

Vital: Bringing Buildings and Sustainable Practices to Life

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ABSTRACT: This work addresses two common shortcomings in building design:

1. many of the indoor spaces where most people in the industrialized world spend the majority of their time inadvertently deprive them of contact with two important requirements for their long-term well-being: nature and change.
2. many simple sustainable practices that could significantly reduce the global environmental and economic running costs of buildings if more widely applied are largely invisible to the public.

In response, the authors have been examining the potential of using the natural movements of the weather to improve the habitability of indoor spaces and increase the visibility of passive environmental control and rainwater harvesting in buildings. A survey of existing architecture was first conducted to identify design strategies that could effectively bring the movements of the sun, wind and rain indoors without undermining the weather-protecting role of buildings. Three simple methods of achieving this were identified: *enclosure* of weather-generated movement in internal courtyards, sunlight *projection* onto interior surfaces, and *back-projection* onto translucent external materials. A series of design studios was then used to determine if these approaches were compatible with passive environmental control and rainwater harvesting techniques involving the same natural elements, and it was found that most could be effectively animated without compromising their environmental performance. The human effects of one of the combinations identified—wind-animated daylighting—were then tested in controlled experiments, which showed it to be both calming and distracting. In light of these findings, it was postulated that weather-generated indoor animation could be of particular value in low concentration/high stress situations, such as waiting or convalescence, where positive distractions have been shown to be beneficial. In order to test this thesis, wind-animated water light shelves were installed in a medical waiting room, where patient responses appeared to confirm their calming effect.

KEYWORDS: Natural Indoor Animation, Well-Being, Sustainability

INTRODUCTION

1.1 Nature, change and human well-being

Over the past thirty years evidence from a range of disciplines has suggested that contact with nature has important physical and psychological benefits for people in buildings. Well-known studies by the health-care environments researcher Roger Ulrich and others, for example, have linked views of outdoor nature with relief of stress (Ulrich 1984), and the presence of indoor planting to improved productivity (Bringslimark 2009). The link between human alertness and perceptible change has likewise been consistently confirmed since first being proposed by Donald Hebb's pioneering work on sensory deprivation in the 1950s and his resulting Arousal Theory, which suggested that unchanging environments lead to a rapid fall off in alertness, and eventually to fatigue and stress when we attempt to maintain concentration over long periods in under-stimulating conditions (Hebb 1955).

The Attention Restoration Theory developed three decades later by Rachel and Stephen Kaplan effectively linked these two areas of inquiry by proposing that contact with nature serves to restore attention and stave off stress due to under-stimulation (Kaplan and Kaplan 1989, S. Kaplan 1995). The Kaplans suggested that many familiar patterns in nature, such as the movement of clouds and water, for instance, stimulate the senses without demanding our active attention, and one of the apparent implications of their work we

wanted to test was that these kinds of familiar natural movement might be able to help people in indoor environments remain alert without being distracted.

1.2 Static indoor spaces

Evolutionary psychology attributes our needs for nature and sensory variation to the fact that early human physiology developed largely outside in response to a constantly changing natural world. Many of us now spend the majority of our lives indoors, however, and as the environmental psychologist Judith Heerwagen has pointed out, one of the consequences of our pursuit of 'optimal' indoor climatic conditions over the last fifty years has been that the natural variation our still bodies require is largely absent from many of the places where we now spend the majority of our lives:

Access to sensory diversity—change, ... is a basic characteristic of the natural world. Sensory change is fundamental to perception.... Our indoor environments are largely devoid of sensory change, and deliberately so. Buildings are kept at constant temperatures and ventilation rates, the light from overhead fluorescent lights is the same day in and day out.... Although many designers and researchers are beginning to express serious doubts about this state of affairs ... there have been relatively few attempts to provide indoor environments that deliberately mimic sensory change as it exists in the natural world (Heerwagen 1990, 270).

The work reported here is aimed at remedying that situation. Rather than attempting to recreate natural change artificially, however, since the real thing is still freely available in the atmosphere around us, we investigated whether there might be practical ways of bringing that change indoors.

