

# OCCUPANT HEALTH AND PRODUCTIVITY: AN AUSTRALIAN PERSPECTIVE

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## Summary

The issue of whether improved building services such as air quality, provision of daylight, thermal comfort etc, have a positive impact on the health and productivity of building occupants is still an open question. There is significant anecdotal evidence supporting the notion that health and productivity of building occupants can be improved by improving the quality of the indoor environment, but there are actually few published quantitative studies to substantiate this contention. This paper reports on a comprehensive review of the worldwide literature which relates health of building occupants with the different aspects of the indoor environment which are believed to impact of these issues, with a particular focus on studies in Australia,

The paper analyses the existing research and identifies the key deficiencies in our existing understanding of this problem. The key focus of this research is office and school buildings, but the scope of the literature surveyed includes all commercial buildings, including industrial buildings. There is a notable absence of detailed studies on this link in Australian buildings, although there are studies on thermal comfort, and a number of studies on indoor air quality in Australia, which do not make the connection to health and productivity. Many international studies have focused on improved lighting, and in particular the provision of daylight in buildings, but again there are few studies in Australia which focus in this area.

**Keywords:** productivity, health, indoor environment, indoor air quality, lighting, daylighting, thermal comfort

## 2. Introduction

There is substantial evidence which links specific aspects of the indoor environment to health and worker productivity issues in buildings. Examples of this include studies on health impacts of the indoor air quality in Schools [1-4], and Office buildings [5-9], and impacts of improved lighting, and in particular access to daylight on productivity in both Schools [10, 11] and Offices [12, 13].

It is clear from a recent survey of the literature that there is a link between both health and productivity and the quality of the indoor environment, and that many aspects of

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the indoor environment appear to be significant. Less clear is how strong the links between each of the potential factors which impact on productivity and the productivity of individuals or populations. Despite the large amount of data available in the literature which comment on these issues, there are actually rather few detailed studies of the links. As a consequence there are still apparent conflicts between different studies, and there is insufficient information to accurately and confidently predict the productivity benefits which will arise from specific changes to the indoor environment.

As an example, in the Collaborative for High Performance Schools[11] Best Practice Performance Guide, there are results of detailed studies which show that daylighting and windows in school classrooms significantly improve learning outcomes. However in one school the improvement was approximately 20%, while in another school, the results were given as 0-3% improvement. Clearly, there may be other factors which are playing a role, and these are not fully understood.

Similarly, recent Danish data from three independent studies in offices (although under simulated working conditions, not actual working conditions) have demonstrated conclusive links between productivity and air quality [14, 15].

This paper reports on a study aimed at understanding the current literature, specifically in the context of Australian buildings and research conducted in Australia. The paper begins with a discussion of the nature of productivity and health impacts, and provides an analysis of the links which emerge from the literature between the building systems and productivity impact factors. We then review the literature available for Australia in the context of the international literature, and outline possible areas for significant future research.

## 2. Productivity

Productivity is both easy to define – the ratio of output to input – but at the same time very hard to measure in an relatively small environment where individual contributions can influence the results, in particular social interactions. Proxies for productivity are often used. Most theories of productivity appear to be founded on **motivation**[16].

One of the fundamental theories of motivation is Maslow's Hierarchy of Needs, illustrated in Figure 1, in which individuals satisfy lower order needs before they move onto higher order needs. In the context of buildings, and productivity in buildings, the indoor environment meets (or does not meet) the lower level needs – physiological and safety – and to some extent can affect the social needs, through the design of the space and the connectedness of people in buildings.

As such the measurement of productivity is difficult, because even if the lower level needs are met, negative impacts on self-esteem due to poor management can lead to reductions in productivity. Therefore the problem is probably best represented by focussing on the impacts of the indoor environment on health (physiological and safety needs) and well-being (or psychological perceptions of safety, physiological comfort and social needs).

