Offices, Windows and Daylight: Call Center Worker Performance

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ABSTRACT

This study looked at 100 workers in an incoming call center located at the Sacramento Municipal Utility District whose performance was continuously tracked by a computer system and measured in terms of time to handle each call. Extensive data was collected about the physical environment at each office worker's cubicle. Multivariate regression analysis was used to determine if any of the variations in environmental conditions were significantly associated with differences in worker performance (both daily and hourly) and to control for other potential influences.

Workers in the Call Center were found to process calls 6% to 12% faster when they had the best possible view versus those with no view. Other physical conditions were also found to have significant associations with worker performance. When variation in hourly performance was considered, higher rates of outside air delivery were associated with faster handling of calls.

Information about the workstation environmental conditions was able to explain 2% to 4% of the total variation observed in performance. Overall, the physical variables represented about 1/8th to 1/5th of our entire ability to predict variation in individual worker performance. This study has shown that indoor environmental conditions can have a measurable relationship to changes in office worker performance and has established a range of likely effect sizes that other researchers can use to refine the needs of future studies. The merits of call centers as study test sites for this purpose will also be discussed.

Introduction

This paper reports on a field study of how office worker performance might be influenced by indoor environmental conditions within an incoming call center at the Sacramento Municipal Utility District (SMUD). A companion study, called the Desktop Study, was conducted at SMUD during the same time period and looked at office worker performance on cognitive tests. These two studies were designed to carry forward earlier studies on the interaction of daylighting and human performance in schools and retail environments, (Heschong and Wright 2002; Heschong, Wright & Okura 2000; Okura 2000) by extending the statistical methodologies used in those inquiries to the office building environment. It is part of a growing field investigating the impact of building design decisions on human performance, collectively termed "evidence-based design." (Fetz & Vance 2004). The impact of the indoor environment on office workers has been of interest to building science researchers for many decades. The progress of current research is being tracked by the Indoor Health and Productivity Project sponsored by the National Science and Technology Council, (IHP 2004) which provides an excellent annotated bibliography on studies relevant to this effort.

Many studies which have focused on aspects of the indoor environment have not controlled for potential influences from electric illumination or daylight, and visa versa. Certainly one of the challenges of field studies is accounting for all of the complexities that occur in real life situations, both in terms of the interrelationship of environmental conditions and other potential simultaneous changes in the social environment.

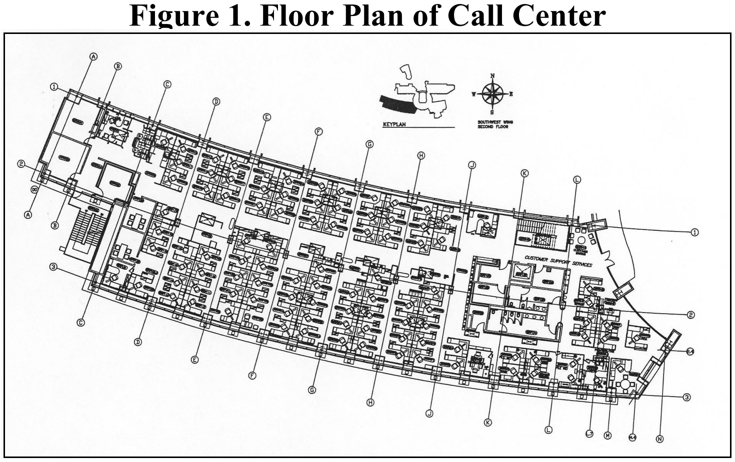
One of the key challenges of any study looking at the relationship between the indoor environment and office worker performance is finding meaningful metrics of office worker performance. While there is much discussion of the value of "productivity," the productivity of office workers is notoriously difficult to assess. In this Call Center study the linkage between individual performance and organizational productivity is clear, since the Call Center's management uses metrics of individual worker performance to assess the average change in performance for the Call Center as a whole. Because of this linkage, we were also able to make a direct translation from changes in individual performance to the overall dollar value of that change.

