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Quantitative improvement in workplace performance through biophilic design: A pilot experiment case study

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ABSTRACT

Numerous studies endorsed by the scientific community affirm that biophilic design in the workplace improves productivity and user well-being. However, it is necessary to go a step further and objectify the design criteria serving as an operator for productivity and well-being in design practice.

In response to the challenges of how to measure the improvement of productivity and well-being through biophilic architecture design, the main contribution of this article is the development of a tool that allows to measure the predicted feature that improve productivity and well-being, based on a scientific method, which is tested by conducting a pilot experiment.

A scheduled pilot experiment, as a small-scale version done in preparation for a major study, has been conducted to test a tool that quantifies the impact of biophilic design features on performance and well-being, to evaluate the influence of variables such as greenery and daylight on improving workplace performance, and look at biophilic design knowledge in greater depth.

The role of natural indoor environments - understood as spaces within buildings provided with elements of nature - has received relatively little attention, compared to the number of studies evaluating occupant impact related to other characteristics of indoor environments derived from mechanical and electrical systems such as thermal factors, noise and vibration, ergonomics and office design. The present study is one of the first studies evaluating and measuring the combination of greenery and daylight into a biophilic design proposal.

The results highlight an improvement in well-being, performance, creativity and health by introducing daylight and greenery into workplace design such as biophilic design features. The tool developed and tested in this pilot experiment opens a way to improve measured workplace performance to a much greater extent in contrast to the existing practice.

1. Introduction

Numerous studies endorsed by the scientific community, affirm that biophilic design, defined as a response to the inherent need of human beings to be in contact with nature [68,76], in the workplace improves productivity and user well-being [23,24]. The first challenge applied to architecture is to increase contact with nature in spaces through an optimal design. *If you cannot measure it, you cannot improve it* [75], so the second challenge that arises is how to objectify and quantify rigorously the features that improve productivity and well-being in biophilic-design spaces.

A tool has been designed to quantify the influence of the use of biophilic design on intellectual performance, creativity, and well-being, following a methodology developed in Keio University, tested by a pilot experiment carried out through physiological tests, psychological tests, and simulated work tasks.

Previous studies have shown that the relationship between indoor building design and wellbeing of occupants are complex [8]. There are many indoor stressors, such as excessive thermal factors, lighting aspects, moisture, noise and vibration, radiation, chemical compounds, and particulates fluctuations that can cause their effects additively or through complex interactions. It has been shown that exposure to these stressors can cause both short-term and long-term effects. In the workplace, a whole range of effects has been associated with these stressors such as Sick Building Syndrome (SBS), building-related illnesses and productivity loss.

The premise that the office environment can influence people in ways that may reduce or improve their productivity is well estab-

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lished [11,28,35,37,45,51,55,70]. Numerous studies have shown that indoor air quality [56,61,73], thermal conditions [17,19,47,56], lighting [7,71], noise [50,54,63], office design [9,22], and ergonomics [5] can influence people's cognitive abilities, their health, their attitudes, and their productivity.

Previous research by Professor Ikaga's laboratory, amongst others, have identified biophilic design features as a key driver of performance and well-being in the workplace. In particular, wooden interiors, temperature, and promotion of physical activity have independent impacts on cognitive function, performance, health, and well-being. [2,4,25,38,40-44,65-67].

Although previous studies have shown associations between indoor stressors and comfort, health and productivity in an office environment, relevant relations between lighting and greenery combination as biophilic design and effects have been difficult to establish. Lighting and greenery are selected in the pilot experiment because they are features included in the WELL certification within the category of Biophilia [27] and because in the State of the Art is possible to find few examples of pilot experiments that combine these two characteristics [8].

In this case study, the term *pilot experiment* is used as a small-scale version done in preparation for the major study [49]. One of the advantages of conducting a pilot experiment is that it might provide an advanced warning about where the main research project might fail, where research protocols may not be followed, or whether the proposed methods are inappropriate or too complicated. Pilot experiments are a crucial element of good study design. Conducting a pilot experiment does not guarantee success in the main study, but it does increase the likelihood. The pilot experiment fulfills a range of important functions and can provide valuable insights for other researchers [69].

