Comfort and Control in the Workplace

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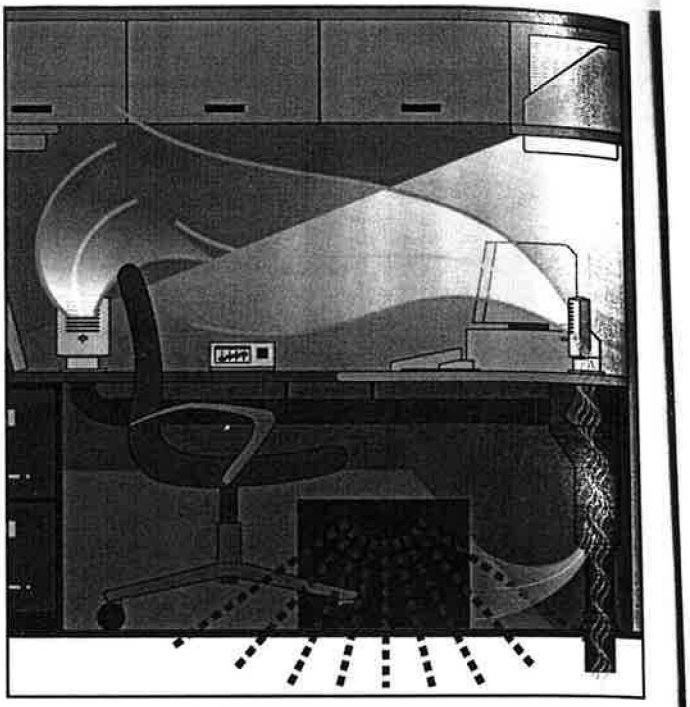

The supplied-air environmentally responsive workstation system uses conditioned air from HVAC systems, and mixes it with ambient air. Units allow for control of radiant heat, temperature, airflow, background noise masking, and task lighting.

While the metrics for measuring productivity and environmental comfort are not standardized, there is growing evidence which demonstrates that comfort of one's own individual environment in the workplace has a positive impact on productivity. Just as important as the physical measures of comfort is the perception of control of one's own environment in the workplace.

Scientific studies indicate that productivity increases as much as 15% when workers are satisfied with their environment. In addition, current case studies show that thousands of dollars can be realized from increased productivity.

The technologies exist both on the large scale with increasingly sophisticated building automated systems and on the small scale with environmentally responsive workstation (ERW) systems to provide maximum comfort and control for occupants.

This article will concentrate on positive productivity gains connected to environmental comfort and individual control in the workplace as well as field-proven benefits associated with using ERW systems, especially when used in an open-floor plan setting.

A Positive Link

ERW system components, which are installed in individual work cubicles as well as offices, usually feature a desktop control panel with adjustable temperature, lighting, airflow and background noise-masking equipment that has been integrated with an occupancy sensor.

Research supports a correlation between environmental comfort and worker productivity in open office settings. In the past 15 years, dozens of scientific studies on productivity in the workplace prove that individuals respond very differently to their environment.[1] Dissatisfaction with indoor environmental conditions has been routinely documented in studies conducted in both North America and Europe.[2] Many managers have already recognized that increased environmental satisfaction helps improve employee productivity.[3]

When environmental factors are carefully designed and controlled to meet the needs of employees, studies have reported productivity gains in the range of 15% for managerial employees and 17% for clerical employees.[4] According to data obtained through research, a 2.8% productivity gain is possible in an open-office setting when employees are given control over their environments.

In fact, the 2.8% improvement is at the low end of what researchers have found. In one study predicting control on productivity, providing employees with ERWs they individually controlled showed productivity increases of as

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much as 8.6% depending on the type of work.[5]

The low-end 3% productivity gain would translate into $2,925,000 per year of productivity improvements in the average 500,000 ft^2 (46 000 m^2) office. This amount is calculated by documented information which estimates at minimum that 1% of the salaries in an average 500,000 ft^2 (46 000 m^2) building amounts to more than $975,000.

This conservative figure is arrived at by using an average hourly pay of $11.54, adding an additional 30% for the cost of benefits, and assuming an average occupancy density of 154 ft^2 (14 m^2) per person.[6] The cost per square foot of salaries in an average facility is anywhere from eight to 13 times the cost per square foot of the building operations, often topping $200 per square foot, per person, per year.[7]

Small Improvements Can Net High Dividends

If the low-end 3% productivity gain can realize nearly $3 million per year of productivity improvements, it can be justified that improvements to the workplace environment are highly cost-effective ways of enhancing employee satisfaction. These improvements also have low payback periods when the cost of salaries is factored into the equation. Because environmental satisfaction means increased productivity, even a small improvement can pay huge dividends for companies and organizations with employees working in open office environments.

