USER EVALUATION OF THE WORK ENVIRONMENT: A DIAGNOSTIC APPROACH

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USER EVALUATION OF THE WORK ENVIRONMENT: A DIAGNOSTIC APPROACH

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RÉSUMÉ

UNE APPROCHE DE L'ÉVALUATION DES ENVIRONNEMENTS DE TRAVAIL : LA MÉTHODE DIAGNOSTIQUE

L'évaluation des environnements de travail est née de la discipline de la psychologie de l'environnement. L'évaluation des espaces vise l'expérience des employés relative à leur environnement de travail plutôt que l'évaluation des activités et des compétences. En examinant de près l'historique de l'évaluation environnementale, on peut constater les diverses orientations développées dans ce domaine. Selon l'approche cognitive, l'environnement de travail se définit selon l'évaluation qu'en font les occupants. La méthode diagnostique sur laquelle porte cet article relève du modèle cognitif des relations personne-environnement. Cette approche a évolué à partir de nombreuses enquêtes menées auprès des occupants des bureaux. Les résultats fournissent non seulement une meilleure compréhension de la psychologie des usagers des espaces de travail, mais aussi une façon systématique d'établir les priorités d'intervention pour améliorer le niveau de confort relatif au fonctionnement des systèmes techniques de l'immeuble à bureaux. Conçue il y a quelques années et facilement adaptée à de multiples usages, cette méthode s'avère être un outil de mesure qui donne des résultats aussi intéressants pour les managers, les designers et les responsables des immeubles que pour les chercheurs concernant l'expérience du confort dans les espaces de travail. Une étude de cas démontre une application de la méthode diagnostique dans le cas d'un projet de construction d'un nouvel espace de travail. Les résultats ont permis aux gestionnaires et aux décideurs de tirer des conclusions importantes concernant l'aménagement intérieur.

Mots-clés : *Psychologie de l'environnement, Évaluation des environnements de travail, Confort, Satisfaction des occupants, Aménagement des aires de travail,* Planification de l'espace.

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I. INTRODUCTION

The study of work environments is a field of research that has emerged out of the discipline of environmental psychology. This paper outlines an approach to the evaluation of workspace by occupants, based on their experience of working in it, which draws on the theory and methods of this discipline. The paper first proposes a theoretical framework for users' environmental evaluation of their workspace, followed by a method for *in situ* user assessment of workspace. To situate this research, a brief overview of themes and issues in research into the psychology of work environments is first provided.

Work environmental evaluation is an area of research that has developed separately and distinct from studies of human psychology and behavior at work. Typically, evaluation research in this latter area is composed of a series of steps designed to measure the adequacy of employees' skills and abilities relative to the activities and needs of the companies that employ them (Dunnette & Hough, 1990, 1991). In this context, evaluation research comprises a variety of diagnostic tools designed to measure specifically the details of employees' skill areas. Recent competency evaluation studies have summarized the various issues addressed by such research (Aubret & Gilbert, 2003). In contradistinction to these initiatives, work environment evaluation looks primarily at the physical characteristics of the workplace as factors that affect human activities and interaction. Typically, work environment evaluation is composed of two interdependent aspects: first, the identification of ways in which ambient environmental conditions affect the performance of tasks, and second, how workers perceive and assess these conditions. In this way, work environment evaluation research can justify its orientation towards studying the resulting psychosocial effects. Work environment evaluation has evolved out of the largely North-American tradition of Post-Occupancy Evaluation (see below, Methods of Evaluation), and is not therefore concerned with evaluating workers or their tasks, but with the nature of the positive and negative influences of environmental factors on behavior and, specifically, with the qualities workers attribute to elements of their physical environment.

There are three general categories of studies of workspace. First, considerable work has been done on the influence of the work milieu on human performance. It is to this category that the greatest number of studies belongs, and it constitutes one of the most active areas of work environment evaluation. In this category, the environment is characterized as exclusively physical, and the environment-behavior relationship is analyzed using a deterministic model. For example, certain variables such as lighting, ventilation and noise can, under certain conditions, generate stress, which, in turn, has a negative effect on productivity (Evans & Cohen, 1987). The obverse of this argument holds that an environment conducive to the performance of work improves performance and morale (Dewulf & Van Meel, 2003).

The second category of research addresses the psychosocial dimensions of work environments in terms of human territoriality. This approach is characterized by two problem definitions: first, the psychosocial values represented by the space in which people work and corresponding to their place in the organization; and second, human interaction with the environmental milieu. Underlying these two approaches is a human behavioral schema that expresses itself in terms of the personalization and appropriation of space: marking territory and constructing boundaries of social and environmental control are areas of study included in the concept of territoriality (Fischer, 1989).

The third research category is environmental cognition. According to this approach, environment is evaluated according to the ways in which workers perceive and assess their workspace. These studies focus more specifically on the psychosocial impact of interior layouts; they constitute a way of defining the work environment based on workers' assessments (Vischer, 1986; Wineman, 1982). In focusing on cognitive processes, this research orientation links up with a well-established paradigm of social psychology, namely Lewin's field theory (1951). It also incorporates the study of users' perceptual differences and how workers' evaluation of their workspace affects in turn their perception of themselves at work (Somat, Tarquinio, & Dufresne, 1999).