In field studies many other influences on worker performance are in play and can potentially mask or confound results, challenging the validity of the findings. This study was primarily an observational field study, where we observed how performance varies with naturally occurring variation in time or space. We did, however, introduce some minor interventions, where daylight and ventilation conditions were artificially altered to increase the amount of variation in the data.

Description of SMUD Call Center

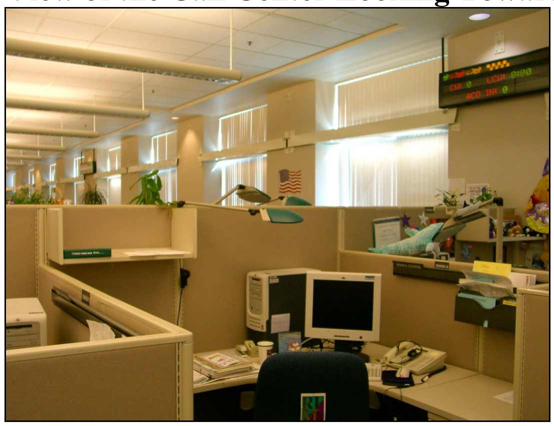
The Sacramento Municipal Utility District (SMUD) Call Center handles all incoming calls from residential and commercial utility customers who have service requests, questions about billing or want information about utility programs. The Call Center is located in the southwest wing of the Customer Service Center (CSC) building, a space 65' wide and 117' long, with the long dimension oriented east-west and with an 11' ceiling height. Along the north and south walls there are large windows designed to maximize daylight penetration into the space. An internal central aisle runs down the length of the Call Center, allowing entry into various subsections of cubicles. Figure 1 shows the floor plan of the Call Center.

Figure 1. Floor Plan of Call Center



Each workstation is provided with operable vents in the floor, and individual task lights. Each worker has a computer with a flat panel 17" screen and a telephone with a headset. Workers take calls, search for information on computer screens, enter data into forms on the computer screens and also refer to printed materials on paper. Figure 2 shows a typical view from a corridor looking towards the south wall.

Figure 2. Typical View of the Call Center Looking Towards the South Wall



The north facing walls of the building have large windows with no external shading, while the south walls have smaller windows with both vertical and horizontal external shading. The windows on the south wall have a clerestory, which is always kept closed with vertical opaque blinds to prevent glare, which were added when the original internal light shelf was removed in this wing. All windows have movable vertical blinds. The light-colored, perforated vertical blinds block 95% of the daylight, allowing employees to eliminate glare while retaining a filtered view.

The electric lighting system uses linear pendant-mounted direct/indirect luminaires and are spaced eight feet on center. These fixtures are arranged in rows running along the length of the plan perpendicular to the windows. The T-8 florescent lamps are on automatic dimmers controlled by photosensors mounted on every third fixture. The minimum light levels of many of these photosensors had been adjusted upwards over time in response to requests from the users, since initial commissioning. Thus electric light levels varied throughout the space somewhat independently of daylight levels. During daylight hours, a combination of controlled daylight and electric lighting provides 30 to 90 footcandles (fc) on the work plane. Electric illumination levels during daytime (with blinds closed) vary from 20 to 30 fc. After dark the pendant luminaires are on at full light output and some additional types of luminaires are activated, providing between 15 to 50 fc on the work plane.

Data Collection

Our data collection strategy was to find the least intrusive method for observing environmental changes in the space so that we would minimize the possibility of influencing our study subjects' behavior. We settled on two primary methods of data collection: observations during non-occupied periods, which would allow us to assess variation in space under different times of day and blinds conditions; and collecting continuous data using miniature data loggers set to automatically collect illumination, temperature and relative humidity data at a fifteen minute intervals. The data loggers selected were small matchbox-sized Hobo data loggers, type H08-004-02 from Onset Technologies.

