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Effects of office workstation type on physical activity and stress

Casey M Lindberg,[1] Karthik Srinivasan,[2] Brian Gilligan,[3] Javad Razjouyan,[4,5] Hyoki Lee,[4] Bijan Najafi,[4] Kelli J Canada,[6] Matthias R Mehl,[7] Faiz Currim,[2] Sudha Ram,[2] Melissa M Lunden,[8] Judith H Heerwagen,[3] Kevin Kampschroer,[3] Esther M Sternberg[1]

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For numbered affiliations see end of article.

Correspondence to
Dr Esther M Sternberg, College of Medicine, Institute on Place, Wellbeing & Performance, University of Arizona, Tucson, AZ 85724, USA;
esternberg@email.arizona.edu

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ABSTRACT

Objective Office environments have been causally linked to workplace-related illnesses and stress, yet little is known about how office workstation type is linked to objective metrics of physical activity and stress. We aimed to explore these associations among office workers in US federal office buildings.

Methods We conducted a wearable, sensor-based, observational study of 231 workers in four office buildings. Outcome variables included workers' physiological stress response, physical activity and perceived stress. Relationships between office workstation type and these variables were assessed using structural equation modelling.

Results Workers in open bench seating were more active at the office than those in private offices and cubicles (open bench seating vs private office=225.52 mG (31.83% higher on average) (95% CI 136.57 to 314.46); open bench seating vs cubicle=185.13 mG (20.16% higher on average) (95% CI 66.53 to 303.72)). Furthermore, workers in open bench seating experienced lower perceived stress at the office than those in cubicles (−0.27 (9.10% lower on average) (95% CI −0.54 to −0.02)). Finally, higher physical activity at the office was related to lower physiological stress (higher heart rate variability in the time domain) outside the office (−26.12 ms/mG (14.18% higher on average) (95% CI −40.48 to −4.16)).

Conclusions Office workstation type was related to enhanced physical activity and reduced physiological and perceived stress. This research highlights how office design, driven by office workstation type, could be a health-promoting factor.

Key messages

What is already known about this subject?

- Office workers are at risk for low levels of physical activity and associated poor health outcomes, and workplace-related illnesses cost the US economy $225 billion a year, yet little is known about how office design elements may impact objectively measured health outcomes.

What are the new findings?

- This study applies recent advances in wearable sensors to the workplace setting.
- It is the first to investigate the effects of office workstation type on objective measures of both stress and physical activity.
- Across four different federal office buildings in the USA, workers in open bench seating exhibited higher levels of physical activity compared with those in cubicles and private offices.
- Higher physical activity at the office was in turn related to lower physiological stress outside the office as measured by heart rate variability.

How might this impact on policy or clinical practice in the foreseeable future?

- Objective measurements using wearable, sensor-based methods can inform policies and practices that affect the health and well-being of hundreds of millions of office workers worldwide.
- The US General Services Administration will use these findings to inform design practices used to provide over 370 million square feet of office space and house over 1 million federal employees.
- The findings demonstrate the need for additional interventional research to improve our understanding of how elements of office design contribute to physical activity levels at work.

Nearly 50 million workers in the USA spend over one-fifth of their time in office settings.[1 2] Technological advancements over the past several decades have led to an increasing share of the workforce being concentrated in office-based occupations. Office workers have an increased risk of physical inactivity at work compared with other professions and do not tend to engage in compensating behaviour outside of work.[3 4] Sedentary patterns and inactivity are related to negative health outcomes, including fatigue, poor mood,[5] as well as cardiovascular diseases and other chronic diseases,[6 7] which are in turn associated with increased rates of work exit.[8] Importantly, lower physical activity levels at work have been linked to higher levels of perceived stress,[9] a major public health risk associated with cardiovascular disease, metabolic syndrome and poor diet.[10 11]

Such health outcomes have enormous economic consequences, as modern office environments in the USA have been linked to workplace-related illnesses costing up to $225 billion, or more than 10% of office workers' contribution to the US

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gross domestic product,[12] and work-related stress and mental health problems in the European Union cost up to €269 billion annually.[13] Thus, although occupational safety and health programmes have eliminated many health risks, changes to policies and best practices in workplace design and operation aimed at health promotion could lead to further positive effects on health measures.

The vast majority of studies investigating how characteristics of the built office environment affect workers are survey-based, and suggest that there are worker performance, worker satisfaction and economic trade-offs between types of office workstations.[14–16] Few studies have included objective, continuous measures of stress in workplace settings,[17–19] and no known study has investigated how characteristics of the built office environment relate to objective measures of stress and physical activity.

The purpose of our study, part of the US General Services Administration's Wellbuilt for Wellbeing research project, was to explore the relationship between workplace design, health and well-being across four federal office buildings. To test whether behaviours and physiological and psychological responses to the working environment may differ based on spatial design characteristics, we measured participants' physiological stress response in real time using heart rate variability (HRV), perceived levels of stress through survey tools and objectively measured physical activity levels.