1.3 Invisible sustainability

Concern for the natural environment has fundamentally altered the professional criteria for measuring the success of building design over the last decade, yet ultimately the project that is sustainability will only succeed if the population at large is involved in its implementation. All too often the only visible sign of the sustainable design of many admirably Green buildings today is a LEED plaque. In response, several commentators have suggested that it is no longer sufficient for sustainable buildings simply to 'do no harm,' rather, they argue that in order to have any meaningful impact on the daunting environmental problems we now face buildings need to actively demonstrate ways of living in harmony with nature (Kellert 2005, Wines 2000). With this in mind, we set out to investigate whether the natural movements of the sun, wind and rain could not only be used to improve the habitability of indoor spaces, but also to raise the public visibility of underused passive environmental control and rainwater harvesting techniques in buildings, which involve the same three natural elements.

METHODOLOGY

A survey of existing architecture was first conducted in order to identify design strategies that could effectively bring the natural movements of the sun, wind and rain indoors without undermining the essential weather-protecting role of a building. A series of design studios was then used to determine whether the three methods identified—*enclosure*, *projection* and *back projection*—were compatible with established passive environmental control and rainwater harvesting techniques. The human effects of one of the successful combinations identified—wind-animated daylighting—were then examined in a series of controlled experiments, and based on those results, a wind-animated water light shelf was field tested in the waiting room of a working medical clinic.

2.1 Bringing the natural animation of the weather indoors

We first had to establish that there were practical ways of effectively bringing the movements of the weather indoors without undermining the primary role of buildings in providing shelter from the elements. Through a survey of existing buildings three simple strategies were identified for achieving this: *enclosure* of weather-generated outdoor movement in internal courtyards; sunlight *projection* onto internal surfaces; and *back projection* onto translucent external materials. Each of these methods allows visible weather-induced outdoor movement to be perceived as effectively part of an interior space without compromising the weather-proof envelope of a building. The three strategies are illustrated in Figure 1 using the example of wind-animated foliage.



Figure 1: Three methods of effectively bringing weather-generated outdoor movement indoors without compromising the weather-roof envelope of a building. From the left: *enclosure* in an internal court; sunlight *projection* onto an interior surface; and *back projection* onto a translucent external cladding material.

2.2 Synergies with passive environmental control and rainwater harvesting

Having established that it was possible to bring the natural animation of the weather indoors while maintaining shelter, a series of design studios at the University of Oregon was then used to test the feasibility of transmitting that movement using established passive environmental control and rainwater harvesting techniques involving the same natural elements. The following combinations were found to successfully transfer weather-generated outdoor movement to an interior space without compromising the environmental performance of the sustainable strategies involved:¹

Direct Animations

- Sun-animated Daylighting
- Sun-animated Shading
- Sun-animated Solar Heating
- Wind-animated Natural Ventilation
- Rain-animated Rainwater Collection

Indirect Animations

- Wind-animated Daylighting
- Wind-animated Shading

Independent Animations

- Wind-animated Rainwater Collection
- Rain-animated Daylighting
- Rain-animated Shading

The successful combinations fell into three broad categories reflecting direct, indirect and independent animations of sustainable practices. The first consists of combinations in which naturally generated movement visibly discloses the primary mechanism underlying a sustainable practice. Visible convection current shadows can serve as a direct indicator of passive solar heating for example. The second group comprises natural animations that can effectively draw attention to a sustainable practice, but without necessarily revealing how it works. Wind-animated indoor shadows, for instance, can make building occupants more aware of shading and solar gain, but their movement is not inherent to either. The final group consists of natural animations that are compatible with but unrelated to the primary environmental purpose of a passive device. A reflecting pool or light court, for example, can effectively bring the sights or sounds of the wind and rain indoors without drawing attention to their daylighting role.

2.3 Water light shelf case study

One of the most effective combinations identified in the design studios was wind-animated daylighting. This led to the development of a water light shelf that combines energy saving and naturally moving indoor sunlight. Conventional light shelves reduce glare and save energy by redistributing excess daylight from immediately inside a window to the darker rear of a room, reducing the imbalance in light levels and the need for artificial lighting and cooling of a space during the day. The water light shelf does the same, but the sunlight it reflects is animated by outdoor air movement disturbing its water surface (Figure 2).

