence and spatial cognition. To cite one example, for wider field of view, the ease of immersion was almost the same for low and high realism conditions whereas for the narrower field of view, the ease of immersion was much greater for the high realism condition compared to the low realism condition [13]. The study also identified significant interactive effects between virtual reality system and content variables on spatial cognition. For example, when the display had a high level of architectural detail, there was hardly any difference in depth perception between smaller and larger screen size, whereas for low level of architectural detail, larger screen size resulted in more accurate depth perception compared to a smaller screen size [13]. These findings were highly useful for development of our subsequent virtual reality lab.

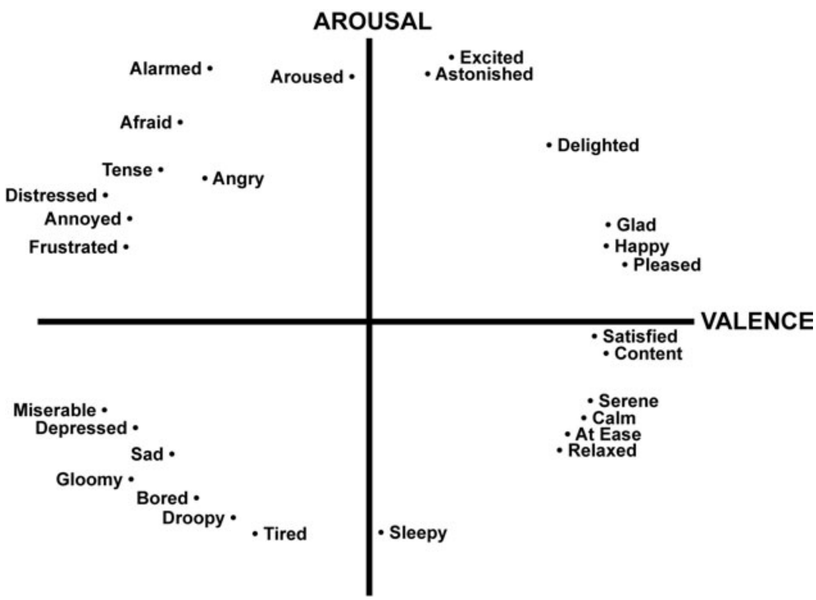
The second study conceptualized variables of virtual reality from a different point of view and approached the technology in terms of its affordances. Balakrishnan [14] looked at the impact of navigability, an important affordance of interactive virtual reality, on spatial presence. The concept of navigability was explicated to identify a locomotive component (traversibility) and a cognitive component (guidance for wayfinding) [14]. Traversibility was further explicated to identify two sub-components: steering control and environmental constraints. These variables were pitted against narrative transportation, a user centric variable where the subjects were either asked to role play a character or not. These variables were systematically manipulated in a large experiment with 240 subjects. Findings revealed that narrative transportation actually detracts from spatial presence while greater steering motion control enhances it even without invoking a mental model of the portrayed environment [14].

4.2. Empirical assessment of architectural experience

There are two primary challenges in measuring the potential psychological effects of an architectural space. The first challenge is that of bridging the gap between the abstract world of theoretical constructs and the world of observable measures for the phenomenon. This challenge is similar to that faced in any social science research and can be solved through established by strategies such as explication [15]. For example, Sas and O'Hare [16] suggest a three-step strategy for operationalization: identifying different conceptual dimensions for a given construct, finding variables within each of those dimensions that can be measured and finally selecting appropriate measures that capture each variable. This is usually achieved through survey instruments such as questionnaires. The process of explication [15] is suggested as a strategy for improving the validity of these measurement instruments. The second and more difficult challenge is to accurately capture the psychological effects of space. Architectural experience unfolds as the observer moves through space and time and it is important to capture the temporal variance in this experience. This is not captured effectively in post test questionnaires where the subject retroactively reflects on the experience. Other commonly used techniques such as think aloud protocols run the risk of interfering with the experience itself. We propose using psychophysiology measures, which are well established in media effects research and in affective computing, to capture the temporal variance in architectural experience.

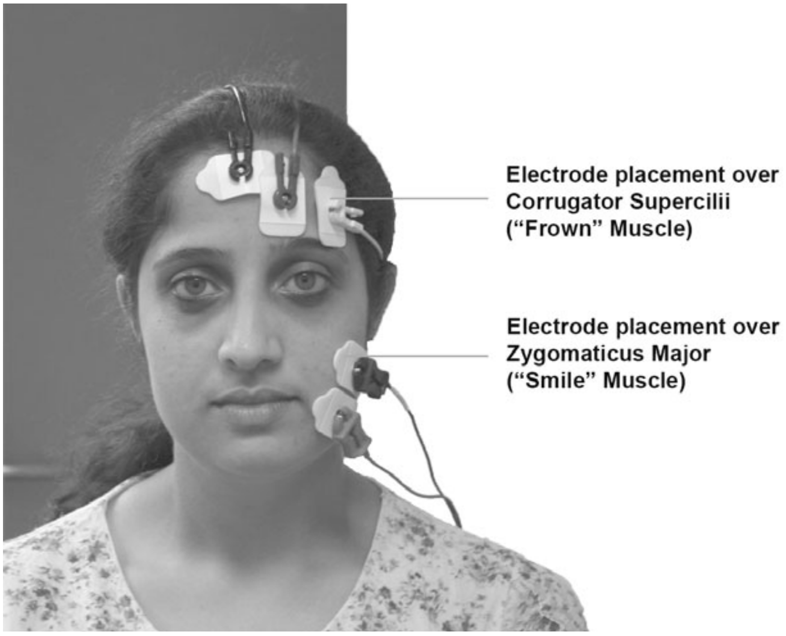
The case for inclusion of psychophysiological measures