We undertook the study of the SMUD Call Center in two phases, an initial pilot study of the daily performance of the customer service representatives during September 2002, and a more detailed hourly study during November 2002.

Illuminance Levels (Electric and Daylight)

In the first phase, we measured horizontal illumination levels along transects across the building, indicated by letters D,F,H, J and K in Figure 3. Measurements were taken during unoccupied periods on weekends, at four feet above the ground, every five feet along the transect, using a Minolta T-1H handheld digital illuminance meter. Measurements were recorded three times during the course of the day in the morning, noon and evening, with the window blinds both open and closed. Electric lighting levels peaked in the middle of the space and dipped at the perimeter. The daylight levels were generally highest along the north wall, quite low in the middle of the space and rose again near the south windows.

Figure 3. Call Center Transects and Hobo Locations, Phase One

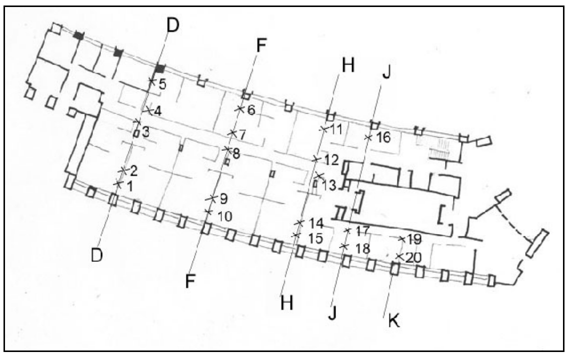
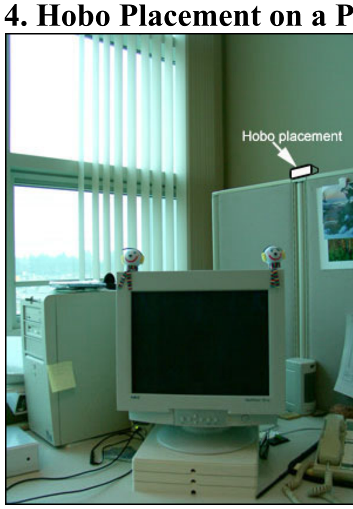


Figure 4. Hobo Placement on a Partition



Hobos were installed on top of the 5' high partitions along the transects, as shown in Figure 4. The Hobos were first calibrated to each other and then to readings from the hand held meter at the time of installation. Handheld readings were extrapolated to derive illuminance readings for each cubicle based on their positions in relation to the transects.

We learned from the first phase that the most variation in daylighting was concentrated near the windows. Therefore in the second phase, we located more Hobos at locations near the windows, so that we could better capture the spatial variation in daylight. We also took handheld illumination readings at every cubicle, rather than just along the transect lines. Three horizontal readings were taken at desk level and at the six faces of a hypothetical cube taken at head height (4' above floor) over each sitting position. This approach allowed us to calibrate each cubicle illuminance level for the November data more closely to the nearest Hobo reading, rather than extrapolating readings from the nearest transect.

View Factor

Two types of views were assessed for each cubicle location, the primary view and the break view. We were interested to see if the influence of view changed depending upon whether it was a constant or occasional event during the workday. While most Call Center workers had some access to views, the quantity and quality varied considerably depending on cubicle orientation, height of partitions, proximity to walls, etc., and thus independent of job status.