For decades, the industry standard for buildings has been set to satisfy 80% of occupants at any one time through a single temperature set point. As a result, conventional environmental systems are designed to satisfy the needs of the "average" person. Zones of conditioned space often serve dozens of people. Yet no one is "average."

Thermal conditions, airflow, lighting and background noise masking for privacy needs are significantly different—and also vary over the course of a day. Individual differences in reactions to environmental conditions can be because of age, gender, personality, metabolism, allergy or hypersensitivity.[8] For example, older employees typically need more light.[9] Women generally prefer warmer temperatures.[10] In addition, because tasks for some employees require them to be at

Facets of Environment	Bottom Line Measures		
	Environmental Satisfaction	Ease of Communication	Job Satisfaction
Enclosure	◆	◆	
Layout	◆	◆	
Furniture	◆	◆	◆
Noise	◆	◆	◆
Flexibility	◆	◆	◆
Participation	◆		◆
Comfort	◆		◆
Communication	◆		◆
Lighting	◆		◆
Temp/Air Quality	◆		◆
Floor Area		◆	◆
Privacy	◆	◆	
Status	◆	◆	
Pathfinding	◆	◆	
Display	◆		
Appearance	◆		
Occupancy		◆	
Windows	Possibly		Possibly

(◆ Indicates Measurable Facet)

Table 1: Buffalo Organization for Social and Technological Innovation (BOSTI) study.

Facet	Managers		Prof/Tech		Clerical	
	Annual Value	NPV 5 Yrs	Annual Value	NPV 5 Yrs	Annual Value	NPV 5 Yrs
Noise	472	1,789	282	1,068	148	560
Temp. Fluctuation	270	1,023	162	613	85	322
Glare	275	1,023	165	625	87	329
Comfort	•	•	234	886	•	•
Relocation Freq.	450	1,705	271	1,026	142	538
Enclosure (Anatomy)	3,423	12,971	2,606	9,873	1,438	5,447
Layout (Physiology)	2,491	9,438	1,646	6,236	1,046	3,964

(NPV = Net Present Value. The greater the NPV number, the greater the problem.)

• = Does not apply

Table 2: Improvement to Facet: annual dollar value impact of various environmental factors on each job function.

their desks for much longer periods than others, the impact of these comfort level variances are not equal.

One of the more carefully documented studies on increases in productivity as a result of improved environmental satisfaction is the West Bend Mutual Insurance Company. This study examined 300 employees, and was based on existing internal productivity measurements.[11] At West Bend, ERWs provide individualized environmental conditioning and allow workers to easily adjust conditions to their liking at any time. Study results document that productivity directly tied to the ERWs increased 2.8%. Productivity dropped 12.8% when ERWs were disconnected as a test.

Dissatisfaction Growing

Dissatisfaction with office air quality and comfort, which has a direct effect on productivity, is as high as 60%,[12] according to some studies. People are less motivated and therefore less productive. In the case of comfort, dissatisfied employees place a greater burden on the facilities management staff to correct problems, which distracts them from other tasks such as preventative maintenance.

A Glance at Other Key Studies

An understanding of the high points of five other studies will be helpful when evaluating an ERW system installation. In quick succession, this data includes a 1983 study by Merck which showed a 43% dissatisfaction with HVAC and 20% dissatisfaction with lighting;[13] a 1988 study by Public Works Canada that put HVAC at 2.8 and Privacy at 2.3 on a scale of zero to five with zero being the most negative;[14] a 1989 Building Operators and Managers Association study that showed HVAC to be the number one tenant problem;[15] a 1989 Lou Harris office survey that discovered 28% of employees are not happy with their workspace quality;[16] and a 1992 Social Security Administration study that showed 56% to 89% of these government workers recognize HVAC is a problem.[17]

Conversely, greater satisfaction can mean fewer maintenance calls. While costs vary, costs may average $75 to process a call and up to $375 in staff time to investigate HVAC complaints.[18]

Another important factor causing dissatisfaction in the workplace is noise. A recent article in *Today's Facility Manager* cites a study by the American Society of Interior Designers (ASID) that found noise reduction to be a major concern of office workers, 70% of whom said they would be more productive if their offices were quieter. "It's interesting to note," the article states, "that issues related to noise are more evident and frequently more disruptive in open plan offices than in any other work environment.