METHODS

Participants and setting

Self-described healthy adult workers involved in a variety of office-based roles for the US government were recruited across four federal office buildings in the Mid-Atlantic and Southern regions of the USA. Buildings were selected for their representation of common office workstation types across the US General Services Administration's portfolio of over 370 million square feet of office space that houses over 1 million employees. Staff in sections of each office building from organisations with leadership approval were offered the opportunity to participate.

After giving written informed consent, participants completed an intake survey consisting of demographic questions. Participants then wore a chest-worn heart and physical activity monitor for three consecutive workdays and two nights while answering hourly surveys on a smartphone during work hours related to a range of items including their current mood. Finally, participants completed an exit survey including a global measure of stress. Pregnant women and those wearing pacemakers or insulin pumps were excluded. Participants taking medication known to affect HRV were noted but not excluded. Participants were enrolled serially across the four sites, between 5 May 2015 and 25 August 2016. Between five and ten volunteers typically participated during each week of observation at each site.

Office workstation type and work type

Office workstation type varied across the four sites of the study and belonged to three categories: (1) private office (completely walled enclosure); (2) cubicle (high-walled partitions that one cannot see over while seated; and (3) open bench seating (no partitions or partitions that are readily seen over while seated) (figure 1).

Because we recruited participants from a variety of work divisions, work type varied and was coded (yes/no) for having 'computer-dominant', 'managerial' and 'technical' qualities. For more information, see the online supplementary material.

Measures of perceived stress

During the intake survey, participants used online survey software (Qualtrics, Provo, Utah) to provide demographic information on age, gender, height and weight (used to calculate body mass index (BMI)), and the highest education level obtained.

While participants were working at the office, ecological momentary assessments (EMA) of current mood were taken over the 3 days of observation. Randomly each hour, but never closer than 30 min apart, participants were prompted on smartphones with Android operating systems using the movisensXS application (movisens, Karlsruhe, Germany) and rated their momentary affect based on the circumplex model. Relevant for the purpose of this study, participants reported how 'tense' they currently felt on a 1–7 scale (1='not at all' to 7='very much').

Finally, during the exit survey, a one-time measure of long-term perceived stress over the past month was taken using the validated Short Form Perceived Stress Scale (PSS-4).[20]

Cardiac activity

Cardiac activity was recorded using a small, chest-worn sensor, EcgMove 3 (movisens). Details of the characteristics of this device have been published elsewhere.[21] To quantify the physiological stress response, we calculated the mean of the standard deviation of normalized interbeat intervals (SDNN).[22] SDNN is a global index of HRV and reflects longer term circulation differences. Lower SDNN values indicate an increase in the sympathetic stress response, and higher SDNN values have consistently been found to indicate better health.[23] SDNN index, the mean of each 5 min period of SDNN, was calculated according to the guidelines of the European Society of Cardiology and the North American Society of Pacing and Electrophysiology.[22] In order to better capture stressful moments, we then calculated the 10th percentile of the SDNN index variable.[24] The 10th percentile value represents relatively low HRV values during

Figure 1 Examples of office workstation types from the study. From left to right, open bench seating, cubicle and private office.

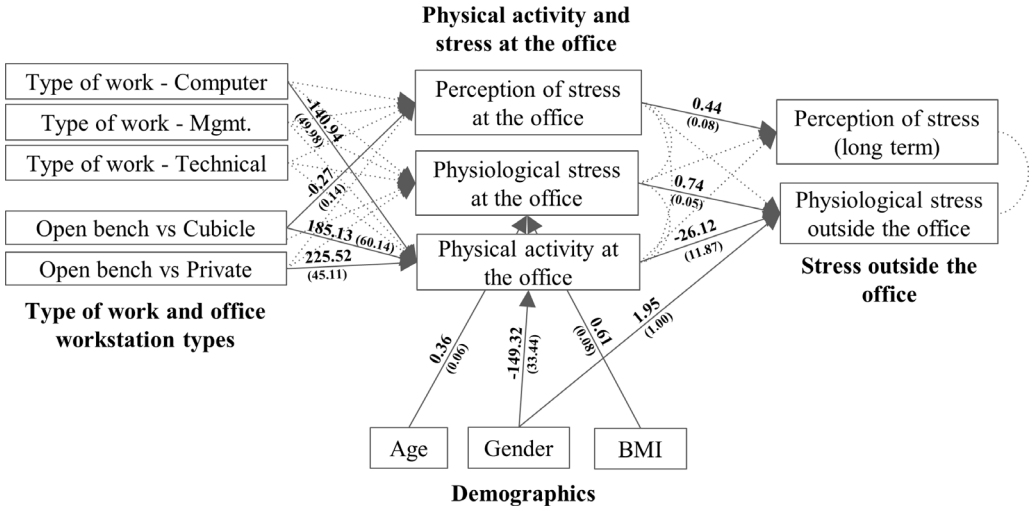

Figure 2 Structural equation model results. Solid lines represent significant paths and include unstandardised coefficient estimates (SE). Minus (–) signs indicate negative relationships between variables. BMI, body mass index.

the observation periods and serves as an indicator of relatively high sympathetic activation.[24] For more information, see the online supplementary material.