Figure 5. Examples of View Ratings 1-5

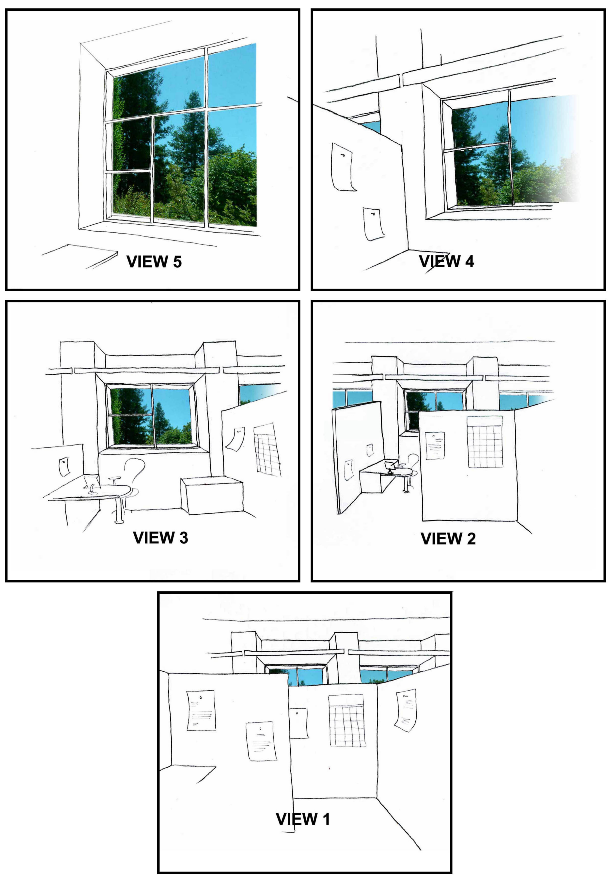


Figure 5 presents images that visually represent the scale used to assess the view in this study. A view rating of 5 almost completely filled the visual field of the observer seated at the cubicle, while a view rating of 1 represented a glimpse of sky or sliver of the outside environment. A view rating of 0 indicated no window within view.

The primary view was rated by sitting in the chair in each cubicle facing the computer monitor. The amount and quality of view visible within a 90 degree cone of the monitor was rated from 0=none to 5=largest. The surveyor then moved away from the desk, still sitting in the workstation chair, and rated the amount of break view available from all other seated positions within the cubicle.

Other Cubicle Observations

The surveyors also collected information about each cubicle to assess the micro-environmental conditions at each worker's desk. They included observations such as: height of partition around workstation, number of task lights at workstation, orientation of chair, and glare potential.

Most cubicles also had under floor ventilation registers. We assessed the position of floor vent on a scale of 0-4, where 0=closed or missing and 4=fully open. An assessment of changes to floor register position during the second phase showed that 25% had their settings changed either up or down at least two points on the scale over the previous two months, however the aggregate average setting for the Call Center remained the same.

SMUD has an automated environmental management system (EMS) which is used to log and control the performance of the air handling units. We used these HVAC data, combined with local weather data to derive outdoor ventilation rates for the two study periods.

Performance and Demographic Data Collection

The most important and commonly used metric to identify performance of a call center and the individual workers is the Average Handling Time (AHT), which is the sum of the time to talk to a customer and complete all steps to process their call. SMUD agreed to share with us both individual and group performance data as collected by their automated computer tracking program for the study period.

The data included information on 100 employees who worked regular eight-hour shifts during the study period. The Call Center is open twelve hours, from 7 am to 7 pm. Ten percent of the workers were termed "rovers" and had variable seat assignments, depending on vacation and sick schedules. In consultation with the Call Center management, we timed to the study periods to avoid anomalous conditions in the workflow.

SMUD also agreed to provide some information about the customer service representatives to supplement the analysis, while maintaining anonymity of the employees. These data provide the demographic control variables needed to support the regression models, such as years with company, group assignment, seniority, etc.

Interventions

We received permission to carry out a simple intervention at the end of the study periods: requesting employees to open or close their blinds for a few days. Our preliminary analysis from phase one had pointed to the strong influence of ventilation on worker performance. Thus, as an additional intervention, we requested that the facilities department disable the Call Center economizers for two days at the end of the study. When they did this, the outside air delivered was reduced to the base levels throughout the day, rather than varying hourly based on weather conditions. This intervention provided us with more variation in hourly outside air ventilation rates.