The diagnostic approach to work environment evaluation described in this paper incorporates elements of all three areas of workspace research, although it is most easily identified as belonging to the first category (effects of physical environmental conditions on behavior) and, to a lesser extent, to the third (how workers perceive and assess physical environmental conditions). In the next section of this paper, a number of theoretical approaches to environmental evaluation, and specifically work environment evaluation, are outlined in order to provide a theoretical context for the diagnostic approach. The diagnostic method is subsequently described. Finally, a case study of the diagnostic method in use indicates how it can be applied in the field, and illustrates the various ways in which study results are used by practitioners (designers, managers, space planners) and researchers.

II. PROBLEM OUTLINE AND THEORETICAL OVERVIEW

The notion of environmental evaluation appeared in some of the first publications in the field of environmental psychology (Craik, 1966; Little, 1968); it refers to the processes whereby users know and judge their physical environment. The basic hypothesis states that the processes of knowing and assessing are linked not only to observable physical features, but also to the attitudes individuals have towards a particular space. Evaluation studies allow researchers to determine the qualities of an environment to the extent that its characteristics affect users' satisfaction or dissatisfaction. Over the years, particular attention has been paid to the cognitive and affective content of users' attitudes, which are habitually

expressed by a tendency to react positively or negatively towards specific environmental characteristics (Marans & Spreckelmeyer, 1981; Ornstein, 1999; Stokols, 1978; Wineman, 1986).

Many of the early studies of this type deal with users' attitudes and needs related to housing and the home. The goal of these studies is to better understand the effects of the built environment on users and to integrate these findings in the planning and design of future housing. This type of study was frequently carried out on government-subsidized housing built after the Second World War. At that time, important design decisions were made without taking into account the experiences, life-styles and attitudes of the social and ethnic groups who would reside in them. A large number of field evaluations were undertaken to inform architects and planners of the results so they would develop architectural solutions better adapted to users needs (Cooper, 1975; Després & Piché, 2000; Gans, 1967; Jacobs, 1961; Michelson, 1975; Preiser, Vischer, & White, 1991).

Another direction for environmental evaluation that has flourished in North America applies to public buildings of all types: libraries, prisons, courthouses, hospitals and the post office (Centre scientifique et technique du bâtiment et Plan, construction et architecture, 1990; Farbstein, 1997). Craik (1968) was one of the first to study environmental properties that generate perceived quality. His approach was expanded subsequently by numerous researchers (Carp & Carp, 1982; Craik and Zube, 1976; Moos, 1973). These studies have identified five types of environmental characteristic that determine users' perception of environmental quality. These are: physical-spatial attributes, type and numbers of objects and equipment, specific environmental features, functionality of the space, its institutional aspects, and the social context. The hypothesis underlying all these studies states that these various environmental properties can be measured in order to determine reliable predictors of user satisfaction with a specific physical environment.

A related approach to environmental research examines the person-environment relationship in terms of users' cognitive and affective processes; this tradition has tended to separate cognitive from affective categories. For example, cognitive processes are often invoked to explain the formation of cognitive maps (Downs & Stea, 1973); whereas affective processes are studied in terms of expressed pleasure, and users' sense of control or degree of dissatisfaction related to place (Russell & Mehrabian, 1978). Certain studies have shown that the emotional content of environmental evaluation can be interpreted as being itself perceived as an environmental quality (Russell & Ward, 1982). A better understanding of these two dimensions and how they affect users' appraisal of their environment at work is essential for analysis and interpretation of evaluation study results. A number of field studies examining the environment-behavior relationship at work have used simple satisfaction or preference ratings to measure the effects of environmental design on work, usually at the scale of individual performance (Davenport & Bruce, 2002). Some studies have linked low satisfaction ratings with the presence of stress, one of which found that people's feelings about the building in

which they worked had a stronger effect on their reported satisfaction than did the functional and measurable environmental characteristics of the building (Burke, 1990; Niemela, Rautio, Hannula, & Reijula, 2002).

As the field of environmental evaluation has matured, numerous empirical studies of user attitudes towards different environmental problems have been reported. Researchers have been obliged to come out of their laboratories to learn about person-environment connections in a variety of different contexts, and their studies have developed in different directions. Some studies examine the natural environment in relation to the exploitation of natural resources and the resulting pollution, noise, and nuclear hazards, for example. Research has looked both at people's attitudes towards these problems, and at negative effects on human health and well-being (Kromm, Probald, & Wall, 1973). This research orientation ultimately led the American government to define and require Environmental Impact Studies (EIS), so that the anticipated physical, economic and social consequences of new projects could be understood. More recently, researchers have turned to nature as an environmental element that humans need to thrive, mentally and physically. A growing area of study targets the effects of access to nature in the form of gardens on healing, especially in health-care environments, where access to and even views into gardens have had positive effects on rates of recovery from surgery and cancer (Cooper, Marcus, & Barnes, 1999; Tyson, 1998; Ulrich, 1991).

One well-established approach to environmental evaluation defines the place being evaluated as an interactive system composed of both physical and social elements. This model posits space as a resource in terms of its inherent potential to make any social system function: habitat, institutional environment, workspace (Lawton, 1982; Perin, 1970; Thiel, 1997). In applying this approach to work environment evaluation, researchers have examined links between workspace design and the organization of work, and attempted to demonstrate ways in which space can be considered an organizational resource to improve productivity (Fischer, 1989; Oseland, 1999; Seiler, 1984). In spite of difficulties defining and measuring productivity, links have been found between worker performance and mechanical ventilation rates, access to natural light, and aspects of the acoustic environment. Most studies of this nature consist in questioning occupants on their perceptions and judgments of workspaces in terms of their « perceived qualities ». Evaluation in this sense includes two essential elements: the functional characteristics of the space that lend themselves to measurement, and are considered factors influencing the performance of workers; and the qualities of a place that cause users to consider it satisfactory or unsatisfactory.

