Designing the work environment for worker health and productivity

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Abstract:

Interest has grown over the last several years in understanding the effects on worker performance of environmental conditions in the office. Worker performance can be understood at two levels: individual tasks (ITP) and group work (CTW). Ambient environmental conditions (lighting, acoustics, ventilation and thermal comfort) affect individual performance, whereas spatial configuration and furniture layout make workgroups more or less effective.

Theoretical models guiding research in this area are described and discussed. The topic of worker productivity in offices is briefly examined and a typology of ways of evaluating productivity and links to worker health is offered. Using examples from current research, a theoretical framework for increasing knowledge of the effects of environmental design on health and performance of workers is outlined. This framework is based on the concept of comfort; at the University of Montreal, empirical studies have been structured around three measurable comfort categories, each of which is described.

Keywords: Environmental psychology; productivity; office design; comfort; user satisfaction.

Office Worker Productivity

Over the past ten years, major changes in office work, technology and environmental design have generated a growing number of questions about links between these and worker productivity. What can we learn about the ways in which workers in offices are affected by features of the physical environment in which they work? In this paper, we look at some of the theories that have emerged to link worker performance to environmental design and we offer some ideas resulting from recent research results to guide future studies.

Perhaps the first major study to link environmental design to worker performance in a systematic way was the BOSTI study (Brill et al, 1985) in which a large number of white-collar workers completed an exhaustive questionnaire survey before and after moving into a new building. Among the many conclusions of this research, the authors offered an economic formula for calculating 'increased return on investment' in workers as a function of giving them workspace conducive to their tasks. They recommended that managers and others used to occupying enclosed private offices were more productive in such settings than they were in open plan workstations. A recent follow-up by the same authors analyzed the results of 13 major office worker surveys carried out since this study (Brill and Weidemann, 2001). It concluded that the trend toward more open work environments had a measurably adverse effect on office workers, such that the investment in individual private offices could be shown to pay off in terms of increasing workers' productivity.

In the late 1980's, a major symposium was held inviting leading researchers in the field to present their state-of-the-art conclusions on the relationship between office worker productivity and environmental design. The presentations indicate the considerable complexity of the question and the wide range of approaches to research developing to respond to it; degree of enclosure of individual workspace is only one variable among many affecting the performance of work (Ward and Dolden, 1986).

More recently, studies have looked at the effects of indoor air quality and ventilation system performance on workers productivity, on various types and levels of lighting, on spatial comfort, density, personalization and furniture layout (Vischer, 1989, 1996; Wells, 2002; Churchman et al, 1990), as well as various acoustic conditions (Veitch, n.d.). In reviewing this literature and summarizing results, two basic categories of office worker productivity emerge, each of which has a slightly different relationship to the environmental design of workspace. These are Individual Task Performance (ITP) productivity, and Collaborative and Teamwork (CTW) productivity.

Many studies examine ITP productivity. Traditional experimental designs favour measuring the effects of different lighting levels, for example, on speed and accuracy of individual task performance. Surveys of Indoor Air Quality (IAQ) and Thermal Comfort in office buildings ask individuals to rate their comfort, satisfaction and health levels. Ergonomic studies that focus on features of the furniture and the performance of tasks are oriented to the comfort and functioning of the individual in a given furniture configuration or workstation.

Fewer studies have looked systematically at CTW productivity. Sociological studies of small group communication and decision-making are well-known, but make little reference of environmental features (Allen, 1977). The effects of the physical setting on team performance are difficult to measure, in that many social and psychological aspects of work typically also change when workers form teams and start to produce a team product (Vischer, 2003).

In addition to these two broad definitions of productivity, a second important question is the choice of measures to be used. Both ITP and CTW productivity can be assessed according to positive and negative criteria. Positive measures of productivity include faster, more accurate output, faster and more effective employee recruitment and retention, better quality service to clients, faster and better quality decision-making. The argument posits that a supportive environment increases these outcome variables, or the rate of their occurrence, to a measurable extent. Negative measures of productivity include rate of absenteeism and illness, employee turnover, product returns or service complaints, error and customer complaint rates, and reducing staff to perform the same amount of work. According to this argument, an effective work environment counters these effects, reducing their incidence and prevalence, often comparing favorably to some previously calculated error rate or quality of output. In many studies, some mixture of both positive and negative outcome measures is used, as summarised in the figure below.