As this article shows, office worker productivity is affected by environmental conditions. Numerous studies show that investing in the indoor environment can be justified on the basis of productivity improvements alone (see *Table 8*). To bridge the gap between research and solutions, the results of numerous studies that correlate comfort and productivity have been organized into four general categories: Thermal Comfort, Lighting, Lack of Individual Control, and Background Noise (Acoustics).

Examining Key Resources

Several of these resources include classic studies and are most important for the present discussion for showing the relationship between environmental satisfaction, control and productivity. These include the BOSTI Study (1984), a survey of The Office of the Environment in the United Kingdom, a report by David Wyon of the National Institute of Occupational Health, Copenhagen, Denmark and a review of studies by Mao-Lin Chiu of the Department of Architecture at Carnegie Mellon University.

Facet	Managers		Prof/Tech		Clerical	
	Annual Value	NPV 5 Yrs	Annual Value	NPV 5 Yrs	Annual Value	NPV 5 Yrs
Noise	850	3,221	509	1,928	267	1,011
Temp. Fluctuation	692	2,281	361	1,367	189	716
Glare	194	735	116	439	61	231
Comfort	•	•	701	2,656	•	•
Relocation Freq.	471	5,574	880	3,334	461	1,746
Enclosure (Anatomy)	2,568	9,729	1,954	7,405	1,079	4,087
Layout (Physiology)	•	•	•	•	•	•

• = *Does not apply*

Table 3: Cost of Decline in Facet: Annual dollar value impact of various environmental factors on each job function.

Value of Facets Taken Together	Managers		Prof/Tech		Clerical	
	Annual Value	NPV 5 Yrs	Annual Value	NPV 5 Yrs	Annual Value	NPV 5 Yrs
	6,316	23,931	4,650	17,668	3,042	11,526
% of annual salary	15%		15%		17%	

Table 4: Collective value of improvements.

Overview of the BOSTI Study

The Buffalo Organization for Social and Technological Innovation (BOSTI) Study (1984)[19] analyzed 18 basic design factors such as lighting, accessibility and temperature and concluded that a well-planned design increases productivity. The 18 facets are listed on *Table 1*. The BOSTI study's most significant effort was to quantify the physical and performance factors by dollar values and provide further implications for office design. The cost benefit analysis indicated that the additional investment on building performance can be justified. BOSTI further suggested that productivity depends as much on the environment as on management and equipment, and encourages thinking of the "office as a tool and not just a place to house tools."

The BOSTI study's five-year research

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Number of Symptoms	0	1	2	3	4	5	6	7	8	9	10
Mean WEP	4.42	4.93	5.07	5.28	5.54	5.80	5.94	6.12	6.05	6.52	6.90

NOTE: Worker Evaluation of Productivity (WEP) is defined as a worker's subjective rating of the perceived effect that a wide range of physical conditions have on the their productivity.

Table 5: Building-related symptoms correlation.

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program was nationwide, involving some 6,000 workers in about 70 organizations (see *Table 1*). People were grouped into three major job types: managers, professional and technical workers, and clerical workers. The questionnaire asked people to describe their environments and their behavior in them, evaluate their environments, and then rate job satisfaction. Most facets of the environment were found to contribute to people's satisfaction with their environment. About half of the facets contributed to ease of communication and job satisfaction.

Values in the BOSTI study were assigned and calculated for the various environmental facets at three job levels: managers (avg. salary $41,500), professional/technical (avg. salary $31,600), and clerical (avg. salary $17,400).

The charts in *Table 2* and *Table 3* show the annual dollar value impact of various environmental factors on each job function. According to the data, the greater the net present value (NPV) number, the greater the problem. Estimated values represent changes in absenteeism and turnover and reflect both the positive impact of improvement and negative impact of facet decline on job performance.

Finally, the BOSTI researchers calculated the value of improvements collectively from all facets of the environment on each job (see *Table 4*).

The BOSTI study has examined a comprehensive number of environmental factors that, when taken together, can have a productivity impact of as much as 15% to 17% of salary impact (*Table 4*).

UK Productivity Survey

The United Kingdom's Office of the Environment Survey looked at three variables and the effect of each on productivity: 1) The number of building-related health symptoms experienced by workers; 2) the number of people in a room and job type; 3) personal control over the office environment.[20]

The study's methodology included a questionnaire survey of 4,373 public and private sector employees in 46 UK office buildings of varied age, type, and quality, with a range of ventilation systems. Productivity was assessed using a one-to-nine Likert scale analysis with one representing the most positive effect and nine the most negative. The Likert attitude scale is a type of multiple-choice question in which the respondent indicates extent of agreement or disagreement with a given statement.

