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Investigating and Influencing How Buildings Affect Health: Interdisciplinary Endeavours

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Abstract

Evidence is mounting that conditions in buildings can influence health; current topics include indoor exposures to lighting, noise, and chemicals; the availability of windows; and, overall housing quality. These findings have had limited influence on building design, construction, and operation, in part because of limited interaction between the relevant disciplines. Barriers to interdisciplinary research and communication include disciplinary culture, language differences, and institutional policies. Researchers who overcome such barriers may influence building practice through participating in the development of codes, standards, and regulations and by developing design guidance.

Investigating and Influencing How Buildings Affect Health: Interdisciplinary Endeavours

Canadians spend 80-90% of their time indoors; and therefore, have long exposures to indoor environmental conditions that may affect their health and well-being. The relations between indoor environmental conditions and health should be an obvious target for research and applications. However, Canadian researchers, and psychologists in particular, have largely overlooked this challenge. For example, the lists of grants awarded between 2000-2001 and 2006-2007 by the Canadian Institutes of Health Research, Natural Sciences and Engineering Research Council, and Social Sciences and Humanities Research Council include 20 for projects relating to the broad topic of indoor environmental health, of which two were granted to psychologists as principal investigator.

A widely-held definition of health is that of the World Health Organization (WHO): "...a state of complete physical, mental, and social well-being and not merely the absence of disease or infirmity" (World Health Organization (WHO), 1948). This definition extends beyond the traditional biomedical emphasis on the negative, instead setting a high bar for human biological, psychological, and social functioning. Under this definition fall many outcomes traditionally studied by psychologists, including sensation, perception, cognition, arousal and alertness, memory, emotion, learning, sleeping, and motor performance. The Canadian Psychological Association's (CPA) own objectives fit this definition: "...To improve the health and welfare of all Canadians; [...] to promote the advancement, development, dissemination, and application of psychological knowledge ..." (Canadian Psychological Association (CPA), 2006). Psychologists clearly have roles to play in understanding influences on health, and in influencing public policy and individual behaviour to support good health.

The study of the effects of building conditions and health is inherently interdisciplinary. Interdisciplinary research is

...a mode of research by teams or individuals that integrates information, data, techniques, tools, perspectives, concepts, and/or theories from two or more disciplines or bodies of specialized knowledge to advance fundamental understanding or to solve problems whose solutions are beyond the scope of a single discipline or area of research practice. (Committee on Facilitating Interdisciplinary Research [CFIR], Committee on Science, Engineering, and Public Policy, National Academy of Sciences, 2005, p. 26).

Indoor environmental health research requires the active contributions of the architectural, engineering, design and building science professions together with those scientific disciplines related to health, including psychology. Psychologists have two roles to play here. They can study indoor environmental health; and, they can facilitate interdisciplinary research by others. Psychological research also informs our understanding of the barriers to interdisciplinary work, particularly through understanding in-group and out-group effects and interpersonal

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communication.

This paper briefly summarizes research topics under which psychologists are active in the broad domain of indoor environmental health, and addresses reasons for these findings' limited effects on building practice. The means to improve the effectiveness of psychologists' indoor environmental health research lie in addressing individual and institutional barriers to interdisciplinary research (in particular communication problems), and in more active efforts by researchers to integrate research results into various parts of building practice. The paper concludes with a summary of means by which Canadian psychologists might exert such influence. The need for clear communication beyond one's usual community of scholars runs throughout the paper.

Physical Environment Effects on Health

Noise, lighting, indoor air quality, and exposure to chemical, biological, and physical toxins are all areas of current concern for researchers and the general public (e.g., Birchard, 2007; Jha, 2007). Among environmental psychologists, restorative environments that can offset stressful experiences and housing quality are two active research areas. This is a brief introduction to the state of knowledge in each of these areas.