By using immersive virtual reality for design visualization and biofeedback for measurement, we can address the challenge of locating the observer inside the design simulation as well as that of capturing the temporal variance in the architectural experience. The idea underlying the use of psychophysiological measures is that psychological states have corresponding physiological correlates and by capturing these physiological states, one can gain an understanding of the respective psychological states. A wide variety of psychophysiological measures including heart rate variability, facial electromyography (facial EMG), electrocardiograph (ECG), electro-encephalogram (EEG) and electrodermal activity (EDA) among others can be used to capture both affective and cognitive components [17-18] of the architectural experience. According to the circumplex model of affect proposed by Russell [19], most affective states can be mapped on a 2-dimensional space where valance (pleasant – unpleasant) and arousal (aroused – unexcited) forms the two primary dimensions that are orthogonal. Please see Figure 2 for details. Different affective states can be located on the 2-dimensional affective space through combination of values for valance and arousal. For example, anxiety induced by a stressful environment will result in high arousal and negative valance. The temporal variance in the affective states can be easily captured by using facial EMG to measure valence and EDA to measure arousal.



► Figure 2. Circumplex model of affect showing multidimensional scaling solution of 28 affect words. (From "A Circumplex Model of Affect" by James A. Russell, Journal of Personality and Social Psychology, 1980, 39, p. 1168. Copyright 1980 by the American Psychological Association. Adapted by permission.)

Face is often referred to as 'window to the soul' since internal emotions are often reflected in facial expressions. Specific facial muscles are associated with positive and negative emotions. The Zygomaticus Major, the 'smile muscle' which extends from the corner of the mouth and the Corrugator Supercilii, the 'frown muscle' on the forehead are of interest for facial EMG measures [20]. This is illustrated in Figure 3. EMG measures record the change in electrical potential originating in the above muscles over time [18]. Architectural simulations of pleasant environments will detect greater EMG activity in the smile muscles compared to the frown muscles and the opposite will be true for unpleasant environments. Since facial EMG can detect subtle changes in emotion, it is much more sensitive than traditional questionnaire and think aloud protocol measures.



◀ Figure 3. Electrode placements for recording EMG over facial muscles to capture valence.

Electrodermal activity is commonly used to measure arousal due to its ease of use. The basic idea here is that the Eccrine sweat glands that are in high concentration on palms and feet are highly sensitive to external emotional stimuli and effectively act as a series of resistors connected in parallel [18]. By measuring the resistance to a small current passed through electrodes attached to the skin surface of the palm, one can detect variations in arousal. By plotting the measurements for valence and arousal on the circumplex model proposed by Russell [19], different emotional states can be identified and their variations over time observed.

One obvious area of promise for combined use of virtual reality technology with psychophysiology in architectural visualization is to evaluate the psychological impact of color schemes. While there are many well developed notions about the emotional impact of different colors and color schemes, there is very little empirical evidence supporting these notions. One of our current research projects brings together the visualization resources in the Architectural Studies department with the psychophysiological resources in the School of Journalism to ascertain the validity of the color image scale developed by Kobayashi [21] as well as assess the psychological impact of specific color schemes.

5. Limitations of the media effects approach

The variable-centered approach to technology offers us a strategy to systematically assess the impact of technology components of various visualization tools on the quality of architectural experience afforded by the simulation. However, this approach is not without limitations. Today's technologies, particularly virtual reality, are very complex and easily yield a number of variables to explore. For example, a high end virtual reality system can be conceptualized as having any number of variable, including but not limited to – display size, display resolution, sensory modalities for feedback and level of photo-realism. Any study involving more than a few variables will require complex experimental design strategies such as fractional factorial design as seen in the study by Kalisperis et al. [13]. Thus, the main limitation of this approach is number of variables that can be studied at any one time. Architectural experience is a multi-dimensional construct and includes a number of cognitive as well as affective factors. As with any empirical research, measuring architectural experience will require a thorough explication process to identify its various dimensions, operationalization of those dimensions and development of measurement strategies. In the research projects described earlier, we based our operationalizations and measurement instruments on well validated questionnaires used in media psychology to measure spatial presence. While we can build on existing empirical research in media psychology and affective computing to capture specific aspects of the architectural experience such as spatial presence and enjoyment, more research needs to happen within our own domain for empirical theory building.

6. Conclusion

In this paper, we made the case for taking a media effects approach for architectural visualization. We illustrated how an approach integrating research methodologies and measurement strategies from media psychology can improve both the development of visualization tools as well as the evaluation of architectural experience. Architectural design is not a linear process like problem solving, but an iterative one of coming up with original ideas and evaluating them for their functional and experiential qualities. While the integrative approach to design, borrowing from biology, computer science and various engineering domains, has given us a number of starting points for creativity, it is important to extend the integrative approach to the evaluation stage, particularly in development of visualization tools that can help during the critique stage. Given that the sensory engagement involved in experiencing physical architecture is far richer than what current VR technologies offer, we still have a long way to go in developing technologies that can simulate true architectural experience. We believe that by following a variable-centered approach, we can identify critical components of a virtual reality system and focus on improving them. The studies mentioned in this paper are illustrative of a systematic approach to understand relative contributions of virtual reality system components on specific cognitive and affective components of the architectural experience. The variable-centered approach can be expanded to include other variables of interest for design visualization and evaluation including the ones relating to individual differences among users. While there is an increase in the number of empirical research projects related to design visualization, a more organized strategy based on the approach presented in this paper will help to improve visualization tools as well as create a more coherent body of theoretical knowledge.

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