Statistical Methodology

All of the analysis was pursued using multivariate regression models run in SAS (statistical analysis software). The analysis used $p \leq 0.10$ as the threshold significance criteria for inclusion of explanatory variables in the models. Preliminary analysis of the data was performed to test for heteroscedasticity and collinear variables. Alternate forms of both dependant and explanatory variables were considered. Ultimately logged variables, using the natural log (nL), were used consistently for all illumination variables in the office studies. Models were judged based on their R^2 (the percentage of variation in the data explained by the model), the parsimony (minimum explanatory variables for maximum explanatory power) and consistency between the models. The variable selection method used was a variant of the backward elimination method.

The information collected from the Call Center and from various on-site investigations was transformed into explanatory variables that could be used in the regression analysis. The explanatory variables can be classified into three basic types:

1. **Demographic variables**, which described the status of the individual employee. These are reported as Personal Status and Group Assignment in the results tables in Figure 6.
2. **Performance variables**, which describe conditions in the Call Center, such as number of incoming calls and the number of staff working at a given time. These are termed Call Center Status in the results tables in Figure 6.
3. **Environmental variables**, collected onsite, which describe the physical environment to which the employees were exposed. These are grouped into the categories Light, View, Temperature and Ventilation in the results tables in Figure 6.

From the data collected in the two phases of the study, three statistical models were created, using multivariate regression analysis.

For the first model, called the September Daily model, the average individual daily AHT was used as the dependant, or outcome, variable. Daily averages were also created for the explanatory variables from data collected in phase one. For the second model, called the November Daily model, we calculated daily averages for all variables based on the scheduled working hours (or shifts) of each individual to increase temporal accuracy. Data collected in phase two was used in this model. For the third model, called the November Hourly model, we also used phase two data, but in an hourly format for both dependant and explanatory variables.

Findings and Discussion

The findings from the three statistical models are presented in Figure 6 in terms of their percent effects[1]. The percentage effect shows how much the dependant variable would change

[1]Full statistical descriptions of the data and models are presented in the full report (HMG 2003).

over a certain range of that variable, if all other factors considered in the regression equation were held constant. Percentage effects are only shown for those variables that were found significant ($p<0.10$). Dashed lines indicate that a variable was not considered in a particular model. Those explanatory variables that have a consistent effect across all three models are underlined.

Figure 6. Percentage Effects of the Three Call Center Models

		Daily Models				***Hourly Model***	
		September		November		November	
Variable Name	**Range**	$R2 = 0.211$		$R2 = 0.223$		$R2 = 0.078$	
Lighting							
Daylight (nL)	if increased by 10% …				-0.2%		
Electric Light (nL)	if increased by 10% …					0.3%	
Total Light Range (nL)	if increased by 10% …		-0.2%				
Number of Task Lights	from none to 1 additional …		-7%				
Daylight Range (nL)	if increased by 10% …	----	----			----	----
View							
<u>Break View</u>	from none to best …	6%		7%		7%	
Primary View	from none to best …	6%					
<u>Partition Height</u>	from none to highest …		-11%		-11%		-18%
Distance to North Wall	if 10 ft more …			3%		5%	
Distance to South Wall	if 10 ft more …						
Temperature and Ventilation							
Indoor Air Temperaure	if increased by 2 deg F …						-2%
<u>Floor Register Status</u>	from closed to open …	10%		3%		4%	
Personal Fan	If yes …						
Outside Air Delivered	if increased by 1 CFM/sf …	----	----			4%	
Call Center Status							
<u>Average Seconds to Answer (nL)</u>	if increased by 10% …		-0.9%		-0.6%		-0.7%
Total Calls Answered	if 100 more calls per hour …			11%		9%	
Population	if 10 people more …				-14%		-12%
Personal Status							
Part Time Worker	If yes …						
<u>Team Leader</u>	If yes …	19%		17%		18%	
<u>Years on Job (nL)</u>	if 10% more …		-0.1%		-0.2%		-0.1%
First Hour of Shift	If yes …	----	----	----	----		
Last Hour of Shift	If yes …	----	----	----	----		
Group Assignment							
group a	If yes …		-8%				
group b	If yes …		-10%				
group c	If yes …		-7%			6%	
group d	If yes …		-5%				
<u>group e</u>	If yes …	3%		11%		17%	
group f	If yes …			9%		15%	
<u>group g</u>	If yes …	5%		9%		15%	
<u>group h</u>	If yes …	4%		10%		14%	
group i	If yes …			6%		11%	

