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Sustainable Lighting and Sense-Rich Environments

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ABSTRACT

Sustainable lighting, considered in the broader context of sustainable design, suggests a return to more natural interior environments with their greater sensory stimulation and experiential richness. Research over the last 50 years has been claimed to provide little evidence of the interaction between the visual, thermal, acoustic, tactile and olfactory senses which might be expected to be essential to sensory richness. A critical evaluation of such research, in the context of understanding gained from recent research in cognitive science and neuroscience, reveals serious flaws in this research into sensory interaction. The nature of these flaws is discussed with examples. Insight gained from studies of visual perception suggests significant changes need to be made to experimental procedures to avoid the problem of "inattention blindness" and to overcome the lack of reality in the rooms and equipment used in laboratory-based studies. In particular, it is argued that the lack of a sense of "place" and of a realistic activity means that the experimental setting will fail to trigger any significant activity in the neural pathway in the visual cortex which has been found to enable interaction with non-visual sensory modalities.

KEYWORDS: sustainable lighting, cognitive science, neuroscience, inattention blindness, interactive vision

1. Introduction

One of the significant opportunities offered by the concept and practice of sustainable lighting (and perhaps arguably the *most* significant of these) would be the return to natural lighting as the principal component of the interior lighting design of public, institutional and commercial buildings. In the wider context of sustainable design, natural lighting and heating and cooling systems based on ambient energy (solar energy and its derivative wind energy) would complement each other. In turn, and as a design consequence, the building interior would be exposed to or presented with the scents, the sounds and the sights of the world external to the building, in a way which has become largely denied in the artificial environments of most contemporary city buildings.

Characteristic features of the artificial environments found in most large modern buildings are their blandness and the lack of stimulation provided for the occupants. The interior environments have been designed to be functionally supportive while eliminating or minimising any sources of sensory discomfort or distraction, and to achieve these two design goals largely independently for each environmental parameter. This essentially negative approach to environmental

design has been described by one author as "the construction of a demeaning and dehumanised specification of the relationship which should exist between people and the buildings they occupy"¹. By contrast, a positive approach to environmental design would focus on generating satisfaction, pleasantness and delight.

Research has almost exclusively supported the 'negative' approach in environmental design; research projects which have clear and uncomplicated goals and which are likely to produce determinate, reproducible and on-time results have a much better chance of receiving funding. Buildings designed on the basis of these research outcomes could be described as "sense-deprived" — they fail to provide a stimulating environment in which it is a pleasure to work. The type of research which would support the design of "sense-rich" environments would be more complex and would need to explore interactions between the sensory modalities.

Sensory richness is a characteristic of natural environments. It is so difficult to imagine any outdoor, "free-running" environment (a streetside café, a surfing beach, a fishing port, a motorcycle speedway arena) with any one of its characteristic visual, thermal, sound, smell, taste or tactile experiences missing, that we can readily accept that our overall experience has been an

integrative one, with each component of that experience complementing and reinforcing the others. However, research into the existence, nature and strength of such sensory interactions has been limited and spasmodic, and much of the evidence remains anecdotal.

2. Research into sensory interactions

2.1 Fundamental problems

Specific research into sensory interactions has often been motivated by unrelated concerns. For example, the potential for energy savings if people's sense of warmth or coolness could be enhanced by the careful design of a lighting installation and/or the lit appearance of a room led to an upsurge in research in this area in the 1960s and 70s. A survey of a representative sample of research into the effects of air temperature on visual perception or preferences and, conversely, the effects of light characteristics on thermal perception, has been carried out by Division 3 of the Commission Internationale de l'Éclairage (CIE)²⁾. It reported that most experiments showed either a lack of or inconclusive interactions, and that where evidence of interactions was found there was disagreement between authors. The authors made no attempt to critique the variety of experimental procedures applied in the reported studies, nor to evaluate the conclusions. (In fact, a check of the papers included in the survey shows that some results were misreported in the CIE document.) The report did note that almost all of the surveyed studies had taken place in laboratories, and many used climate chambers of the type set up to study thermal comfort and simply added a range of lighting equipment. In no case was daylighting used, although the authors of the report were at the time carrying out their own investigation which did include natural light³⁾.

Criticism of climate chamber studies^{1,4)} has revealed a number of problems and shortcomings. In summary:

- (1) The test chamber itself and the activities (if any) undertaken by the subjects in that chamber are most unlikely to bear any significant resemblance to spaces and activities in the real world.
- (2) By way of questionnaires or other ways of responding, the subjects had their attention unnaturally focussed for all or part of the time on some aspect of the environment in the chamber.
- (3) Untrained subjects may have had difficulty in providing an in-depth articulation of their response.