A number of work environment studies test users' satisfaction in reference to specific features of their work environment (Becker, 1990; Brennan, Chugh, & Kline, 2002; Hedge, 1991; Marans & Spreckelmeyer, 1981). According to this approach, environmental satisfaction is considered a prerequisite of job satisfaction and therefore of better work performance. An important advance in the field attempted to link environmental features not just with levels of satisfaction, but also directly

with the productivity of individual workers (Brill, Margulis, & Konar, 1985). This longitudinal study examined employee behaviour before and after an office move and attempted to measure the costs of worker productivity lost through poorly-designed or dysfunctional workspace. The results showed, among other things, that people working in open plan workstations may be more productive in enclosed offices. Subsequent studies have attempted to measure the economic value of workers' productivity increases that are considered to result from environmental improvements, such that the return on investment of an environmental intervention can be calculated (Brill & Weideman, 2001; Springer, 1986; Vischer, Canuel, & Castonguay-Vien, 2004). From this viewpoint, environmental evaluation of workspace may be construed more as psychosocial intervention than as research, and as such may also consider the interactive effects of environmental features in terms of the effects that workers' perceptions of workspace may have on their own sense of themselves and their abilities (Fischer, Tarquinio, & Vischer, 2004).

Many of the field studies that have been carried out on work-places cause researchers to confront conceptions of the physical environment that differ from their own, for example, those of designers, workers and managers. In other words, work environment evaluation is an activity affecting stakeholders whose evaluation of their space is determined by their status, position in the organization and task requirements; thus the process of evaluation is also a mechanism for revealing divergent experiences and points of view. Researchers seek to ensure the scientific validity of their results, managers want workers to be comfortable and productive, and designers and facilities personnel seek solutions to building problems.

In summary, the field of work environment evaluation can be characterized by a double orientation. Its theoretical aim arises out of experimental research in environmental psychology and seeks to validate perceived environmental quality as factors that facilitate (or not) work tasks; in this sense, evaluation can be defined as a function of the perceived congruence between individuals' needs and the possibilities offered by their space (Stokols, 1981). The other aim is more practical and consists of using evaluation as a diagnostic tool to assess the functionality of workspaces and to improve their effectiveness for users.

III. METHODS OF EVALUATION

Work environment evaluation has led to a range of methodological approaches. Generally, their aim is to determine indicators of quality of places where work is performed. Research studies typically focus on the effects of a range of environmental features on either users' qualitative judgments, or on quantitative measures of human performance. Two major methodological categories are presented below. They are known as: post-occupancy evaluation (POE), and building performance evaluation (BPE).

III.1. Post-occupancy evaluation

The term POE is generally applied to a case study of a single building, or part of a building, that is newly occupied, about which one seeks feedback from occupants. It may also be used to diagnose specific conditions in 'problem' buildings in order to make corrections, or in buildings where new workspace is being planned for employees in order to aid and inform the design process. Post-occupancy evaluation is therefore focused on user judgments and reports of their experiences relative to the space they occupy.

In most POE studies, the researcher seeks occupant responses to various questions concerning features of the work environment, for example furniture comfort, file storage, spatial orientation, and ambient environmental conditions (ventilation, lighting, thermal comfort). One of the first theoretical approaches to POE was advanced by Friedman, Zimring, and Zube (1978), in terms of designing both a structure and a process for the evaluation study that takes into consideration the context in which the building operates. Preiser and White (1988) describe a theoretical model to guide the design of a post-occupancy evaluation study by proposing three levels of intervention of increasing complexity. The choice of intervention depends on the resources available and the needs of decision-makers in each situation. More recently, Preiser (2001) has indicated that current approaches to POE "emphasize a holistic, process-oriented approach to evaluation, [in which] not only facilities, but also the forces that shape them (political, economic, social) are taken into account" (p. 9).

III.2. Building pperformance evaluation

The BPE approach incorporates Post-Occupancy Evaluation as one phase in a multi-phase process of feedback and evaluation. The BPE model is a method of ensuring that the user perspective is systematically incorporated into all phases of the planning, programming, design and construction process, as well as during building occupancy (Preiser & Vischer, 2004). In its application to environmental evaluation, BPE measures how users are affected by their physical context by focusing primarily on the performance of building systems. These include mechanical (ventilation, thermal comfort) electrical (lighting, communications) and structural (materials performance, energy consumption). Some BPE studies also include cost factors, initial as well as operating, which can be linked into life-cycle costing of existing and proposed buildings (Bon, 1989).

The BPE model of environmental evaluation attempts to match users' satisfaction and comfort ratings in a given environment with technical measures of ambient environmental conditions derived from calibrated instruments. Ventre (1988) coined the term "building diagnostics" as part of an effort to define a range of testing protocols in buildings that would

yield data of a type and legibility that facilitate comparison with human comfort ratings. Extensive data collection and analysis by Public Works Canada (1985) on energy consumption, thermal comfort, lighting and acoustics was accompanied by detailed questionnaire surveys of occupants in five federal government office buildings. Results indicated that few of the data-gathering instruments yielded data that corresponded easily to user comfort ratings, primarily for two reasons. *First,* instruments measure specific conditions independently of each other (for example, volatile organic compounds in indoor air samples) whereas people's experiences are based on experiencing all environmental attributes together and simultaneously (for example, temperature and ventilation), and their judgments are made accordingly. *Second,* instruments are limited temporally by either sampling actual building conditions (snapshot) or recording ongoing variation in the conditions being measured over a prolonged time period (data recorders). Human users, on the other hand, draw on experiences outside the immediate time-frame of the present to make their summary judgments of comfort conditions, thereby referring to a context outside the scope of conventional instrumentation (Vischer, 1993).