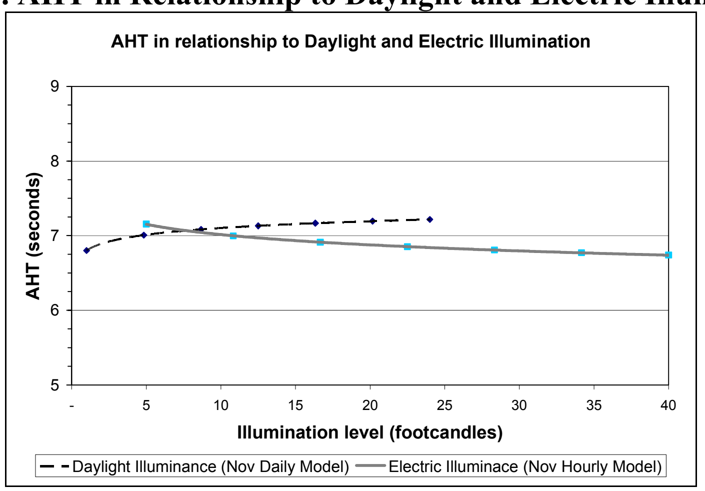
The positive effect shown in the white column indicates improved (faster) performance. A negative effect shown in the gray column indicated poorer (slower) performance. For example, in the daily September model workers with the best *Primary View* are seen to perform 6% faster than those workers with no *Primary View*, but to have no significant change in the November models.

The Average Handling Time for our data sets was approximately 7 minutes per call. Thus, a +10% improvement indicates handing calls 10% faster on average, or within 6.3 minutes.

Illumination

Daylight was found significant in only one model, November Daily, and was found to slow overall performance slightly, by -0.2% for every 10% increase in average daily daylight horizontal illumination level. The intensity of electric illumination, on the other hand, was found to increase performance by about the same amount, +0.3% in the November Hourly model. It seems a bit counterintuitive, that daylight illumination, which varied hourly, would be significant only in the daily model while electric illumination which had very little variation, would be significant only in the hourly model. The relative effect of these two findings is shown in Figure 7, where the dashed line is average daily daylight illuminance and the solid line is electric illuminance.

Figure 7. AHT in Relationship to Daylight and Electric Illumination



Since we know from our illumination transects that electric light increases in the center of the Call Center and daylight increases at the perimeter, these two effects are basically complements of each other, indicating relatively faster performance for workers located in the core. It is possible that people in the core are functioning slightly better than people at the perimeter for some other reason than illumination, although we tried to control for any such confounding effects with the 'Distance to Window' variable. In a potentially related effect, we can see that being further from the north windows predicts a positive effect of handling calls 3% to 5% faster in both the November models.

View

The findings about view are perhaps the most striking findings in this study. A better break view consistently predicts 6% to 7% faster performance. A better primary view also predicts an additional 6% faster performance in the September Daily model.

As a complementary finding, those employees at a workstation with partition heights above eye level on two sides are seen to be performing 11% to 18% slower than those with all their partitions below eye level. Workers with high partitions have fewer opportunities for views, especially primary view.