Performance is defined as what people can produce with the least effort [52]. Sutermeister simply defines performance as output per employee hour, quality considered [62]. Dorgan defines performance as the increased functional and organizational performance, including quality [14]. An increase in performance is expressed as a directly quantifiable reduction in absenteeism. However, the improvement in performance can also be the result of an increase in the quantity and the quality of production during the period that employees are actively working [51].

The United Nations predicts that by 2030, 60% of the world's population will live in urban environments [1]. It is therefore imperative that we consider how the connection between people residing in cities and nature can be maintained, and what are the most impact parameters in human's well-being, health, and performance. Relevant authors have stated that the answer to this challenge is biophilic design [10].

The American biologist and entomologist, Edward O. Wilson, was the first to formulate the hypothesis that contact with nature is essential for the psychological development of people. His theory says that for millions of years our species was related to its wild environment, created a kind of dependency, an overwhelming emotional need to be in contact with other living beings. This inherent need was called Biophilia [76,77].

Between 1993 and 1995, the scientists Roger S. Ulrich and Stephen Kellert specified the final approach to the term Biophilia defining it as "the innate human affinity for nature" [30] and established the basis of what application of this sensitivity to design and architecture will be [31].

The incorporation of the concept of biophilia means bringing nature closer to the urban environment, evoking the double essence of the human being: social and natural. [10].

The challenge of biophilic design is to address the shortcomings of contemporary architecture in buildings, landscapes, and the interior, initiating a new framework for the beneficial experience of nature in the urban environment [32].

A report on human space in Europe, the Middle East and Africa, published in 2014 [80]), specifically examined the impact of biophilic design in that geographic area and served as the basis for a global research project. This research quantifies the benefits of biophilic design in workspaces collecting data from 16 countries around the world, in today's urban environment, people are increasingly isolated from the beneficial experience of natural systems and processes. By imitating these natural environments in workplaces, they are provided with positive emotional experiences [10].

Research carried out among workers to find out which elements are most valued in their work environment, shows that natural light is the most sought-after element within the workplace. Similarly, indoor plants and vivid colors are ranked in the top five. [23,24,29].

At work, when we focus our attention on a demanding task, the factors in our environment that interrupt us can lead to mental fatigue. However, workplaces that incorporate nature provide calmer adjustments that facilitate easier attention and can restore our mental capacity. This is known as the Theory of Restoration of Attention, which postulates that seeing and experiencing nature involves a different part of the brain that is used in the high-attention approach [15].

There is a continuous and dynamic interaction between people and their surroundings that produces physiological and psychological strain on the person, which consequently lead to changes in health, well-being and performance ([11,34,46]). In this research, the appearance of certifications that guarantee that a workplace responds to the criteria of biophilia is highlighted, and therefore contributes to performance, well-being, and people's health, such as Fitwell [16] or WELL [13,27] certifications.

It is a concerted effort of researchers, technicians, and practitioners to find out how to qualify the effects of indoor architecture on occupants' performance [33,34]. However, it is necessary to go a step further and objectify these criteria.

There are many factors among others such as level of education, skills, age, gender, circadian cycle, emotional states and response bias that should be considered when investigating the relationship between indoor architecture and human performance [11,33,46]. Consequently, the accurate selection of experimental subjects was a part of the tool presented in this article.

Accuracy and speed are the two distinct aspects of human performance. Accuracy is a measure of the quality of behavior. Measures of accuracy include number correct, percent correct, and the probability of correct detections [18]. Laboratory studies typically assessed work performance by having subjects performing cognitive tasks that simulated aspects of actual work and by subsequent evaluation of the speed (response time) and accuracy (percent errors). For example, subjects typed per unit time, number of completed addition or multiplication units per unit time, etcetera [6,33,34,73,74,78,81,82].

In this article, a holistic approach to measure human performance and well-being was proposed, and the tool was checked experimentally with a pilot experiment.

2. Objectives

The improvement in well-being and performance in the workplace are economic and social critical factors since the loss of productivity for companies means a cost of up to US$ 550,000 million per year [58].

The purpose of this pilot experiment is to test a tool to quantify objective variables and to assess how much greenery and daylight influence users' perceptions, and its effect on performance, creativity, well-being, and health.