	POSITIVE MEASURES	NEGATIVE MEASURES
ITP (individual productivity)	Faster, more accurate output; employee recruitment and retention.	Absenteeism and illness; employee turnover; reduced task speed.
CTW (group productivity)	Better quality output; lower costs; better decisions.	Error rate; shrinking group size; customer complaints.

Depending on whether ITP or CTW is the focus of the research, and how data can be applied to outcome measures in each situation, environmental influences on, and support for productivity, can be defined differently. For example, light levels, thermal comfort and other types of ambient environmental condition affect individual performance and can be assessed in terms of positive outcomes. Other the other hand, furniture layout and configuration, acoustic conditions and the convenience and adequacy of group workspace in a building are likely to affect team performance and collaborative tasks, and can perhaps be assessed more tellingly in terms of negative outcomes.

Environmental Influences on Productivity

What theoretical models exist to help guide current research on the work environment towards a better understanding of its effects on productivity? A close look at three existing models suggests their usefulness and viability for modeling both the complex relationship between individual and group productivity, and positive and negative outcomes. Further refinements for advancing a useful theoretical framework can then be outlined.

User Satisfaction Model

The most prevalent theoretical model, which has guided – explicitly or not – the majority of studies of environmental effects on productivity to date can be characterized as the User Satisfaction model (Vischer, 1985). It is easily recognized by its use of surveys to question users on whether or not they 'like' or 'dislike' one or another environmental feature, whether they are 'satisfied' or 'dissatisfied' with their workspace, and if they have a preference for an existing or future environmental feature. As most interior office configurations resemble each other, workers' lists of likes and dislikes tend to be predictable, and yet studies continue to report with genuine surprise that occupants dislike high noise levels, lack of natural light, shortage of parking spots, slow elevators and so on. Widespread use of this approach has given

us an exhaustive knowledge of workers preferences without yielding much concrete information about ITP or CTW or other functional measures of worker productivity. Moreover, carefully-designed workspaces all over the globe have been submitted to 'evaluation' characterised by whether or not users 'like' them – a poor and unsupported criterion often causing unnecessary condemnation of a well-intentioned office design. This is particularly evident in situations where workers have moved into new and unfamiliar workspace, as their likes and dislikes inevitably relate to the known and familiar and have little to do with whether or not the new environment works.

Employee Motivation Model

An important but not widely-studied theoretical model was outlined early on in the 20th century by sociologist Frederick Herzberg (1966). Herzberg was not concerned only with the effects of environmental factors on behavior, but he also elaborated on a range of influences on workers' motivation. Among his categories of influence, the physical environment was identified as having a unidirectional effect on worker motivation; that is to say, when the physical setting was appropriate to the task, and problem-free, workers' motivation was not affected. However, when the physical setting was adverse, and slowed down work, it had a 'demotivational' influence on workers. Thus Hertzberg concluded that it was important to maintain a comfortable, safe, supportive physical environment to help workers stay motivated, in other words, productive. Recent studies have looked at personality characteristics, employee morale and availability of choice (McCusker, 2002) in terms of changing workspace design, thus drawing on Herzberg's original model incorporating the psychosocial aspects (which he calls motivation) into definitions and outcome measures of worker productivity.

Adaptation and Stress Model

The third theoretical model has been evolving since the 1970's, and can be called the behavioral

adaptation/stress model (Evans & Cohen, 1987). The theory that adverse environmental conditions cause stress at the point at which users are not able to adapt, or can only adapt with difficulty, has its origins in psychological studies of several decades ago. They provide an important formulation of the long-term relationship between people and their environment. In the context of worker productivity, environmental adaptation behaviour is a useful (positive) outcome measure, as is evidence of stress (negative) when adaptation behavior fails. Thus the theory states that an effective and supportive environmental design does not mean users make no adaptation to the environment, but keeps the need for such behavior within comfortable boundaries.

A variation on this approach is the concept of environmental competence. Applied mainly to the study of residential environments designed for handicapped and elderly users, this model postulates user competence as an outcome measure: successful environments enable people to function to the best of their ability with the skills they have, however limited (Pastalan, Unsuccessful environments create 1983). insurmountable problems for users and confine them within their physical or mental limitations. The notion of competence can therefore be considered akin to that of successful adaptation, such that the stress to users caused when adaptation efforts fail is similar to that caused by occupying an environment that creates incompetence.