Despite the doubt cast by this criticism on the outcomes of any research undertaken in this way, a significant number of the papers reported in the CIE document do justify more careful consideration of the experimental technique before the validity of the results can be evaluated. Serendipitously, recent research findings in cognitive science and neuroscience have

been able to be brought to bear to explain why these sensory interaction experiments were either unable to detect interactions or found them to exist only in particular circumstances. A detailed discussion of these issues has been presented elsewhere⁵⁾; a summary of part of this discussion is presented in the following section.

2.2 Input from cognitive science and neuroscience

Two of the experiments reported in the CIE publication can be discussed to provide an illustration of the new insights that are now available and of the need to rethink the way in which sensory interaction is explored in the laboratory. In one experiment, the researcher required the subjects to engage in a task which would have absorbed much of their attention⁶⁾. The subjects used standard automobile controls to guide the motion of a model car on an endless-belt roadway; a task based on a simulator approach to driving instruction. The roadway was in front of the controls and sloped upwards away from the subject. The setting was in a space approximately 1.2m × 3.0m and painted white. The ceiling height was 2.4m at the end behind the subject, sloping down to just 1.5m at the end faced by the subject. The ceiling itself was translucent, lit from above by, alternately, blue fluorescent lamps or daylight white lamps, the latter either bare or covered with yellow, amber or green theatrical gels. The intended effect was a noticeably coloured illumination of the room that changed with each trial. During the trials, the air temperature was raised from 22.2°C at the rate of 1.1°C per minute by six 1000 watt blower-heaters that were claimed to be concealed in the room.

The subjects were asked to indicate when they began to feel uncomfortably warm. It was claimed that the "subjects were unaware of the experimenter's interest in their judgments of comfort and temperature". The sloping ceiling was designed to force the subjects to include a significant part of the lighting diffuser in their field of vision and from the results it was concluded that the colour of illumination did not influence the temperature at which the subjects indicated the onset of discomfort. The report makes no mention of the possible effect of any differences in the clothing worn by the subjects, the degree to which each subject monitored the warmth in the space while concentrating on guiding the model car, and the possible effects of perceptual constancy on the apparent colour of the illumination. While these omissions could be discussed at some length, a potentially more significant point would be the unquestioned assumption that the subjects must notice the colour of the ceiling because the ceiling was forced to be in their field of view. The question which must be asked is "Is that assumption correct?".

Recent research in an area of cognitive sciences called change blindness and inattentional blindness⁷⁻⁹⁾ suggests strongly that the answer is “No, the assumption is not correct”. Despite the fact that we experience a visual world that is rich in detail, research suggests that we retain little, if any, of this detail as we move from one view (or eye fixation) to the next. The lack of retained detail shows clearly in the frequency with which changes in detail go unnoticed, a phenomenon known as ‘change blindness’. The most widely-held hypothesis to explain the sparse rather than detailed internal representation that we build of the visual world is that we do not need a detailed internal representation when the visual world acts as an ‘outside memory’ which can be accessed when needed and has sufficient stability for most purposes^{10,11)}.

The phenomenon of sparse rather than detailed internal representations of the visual world can lead, in laboratory settings, to some stimuli being unattended either because they are not a part of the experiment or because they are part of the experiment but the subject’s attention has been drawn to a task or to one or more other stimuli. This is called ‘inattentional blindness’. The brain, meanwhile, is left with more capacity to deal with the tasks it is focussed on, in this case guiding a model car on an endless-belt moving roadway.

It should be noted in passing that change blindness has a longer history than this recent research suggests. Continuity editors in the film industry have long employed a collective wisdom, spelled out in guide books, as to what type of details have to be consistent from one scene to the next and what discontinuities can be safely overlooked because they simply will not be noticed. That this rich resource of observation and understanding was not known about and tapped into earlier by psychologists must strengthen the case for interdisciplinary research to become a significant component of most contemporary quests for knowledge.

A number of experiments on change blindness and inattentional blindness have been carried out over the last eight years, with a great increase since 2000. One of the more bizarre experiments was based on two teams of three playing a form of basketball in a confined space (in fact, a lift lobby)¹²⁾. A short video was made of the game and subjects were asked to watch this and count the number of times one of the teams successfully passed and caught the ball. During one of the video clips, a woman walked through the game with an opened umbrella and in another an actor in a gorilla outfit walked through the game. The subjects were asked if they noticed anything unusual; 35% had not. To draw more attention to the gorilla, a further video was made in which the gorilla stopped, turned to the camera and beat its chest before continuing walking.