Physical activity

Participants' average physical activity levels were assessed in mG from the EcgMove3's triaxial accelerometer sensor using algorithms[25 26] validated for day-to-day monitoring.[27] The intensity level of physical activity has been shown to be a reliable predictor of physical health.[28] This method captures the overall intensity of movement throughout the entire workday. It provides a finer granularity of movement data for office workers, who tend to sit for the vast majority of their time at the office, than traditional parameters such as step counts and sit-stand transitions. In other words, the method used in this study captures the intensity of movement throughout the entire workday during all activities (eg, sitting, standing, walking). For more information, see the online supplementary material.

Statistical methods

Structural equation modelling (SEM) was used to estimate the direct and indirect effects of aspects of the office environment on outcome measures (figure 2). SEM is a multivariate statistical analysis technique that is used to estimate the relationships among multiple variables simultaneously in a single analysis.[29] It is a suitable data analysis method in this study because it allows for the exploration of complex relationships between types of office workstations, types of work, individual characteristics, and physical activity and stress outcomes within one comprehensive model. Significant, unstandardised path coefficients (B) represent the total effect of one variable's influence on another, taking into consideration all of the other variables' contributions to the model. We reverse-coded 10th percentile SDNN values for ease of interpretability, as they are inversely proportional to physiological stress. To facilitate further understanding of the SEM results, the total effects for work type and office type on workers' stress outcomes and physical activity were also analysed using analysis of variance (ANOVA). For more information, see the online supplementary material.

RESULTS

Participants

A total of 248 office workers expressed interest in participating in the study, representing approximately 12% of the workers located in areas of the office buildings where recruitment took place. Due to scheduling problems, sickness and exclusionary criteria, 17 office workers did not participate, resulting in a total enrolment of 231 participants. Due to unexpected changes in work schedules, 8 of the 231 participants were only observed for two workdays, rather than the full 3 days. Demographic characteristics and descriptive data for measures of interest are provided in tables 1 and 2.

Type of work characteristics are not mutually exclusive, and thus sums across rows may not equal office workstation type frequencies. The total for type of work and office workstation type, along with missing values, can be found in table 1.

Effects for office workstation type and work type

Stress and physical activity

All results described below are based on the SEM, unless otherwise specified. Workers in open bench seating exhibited significantly higher physical activity compared with workers in private offices (B=225.51 mG; 95% CI 136.57 to 314.46). Workers in open bench seating also exhibited significantly higher physical activity compared with workers in cubicles (B=185.13 mG; 95% CI 66.53 to 303.72). To further illustrate the magnitude of these differences, we compared the mean differences between office workstation types. Workers in open bench seating exhibited 31.83% higher physical activity compared with workers in private offices, and 20.16% higher physical activity compared with workers in cubicles.

Workers in open bench seating experienced significantly lower perceived stress at the office compared with those in cubicles as measured by the average 'tense' EMA ratings (B=−0.27 units; 95% CI −0.54 to −0.02). Importantly, the significant differences found between the types of office workstations reflect differences above and beyond any differences found due to types of work being performed. Only one work type difference was found in the model, where workers with computer-dominant jobs exhibited significantly lower physical activity compared with those with jobs that were not rated as

Table 1 Sample characteristics

Variable	n (%)
Age, mean (SD)	44.15 (12.22)
Missing	30 (12.98)
Gender	
Male	88 (38.09)
Female	115 (49.78)
Missing	28 (12.12)
BMI, mean (SD)	27.60 (6.10)
Missing	31 (13.41)
Ethnicity	
African–American	32 (13.85)
American Indian, Alaska Native, Native Hawaiian or other Pacific Islander	4 (1.73)
Asian	14 (6.06)
Hispanic	16 (6.92)
White, non-Hispanic	134 (58.01)
Other	3 (1.30)
Missing	28 (12.12)
Education	
No high school degree	1 (0.43)
High school degree	5 (2.16)
Some college	15 (6.49)
Two-year college degree	3 (1.30)
Bachelor's degree	76 (32.90)
Master's degree	86 (37.23)
Doctorate degree	16 (6.93)
Missing	29 (12.55)
Computer-dominant work	
Yes	93 (40.26)
No	118 (51.08)
Missing	20 (8.66)
Management work	
Yes	69 (29.87)
No	142 (61.47)
Missing	20 (8.66)
Technical work	
Yes	90 (38.96)
No	121 (52.38)
Missing	20 (8.66)
Office workstation type	
Open bench seating	97 (41.99)
Cubicle	66 (28.57)
Private office	42 (18.18)
Missing	26 (11.25)
EMA 'tense' ratings at the office, mean (SD), 1–7 scale	2.81 (0.98)
Missing	7 (3.03)
10th percentile SDNN at the office, mean (SD), ms	51.98 (16.99)
Missing	17 (7.36)
ActLevAvg at the office, mean (SD), mG	1198.98 (452.07)
Missing	13 (5.63)
PSS-4: long-term perceived stress, mean (SD), 1–7 scale	3.13 (1.17)
Missing	45 (19.48)
10th percentile SDNN outside the office, mean (SD), ms	48.12 (16.36)
Missing	48 (20.78)
Duration of study	5 May 2015–25 August 2016
Total data in hour:minute (postprocessing)	2883:35:00