Indicators of stress include muscular-skeletal complaints related to furniture design and layout, such as Repetitive Strain Injury (RSI); upper respiratory and infectious disease complaints related to IAQ and ventilation problems; and increased rates of absenteeism due to illness and burnout. However, stress studies are complicated by the need to distinguish between stress caused by factors other than environmental factors (employer-employee relations, family problems, promotional prospects), and stress caused by 'fighting against' the environment to perform work. As a result, cause-effect connections between stress and environmental design are difficult to identify.

To summarise, the three theories that have dominated office environment research thus far are the user preferences model (do workers like or dislike features of their environment), the motivational model (adverse working conditions demotivate workers) and the adaptation model (conditions can be considered adverse if they require excessive adaptation from occupants, thereby causing stress). Of the three, the adaptation model with its connection to stress is the most likely to incorporate assessment of worker health. However, few published studies refer specifically to the theoretical models they apply, and few have made explicit the ways in which these and other theoretical constructs have been operationalised to frame the dependent and independent variables in terms of research. Almost none have made a distinction between ITP productivity and CTW productivity. The next step is therefore to look at how current office environment research is explicitly or implicitly testing these models and elaborating them into a more functional paradigm for studying the effects of office design on productivity.

Measuring Worker Comfort

In 2000 the Groupe de recherche sur les environnements de travail (New Work Environments Research Group) was formed at the University of Montreal to study the relationship between workspace design and human behaviour. Since its formation, researchers have grappled with operational definitions of worker productivity and ways of approaching the user-environment relationship in useful and measurable terms. Although the three models cited thus far have merit, each pose problems of definition and measurement in field settings. The shortcomings of the satisfaction model have already been identified: other than providing predictable lists of workers' likes and dislikes, the model used alone yields little in the way of a working knowledge of effects on individual and group performance, individual morale and

effective teamwork. The psychosocial motivational model was developed at a time when office work was oriented more to individual tasks than to collaborative work; it places physical features in a broader context of environmental influences - both intrinsic and extrinsic - on individual performance, but it has inspired a tentative direction for research on psychosocial aspects. However, by postulating a binary choice between a neutral or a negative outcome, this model ignores positive outcome criteria. The adaptation and stress model offers a rich range of possibilities for empirical research. It is complicated by the diversity of sources of stress likely to affect office workers, as well as by individual differences in adaptational ability (environmental competence). In order to develop operational definitions and guide empirical studies of worker-workspace interaction, therefore, the Research Group has developed the concept of comfort.

The idea of human comfort has a long history. Applied traditionally to architecture and interior design historical research to enable scholars to understand how people used space in their homes and community buildings to make themstandards developed out of earlier notions of health and safety, in recognition of people's need to be more than simply healthy and safe in the buildings they occupy. Studies of thermal comfort, for example, have led to prescriptive standards for ambient temperature, relative humidity, airspeed and level of clothing that ensure that 80% of the occupants of any given building interior will feel that the temperature is 'comfortable'.

Thus the model guiding our research has taken the adaptation and stress theory one step further by postulating that user comfort can be measured both in environmental as well as in behavioral terms. Effective task performance is directly related to it, and user comfort can be empirically measured. In order to operationalise these claims, we have broken down the concept of comfort into three separate but mutually supportive categories: physical comfort, psychological comfort, and functional comfort.

The model is presented graphically below: According to this model, users require physical comfort as well as psychological and functional comfort in order to use their environment to perform their tasks well; an effective and sup-



selves 'comfortable', it has more recently been applied to defining norms and standards for interior environmental conditions in public spaces such as office buildings. In fact the notion of comfort as a basis for setting environmental portive environment provides comfort at all three levels. These different experiences of comfort are amenable to objective measurement and can be integrated to provide a reliable outcome measure of environmental effectiveness.

Using the Comfort Model in Field Research

The research studies we have designed examine comfort in the three categories by using separate instruments for data collection and analysis. Each category is described below.