Using this conceptual framework allows us to move towards a view of productivity in which there are certain key impact factors (related to the individual occupant of a building) which influence productivity. These we have identified through the literature as “well-being” and “health”, with a third impact factor identified in numerous sources as “stress”. Stress in this context can be physical stress introduced by poor design of

Maslow's Model of Motivation

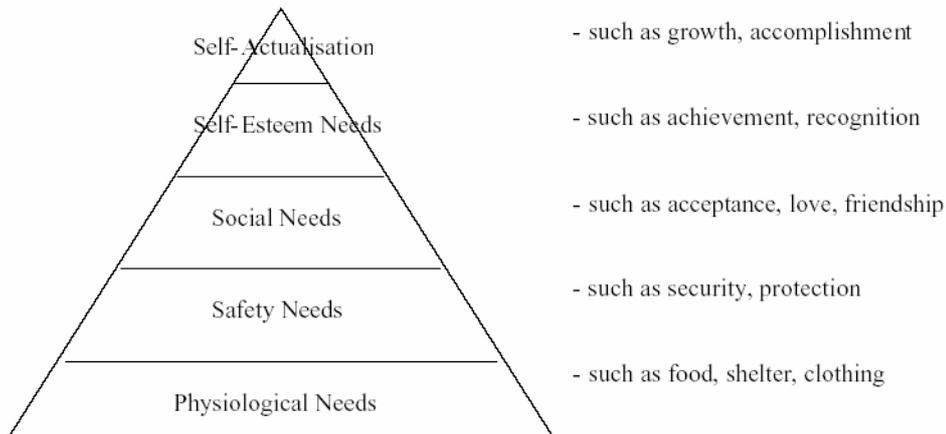


Figure 1. Maslow's Hierarchy of Needs

the indoor environment (layout etc), poor environmental quality (poor lighting, poor ventilations etc) or emotional stress which is related to the social environment, and in a work situation, usually the employer or supervisor.

The factors over which the building designer and building services engineers (in the design phase) and the building manager and occupant (in the operating phase) have control over are then the thermal, visual, acoustic comfort, indoor air quality, and the “architecture” of the space. These in turn are subject to external influences, such as the climate.

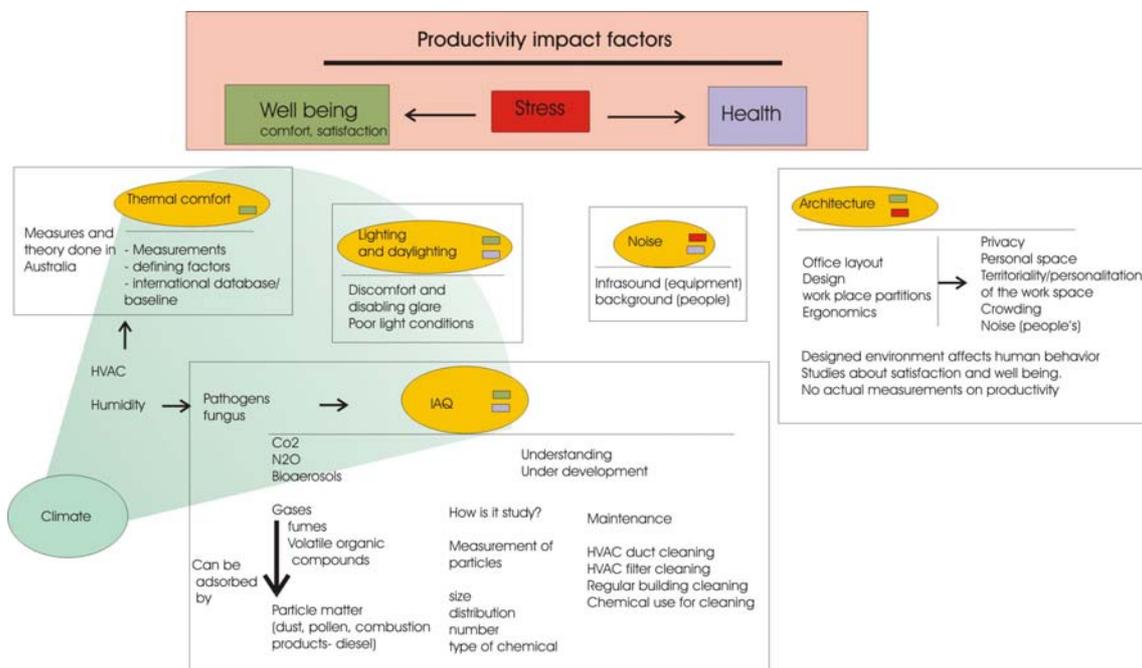


Figure 2. Productivity impact factors identified in this work

### 3. The Literature Survey

A comprehensive literature survey has been conducted to identify:

- the current state of knowledge regarding the impact of the indoor environment on productivity; and
- specific knowledge in the Australian context relating the indoor environment on productivity.