Noise

Noise exposure has been the focus of research attention for nearly forty years, since the classic work by Glass and Singer (1972). Several studies have documented adverse effects of chronic noise exposure on children, including disrupted reading acquisition (Bronzaft & McCarthy, 1975; Evans & Maxwell, 1997), memory impairment (Hygge, Evans, & Bullinger, 2002), and physiological stress responses (Evans, Hygge, & Bullinger, 1995). Fortunately, these effects appear to be reversible: The introduction of noise attenuation strategies resolved reading problems in elementary school children (Bronzaft, 1981), and the end of chronic noise exposure (because of the closing of a nearby airport) reversed the adverse effects on memory (Hygge et al., 2002). There is mounting evidence that chronic noise exposure has adverse effects on cardiovascular health and other outcomes (e.g., Ising & Braun, 2000; Ising & Kruppa, 2004), leading the WHO to formulate guidelines for urban noise levels (World Health Organization Regional Office for Europe, 2007) – translating from health research to community planning recommendations.

Chemical Exposures

The adverse effects of childhood exposure to lead and mercury — developmental disabilities and cognitive malfunctions — are well-known (Graff, Murphy, Ekvall, & Gagnon, 2006; Grandjean & Landrigan, 2006; Mendola, Selevan, Gutter, & Rice, 2002), and this knowledge has led to policy changes aimed at limiting exposure, such as the banning of lead additives in gasoline and interior paints. Many other chemicals remain unregulated because, despite suspicion that they may cause neurotoxic effects, the evidence is not strong enough to convince policy-makers (Grandjean & Landrigan, 2006). Moreover, environmental exposures occur simultaneously to many chemicals at once, rather than to the single compounds that are the focus of most investigations, and the consequences of the combinations are unknown (Bellinger, 2007). Some authors believe that exposure to certain compounds contributes to the development of attention deficit hyperactivity disorder and autism (Colborn, 2004; Windham, Zhang, Gunier, Croen, & Grether, 2006), although others disagree (Fitzpatrick, 2007).

Children from poor families are disproportionately likely to be exposed to neurotoxins (Evans, 2004). Ongoing research into these issues recognizes these broad contextual environmental issues, as well as genetic, chemical, and biological variables that are potential moderators (e.g., Hertz-Picciotto et al., 2006).

Lighting

Both physical and mental health could benefit from increased daily light exposure (Commission Internationale de l'Eclairage (CIE), 2004). Small increases in light exposure have been found to improve mental well-being in healthy people (e.g., Espiritu et al., 1994; Leppämäki, Partonen, & Lönnqvist, 2002). Being in a sunny hospital room has been associated with lower mortality rates among cardiac patients (Beauchemin & Hays, 1998) and with faster symptom remission for depressive patients (Beauchemin & Hays, 1996). Some writers are enthusiastic about the possibilities of such findings for immediate changes to lighting design and practice (Bommel & Beld, 2004). Others are more circumspect, recommending more thorough investigation (Boyce, 2006; Veitch, 2005).

Housing Quality

Both cross-sectional and longitudinal studies have found that objectively assessed housing quality influences mental health (Evans, Wells, Chan, & Saltzman, 2000). Gifford and Lacombe (2006) studied two Canadian samples (one in Quebec and one in British Columbia) using an adaptation of the Evans et al. (2000)

housing quality scale, and found that the quality of the home's interior, exterior, and neighbourhood predicted children's socioemotional health as rated by their parents, after controlling for parental income, parental education, parental mental health status, the child's sex, and the family's tenure in the house. Evans, Wells, and Moch (2003) reviewed the literature on housing and mental health and provided an excellent methodological critique of issues in this area.

Controlling for socioeconomic status is a common practice that obscures an important relationship: Children of low socioeconomic status are more likely to experience various physical and social environmental stressors (Evans, 2004). Children's cumulative exposures to potential stressors predict physiological stress responses, emotional regulation, heightened cardiovascular and neuroendocrine parameters, increased deposition of body fat, and result in a higher summary index of the total physiological demands to maintain homeostasis (allostatic load) (Evans, 2003). SES should be considered an explanatory variable in its own right (Evans, 2004).

