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An experimental exploration of the relationship between subjective impressions of illumination and physical fidelity

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Abstract

Two experiments were carried out to explore the effect of rendering and interface fidelity on subjective impressions of illumination and perceived presence after exposure to a virtual environment (VE). In particular, a study that compares a real-world task situation to its computer graphics simulation counterpart is presented. The computer graphics simulation was based on photometry data acquired in the real-world space and was displayed on either a Head Mounted Display or desktop display utilising either monocular or stereo imagery and interaction interfaces such as the common mouse and head tracking. 105 participants across five conditions were exposed to the real and computer graphics environment and after completing a spatial task, subjective impressions of the illumination and sense of presence assessments were acquired. Relevant results showed a positive correlation between presence and subjective impressions of lighting (e.g. 'warm', 'comfortable', 'spacious', etc.) for the HMD monocular conditions. For the second study, the computer graphics scenes were rendered in varied levels of shadow accuracy utilising flat-shaded and radiosity rendering and were displayed on a stereo, head tracked Head Mounted Display (HMD). A total of 36 participants across three visual conditions were exposed to the scene and after completing a spatial task, subjective impressions of the illumination and sense of presence assessments were acquired. Relevant results showed a positive correlation between presence and subjective impressions of lighting (e.g. 'warm', 'comfortable', 'spacious', etc.) associated to the high-quality, full-shadow accuracy rendering condition. There was no effect of viewing condition upon subjective impressions of illumination for both studies, because of constant luminance levels. How real-world impressions of illumination could be simulated in a synthetic scene is still an open research question.

Keywords: Virtual environments; Illumination; Simulation; Visual perception; Presence

1. Introduction

It is not computationally feasible to immerse an observer into an *interactive* artificial environment which mimics the panoply and complexity of sensory experiences associated with a real-world scene. For a start, it is technologically challenging to control all of the sensory modalities to render the exactly equivalent sensory array as that produced by real world interaction [1–6].

Perceptual fidelity is not necessarily equivalent to physical simulation. The ultimate goal, as often argued, is to create synthetic spaces that are going to induce a sense of 'presence' similar to the real world. This goal is not necessarily achieved by accurately simulating the geometry and illumination of real-world spaces. Assembling a Virtual Environment (VE) system to match the

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human perceptual and motor systems is essential. For any given task or for any application that requires a high level of simulation fidelity and mainly targets, for instance, transfer of training in the real world, the ability to induce spatial awareness and impressions of illumination similar to the real world could be essential for a particular task situation.

Light has the obvious function of providing visibility for visual task performance. Flynn [7,8] however, argues that lighting properties should begin with the overall user well being, the visual quality of a room and should not be limited to task visibility. Acquiring subjective impressions of a lighting indicates a move towards assessing lighting designs from an impression point of view rather than a task point of view. One could argue that the presence related research for VE technologies is striving to achieve similar goals: to assess a software platform or a virtual interface generically, not by necessary linking this assessment with task performance even if the relationship between presence and task performance is often considered crucial.

One of the goals of research conducted by Rushmeier et al. [9] on perceptual image quality metrics was to relate subjective impressions of an environment to values computed from measured luminance images. In a more recent study focused on comparability of real and virtual environments for environmental psychology, factor analytic dimensions of evaluation, ambience, privacy and security were similar for both real and flat-shaded simulation of the real-world space, however, a fifth dimension termed arousal was absent in the VE [10]. The studies presented in this paper utilise ratings of impressions of illumination and presence in order to explore the relationship between impressions of illumination and physically-based simulation of computer graphics scenes of varied interface (Study 1) and visual (Study 2) fidelity. It is also valuable to identify whether statistical correlations exist between lighting impressions and perceived presence.

2. Background

2.1. Subjective responses to lighting

James Gibson has suggested that 'the optic array from the (real) world can provide the same information without providing the same stimulation. Hence, an artist can capture the information about something without replicating its sensations' [11]. Flynn [7,8] noted that many lighting systems are designed merely to function in a 'permissive' way, i.e. simply to allow performance or participation in an activity that involves vision, without attempting to affect observers' impressions or behaviour. Many lighting designs, however, especially in a commercial context may intentionally or unintentionally function more actively as shifting selectively human visual experiences: focusing attention, guiding spatial awareness and route comprehension and generally affecting subjective impressions of a room or task situation. A procedure for investigating the effect of light on impressions and behaviour is based on the use of Semantic Differential (SD) rating scales, including adjectives such as 'clear-hazy', 'pleasant–unpleasant', etc in [7,8]. Work with such scales has identified several broad categories of impression that can be applied to lighting (Table 1). The categories of impression of particular interest are:

- *Perceptual* categories such as visual clarity, spaciousness, spatial complexity, colour tone, glare.
- *Behaviour* setting categories such as public vs. private space, impressions of relaxing vs. tense space.
- *Overall preference* impressions such as impressions of like vs. dislike or impressions of pleasantness.

Subjective impressions of lighting have proved to be similar when utilising similar light settings in different rooms and with different object arrangements or activity settings indicating that the modifying effect of lighting is consistent across rooms [7]. This reinforces the theory that subjective impressions are more a function of the actual lighting characteristics than the actual environment in question.

Flynn [8] also suggests that visual patterns such as railroad signals and traffic shapes communicate certain categories of information. Visual patterns are used to guide individual and group behaviour and communicate 'meaning' without words that affects humans' sense of place. The specific information and visual content associated with visual stimuli suggest that when generic lighting modes comprising of the patterns of light, shade and colour are altered, the impression or meaning for the typical room occupant or experimental participant is also affected.

Table 1 lists the set of bipolar adjectives related to participants' subjective impressions of the illumination utilised in Study 1 and 2. The instructions were communicated as follows: 'The following questions relate to your impression of the 3D room. Please, circle the appropriate step on the scale from 1 to 7, for each question'.

2.2. Presence

What sets VE technology apart from its ancestors is that in VE systems users can receive a number of distinct multi-sensory stimuli (i.e., visual, auditory, haptic) which are intended to provide a sensation of natural interaction with the virtual world and, consequently, an illusion of being present in a VE. Presence generally, refers to the sense of being present in time or space in a