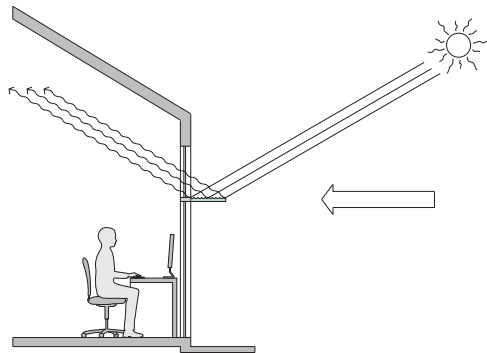


Figure 2: Section through a water light shelf, which diverts excess light from near a window to the rear of a room while introducing wind-generated movement into a space.

Before testing the effects of the wind-animated light from the water light shelf on building occupants, we wanted to confirm that introducing movement had not compromised its environmental performance. This was tested using a scale model and artificial sky to compare the water light shelf's indoor daylight distribution to an equivalent static light shelf. The daylight distribution of the wind-animated water light shelf was found to be almost the same as its static equivalent, confirming that there was no significant environmental trade off as a result of introducing movement to the reflected light (Figure 3).

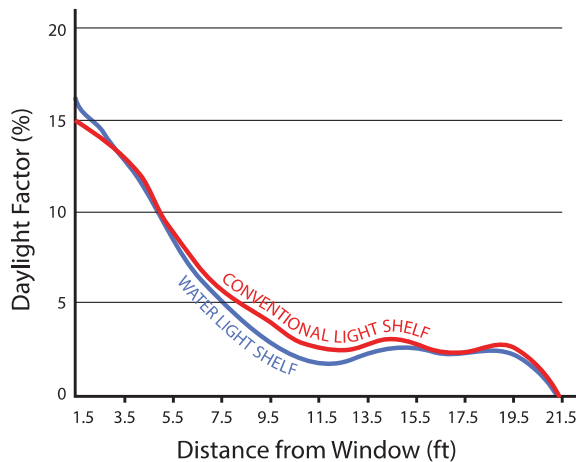


Figure 3: The indoor daylight distribution of a wind-animated water light shelf compared to an equivalent static light shelf.

2.4 Human effects of fan-animated artificial light

Having confirmed that the wind-animated water light shelf was as effective as a static light shelf in redistributing indoor daylight, we proceeded to test the effects of its moving light on people. This was initially done through a series of controlled experiments in the test room arrangement illustrated in Figure 4. In order to maintain the consistency of the light patterns experienced, the effects of the sun and wind on a water surface were represented by a theater lamp and a fan respectively. These generated less intense and variable reflected light patterns than natural sunlight and wind do, but we wanted to see whether this reduced version of the lighting effect had any potential benefits before deciding whether to conduct field tests in working buildings.

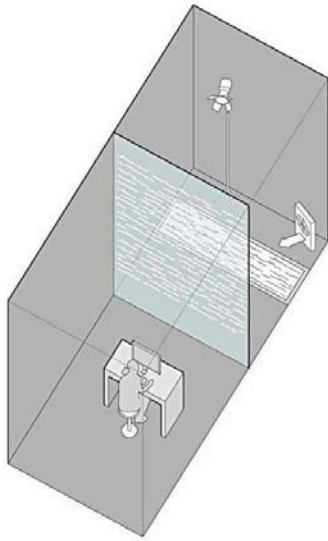


Figure 4: Test room arrangement for measuring the effects of wind-animated indoor light on building occupants' stress and attention. Moving light patterns reflected from a fan-disturbed water surface were projected onto the back of a translucent screen in front of the subject. In stress tests, subjects waited inactively with the illuminated background screen static and animated. In attentional tests, subjects performed a computer-based vigilance task against the same static and animated backdrops.

2 Effects of fan-animated artificial light on heart rate

This experiment was intended to simulate waiting, a common source of stress in everyday life similar to the inactive conditions in Roger Ulrich's well-known studies on the effects of natural views on recovering hospital patients (Ulrich 1984). The heart rates of twenty-five student subjects were recorded with a chest monitor as they waited inactively in the test room with fan-animated light patterns back-projected onto the screen in front of them and with the screen illuminated to the same brightness with static light.² Average heart rates were found to be slightly lower in the animated room than the static condition, but the difference was not statistically significant (Figure 5).