Restorative Environments

Natural settings are particularly associated with restoration from stressful conditions (e.g., Kaplan & Kaplan, 1989). Ulrich (1984) found that hospital patients in rooms with windows that looked onto a nature view recovered more quickly from surgery than those with windows overlooking a brick wall. Further investigation has found that images of nature are more restorative than images of urban settings (Ulrich, Simons, Losito, Fiorito et al., 1991), and that time spent in nature is more restorative than time spent in built settings (Hartig, Mang, & Evans, 1991). Homes with views of nature from their windows, as opposed to views of other buildings or urban scenes, have been associated with greater resident well-being (Kaplan, 2001), and children's cognitive function and ability to cope with stressful life experiences are improved by having access to green space near their homes (Wells, 2000; Wells & Evans, 2003). Stephen Kaplan's Attention Restoration Theory (Kaplan, 1995) is a framework for understanding the beneficial effects of restorative environments that takes into account both cognitive and physiological outcomes.

Integrating Across Disciplines

Beyond Individual Sciences

Physical conditions in buildings influence human health, but not through simple, deterministic relationships; for example, SES is a likely moderator and possible mediator of effects. Psychologists are trained and equipped to seek complex, multivariable explanations involving both mediated and moderated relationships, but they have not as yet achieved many practically significant influences on conditions within buildings. Except for the definition of temperature and humidity conditions on thermal comfort (American Society for Heating Refrigerating and Air Conditioning Engineers (ASHRAE), 2001), concerning which there remains debate (cf., Brager & de Dear, 1998) there have been few building design or operation recommendations based on health evidence (cf., Evans & McCoy, 1998).

Environmental psychology is the branch of psychological science that should be most concerned with understanding how the physical environment can affect health and well-being. This subdiscipline of psychology is an inherently multidisciplinary perspective on human behaviour in relation to the physical and social environment (Canter & Craik, 1981; Stokols, 1995); however, the list of allied disciplines named is generally limited to other social sciences. For example, Stokols, writing in the *Encyclopedia of Psychology*, listed: "...architecture, urban planning, psychology, anthropology, sociology, geography and other fields" (Stokols, 2000, p. 217).

This limitation has probably contributed to our weak understanding of the influences of interior conditions on human health. Collaborations between psychologists and scientists from engineering, building physics, and the natural sciences have been comparatively few (the notable exception being thermal comfort research, key contributors being psychologist Fred Rohles [e.g., Rohles, 1980] and engineer Ole Fanger [e.g., Fanger, 1970]); and yet these disciplines develop the key information about the development of specific interior conditions. Papers cited here include work by authors from medicine, engineering, physiology, acoustics, epidemiology, and architecture, as well as psychology. Research topics in the broad area of buildings and health also will require the skills of toxicologists, mycologists, geneticists, neuroscientists, physicists, mathematicians, chemists, and microbiologists.

Thus, among the limitations of current knowledge about buildings and health is a divide: Researchers from the psychological, biological, or medical communities emphasize the validity and reliability of their outcome measures, but attend less to objective measurement of the physical environment (Evans, 1999; Lawton, 1999). Conversely, engineers' and physicists' expertise (for example) often results in very precise measurements of physical conditions, but their investigations rarely include validations of the behavioural measurement scales they use, nor do they include examinations of moderating and mediating variables. As a result, even well-accepted

relationships such as the effect of air temperature on thermal comfort ratings explain comparatively small percentages of variance (Newsham & Tiller, 1997), unless contextual variables are taken into account (Brager & de Dear, 1998).