> There are very large individual differences in the tolerance of suboptimal thermal and air-quality conditions, according to Dr. David Wyon. Productivity is probably reduced more, the Wyon study notes, when large numbers of employees work at reduced efficiency than when a few hypersensitive individuals are on sick leave. Commonly occurring thermal conditions, within the 80% thermal comfort zone, can reduce key aspects of human efficiency such as reading, thinking logically and performing arithmetic by 5 to 15%, according to Wyon.

The study's analysis in *Table 5* shows there is a significant linear correlation ($r=0.98$, $p<0.001$) between the number of building-related symptoms (i.e., dry, itching, or watering eyes; dry throat; lethargy; headache; blocked, stuffy, or runny nose; flu-like illness; difficulty breathing; and chest tightness) and Worker Evaluation of Productivity (WEP). WEP is defined in this study as a worker's subjective rating of the perceived effect that a wide range of physical conditions have on his or her productivity. Results indicate that the indoor environment should be improved so as to reduce building-related symptoms to fewer than three (WEP<5.0).

According to the Office of the Environment Survey, the probability that productivity decreases as the number of people in a room increases is significant. ($F=8.77$, $df=4058, 4$, $p<0.001$). This is attributed to a number of factors, including control over lighting, ventilation and temperature, noise and privacy. Using a ResWEP score (the difference between each individual's WEP score and the mean WEP for his or her building), results indicate that office environments should aim for five people or fewer sharing a room unless there is at least a moderate degree of control over the indoor environment. (see *Table 6*).

According to the study, a significant effect was shown on productivity in terms of respondent's control over their own temperature, ventilation and lighting. In the case of temperature (and to a lesser extent ventilation) there is a marked increase in productivity at the highest level of control. The study's analysis confirms that productivity increases with level of control whatever the number of people in the room (the difference is largest between medium and high control). An intermediate number of people is associated with low productivity at low control levels, but associated with high productivity with high levels of control.

Respondents also rated various aspects of their typical office working conditions (i.e., comfort, temperature, ventilation, air quality, humidity, and satisfaction) in both winter and summer using a one to seven Likert scale analysis. Ratings all indicated that productiv-

ity was higher when the conditions were better ($F=14.88$, $df=3437, 1$, $p<0.001$).

Implications in this study are that improving personal control over the indoor environment over lighting, windows that can be opened and local temperature improves self-rated productivity.

Providing for Difference

There are very large individual differences in the tolerance of suboptimal thermal and air-quality conditions, according to Dr. David Wyon.[21] Productivity is probably reduced more, the Wyon study notes, when large numbers of employees work at reduced efficiency than when a few hypersensitive individuals are on sick leave. Commonly occurring thermal conditions, within the 80% thermal comfort zone, can reduce key aspects of human efficiency such as reading, thinking logically and performing arithmetic by 5 to 15%, according to Wyon.

In another study, Wyon looked at four types of work.[22] Work requiring concentration decreased 30% in performance when temperatures rose to the sweating threshold (27-30°C) (80.6°F-86°F) vs. 20°C (68°F). Routine office work (typing) decreased 30% at 24°C (75.2°F) vs. 20°C. Work involving manual dexterity decreased a maximum of 20% at a [differential] temperature 12°C (21.6°F) below neutrality. Here neutrality in tasks requiring finger speed and sensitivity (rapid keyboard operation, paper sorting, repair and assembly) performance was maximized at [a differential temperature of] 6°C (10.8°F) above neutrality and decreased 50% at [a differential temperature of] 12°C (21.6°F) below neutrality.

Targeting a "group-average" acceptable temperature can have a significantly unfavorable effect on group performance. Wyon calculated the weighted average number of degrees above or below the temperature at which maximum group performance is expected for each of the four tasks. Performance decrement was then predicted using regression analysis based on test experience noted above. He then calculated expected performance improvement for each task based on individual ability to adjust temperature control within a range of 3±°C (5.4±°F). The chart in *Table 7* summarizes expected group performance increase percentage when individuals are allowed 3±°C (5.4±°F) of individual control, even when room temperature is equal to a group average neutral temperature.