Over 500 literature sources have been reviewed and classified by location (country), building type, the outcome focus of the study, the methods used and the building attribute (or attributes) which were considered. The details of the classification scheme are shown in Table 1.

Table 1. Classifiers and Keywords used to categorise and analyse the literature

<b>Classifier</b>	<b>Keywords</b>
Geographic Location	Country, Subregion (eg Australia, NSW)
Building Type	Office, Low Rise/High Rise Domestic, Low Rise/High Rise/House Commercial, Retail/Industrial School/University
Data Type	Quantitative/Qualitative Survey/Interview Measurements, on-site/laboratory Case Study
Outcome Focus	Occupant, Health/Productivity/Well-being/comfort Operation, Energy/Maintenance/Environmental
Building Attribute	Indoor Air Quality Daylight/Lighting Thermal Comfort Noise Architecture

Using this classification of the literature, we can identify subgroups of papers which focus on specific issues, building types and locations. This classification system has enabled a breakdown of the studies conducted in Australia which focus on health and productivity issues.

Preliminary results (which has not identified all duplicate sources – ie where a specific study has resulted in several papers) from a detailed analysis of this literature show that the majority of the research in this area has been conducted in the United States, and very little in Australia. Figure X shows the breakdown of the literature for office buildings between Europe (including the United Kingdom), the United States and Australia, and identifies the actual field studies conducted, as well as the number of papers. There have been a number of studies on thermal comfort in Australia (mainly conducted under the Auspices of ASHRAE but Cena and de Dear [17-19]. However there are very few studies of the impact of lighting on occupants, as the study by Stefano et al [10] focused on energy use only. There is only one productivity study [20] and this is based on interviews with managers, and does not involve any measurement or control over the indoor environment.

#### **4. Conclusions**

There are several important papers which demonstrate the link between productivity and health of occupants in the workplace and the indoor environment. Therefore the

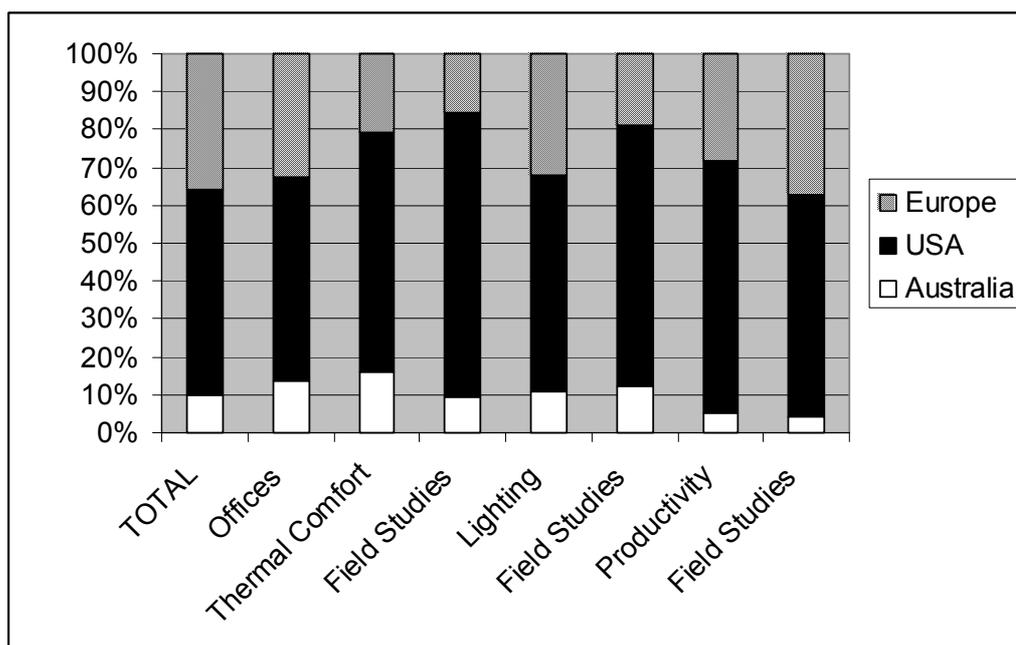


Figure 3. The relative proportions of research on indoor environments reported in the literature, broken down by country, and then for office buildings, and thermal comfort, lighting and productivity.

question which can be asked is whether there is a need for Australian studies in this area.