Housing research is a case in point. Fuller-Thomson, Hulchanski, and Hwang (2000) identified four categories of housing research, three of which concerned specific physical conditions; the fourth concerned social, cultural and community contexts. There appeared to be no studies that crossed the boundary, and the authors noted methodological issues related to measurement in all categories. Lawrence (2002) has argued that attempts to develop sets of static standards to define optimal indoor environmental conditions for housing are futile — that suitable conditions necessarily vary in response to cultural, seasonal, and individual differences. This position differs sharply from the approach taken by the building science, construction, and regulatory communities (that specific desired conditions may be specified, sometimes using international standards), and is open to debate; but certainly the answer to the question will demand interdisciplinary research approaches that have rarely occurred to date.

Consider the case of noise effects on cardiovascular health and other strains, such as neuroendocrine function (Cohen, Krantz, Evans, & Stokols, 1981; Evans et al., 1995). One (although certainly not the only) mechanism by which these effects might occur is via a mediated mechanism in which noise exposure influences interpersonal communication (cf., Baron, David, Brunsman, & Inman, 1997) which in turn could reduce the availability of social support (Cohen, 1980). Social support is known to moderate the effects of stressful experiences; reduced social support would reduce the individual's ability to cope, not only with the noise exposure itself, but with other stressors (Cohen & Wills, 1985). An interdisciplinary approach to this model would include not only tests of the links between noise and strain, but would also engage building scientists to identify ways in which building materials, designs, and construction techniques contribute to noise exposure in buildings. Identifying communication as a mechanism would influence the choice of acoustic indices that one would study and attempt to control. Such an integrated model could result in changes to building practice that would improve occupants' probability of effective coping.

There exist few examples of this type of interdisciplinary research involving building research (although there are some addressing other aspects of environmental sustainability; see Uiterkamp & Vlek, 2007). One example from the buildings domain is the NRC Institute for Research in Construction (NRC-IRC) project titled "Cost-effective Open-Plan Environments" (COPE), which ran from 1999 to 2003 (NRC-IRC, 2006). COPE was conceived deliberately as an interdisciplinary project involving engineering, interior design, architecture, acoustics, and psychology expertise. The goal of the project was to determine how open-plan office design choices (workstation area, panel height, layout, and materials) influenced the physical conditions in offices; and in turn, how the physical conditions affected satisfaction with environmental features, overall environmental satisfaction, and job satisfaction. Teams of researchers involved in various subtasks used literature reviews, laboratory experiments, computer simulations, and a large, integrated field study, to address the overall model and produced, in addition to research reports, conference presentations, and journal papers, extensive web-based material for designers and the public and an online software tool (COPE - Office Design Evaluator) to enable the prediction of the physical conditions that would be created, and potential satisfaction benefits and drawbacks (NRC-IRC, 2007).

Barriers to Interdisciplinary Research and Application

One reason for the scarcity of interdisciplinary building and health research is the scarcity of venues through which individuals with complementary interests may encounter one another. One new venue is the Canadian Building and Health Sciences Network (CBHSN); see http://irc.nrc-cnrc.gc.ca/health/cbhsn_e.html. Internationally, there is the International Society for Indoor Air Quality and Climate (<http://www.isiaq.org/>), although as the name suggests its focus is primarily on air and ventilation. The Environmental Design Research Association (<http://www.edra.org/>) addresses behaviour and design, but has relatively weak connections with the building sciences (engineering and physics) or the medical sciences.

Latham and Latham (2003), writing about the divide between industrial-organizational psychologists and their human resources management counterparts, provided a cogent analysis of problems of interdisciplinary research. Parties to such work must overcome individual and group-level cultural and language differences between the disciplines, challenge institutional policies that may stand in the way of such work (particularly those related to promotion and pay decisions), and address interpersonal behaviours that may be off-putting to their counterparts (for example, by learning to listen to others first, and speak second).