Personal differences in thermal comfort show significant variation. Most (95%) of a normally distributed population should be comfortable within a range of four standard deviations, or 6.4°C (11.52°F) using PMV equation procedure. However, Grivel and Candas[23] found a 95% neutral range of 10.4°C (18.72°F) among French subjects and Rohles[24] found a neutral range of 13.6°C (24.48°F) among American subjects.

A History of Productivity Measures

As noted earlier in this article, there are several other studies that have researched the correlation between productivity gains and an environmental satisfaction in the workplace. For example, Mao-Lin Chiu recaps a number of productivity studies in his 1991 Carnegie Mellon dissertation.[25] Adams, et al. noted a 3 to 7% increase in reading speed and error reduction when glare was reduced. The Federal Energy Administration saw a 5% increase in proofreading speed and accuracy due to increased illumination. In a Pennsylvania Power & Light study, there was a 13% increase in the number of drafting drawings produced per hour with a lighting redesign. A number of studies document the effect of the environment on typing. Wisner found a 30% decrease in typing errors with a 20dB reduction in noise. The GSA saw a 2.5 to 9% increase in typing speed through the effect of air conditioning.

Number of people in a room	Mean ResWEP
1	0.34
2-4	0.09
5-9	-0.08
10-29	-0.17
30+	-0.09

Note: A higher mean ResWEP, indicates a more positive effect on productivity

Table 6: Room capacity correlation.

Thinking	Typing	Skill	Speed	Mean
2.7%	7.0%	3.4%	8.6%	5.4%

Table 7: Increased group performance by activity type.

Summary: Environment Affects Productivity

It is clear from all studies cited in this section that the physical environment can have a measurable impact on worker productivity of about 3% to 15%. In addition to showing the relationship between environmental satisfaction and productivity, this section has discussed the importance of individual control especially as it relates to diverse responses to environmental conditions. The role of the ERW provides workers with complete control over such conditions as airflow, filtration, temperature, lighting and acoustics. As it has been stated, zone heating, cooling and ventilation of open-plan offices create an environment that satisfies the "average" building occupant. Building systems, which inadequately provide good thermal conditions, air quality, lighting, noise levels and a sense of privacy, create significant levels of occupant dissatisfaction with the indoor environment and hence negatively affect productivity and the organization's bottom line.

Updating HVAC systems, retrofitting lighting, offering flexible workstations, finding ways to dampen noise levels all on a system-wide basis will generally help increase levels of productivity. Yet, recent advances in controls technology have broken the play-by-the-averages barrier. ERW technology has turned over much control of the above factors into the hands of individual workers. Turning control of lighting, temperature, ventilation and acoustics over to the "experts"—individuals who occupy the workspaces for several hours a day—has been shown to have dramatic effects on productivity, as was demonstrated in the West Bend Study.

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Analysis of Environmental Satisfaction-Productivity Studies

Study	Environmental Condition	Result
Greening the Buildings & Bottom Line 1994	Lighting	6% prod. gain, reduced defects, $25k increase in product quality,
		13% prod. gain, 25% less absenteeism
	Noise & Daylighting	15% prod. gain + 15% less absenteeism
	New Building	15% less absenteeism
West Bend Mutual 1992	Individual Control	2.8% prod. gain/could be up to 6%
		12.8% prod. drop when disconnected
Mau-Lin Chiu/Carnegie Mellon 1991	Lighting	Cites 4 Studies
According to Chiu, six factors influence office productivity: (1) Spatial Quality (2) Thermal Quality (3) Visual Quality (4) Acoustic Quality (5) Air Quality (6) Long-Term Building Integrity	Noise	Cites 5 Studies
	Temp & Air Quality	Cites 5 Studies
Economic Benefits of a Healthy Indoor Environment (Wyon) 1994	Thermal Air Quality Individual Control	5-15% incr. efficiency in concentration 34% improvement in Sick Building Syndrome
Predicting the Effects of Individual Control on Productivity (Wyon) 1995	Individual Control	3-25% efficiency gains 3-15% for concentration and 7-25% for routine office tasks
Indoor Air '96 Conference (Wyon) 1996	Individual Control	2-10% increase in group efficiency
BOSTI 1984	Noise Temperature/Air Quality Lighting Comfort	These each have dollar figures for three job types representing improvements to absenteeism and turnover.
UK Office of Environment 1990	Air Quality Space (People per room) Individual Control	These are all self-reported results. People feel they are more productive when air quality is better, they are less concentrated, and have environmental control.
Worker Productivity: Hidden HVAC Cost 1990	Air Quality	One lost working day due to a sick building = 60% of annual energy costs.

Table 8: Analysis of environmental satisfaction-productivity studies.