III.3. The diagnostic method

The diagnostic approach to evaluating workspace, known as Building-In-Use Assessment, derives from both the post-occupancy (POE) and the building performance (BPE) traditions of evaluation (Fischer & Vischer, 1998; Vischer, 1989; Vischer, 1996; Vischer, 2001). It was developed to respond in part to the limitations of POE by going beyond simple user satisfaction measures, to gather feedback from users linked more directly with the performance of building systems. The diagnostic approach makes human judgements the focus of study, thereby avoiding the temporal and calibration limitations of instrument-based data collection. However, if appropriate, measurements of building systems performance are carried out as a follow-up procedure to help understand the meaning behind the feedback yielded by users on their perceptions of building conditions.

Traditionally human comfort measurements have been linked to individual building systems (lighting, ventilation, temperature) in order to enable standards of comfort and health to be established, and thus to guide the design of buildings. The theoretical basis for Building-In-Use (BIU) Assessment is analysis of users' functional comfort. Functional comfort is defined by the degree to which workers can perform their tasks in the place they occupy; it is derived from notions of comfort as defined by environmental standards, with the added precision that users' experience of comfort varies with the requirements of the tasks they have to perform. Therefore one of the outcome measures of diagnostic evaluation is whether people can perform tasks easily, with difficulty, or not at all in the workspace they occupy. In this way, the results of BIU Assessment, a building-oriented evaluation of the work environment, can

eventually be linked more systematically with the psychologically-oriented evaluation of tasks and skills in the workplace.

The diagnostic approach was designed to learn more about how people work and how space affects work performance, as well as to understand the impact of changing office technologies on the performance of work and space-use. Combining the best of POE and BPE methodologies enables researchers to develop a more detailed grasp of human comfort *in situ,* and how this is affected by buildings and building systems. Furthermore, a major purpose of Building-In-Use Assessment is to provide a measurement tool for managers, designers and planners that provides a simple but accurate profile of user comfort in a given work environment. One possible application of results is to define follow-up actions for correcting problems and improving environmental quality at work.

IV. BUILDING-IN-USE ASSESSMENT: THE DIAGNOSTIC APPROACH

IV.1. ORIGINS AND DEVELOPMENT OF THE METHOD

Building-In-Use Assessment comprises a short, standardized questionnaire survey of office building occupants that allows respondents to rate how comfortable they are according to seven critical dimensions of the interior work environment. This tool was developed from a comprehensive survey of human comfort in office buildings that was carried out in the 1980's in five buildings in Canada, in which 35 5-point scales covering all possible aspects of human comfort at work were administered to some 2,300 government office workers. The different building surveys were merged into a single database containing survey data from all the buildings and digitally stored in statistical analysis software.[1] Each of the comfort scales was termed a "variable" and submitted to a series of exploratory factor analyses. Six analyses were performed, combining three Factor Analysis methods with two rotation techniques. Principal Factor Analysis, Iterated Principal Factor Analysis and Maximum Likelihood Factor Analysis were all performed and their factors rotated with Varimax and Equamax rotations (Dillon & Vischer, 1988). The proportions of variance and factor loadings retained were those obtained from the Iterated Principal Factor Analysis with Varimax rotation. The seven factors were named Air Quality, Thermal Comfort, Spatial Comfort, Privacy, Lighting Quality, Office Noise Control and Building Noise Control, and together they account for 45% of the variance in the original scales. The component scales with factor loadings above 0.50 are listed in TABLE 1.

1. Statistical Analysis System (SAS).

TABLE 1

Component scales with varimax rotation loadings above 0.50

Liste des facteurs accompagnés des variables
ayant une association au-delà de 0,50

Factor	Scale variable	Varimax rotation loading
1. Air Quality	Air movement	0.88
	Air freshness	0.85
	Ventilation comfort	0.79
	Odours	0.50
2. Thermal Comfort	Cold temperatures	0.77
	Temperature Comfort	0.61
	Temperature shifts	0.60
	Drafts	0.58
3. Lighting Quality	Electric lighting comfort	0.67
	Glare from lights	0.66
	Too bright	0.55
	(Colours)	0.47
4. Spatial Comfort	Amount of space in workspace	0.65
	Work storage	0.65
	Furniture arrangement	0.59
	Personal Storage	0.56
5. Privacy	Voice Privacy	0.80
	Telephone Privacy	0.73
	Visual Privacy	0.50
6. Office Noise Control	General office noise levels	0.87
	Specific office noises	0.82
	Noise distractions	0.75
7. Building Noise Control	Noise from the lights	0.68
	Noise from air handling systems	0.55
	Noise from outside the building	0.55

To validate the factors, separate factor analyses were performed on each of the buildings; essentially the same factors emerged with minor variations. Subsequently, simplified factor scores were calculated using the means of the scales (minimal set) presented in Table 1, that is, with factor loadings of 0.50 and above. These factor scores were shown to be highly correlated to those calculated using the larger number of scales with factor loadings of 0.30 and above (large set), thus permitting the

minimal set of scales to be retained and used in subsequent surveys to predict factor scores.

In a second stage of analysis, the minimal set of scales was used to calculate the mean and standard deviation for each of the seven factors. These are presented in Table 2.