Among the more difficult barriers to overcome are institutional barriers (CFIR, 2005). Interdisciplinary researchers are more likely to publish their work in interdisciplinary journals that are unfamiliar to their disciplinary colleagues, and which may have lower impact factors than more mainstream journals because they appeal to a narrower readership. Interdisciplinary work also takes longer, because teams must spend time to develop working

relationships and overcoming misunderstandings about theory and methods in order to establish their projects; this can result in a lower publication rate for the interdisciplinary researcher. Further, for the researcher who aims at practical applications for the work, publications and presentations aimed at application (e.g., written for relevant practitioners or for the general public) take time away from writing for peer-reviewed journals. Overall, outside a supportive institution, researchers who choose an interdisciplinary path may find their career progress impeded. For this reason, some would argue that this is a path only for the established scientist.

Overcoming individual and group-level barriers to interdisciplinary research involves the application of social learning theory (Bandura, 1977) and intergroup relations research (Brewer, 2007). Members of interdisciplinary teams need not hide or dismiss the standards, practices, and language of their disciplines; however, they must learn to communicate them clearly to members from other disciplines (which requires self-awareness), and they must learn some of the language, practices, and standards of their counterparts (which requires tolerance). Psychologists should understand the value of modelling the expected behaviour – of taking the lead in learning about the other fields and how their perspectives may contribute to the project at hand, and of practicing open, clear communication with colleagues. This will require repeated practice; for part of the challenge in successful interdisciplinary work is to overcome stereotypes and prejudices that one holds about other disciplines (e.g., “Engineers want to control everything”), and that others may hold about psychology (e.g., “Psychology is too soft to be considered a science”). Those who model this behaviour for their students will shape future generations who possess the necessary communication skills and attitudes (CFIR, 2005).

Despite the barriers, interdisciplinary research offers interesting intellectual challenges, and the prospect of understanding more complex problems. Psychological research methods and statistical tools have widespread application that other disciplines may appreciate once they become known. In the case of building-health research, nested research designs (e.g., students in classes in schools; residents in houses in neighbourhoods) can be particularly powerful analytic tools — but they are not well-known in other disciplines. Behavioural genetics offers another suite of research methods suitable to disentangling the effects of genetics, environment, and behaviour (e.g., Caspi, Taylor, Moffitt, & Plomin, 2000). Deeper understanding of the mechanisms involved in the effects of interior conditions on health, including estimates of the sizes of various effects, should underlie practical decisions about building design, construction, and operation.

Influencing Building Practice

Research into the effects of buildings on health is an applied pursuit, not aimed only at adding to the sum of human knowledge. How, then, shall psychologists ensure that their work has influence? Kuo (2002) proposed five hypotheses about conditions under which research is more likely to influence policy-makers:

- Select “applied” rather than “basic” funding sources.
 - Select independent variables that decision-makers can control.
 - Select dependent variables that decision-makers care about.
 - Select research designs that decision-makers find compelling.
 - Present findings in forms that decision-makers find accessible.
- (p. 345).

One corollary to these hypotheses is that researchers who want to change the world need to involve themselves in the world. This means doing interdisciplinary research. Researchers concerned with improving the built environment need to understand buildings and physical conditions in buildings — not to the same level as an architect or engineer, but sufficiently to choose or to measure the right independent variables, and to do so with sufficient specificity and attention to validity that the information learned can fit into the cognitive framework of the right decision-makers. Decision-makers focus heavily on external validity, and will be unpersuaded by studies, however high in internal validity, that involve conditions different from those that naturally occur. Working with professionals from the other disciplines is the best way to achieve conditions that fulfil Kuo’s (2002) five hypotheses.

Involvement in the world also means making efforts to have influence. One may make results accessible in several ways, many of them novel actions for psychologists. Communication challenges will remain, particularly when developing presentation materials concerning complex, multivariable effects, but aimed at audiences accustomed to simple determinism. As difficult as that may be, only researchers trained in understanding the methodology and findings have the skills to make the translation. Here follow several avenues by which Canadian researchers may have an influence; all require applying the same principles of communication and intergroup relations that one would use to develop an interdisciplinary research team.