PhysicalComfort:

This is the area of user comfort most closely related to the ability of the designer. Physical comfort is almost guaranteed in modern buildings if the architect/designer respects existing standards and makes responsible design decisions. Standards that exist to ensure occupant health and safety are often legally required. Additional standards exist for all areas affecting users' physical comfort, including ventilation and indoor air quality, thermal comfort, ergonomic comfort, light levels, and sound absorption ratings. Most are prescriptive, and some are performance standards. Organizations responsible for testing - such as ASHRAE for ventilation and thermal comfort, NIOSH for indoor air quality and IES for lighting - develop and revise the standards. Instrument testing can be used to measure the degree to which the specified standards are met in a given building.

In terms of its effects on worker performance, users' physical comfort must be assured. Any interruption or deficiency in basic building services, such as elevators, bathrooms, parking (if appropriate), and cleaning and maintenance, have a marked deleterious effect on worker behavior. In previous work I have characterized this basic level of building habitability as "building convenience" (Vischer, 1996). Workers can be questioned on their perceptions of building convenience, but in modern buildings, built to responsible standards, few negative evaluations of physical comfort are likely to be received. When workers identify a physical comfort problem, it tends to have a negative effect their judgment of all other workspace features.

Psychological Comfort

In spite of the influence of Herzberg's thinking, psychological comfort is only beginning to be measured in the office environment (Fischer et al, 2003). A primary component of psychological comfort is sense of territory, both individual territory (office, workstation) and group territory (team workspace). The concept of territory can be applied equally to ITP and CTW productivity assessment. Our research suggests that sense of privacy, sense of status and sense of control are fundamental components of territoriality, and that people define themselves and their work in part according to these criteria (Vischer et al, 2003). Thus many studies have found that people moving out of private enclosed offices into open workstations judge their environment more negatively, citing lack of privacy, acoustic conditions, and confidentiality problems as reasons for their discomfort. We found significantly more negative assessments of these factors by senior staff, compared to lower level employees.

Results indicate that workers at different levels have different perceptions of their territorial boundaries, with more senior workers having more physical boundary markers over a wider area than clerical workers. Moreover, measures of office personalization indicate that differences depend on people's longevity with the company and the type of work they do, rather than on any physical characteristic of the office or workstation.

Recent accounts of major office redesign and renovation projects that have attempted to replace traditional office concepts with more 'dynamic' open environments indicate slow acceptance by workers, and in some cases, outright rejection (Berger, 1999). Several writers have concluded that a major change in the spatial environment needs to be managed rather than imposed in order to be successful. Involving and informing workers about changes to their workspace can speed up acceptance of innovation as well as provide useful ideas to designers. Measures of environmental empowerment (which can take a variety of forms) indicate that empowering workers with regards to their work environment is one effective way of ensuring psychological comfort.

Functional Comfort

The notion of functional comfort has been discussed at length elsewhere (Vischer, op.cit.). This aspect of comfort addresses how effective workspace is in helping users perform their tasks. It is therefore independent of individual preferences and needs, and anchored in generic human requirements for tools to perform their tasks. Indeed the subtitle of a previous publication is "Environment As A Tool For Work". As the range and types of task performed in offices grow, and become more complex, so the concept of functional comfort becomes more important: workspace has to facilitate a wider variety of tasks without itself becoming complex and costly to build. As a result, users' assessment of their functional comfort provides an important indicator to managers and designers of how well workers feel they are functioning and whether or not improvements need to be made to help people perform their tasks better and more quickly.

Our research has yielded a number of key dimensions of functional comfort that tend to be standardized across different types and locations of office building. These include Air Quality, Thermal Comfort, Spatial Comfort, Privacy, Lighting Quality, Office Noise Control and Building Noise Control. Other less commonly present dimensions include Collaborative or Team Workspace, Visual Comfort, and Security. These are measured by asking occupants to evaluate a standardized number of environmental conditions on a 5point scale. Data from some 6,000 respondents have contributed to the establishment of normative scores on each of the functional comfort dimensions, to which results from new surveys can be compared. Deviations from the norm in either a positive or a negative direction indicate either adequate functional comfort for users, or problems in performing tasks; and follow-up actions can be taken accordingly. The user is the instrument of measurement of functional comfort, ensuring that functional comfort can be measured in a reliable empirical way. In addition, functional comfort is a predictor of environmental competence, in that a workspace that supports the performance of tasks increases the environmental competence of its users.