TABLE 2

Mean score and SD for each of the seven factors

Liste des facteurs avec les moyennes et écarts types

Factor	Mean score (between 1, low comfort rating, and 5, high comfort rating)	Standard deviation
1. Air Quality	2.6	1.0
2. Thermal Comfort	2.9	1.0
3. Lighting Quality	3.2	0.9
4. Spatial Comfort	3.3	0.9
5. Privacy	2.3	1.1
6. Office Noise Control	2.9	1.1
7. Building Noise Control	4.3	0.7

A series of analyses of variance were performed to determine significant variation on the seven factors among the five buildings. Results showed small differences in factor scores, although the large sample size showed these to be highly significant. However, scores were consistent across buildings for five of the seven factors. The two factors that varied were Office Noise Control and Building Noise Control, and differences could be explained by variations in building use and interior configuration. There were also significant and meaningful differences between factors. These differences, as well as the low level of variation, reveal the utility of the factors as real constructs underlying occupant response patterns to building conditions.

The seven simplified factors were used to construct a model to predict three criterion variables: workstation satisfaction, a global rating of users' satisfaction with their work environment; workability, a variable describing occupants' ratings of how much the environment helps or hinders the performance of their tasks; and job satisfaction. Table 3 shows the results of a multiple regression procedure for determining the best combination of factors to predict the criterion variables.

TABLE 3

Results of regression to test predictability of three criterion variables from the seven factors

Résultats de la régression pour prédire les trois variables globales à partir des sept facteurs

Criterion Variable	R^2	F	p	Significant predictors
Workstation satisfaction	0.24	70.14	0.0001	Spatial comfort ($t(4) = 10.83$, $p < 0.00$) Privacy ($t(5) = 6.49$, $p < 0.00$) Air Quality ($t(27) = 3.32$, $p < 0.00$)
Environmental workability	0.40	150.63	0.0001	Spatial comfort ($t(2) = 14.94$, $p < 0.00$) Office Noise Control ($t(3) = 9.41$, $p < 0.00$) Privacy ($t(4) = 7.54$, $p < 0.00$) Air Quality ($t(9) = 4.94$, $p < 0.00$)
Job satisfaction	0.14	37.27	0.0001	Privacy ($t(4) = 7.14$, $p < 0.00$) Spatial Comfort ($t(6) = 5.47$, $p < 0.00$) Lighting Quality ($t(8) = 4.95$, $p < 0.00$)

Subsequently, a short survey questionnaire was designed using the minimal set of scales and used to collect data from users in office buildings. Since the development of this instrument, over one hundred office buildings have been surveyed and results stored in the Building-In-Use database. The seven factor scores yielded in each case provide the Building-In-Use Profile of that building, or part of the building. The factor scores from each building are compared with the original scores in the BIU database (BIU norms), and the difference between scores and norms tested for significance in order to help planners, managers and designers determine priorities for follow-up action. Where a building's scores are significantly lower than the norms, some corrective or remedial intervention is called for. Consequently, additional information is usually required to determine the causes of occupant discomfort or building system problems. This may be provided from a planned and targeted series of building instrument measurements, by follow-up meetings with or questioning of users, and-or by closer expert examination of building systems.

Some companies and government organizations have developed their own BIU database from surveying large numbers of their own employees,

the results of which have enabled them to calculate their own normative scores as a basis for comparison. Factor scores from each individual building survey could then be compared to their own norms rather than to those in the reference (BIU) database. The BIU database norms were updated some years after the original research was completed, using data from office buildings surveyed more recently and therefore having more office technology, updated ventilation systems and modern lighting. It must be emphasized that this approach does not evaluate whether performance of a building on the factors is good or bad, right or wrong. Rather, the comparative approach will allow building owners and managers to determine whether the performance of a sample building is better, worse or the same as that of known buildings.

The process used to collect data on the seven factors is as follows. A target group of users is identified (a department, a floor, or a whole building) and letters are sent out to advise them of the timing and purpose of the questionnaire survey as well as of how the results are to be used. About one week later, the questionnaire (comprising the 24 "minimal set" scales plus two global rating variables) is distributed to all or to a randomly-selected sample of the targeted users with the instruction to complete the survey within twenty-four hours (see table 4). Respondents are typically asked to draw on their long-term experience of comfort levels in their workspace and to make an assessment of how effectively these aspects of the work environment support (or fail to support) their tasks. Respondents are not asked for details of their tasks at this stage, although this may well be an area of follow-up inquiry during the stage of results interpretation. Each completed response is entered into a PC-based statistical analysis system, and scores on each of the seven factors are calculated and compared to the seven norms.[1] As the objectives of the research are inquiry into users' perceptions of environmental conditions and relating these to actual features of the building and its systems, no data are collected on individual differences such as length of time in the building, variations in job type and technology use, and psychosocial aspects. The survey can be administered manually (by dropping off and picking up paper questionnaire forms) or digitally (by providing access to the questionnaire through individual, networked computers).