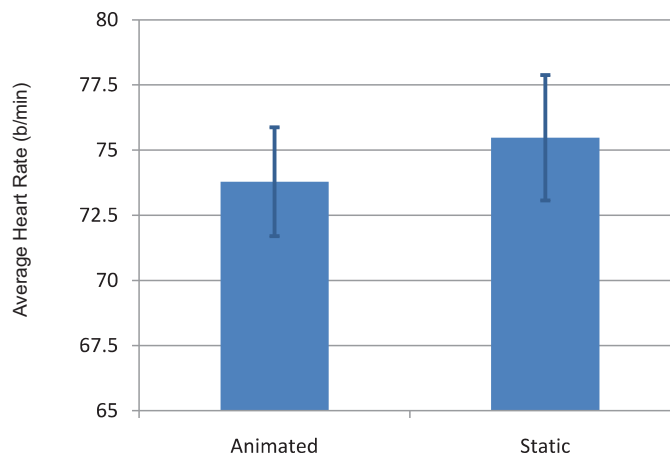


Figure 5: Subjects' average heart rates while waiting inactively in a room with fan-animated and static light (with standard errors).

2.6 Effects of fan-animated artificial light on recovery from stress

This test was intended to determine whether natural animation in a room could hasten recovery from already heightened stress. A different group of twenty-five student subjects was intentionally stressed by being asked to perform a series of timed mental math problems. Their subsequent recovery as they waited inactively in the same test room was then recorded under static and animated lighting conditions. Average heart rates compared at the same points during their recovery were again lower in the animated light, this time significantly so (Figure 6).

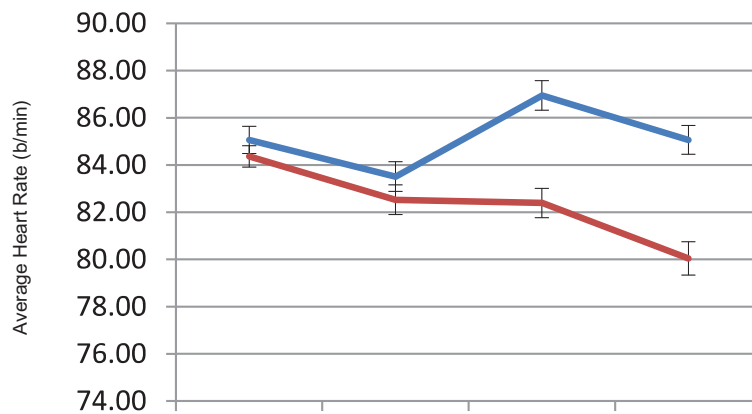


Figure 6: Subjects' average heart rates measured at the same four times during recovery from induced stress in a static room (red line) and fan-animated room (blue line).

The main differences between the moving light used in these controlled experiments and that created by natural wind and sunlight were lower variability and intensity, both of which tended to reduce the visibility of the moving patterns. This suggested that any stress-reducing effects could be expected to be at least as great with natural wind and sunlight, which prompted us to proceed with field testing of the water light shelf in a working building, the results of which are reported later in this paper.

2.7 Effects of prior exposure to fan-animated artificial light on task performance

This experiment was intended to determine whether exposure to animated indoor light increased subsequent alertness in the way that walks in outdoor nature have been found to do in other studies (Kaplan and Kaplan 2002, Hartig 2003).³ Subjects' performance on a standard computer-based letter recognition task was first tested in a static room, and again after a thirty-minute rest period spent in a static room or in a room with fan-animated light.⁴ While there was no significant difference in the accuracy of responses following these different rest conditions, the average speed of response was noticeably slower following exposure to the animated light, suggesting that—in contrast to prior exposure to outdoor nature—natural indoor animation was apparently acting to *reduce* subsequent alertness (Figure 7).