As demonstrated in Figure 2, there are several areas in which climate is an important factor: lighting and daylighting, thermal comfort and indoor air quality. The sources of heat, light and air in buildings, and the materials used in the construction of buildings are quite different in Australia from other parts of the world. Therefore it is important to establish not only that there is a link between these impact factors and occupant productivity, but also how strong this link is. The strength of the link will have a direct bearing on the value any changes in building design and construction will have on the downstream value to the owner/tenant of productivity increases. Therefore this is critical to establish under Australian conditions.

The key issue which remains to be established before a viable research strategy can be developed is the strength of the dependence of productivity and health on indoor environment variables. This will be developed further during the final stages of this work.

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## 6. References

- [1] Daisey, J.M., W.J. Angell, and M.G. Apte, "Indoor air quality, ventilation and health symptoms in schools: an analysis of existing information", *Indoor air*. 2003. 53-64.

- [2] EPA\_402-F-00-009, "Indoor Air Quality and Student Performance". 2000, Office of Air and Radiation, United States Environmental Protection Agency: Washington, D.C. DC 20460, USA.
- [3] Ahman, M., et al., "Improved Health after Intervention in a School With Moisture Problems", *Indoor Air*. 2000. 57-62.
- [4] Daisey, J.M. and W.J. Angell, "A Survey and Critical Review of the Literature on Indoor Air Quality, Ventilation and Health Symptoms in Schools, IEQ Strategies". 1998, Department of Energy California State Environmental Protection Agency: Sacramento, California.
- [5] Milton, D.K., P.M. Glencross, and M.D. Walters, "Risk of Sick Leave Associated with Outdoor Ventilation Level, Humidification, and Building Related Complaints", *Indoor Air*. 2000. 212-221.
- [6] Nelson, N.A., et al., "Health Symptoms and the Work Environment in Four Nonproblem United States Office Buildings", *Scand Work Environ Health*. 1995. 51-59.
- [7] Myatt, T.A., et al., "A Study of Indoor Carbon Dioxide Levels and Sick Leave Among Office Workers", *Environmental Health: A Global Science Source*. 2002. 1-10.
- [8] Fisk, W.J., Mendell, M.J., Daisey, J.M., Faulkner, D., Hodgson, A.T., Macher, J.M., "The California Healthy Building Study, Phase 1: A Summary", *Indoor Air*. 1993. 246-254.
- [9] Graudenz, G.S., et al., "Upper Respiratory Symptoms Associated with Aging of the Ventilation System in Artificially Ventilated Offices in Sao Paulo, Brazil", *Chest*. 2002. 729-735.
- [10] Stefano, J.D., "Energy efficiency and the environment: the potential for energy efficient lighting to save energy and reduce carbon dioxide emissions at Melbourne University, Australia", *Energy*. 2000. 823-839.
- [11] The Collaborative for High Performance Schools, "Best Practices Manual". 2001, Eley Associates: San Francisco.
- [12] Abdou, O.A., "Effects of Luminous Environment on Worker Productivity in Building Spaces", *Journal of Architectural Engineering*. 1997. 124-132.
- [13] Küller, R. and L. Wetterberg, "The subterranean work environment: impact on well-being and health", *Environment International*. 1996. 33-52.
- [14] Wargocki P, W.D., Fanger PO, "Productivity is affected by the air quality in offices, 2000: Helsinki. 635-640.
- [15] Wyon, D.P., "Enhancing Productivity While Reducing Energy Use in Buildings", *E-Vision 2000*. 2000, U.S Department of Energy: Washington D.C.
- [16] Daft, R.L., "Leadership: Theory and Practice". 1999, The Dryden Press.: Fort Worth, Texas.
- [17] Cena, K. and R. de Dear, "Thermal Comfort and Behavioural Strategies in Office Buildings Located in a Hot-Arid Climate", *Thermal Biology*. 2001. 409-414.
- [18] de Dear, R. and M.E. Fountain, "Field Study of Occupant Comfort and Office Thermal Environments in a Hot-Humid Climate". 1994. 457-475.
- [19] de Dear, R., "A Global Database of Thermal Comfort Field Experiments", *ASHRAE Transactions*. 1998. 1141-1152.
- [20] Crouch, A. and U. Nimran, "Perceived Facilitators and Inhibitors of Work Performance in an Office Environment", *Environment and Behavior*. 1989. 206-226.[