As a tool for simple measurement of general comfort levels in the work environment, this survey questionnaire has been used to measure functional comfort in a wide range of situations. Some companies use the results to set priorities on building maintenance and renovation; some use the diagnostic approach to respond to long-term employee complaints; others have applied results to the design of new or renovated workspace for employees. The survey has also been used to compare responses from occupants with new furniture or new lighting to comfort ratings from other areas. Data collected before a move or major building change can be compared to occupants' comfort ratings after the change. Some companies survey once a year to monitor fluctuations in comfort ratings;

1. Statistical Package for the Social Sciences (SPSSPC).

TABLE 4

Survey form/Questionnaire

QUESTION	ANSWER: FROM 1 (NEGATIVE) TO 5 (POSITIVE)	QUESTION	ANSWER: FROM 1 (NEGATIVE) TO 5 (POSITIVE)
1. Temperature Comfort	UNCOMFORTABLE... COMFORTABLE	2. How cold it gets	TOO COLD... COMFORTABLE
3. How warm it gets	TOO WARM... COMFORTABLE	4. Temperature shifts	TOO FREQUENT... CONSTANT TEMPERATURE
5. Drafts	TOO FREQUENT... COMFORTABLE	6. Ventilation Comfort	UNCOMFORTABLE... COMFORTABLE
7. Air freshness	STALE AIR... FRESH AIR	8. Air movement	STAGNANT AIR... GOOD CIRCULATION
9. Odours	UNPLEASANT... NO ODOURS	10. Dry air	TOO DRY... COMFORTABLE
11. Noise distractions	TOO DISTRACTING... COMFORTABLE	12. Background noise levels	TOO MUCH NOISE... COMFORTABLE
13. Specific noises (voices and equipment)	TOO NOISY... COMFORTABLE	14. Noise from air systems	TOO NOISY... COMFORTABLE
15. Noise from outside the building	TOO NOISY... COMFORTABLE	16. Noise from lights	UNCOMFORTABLE... COMFORTABLE
17. Furniture comfort	UNCOMFORTABLE... COMFORTABLE	18. Work storage	INADEQUATE... ADEQUATE
19. Personal storage	INADEQUATE... ADEQUATE	20. Amount of space in your workstation	UNCOMFORTABLE... COMFORTABLE
21. Furniture layout	UNCOMFORTABLE... COMFORTABLE	22. Visual privacy	UNCOMFORTABLE... COMFORTABLE
23. Conversation privacy	UNCOMFORTABLE... COMFORTABLE	24. Telephone privacy	UNCOMFORTABLE... COMFORTABLE
25. Electric lighting	UNCOMFORTABLE... COMFORTABLE	26. How bright it gets	TOO BRIGHT... COMFORTABLE
27. Glare from lights	UNCOMFORTABLE... NO GLARE	28. Colours	UNPLEASANT... PLEASANT
29. Esthetic aspects of workspace	UNPLEASANT... PLEASANT	30. View from windows	INADEQUATE... ADEQUATE
31. Maintenance and repair	INADEQUATE... ADEQUATE	32. Security of the building	INADEQUATE... ADEQUATE
33. Workspace helps or hinders work	MAKES WORK DIFFICULT... MAKES WORK EASIER	34. Overall satisfaction	DISSATISFIED... SATISFIED

others survey users in several different buildings, and then compare them to each other to determine where (and if possible, why) people are more or less comfortable.

IV.2. Case study: example of BIU assessment applications to decision-making

An analysis of how the diagnostic approach was used in one particular instance shows not only that the results can be compared before and after an environmental change, but also how the findings of the evaluation study are meaningful to researchers, designers, corporate managers and employees. In this example, a large financial services and investment company occupying offices in several different buildings in downtown Montreal, Quebec, began work on a new, state-of-the-art headquarters in which all the different groups and subsidiaries would be located together under one roof. Several innovative features were planned for the new building, including a larger percentage of open-plan workstations and fewer private offices, more collaborative space and places to meet, use of interior glass to ensure transparency, and abundant natural light. In order to test out some of the new concepts, one department of 25 people volunteered to move out of their offices and into an experimental workspace in another building designed to simulate the furniture, lighting and dimensions of their future offices. Their responses and comments were to provide feedback to the planners and designers on correcting problems, making improvements and evaluating furniture prior to specification and purchase.

The diagnostic survey questionnaire was used in the group's existing offices before the move into the experimental workspace. As well as extensive interviews and observation, the questionnaire survey was re-distributed to occupants some six months after their move into the new space. The comparison of scores on the seven dimensions of functional comfort is shown below.

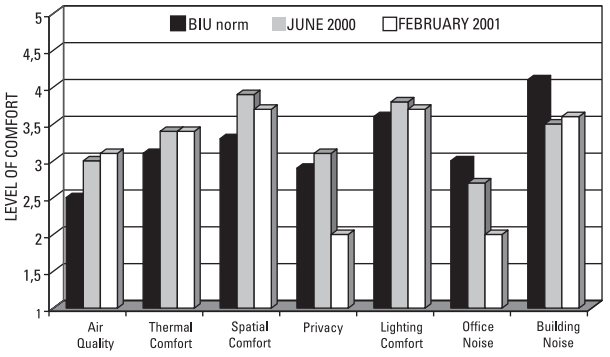

Fig. 1. — *Comparison of BIU scores with BIU norms before and after office move*

Comparaison entre les niveaux de confort avant et après déménagement, avec les normes de la performance de référence

This figure compares the BIU database norms with the scores received from the first office, before workers moved into the test space (June 2000). In addition, the figure shows the scores received from the same group of employees after six months in their new workspace (February 2001). The pre-move office environment rates above the BIU norms on all dimensions except Office Noise Control and Building Noise Control. One can infer from these results that, while considering it overall a high quality office environment, this group has a problem with noise. In the new office, after the move, Air Quality and Building Noise Control have improved slightly, with Air Quality again being higher than the BIU norm, and Building Noise Control staying below the BIU norm. The dimensions of Privacy and Office Noise Control are considerably worse in the new office than in the old one, and are significantly below the norm for functional comfort.