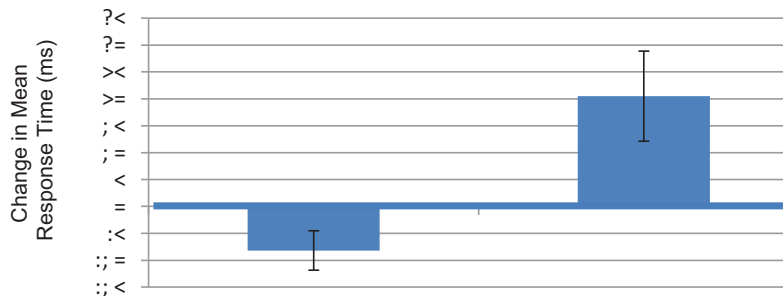
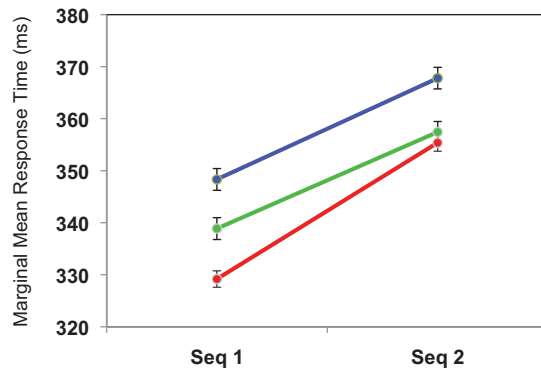


Figure 7: Changes in subjects' mean response times to a computer-based vigilance task following rest periods in a static room (left), and fan-animated room (right).

2.8 Effects of simultaneous exposure to wind-animated sunlight on task performance

In this study a video recording of a moving sunlight pattern reflected from a natural wind-disturbed water surface was played on a computer screen as the background to the same letter-recognition task. Subjects' performance with the naturally-animated screen was then compared to that with a similarly moving digitally-generated background, and with a static screen, each of the same brightness and contrast. Both the natural and the digitally-generated moving backgrounds were found to slow subject response times in comparison to a static background, but the distraction was noticeably less with the natural movement (Figure 8).



Sequence 1: No Movement, Natural Movement, Artificial Movement
Sequence 2: Natural Movement, Artificial Movement, No Movement

Figure 8: Computer-based vigilance task response times recorded against a static background (red line), naturally animated background (green line), and artificially animated background (blue line).

2.9 Responses to wind-animated sunlight in a health-care clinic waiting room

The controlled experiments seemed to show that while wind-animated light reduced stress, it could also be distracting. This suggested that it might of value in low concentration/high stress situations, such as waiting or convalescence, for example, where positive distractions have previously been found to be beneficial. In order to test this thesis, water light shelves were installed outside the waiting room windows of a medical clinic, and over a six-month period patients were asked to complete a voluntary questionnaire seeking their responses to the shelves' wind-animated sunlight patterns reflected on the ceiling of the space (Figures 9 and 10).



Figures 9 and 10: Left: water light shelves installed outside the windows of a Women's clinic waiting room in Eugene, OR. Right: wind-animated sunlight patterns reflected from the water surfaces of the light shelves onto the ceiling of the waiting room.

Patient responses were generally positive, and seemed to confirm the calming effect observed in the controlled experiments (Figure 11). Significantly more respondents described being 'fascinated' rather than negatively distracted by the moving light, suggesting that it was generally seen as a welcome diversion. The predominantly female subject pool and the small proportion of patients who responded however (less than 2%) limit how much can safely be read into this particular result.⁵

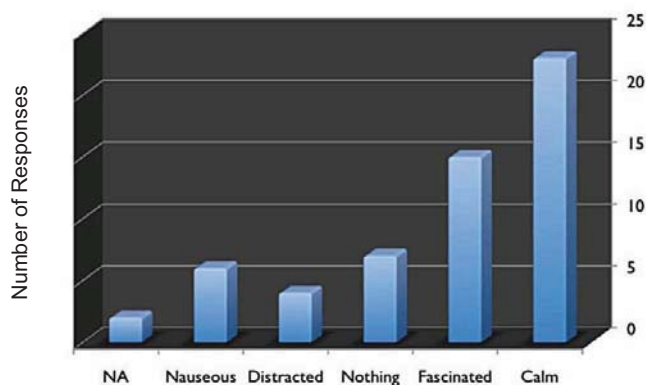


Figure 11: Patient responses to the question: "which of the following terms best describes how the moving sunlight patterns make you feel?"