Canada's National Building Codes

Canada has a national system for the development of model building codes, which is overseen by the Canadian Commission on Building and Fire Codes[†] (CCBFC) (CCBFC, 2002). These codes may become legally enforceable when referenced in legislation by a province, territory, or municipality, which have jurisdiction over building regulation. The *National Building Code* is revised approximately every five years; the most recent edition was published in 2005 (CCBFC, 2005). The current edition is the first to be objective-based. That is, every code requirement is linked to a specific code objective: It contributes to either health; safety; accessibility; or, fire and structural protection of the building. Where referenced in legislation, the code's provisions are legally enforceable requirements for new buildings and buildings undergoing renovations or changes in occupancy.

In the context of the *National Building Code*, health has a relatively narrow definition, being restricted to the avoidance of illness caused through indoor conditions, sanitation, noise, vibration, or toxic exposures (CCBFC, 2005). One reason for this limited definition is that building codes establish minimum acceptable conditions, not optimal conditions. They are intended to exclude the bad, not to require the best (Clemmensen, 2003). Nonetheless, there is room for psychologists to involve themselves in the codes development process. The findings related to noise and cardiovascular health, for example, fall clearly within the existing code objectives, but have not yet resulted in specific code provisions under the *National Building Code of Canada* (CCBFC, 2005).

The Canadian codes development process is open; anyone may request a change to the codes (CCBFC, 2002), which then receives consideration by the appropriate standing committee, which may undertake further study of the issue, may alter the wording of the resultant proposed change, or may reject it. Proposed changes that are approved by the standing committee also undergo a period of public review, which provides an opportunity for informed comment by the broadest possible range of experts. The standing committee then reviews the comments and may modify the proposal in response to them; then the provinces and territories review the proposed changes; and finally, the CCBFC itself reviews the proposals. Those that are approved by the CCBFC will appear in the next edition of the code.

Standards

Standards are “publications that establish accepted practices, technical requirements and terminologies for products, services and systems” (Standards Council of Canada, 2006, p. 'About the SCC'). Standards define safety requirements or performance requirements of products or systems, or they may define processes or procedures to address issues of social or environmental concern. Standards become legally enforceable when referenced in legislation.

As with the building codes system, the standards development process has many opportunities for public involvement. The Standards Council of Canada (SCC) co-ordinates the national standards system, overseeing the practices of accredited Canadian standards development organizations and acting as the point of contact for Canadian involvement in international standards organizations such as the International Organization for Standardization (ISO). Each of these bodies, in turn, has committees of volunteers that develop standards within their domains of interest. Over 15,000 Canadians are said to volunteer in the various standards-writing committees co-ordinated through the SCC. Many others may become involved at the public review stage of document preparation.

Canadian involvement in international standards related to buildings and health is limited, but psychologists may play roles both as members of technical committees and working groups, and by commenting on documents during public review. Canada is not a participant in ISO Technical Committee (TC) 205, “Building environment design”, but Canadians currently participate as observers in the work of ISO TC 159 – Ergonomics. This committee has published many standards related to the design of offices with computers, the management of workload, and auditory communication in workplaces (ISO, 2007). Canadians were also involved in the writing of an international standard on lighting indoor workplaces (Commission Internationale de l'Eclairage (CIE), 2001), jointly published by ISO and CIE.

Regulations

Under Canadian law, regulations are rules that set out general requirements or limitations on actions of individuals or organizations to achieve public policy objectives (Treasury Board of Canada Secretariat, 2006). A legislative body (e.g., Parliament) sets out in legislation a general public policy objective (e.g., energy efficiency) and delegates authority in this area to a person or body (e.g., the Minister of Natural Resources), which in turn develops specific regulations to achieve the objectives. These regulations have force of law. The bodies that develop regulations have mechanisms for public comment and consultation. For example, in the spring of 2007 it was

[†] Comprehensive information about Canada's national building codes is available at <http://www.nationalcodes.ca/>.

announced that energy efficiency regulations governing light sources would be revised to eliminate the least energy-efficient incandescent lamps by 2012 (Natural Resources Canada, 2007). An interdisciplinary group of lighting researchers provided input to this debate through the Canadian National Committee of the CIE. The final regulations had yet to be announced at the time of writing.