These results are not surprising for employees moving from private, enclosed offices to largely open plan workspace. It is reasonable to suppose that people who are accustomed to solitude and enclosure will take time to adapt to a more open environment. In addition, the few remaining private offices in the experimental office-space are both a smaller size than previously, and enclosed by full-height, demountable partitions rather than constructed walls. For the occupants, therefore, behavior such as using hands-free telephones, holding meetings in their offices, and talking loudly on the telephone, increased the overall noise level and disrupted co-workers.

These results were useful in several ways. First, the project manager and design team took note of these results in the placement and orientation of offices and workstations, and also in the selection of furniture and equipment to ensure the highest possible level of acoustic protection. In addition, sound pressure meters were brought in to take spot measurements of background sound levels, in order to determine whether the new under-floor ventilation system was too noisy. The positive lighting comfort rating helped the client decide to install low levels of indirect lighting throughout the new building, with bright desk lamps on the worksurface. Managers used the results to prepare employees from other departments for moving into the new building, for example, by finding ways of reducing noise in the new, open environment. From the research perspective, the results confirmed hypotheses about users' adaptation behavior and the transition from private enclosed offices to open plan workstations with separate rooms for collaborative work, for example, that some behavioral adjustment is necessary to adapt to an open work environment. In sum, the diagnostic evaluation served a valuable purpose for designers, client and project manager, enabling appropriate interventions to assure a high level of functional comfort in the new office building.

IV.3. Recent updates and applications of the method

The Building-In-Use Assessment method of work environment evaluation has been in use for about ten years. A recent study was undertaken to update and enrich the number of functional comfort

dimensions in view of the social and technological changes in the workplace that have taken place during this period of time. In addition, the survey questionnaire needed to be enlarged according to the new functional comfort criteria to be developed. A recent study of 520 employees of an insurance company in seven office buildings in Quebec, Canada, indicates that the seven basic dimensions of human

TABLE 5

Revised factors with scale variables with loadings of 0.60 and above

Liste des nouveaux facteurs avec les variables
ayant une association au-delà de 0,60

Factor	Scale variable	Varimax rotation loading
1. Workstation Comfort	Adequate work surfaces	0.81
	Work storage	0.84
	Dimensions of workstation	0.80
	Personal storage	0.65
2. Thermal Comfort	Temperature comfort	0.83
	How cold it gets	0.83
	Drafts	0.71
	Temperature shifts	0.70
3. Air Quality	Air movement	0.80
	Air freshness	0.76
	Dryness of air	0.65
4. Privacy	Voice privacy	0.82
	Telephone privacy	0.81
	Visual privacy	0.70
5. Lighting Quality	How bright it gets	0.79
	Electric lighting comfort	0.78
	Glare from lights	0.76
6. Noise Control	General background noise levels	0.82
	Noise distractions	0.81
	Specific noises from voices and equipment	0.77
7. Spatial Comfort	Colours	0.70
	Chair comfort	0.67
	Esthetics of the work environment	0.63
	Furniture comfort	0.60
8. Collaborative Work	Places to meet coworkers	0.77
	Places to meet visitors	0.73
	Space for working together	0.60
9. Daylighting	Natural light	0.89
	View from windows	0.89
10. Safety	Building safety	0.88
	Personal safety	0.88

comfort at work remain largely unchanged, although the scales from which they are composed vary slightly (Vischer, McCuaig, Melillo, & Nadeau, 2003).

In this study, a total of 53 questions (the 35 original scales plus a series of new ones related to computer use, building maintenance, aesthetic appearance, and collaborative work opportunities) were administered to a stratified random sample of workers in open plan workstations. The results were again submitted to a series of factor analyses, in addition to Principal Components Analysis. The retained solution (Principal Components Factor Analysis with Varimax rotation) generated 14 factors, of which 10 were retained. Table 5 lists the scales having a factor loading of 0.50 and above, related to each factor.

In comparing this table with Table 2, it can be seen that whereas the first set of seven factors were limited to users' assessment of ambient environmental conditions, the updated set of factors –now numbering ten– has expanded to include issues of computer use, working collaboratively with co-workers, and overall comfort and safety in the building. In addition, factor scores generated by the factor analysis procedure were used to calculate mean scores or norms on the ten new factors. These are reported in Table 6.

TABLE 6

Mean factor score for each of the ten factors

Liste des nouveaux facteurs et moyennes

New Factor	Mean score (between 1, low comfort rating, and 5, high comfort rating)
1. Workstation Comfort	3.6
2. Thermal Comfort	3.2
3. Air Quality	3.1
4. Privacy	2.8
5. Lighting Quality	3.9
6. Noise Control	2.8
7. Spatial Comfort	4.2
8. Collaborative Work	3.5
9. Daylighting	3.0
10. Safety	4.3

The results indicate that, overall, users' comfort ratings are somewhat higher than they were in government buildings in the 80's. This is likely due to better building ventilation and more ergonomic furniture, as well as modern lighting designed to accommodate screen-based work. However, simple improvements in baseline comfort scores do not ensure

smaller differences between building scores and norms: significant differences between the norms and the scores for different groups of users indicated the need for follow-up action in certain buildings. Moreover, a number of psychosocial variables were included in this study, and analysis determined that factors such as job-rank (professional, technical or clerical), length of time in the job, and type of workspace previously occupied (small open workstation, large open workstation or private enclosed office) all affected users' comfort ratings. Respondents in the professional category had significantly more negative ratings of their privacy (specifically, acoustic privacy) than those in the technician and administrative categories ($\chi^2(15, N = 509) = 34, p < 0.00$). It was also found that employees who had worked there longer were more likely than the others to bring personal objects into their workspace ($\chi^2(16, N = 501) = 31, p < 0.00$). And workers who had moved out of enclosed private offices reported lower overall comfort levels than those who had previously occupied open workstations ($\chi^2(9, N = 502) = 23.4, p < 0.02$).