The positive impact of the view variables could potentially be explained by a number of causal mechanisms. These include theories that a relaxing view improves performance via stress reduction, that an interesting view improves ability to maintain mental focus, or that higher luminance levels viewed by the eye may help enhance performance via a physiological circadian stimulus. It should be noted here that the daylight variable, as considered in this study, is the horizontal daylight illuminance at the head position of the employee, and is hence not necessarily an indicator of vertical illuminance received by the eye. The view variable however, may be a potential proxy for the vertical daylight illuminance, although we did not attempt to confirm this.

Temperature and Ventilation

From the results we find that cooler temperatures are associated with faster performance handling calls in the November Hourly analysis. A small increase in air temperature inside of the space, from the average of 74°F to 76°F was seen to slow worker performance by 2%.

'Floor Register Status' was one of the most powerful explanatory variables. Those workers who had their floor registers set to fully open, presumably to maximize ventilation near their workstation, were consistently seen to have faster performance than those with their floor registers fully closed. This finding could potentially be related to increased local air flow, or to lower local air temperature. Upon examination of the facility records for the study period we confirmed that the delivery air temperatures were substantially cooler than average room air temperatures for the Call Center. In September the delivery air ranged around 58°F, about 15°F cooler than the room air, while in November the delivery air was at about 64°F, or about 10°F cooler than the average room air. Thus, people with their floor registers open were receiving both more ventilation air and cooler local temperatures than those with their registers closed.

In November we were able to include a variable indicating the amount of outside air introduced into the space on a daily or hourly basis ('Outside Air Delivered'). The variable was found significant in the November Hourly model. As the rate of outside air per square foot increased, hourly performance also improved. Increasing the rate of outside air by one cubic foot per minute per square foot (CFM/sf), or double the average rate, was associated with 4% faster handling of calls.

Monetary Savings Potential

The dollar value of these changes in worker performance is enormous. Per the management at SMUD, a 10% improvement in Call Center worker performance is worth a savings of $9,000 per year per employee. For the Call Center as a whole this translates to $118/sf per year. In comparison, typical lowrise office construction costs in California currently range from about $85 to $121/sf.[2]. Thus, for example, improving worker performance by 10% would fully justify doubling construction costs, while maintaining a one-year payback on the investment!

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[2]Average to high-end range, average construction cost per square foot for offices 1 to 10 stories in Sacramento, California (Means Cost Data, 2002).

The SMUD Customer Services Center building cost about twice normal construction costs at the time. Thus, with the improvements in worker performance associated with the window views and enhanced ventilation features included in the building, this study has shown that the SMUD management was more than justified in making that investment in their facilities.

Energy Saving Potential

The main focus of this project was to understand the comfort and productivity related issues with daylighting in office spaces. However there are energy efficiency aspects with daylit offices that are also significant.

Based on simulation analysis done at the time of design (ESS 1994), the incremental energy savings due to the addition of daylighting controls to the base case, resulted in a total of 69,000 kWh/per year of lighting energy savings (0.37 kWh/sf) and a total of 112,000 kWh of electric energy savings (0.6 kWh/sf) when the additional cooling energy savings are included. The design also produced an electricity peak demand reduction for lighting, due to electric lights turned down during the day, of 49 kW for the building (an average reduction of 0.26 W/sf over the gross sf of the building).

Figure 8 shows the incremental cost savings for SMUD per year from adding daylighting controls to the base case, calculated using 1994 SMUD rates and dollar values. The results indicated a total utility savings of $10,090 per year ($0.055/sf) from the daylighting controls. Note that the value of the demand savings in Figure 8 (based on SMUD's 1994 office rate utility schedule) is almost equal to the value of the electric energy savings. This estimate, based on a real office building design, is a very good indication that the potential value of daylighting controls also includes significant demand savings that may double the value of the energy savings.