CONCLUSION

Three design strategies were identified for effectively bringing the natural movements of the sun, wind and rain into indoor environments while maintaining physical shelter from the weather. These were found to be compatible with a range of established passive environmental control and rainwater harvesting techniques, offering a potentially simple means of raising the public visibility of these important but underused sustainable practices.

In controlled experiments and live field tests one such combination—wind-animated daylighting—was found to have a calming effect on inactive subjects, but also seemed to distract attention from a visual task. While improved attention with naturally-animated movement patterns compared to digitally-generated ones appeared to support the Kaplans' theory that familiar, naturally-generated movement is less distracting than artificially-generated change, but both slowed task responses compared to a static background, seemingly disproving the notion that natural movement patterns might not be distracting at all. The distraction we observed may have been exaggerated, however, by placing visible movement in direct competition with a task requiring unusually intense visual concentration.⁶ Most everyday work allows people to momentarily glance elsewhere as a way of renewing concentration, and *choice* as to whether or not we look at movement could well be critical to its perception as either welcome or distracting.

Reduced alertness following rest periods in a naturally-animated room compared to a static room was the reverse of what has previously been found with prior exposure to outdoor nature (Hartig 2003). This would seem to have two possibly significant implications. The most obvious is that outdoor nature has attention-restoring attributes that are absent from weather-generated indoor movement. A key characteristic of restorative environments identified by the Kaplans, for example, was the feeling of 'being away,' and it would make sense if this were somehow lost in the process of bringing nature to us indoors (Kaplan and Kaplan 1989). The fact that subjects' responses were slower following rest periods in a naturally animated room, however, also raises the possibility that this kind of movement may be so relaxing that it acts to reduce alertness.

These initial findings suggest that the animation of the weather could offer a more widely accessible means of reducing stress in building occupants than external views of nature (Ulrich 1984), which are not available from many indoor spaces, and that they could be of most particular value in situations that combine inactivity and heightened stress, such as waiting and health care spaces.⁷

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ENDNOTES

¹ Each of the naturally-animated passive techniques listed was quantitatively tested in comparison to its static equivalent in order to confirm that introducing movement had not compromised environmental performance.

² The subjects of the controlled experiments were University of Oregon students between the ages of 19 and 24 with an approximately even balance of genders.

³ The Kaplans' original self-reported findings on the benefits of walks in nature on subsequent alertness were later confirmed quantitatively using a computer-based vigilance task similar to the one we employed. See T. Hartig, *et al*, "Tracking Restoration in Natural and Urban Field Settings," *Journal of Environmental Psychology* 23 (June 2003): 109-23.

⁴ The vigilance task involved clicking a computer mouse when a randomly generated letter that was *not* the designated target letter appeared momentarily on the computer, and refraining from doing so when the target letter appeared. Attention was measured in terms of both the accuracy and speed of responses.

⁵ The voluntary questionnaire was left at the reception desk and consisted of preliminary questions intended to confirm that respondents had seen the moving lighting patterns. The spike in respondents who felt the movement made them feel nauseous might have been related to the high proportion of patients who would have been either pregnant or receiving hormone therapy at this particular clinic, although we were not able to quantify this.

⁶ Work by Shibata and Suzuki has indicated that while creative work is aided by the presence of indoor plants, for example, those requiring concentration are not. See S. Shibata and N. Suzuki, "Effects of the Foliage Plant on Task Performance and Mood," *Journal of Environmental Psychology* 22 (2002): 265-72.

⁷ These findings also raise the possibility that wind-induced movement may play some role in the stress-reducing effects of external natural views. Studies have shown that indoor planting is significantly less effective than outdoor views of nature in reducing stress. See for example, C. Chang and P. Chen, "Human Responses to Window Views and Indoor Plants in the Workplace," *Horticultural Science* 40 (2005): 1354-59. This might be due simply to a perception of indoor plants as 'less natural' than their outdoor equivalent, but one of the most obvious visible differences is that they tend to be static in comparison.