V. DISCUSSION

The diagnostic approach to evaluating work environments is based on an integrated model of environmental evaluation. The model combines elements of post-occupancy and building performance evaluation in an interactive approach identified as the functional comfort model. The factors derived from factor analysis of large amounts of user survey data are considered as significant dimensions of functional comfort, that is, as interdependent components of the work environment for users; they have an interactive effect on behavior, similar to other, related aspects of users' environmental perception. According to this model, the psychological impact of the work environment is not studied, as in previous evaluation research, as an additional determining influence on or stimulus of behavior at work (for example, the effects of noise levels on productivity). The psychological impact is in fact redefined according to the judgments users make of different environmental features of the space in which they work.

The results of the diagnostic approach to evaluation, orient researchers, therefore, towards drawing conclusions on two, complementary levels: first, the qualitative nature of the physical environment, which becomes apparent through users' perceptions of a place's qualities; and second, the quantifiable level of functional comfort experienced by the user. In addition, the model integrates two dimensions that are typically dissociated in other evaluation research: the technical data yielded by measures of environmental features, and cognitive-psychological data yielded by the user survey. The results yielded by the diagnostic method illuminate an essential dimension of users' experience of the work environment; the process of evaluation is itself a process

whereby users qualify the adequacy of both the technical and the psychosocial functioning of their environment.

In conclusion, the diagnostic model of work environment evaluation has the advantage of elaborating on previous models constructed around subjective measures of occupant satisfaction by applying a more sophisticated definition of occupant behavior, namely the concept of 'comfort' related to task performance. User comfort is a complex concept with physical, psychological and functional attributes. Future trends in environmental evaluation, as suggested by the results of the updated research described above, will look for more systematic patterns of psychosocial responses to environmental conditions in the workplace.

Although the diagnostic data collected from users do not include data on tasks or skills, the possibility of including information of this type at the stage of results interpretation offers the possibility of interesting future research directions connecting work environment evaluation with established job evaluation research activities. Making the link with workers' tasks would eliminate the need for measuring worker productivity as a separate and distinct outcome variable, as superior task performance is clearly an indicator of productivity.

Finally, the diagnostic approach offers the possibility of following up on users' environmental feedback with instrument measurements oriented to the feedback received. Such a targeted use of technical data on building performance will increase the precision of instrument measurements, and in the long term will contribute to our understanding of how to reconcile human and instrument feedback on the performance of the work environment.

VI. CONCLUSIONS

From its inception, the field of environmental evaluation has relied on direct questioning of users to provide data on the suitability and appropriate-ness of the environment they occupy. In the context of evaluating environments for work, there are an increasing number of ways in which occupant survey instruments have been developed as tools for assessing how well people can work in the offices they occupy, as well as inquiring into how employees' psychological processes adapt to and are affected by environmental conditions at work. Although efforts to determine systematic links between user feedback and instrument measurement of environmental conditions have been limited and not always successful, the diagnostic approach as exemplified by Building-In-Use Assessment demonstrates that the two approaches to environmental measurement can and should be complementary.

However, work environment evaluation studies have tended to focus on occupant satisfaction as the single outcome variable, thus limiting their value in the research arena. Researchers have supported this approach by assuming a connection between environmental satisfaction and job

satisfaction, and, by implication, that reduced levels of satisfaction generate stress. As a result, most direct questioning of office occupants has examined either general user satisfaction, or comfort related to a specific ambient condition. While this may work for diagnosing discomfort and dissatisfaction with a view to solving building problems, it has added little to our understanding of how people perceive their workspace and the of effects of their social relationships and self-image on these perceptions.

Future approaches to environmental evaluation will go beyond the practical concerns of designing and operating office buildings. The diagnostic approach will increasingly consider the range of factors, both social and physical, that affect employees' perceptions, and therefore their judgments of the spaces they work in. This shifts the emphasis of environmental evaluation beyond the immediate range of the knowledge that designers, managers and builders need to create comfortable and effective workspace. Future evaluation research will need to refine methodological approaches that will be able to acquire more and better knowledge about how space affects people at work. This knowledge will not simply be applied to the manipulation of the physical environment to make employees more productive, but will ensure a better understanding of human behavior at in the workplace. This research will enrich our knowledge of the various dimensions of the person-environment relationship, and ultimately will enable society to define more precisely the meaning of work –and of the buildings where work is done.

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SUMMARY

The paper provides an overview of environmental evaluation as a field within Environmental Psychology. The evaluation of work environments is a relatively new area of interest. The paper traces the development of certain methodological approaches and theoretical models. These tend to distinguish between user evaluation, referring to cognitive and psychosocial influences on users' perceptions of the work environment, and technical-functional building assessments that evaluate the performance of building systems. The diagnostic approach reconciles these approaches by measuring users' functional comfort with a survey questionnaire, and then using results to guide technical measurements, as necessary. A case study is offered to demonstrate how this system works and ways in which managers, designers and building owners can use the results to increase occupant comfort at work.

Key Words: *Environmental Psychology, Work Environment Evaluation, Building Performance Measurement, User Survey, Functional Comfort, Office Design, Space Planning.*

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