Conclusions

Although many published studies that measure human response to varying environmental conditions advance the argument that happier and more contented workers are likely to be more productive (work harder) than unhappy or dissatisfied workers, the conclusive link between these two psychological phenomena has yet to be made empirically. In view of the numerous attempts to quantify that proportion of worker productivity that can be said to depend on support from the physical environment (ranging from 5% to 25 or 30%), assuming this percentage to be a function of users' level of satisfaction does not appear to be a strong argument. Many companies are satisfied that standard office layouts in generic office buildings are more than adequate to support their employees' work, and fail to see any advantage to investing additional effort in workspace design simply in order to make people feel happier.

The analysis of task requirements and the relationship between environmental design and task performance (effectiveness at work), however, can be empirically linked to environmental measures. For example, people working at screens all day long require low background light levels and preferably indirect lighting sources; people who spend a lot of time in meetings need small, functional meeting-rooms nearby that can be used informally and do not require reservations; people who have special equipment or documents may need larger-sized work surfaces or higher partitions. These environmental items are necessary tools for the performance of work. Thus regardless of the individual preferences of workers, the idea of comfort signifying the degree of support that a workspace provides to the performance of tasks links it directly with people's productivity, that is, how fast and well they can work. Replacing the theoretical concept of individual satisfaction with the complex idea of comfort both increases the validity of user-environment interaction studies, and can be applied to measuring both ITP and CTW productivity.

In reviewing the bearing that the tri-partite definition of comfort has on the other two theoretical models of worker-environment productivity, several recent studies are looking at stress that is caused by attempting to perform tasks in nonsupportive workspace. Sustained stress leads to health problems, absenteeism and employee turnover. The stress-health approach links into a well-established research tradition in environmental psychology, and indeed in psychology generally: understanding human adaptation to environment. Environmental studies have shown that people are generally adaptable to a wide range of physical conditions, but more needs to be known about factors - often intrinsic rather than extrinsic - that affect this adaptability, and how to recognize the point where it breaks down, and failure to adapt causes stress. Moreover, can this breakdown point be generalized to certain types of workers performing certain types of tasks in offices characterized by unsupportive design, rather than being attributed to individual differences?

Finally, more study is needed of the links between environmental performance and worker motivation. To characterize the workspace as only having a neutral or a negative effect on motivation may have been more appropriate in the 1940's than now, when office space is both more diverse, and more prevalent as a work environment. Nowadays it may be plausible to consider aspects of the work environment as positively motivating to employees, although we do not yet know much about the conditions under which this could or does occur. interesting link between worker motivation and environmental competence bears examination, in that an environment in which workers feel incompetent is likely to have a powerful effect on their motivation to perform - for example, where wayfinding is difficult and needlessly complex, so that people get lost easily.

The model we have developed at the University of Montreal, in which environmental effects on workers' experience can be grouped into three areas of activity - physical, psychological, and functional comfort - offers a handle for applying each one of these theoretical models more systematically than has previously been the case, to person-environment research on workspace. Feedback from office workers in each of the three areas of comfort can be analysed in terms of building habitability (physical comfort), task performance (functional comfort), and territoriality (psychological comfort). Research results to date suggest that that user feedback does not always indicate whether the comfort assessments refer to psychological, functional or physical categories, as people criticize physical conditions, for example, when they are psychologically uncomfortable. The researcher's job therefore is to identify and classify the pattern of comfort that characterises each user evaluation of the work environment.

Learning more about the three ways in which people experience and assess their comfort will help us understand the concepts of worker motivation, adaptation and stress, and environmental competence. Thus field studies must measure all three areas of worker comfort before conclusions can be drawn regarding the degree of support they are receiving from their workspace and/or the degree of environmental competence they enjoy. The three-pronged approach to comfort as an outcome measure avoids excessive reliance on a single notion – for example, that of worker satisfaction – as a predictor of environmental effectiveness and worker productivity.

Future research will focus on before and after measures of environmental effectiveness and links to changes in worker performance, as well as on additional parameters of psychological comfort. To date, our limited knowledge of how people define territorial boundaries and how they defend them, of the complex notions of privacy in offices, a well as of environmental empowerment and strategies of teaching environmental competence, is not fully integrated into space design and management practices. Ultimately, the three-pronged approach to comfort will help office workers become more productive through making better use of the environments they occupy.

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