Design Guidance

Providing information to designers that could lead to more effective design has long been a goal of environmental psychology (cf., Kaye, 1975). Design guidance, being less formal and more varied than codes, standards, or regulations, offers the most flexible means to reach architects, interior designers, urban planners, and engineers. Guidance – taking the form of rules of thumb, practical implications of a specific study, or more structured design guidelines – may be written by professional associations, industry groups, or interested experts, and they may be communicated via magazine or trade journal articles, books, web sites, or public presentations (including TV, radio, and newspaper), or any combination of these modes.

Eminent environmental psychologist Robert Sommer (2006) recommended that for psychologists to have an influence, they should write articles aimed specifically at policymakers or the general public, to complement their scholarly writing in peer-reviewed journals. Kuo (2002) and Sommer (2006) have both provided guidelines for writing in nontechnical ways to reach beyond disciplinary colleagues. Professional association, trade, and industry magazines and newsletters are often delighted to receive well-crafted descriptions of interesting results. As Sommer noted, such publications can also lead to speaking invitations and even to unexpected possibilities for funding new research. For example, Carpman and Grant (2002a) wrote a short article with specific wayfinding guidelines aimed at facilities managers in healthcare facilities based on their more scholarly chapter in the *Handbook of Environmental Psychology* (Carpman & Grant, 2002b).

Monographs aimed at design professionals are longer than a magazine article, but less technical than a journal paper. Publishers may be professional associations, or institutions, or they may be self-published with funding from research sponsors. Two examples in environmental design are *Disproving widespread myths about office design* (Brill, Weidemann, & BOSTI Associates, 2001) and *Workstation design for organizational productivity* (Charles et al., 2004). Taking this approach allows for a broader scope, but may require more effort to market the document, to make people aware of its existence.

Another means for information transfer from research to practice are online tools aimed specifically at this, such as the online magazine Research-Design Connections (<http://www.researchdesignconnections.com/>), and the summarizing site Informed Design, an activity with founding support from the American Society of Interior Designers (<http://informedesign.com/>). In the former case, one could suggest a topic to the editor, or submit a short article. In the latter case, one could bring a scholarly article to the attention of the site developers, and suggest its inclusion in their database. These venues are among the means to make practitioners aware of other resources.

Where research results warrant it, predictive design tools provide another means to communicate design advice. These tools can combine the complete set of research concepts, bringing together the building sciences and behavioural and health sciences and providing integrated results. This is not a likely to be an approach used by individual researchers, but can bring together the results of interdisciplinary teams to demonstrate how changes in design parameters lead to changes in physical conditions and, in turn, to health and behavioural outcomes (e.g., NRC-IRC, 2007).

Many academics may think that these activities are unimportant and not rewarding. These forms of publication may not be among those counted towards tenure and promotion decisions, which constitutes a barrier to interdisciplinary research and to its application. Experience suggests that there are other rewards, most notably the awareness that one's applied research is being applied in buildings, with beneficial results for the well-being of the people in them.

Concluding Remarks

Empirical evidence shows that buildings influence our health and well-being, and that choices made in their design, construction, and operation can lead to benefit or harm. Our understanding as to which choices ought to be made is as yet incomplete, in part because it requires interdisciplinary research. Building such research teams is not easy; it requires members to overcome institutional barriers, which act as disincentives, and individual barriers that impede communication between disciplines. Some successful examples of such research exist that may serve as models, and there are many avenues by which research results can influence design and building practice. If we take our responsibilities to their necessary conclusions, beyond the scholarly publication and into the realm of influence, we may all reap the rewards of better buildings for ourselves and our families.

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