Again, about 35% did not notice, so focussed were they on counting successful passes. Who, then, can blame anybody for not noticing a coloured luminous ceiling when guiding a model car?

The second surveyed experiment of note from the CIE report involved direct comparisons of pairs of visual stimuli being made under three different thermal conditions corresponding to hot (about 40°C), cool (about 16°C) and cold (a few degrees below zero)¹³⁾. Comfort votes were recorded in each set of conditions. In the hot and cold conditions, which the comfort votes revealed to be stressful, visual preferences were found to be influenced by hue. In the cold condition, preferences were positively correlated with the wavelength of light and in the hot condition preferences were inversely related to wavelength. Under cool conditions, no significant relationships were found. Put another way, the finding is that it is only under conditions of thermal stress that there is interaction between thermal and visual stimuli and that other factors influence environmental preferences under non-stressful conditions.

Recent work in neuroscience has offered an explanation. Integration has been demonstrated to occur between, in this case, visual and auditory information, and it is suggested that the evolutionary impetus to achieve such an integration has been driven by the basic need to take appropriate actions in order to survive (“it looks like a rock but it sounds like a rattlesnake”). It is in moments of survival stress that we find all our senses pricked (i.e. alert and working together) to gain the best possible environmental information on which to base a response action. The accompanying theoretical debate has included a critique of what has been called ‘pure vision’ (where vision operates independently of other sensory modalities, of previous learning, and of the planning and execution of appropriate actions) and its replacement by what is called interactive vision¹⁴⁾.

3. Further research in visual perception

From the 1960s, increasing research effort in visual perception has been focussed on the transmission and processing of information, gained from visual stimuli, along the visual pathways from the eyes to the visual cortex area of the brain, and then within and beyond the visual cortex. Particular effort has been put into examining the structure of the visual cortex, the variety of cell types found there and their characteristics, and the complex array of interconnections between regions both within and beyond the visual cortex. Very little of the research output was given a direct application to lighting design, or to art or architecture as a whole. One exception was a general discussion paper by Liv-

Livingstone¹⁵⁾ which described the processing of visual signals through three separate pathways, each with its own distinctive function, response time and level of detail resolution. One subsystem appeared to process information about colour and shades of grey but not about movement, shape discrimination or depth; the second subsystem carried high-resolution information about borders and seemed to be important in shape recognition; and the third subsystem carried information about movement and stereoscopic depth.

Livingstone demonstrated how, in the past, this structuring of visual perception has been used instinctively by artists to produce particular effects and how it could be used consciously by advertisers, graphic designers, in the design of surveillance systems and automatic navigation and in the transmission of information in the television industry. A paper presented to the 1993 Lux Pacifica conference in Bangkok¹⁶⁾ applied this to an explanation of the techniques used, unconsciously or instinctively, by Byzantine and Baroque architects in Europe to achieve the brilliant spatial qualities for which the best architecture of those periods was noted; and to outline a set of guidelines by which contemporary architects could also employ lighting and colour to achieve a similar quality of spatial experience. In particular, the possibility was suggested of making the enhancement of spatial experience the *focus* of lighting design, rather than relying on this enhancement being achieved as a by-product of the lighting of surfaces.

Bruce, Green and Georgeson¹⁷⁾ have provided a detailed overview and discussion of the development of the knowledge and competing theories of visual perception over the last 50 years. Much of the most recent research has involved studies of which aspects of visual perception were affected by highly-localised lesions of particular parts of the visual cortex, while other understanding has come as a by-product of research into more general disorders such as Alzheimer's Disease and Parkinson's Disease. Early evidence pointed to parallel pathways which could operate independently to analyse particular properties of visual input. A dominant theory in the 1980s suggested there were two pathways: a 'dorsal' pathway responsible for extracting information about motion and stereoscopic depth and a 'ventral' pathway extracting information about the colour, shape and identity of objects, with both pathways contributing to the goal of creating a representation of a person's surroundings. This theory assumed that the control of a person's movement used information from this representation but that these control processes were located elsewhere in the brain. Both pathways were seen to involve interactions within regions in and beyond the visual cortex, but these interactions were more complex and difficult to investigate in the ventral

pathway, leading to the possibility of that pathway being split into two to give Livingstone's three subsystems.