Figure 8. Incremental cost savings (1994) for SMUD CSC building by adding daylighting controls to base case

Annual Cost Savings	Cooling + Lighting		Heating	Total Utility
Units	*$ Usage*	*$ Demand*	*$ Usage*	*$ Savings*
Savings for SMUD	$5,190	$4,750	$150	$10,090
Savings per sf	$0.028	$0.026	$0.001	$0.055

We calculated the energy savings that would result from daylighting controls if all offices in California[3] were constructed to have daylighting potential similar to that of the SMUD Customer Services Center building (roughly 30% of the space side-lit and an additional 20% top-lit, with dimming controls set to a minimum of 10% light output, lighting power density of 0.9 W/sf) and were operated in a similar climate (California's Central Valley). Based on these admittedly crude assumptions, the addition of daylighting controls to all new office buildings in California would result in annual electric energy savings of 24,800 MWh/yr in the first year as shown in Figure 9.

[3]Using data from the 2003 CEC California new construction database, which predicts the addition of 30.9 million sf of large offices (>50,000 sf) and 9.9 million sf of small offices (<50,000 sf) per year.

Figure 9. Energy savings potential for daylit offices in California from lighting controls only for new construction

Description	Area	Lighting		Cooling		Total Electric	
Units	*sf/yr*	*MWh/yr*	*MW*	*MWh/yr*	*MW*	*MWh/yr*	*MW*
Savings for SMUD		69	0.049	43	0.00	112	0.05
Statewide Lg Office	30.9 Million/yr	11,600	8.25	7,200	0.00	18,800	8.25
Statewide Sm Office	9.9 Million/yr	3,700	2.64	2,300	0.00	6,000	2.64
Statewide Savings Potential	40.7 Million/yr	15,300	10.88	9,500	0.00	24,800	10.88
Statewide 10 Year Savings	*407 Million*	*153,000*	*108.84*	*95,000*	*0.00*	*248,000*	*108.84*

Based on average electric costs of $0.1487 Kwh (CEC 2004) in California in 2003, the economic value of the energy savings calculated in Figure 9 is $3.7 million dollars per year for the first year of new construction. This would increase by tenfold to $37 million dollars per year after 10 years of accumulated construction. This value does not account for the value of any associated demand savings, but based on the SMUD example, might be approximately doubled in value.

Conclusions

This study is one of a few in this relatively new field of building science which is trying to understand the impact of building design choices on human performance. The statistical models discussed in this study do a modest job of describing the influences on worker performance measured by our outcome metrics. For the Call Center, our models are explaining a little over 20% of the variance in workers' daily performance, and 8% of their hourly performance. (per Figure 6, Model R^2 = Sept Daily, 0.211; Nov Daily, 0.223; Nov Hourly, 0.078)

The significant physical variables are each found to explain from about 0.5% to 1% of the variation in performance (please see the appendix of the original report for full statistical details). All together, information about variation in the physical environment is found to explain about 2% to 5% of the variation in worker performance. It should be noted that this variation was in a modern, state-of-the-art office building where environmental conditions were always maintained within accepted comfort conditions.

On the one hand, this might seem to be a very small, even trivial amount of explanatory power. However, when the power of the physical environment is held up in comparison to our ability to predict performance based on other information about people—such as their age, sex or job classification—then we see that information about workspace conditions provides about $1/8^{th}$ to $1/3^{rd}$ of our ability to predict variation in individual worker performance in the field. This range of explanatory power is in the same range as was found in the companion study of an elementary school district (HMG 2003).

This suggests that human resource and management decisions can make meaningful contributions to perhaps $2/3^{rd}$ to $7/8^{th}$ of the worker performance equation. The remaining $1/8^{th}$ to $1/3^{rd}$ which can be contributed by decisions about subtle changes to the physical conditions is not trivial. Furthermore, once made these design decisions are likely to last for the life of the measure or the building, easily five years, and perhaps 50 years or more. This is important news for managers, architects and anyone who makes investment decisions about the physical environment.

Acknowledgements

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