A subsequent influential theory¹⁸⁾ assigned a further role to the ventral pathway of identifying the spatial layout of objects in the surrounding world, so that it was able to build up a representation of a person's surroundings on its own. The dorsal pathway was then specifically focussed on providing information for controlling movement. Experimental support for this theory continues to grow. One of the most significant implications for architectural design comes from the fact that both pathways now need to build a spatial perception, but in the case of the ventral pathway it is concerned with the relationship of objects in the surrounding world *to each other* whereas for the dorsal pathway the concern is for the relationship of objects *to the person*. It is this latter form of spatial perception which is at the heart of architectural design, and of the way that the lighting of interiors and other sensory inputs can shape the experience that each person has of their environment.

4. Sense-rich architecture

The finding from neuroscience that sensory interaction can occur under conditions of stress and only under such conditions, and becomes the basis for survival-related actions, suggests that sensory interaction is associated with the dorsal pathway in visual perception. It can therefore be argued that sensory interaction may also be available to the other role of the dorsal pathway, the spatial perception of the surroundings relative to a person. One way of pursuing this argument is through the proposition that the concept of stress is not confined to 'survival'-type situations, as implicit in the neuroscientific discussion papers, but rather can be extended, and perhaps renamed, to include all situations where people will attempt to maximise either the success in an undertaking or the reward for an action or behaviour and for this reason will have 'all their senses pricked'. In this way, these situations can be hypothesised to include the attainment of pleasure and delight. The results could then be seen to apply to a range of design situations.

For example, by comparison with listening to a musical performance on CD in the dark, the rewards from attending a live performance derive from seeing the performers as they play and appreciating the physicality and emotion associated with their musicianship, from experiencing the atmosphere in the concert hall and from sharing this with a large number of other people. By extending the concept of "stress" in this way, it becomes more aptly named "heightened sensory awareness". The role of lighting in such a situation can be to enhance the visual component in a way which

complements and extends the overall sensory experience. The concept of "space" now seems too abstract and it too may be more appropriately named as "place". As the Dutch architect Aldo van Eyck remarked¹⁹⁾: "Whatever space and time mean, place and occasion mean more. For space in the image of man is place, and time in the image of man is occasion."

Among contemporary architects, an excellent example of a practitioner whose buildings embody sensory richness would be the Swiss architect Peter Zumthor. He has written of the way he has built up, since early childhood, a rich experience of such things as the heaviness or lightness of doors, their materials, the shape and height of their handles and the sound they made when they were closed; the texture and the hardness or softness, warmth or coolness of floors and other building surfaces; the acoustic and light-reflecting properties and the smell of materials; and his works, such as the Thermal Baths at Vals (Switzerland) and the Swiss Pavilion at Expo 2000 in Hanover, have been extensively described in publications²⁰⁾²¹⁾. The text and the visual appearance of the buildings can be seen in the publications; their full sensory richness can only be experienced at first hand.

5. Conclusions

The implications for "sustainable lighting" of the above discussion are that current approaches to research into lighting, and into the relationship between lighting and other environmental parameters in the context of people's perception and experiencing of building interiors, are inappropriate and inadequate. Without a new direction to the research, sustainability might be achieved only in the limited and readily quantifiable sense associated with such things as energy efficiency and the consumption of material resources. Sustainability in the broader sense which embraces seizing the opportunity to enhance the quality of the interior environments experienced by people will require a radically different approach to the research needed to support this undertaking.

The problem is not simply one of reworking the experimental procedures for studying interactions between various sensory modalities, in order to avoid the occurrence of inattention blindness. A more fundamental problem is that the visual pathway which is most likely to support interaction between visual perception and other sensory modalities is the dorsal pathway — the one which deals with visual input to the control of actions and which also establishes information on the spatial relationship between a person and their surroundings. In the context of sensory richness, the latter function of the dorsal pathway might be argued to be that of establishing a sense of

"place". A telling distinction has been made by Fodor and Pylyshyn which reinforces the significance of "place". They distinguished between the processes of "seeing" and "seeing as", where the latter requires some knowledge of the world to achieve perception. As they put it (Reference22), p. 189): "What you see when you see a thing depends upon what the thing you see is. But what you see the thing as depends on what you know about what you are seeing."

Typical experimental situations (sometimes nothing more than boxes to look into) require people only to "see" rather than "see as". These experiments avoid the intrusion of the real world. Similarly, if any action at all is required, it is often unrelated to a realistic situation, and in some cases unlikely to be affected by changes in any environmental conditions. The experimental situations effectively focus on the functioning of the ventral pathway in the visual cortex and therefore cannot reveal any integration between visual perception and other sensory modalities handled elsewhere in the cortex. Without a significantly different approach to this area of research, it is likely that any achievement of the potential for sensory richness in sustainable design will be despite the research-based advice on offer, rather than because of it.

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