ActLevAvg, average physical activity level; BMI, body mass index; EMA, ecological momentary assessment; PSS-4, Short Form Perceived Stress Scale; SDNN, standard deviation of normalized interbeat intervals.

Table 2 Distribution of office workstation type and type of work across the four sites

Office workstation type	Site	n	Computer-dominant	Managerial	Technical
Open bench seating	1	85	37	26	34
	2	10	2	6	3
	3				
	4	2	1		1
Cubicle	1				
	2	5	2		4
	3	48	20	15	19
	4	13	5	2	5
Private office	1	1			1
	2				
	3				
	4	41	19	15	13

computer-dominant (B=−140.94 mG; 95% CI −239.49 to −42.39).

We then further tested the relationships identified between office workstation type and types of work on outcome variables at the office in one-way ANOVA models. We found significant differences between office workstation types in 'tense' EMA ratings at the office ($F(2,194)=3.377$, $p=0.036$, $\eta^2=0.03$), between office workstation types in physical activity at the office ($F(2,188)=9.476$, $p<0.001$, $\eta^2=0.09$), and between workers with and without computer-dominant jobs in physical activity at the office ($F(1, 200)=6.179$, $p=0.0137$, $\eta^2=0.03$), thus revealing effects that converge with the findings obtained from the SEM.

Consistent with the idea that there may be elements of the workplace that we take home in the form of stress, higher physical activity at the office was significantly related to lower levels of physiological stress outside the office as measured by the 10th percentile SDNN (B=−26.12 ms/mG; 95% CI −40.48 to −4.16). To further illustrate this relationship, a median split of physical activity at the office showed that compared with workers with lower physical activity, those with higher physical activity had 14.18% lower physiological stress outside the office. However, physical activity at the office was not significantly related to physiological stress while at the office. Furthermore, physiological stress at the office was significantly related to physiological stress outside the office as measured by the 10th percentile SDNN (B=0.74; 95% CI 0.64 to 0.85).

In line with what is understood in the literature about the relationship between age, body composition and HRV,[30 31] we found that physiological stress at the office was significantly higher among older participants (B=0.36; 95% CI 0.24 to 0.48) and was significantly higher among participants with higher BMI (B=0.61; 95% CI 0.46 to 0.76). We also observed that, compared with male workers, female workers exhibited significantly lower physical activity at the office (B=−149.32 mG; 95% CI −215.26 to −83.38) and significantly higher physiological stress outside the office (B=1.95 ms; 95% CI, 0.01 to 3.92). Lastly, higher perceived stress at the office was significantly related to higher long-term perceived stress as measured by the PSS-4 (B=0.44; 95% CI 0.27 to 0.60).

Model fit

The SEM exhibited good model fit with a comparative fit index of 0.983 and a standardised root mean square residual of 0.032. The solid and dashed directed lines in figure 2 indicate significant and non-significant coefficients in the model, respectively.

DISCUSSION

Key results

We found a statistically significant relationship between participants' office workstation type and their physical activity while at the office using a statistical model controlling for factors including type of work, demographics, and perceived and physiological stress levels. Workers in both private offices and traditional, high-partition cubicles exhibited lower levels of physical activity than workers in open bench seating arrangements at a degree shown to be clinically meaningful in other populations.[32] Furthermore, we found that higher physical activity levels at the office were related to lower physiological stress levels outside the office. The magnitude of this association has also been shown to be clinically meaningful in prior research.[33] This finding is consistent with research showing that the effects of certain office characteristics may carry over to non-office hours and affect diurnal patterns of physiological stress.[17] Consistent with prior research, we found higher stress levels at the office among older participants and those with higher BMI. Interestingly, our analyses also revealed that women exhibited both lower levels of physical activity at the office and higher levels of stress outside the office compared with men. This observation warrants further investigation of workplace and non-workplace factors and mechanisms contributing to these gender differences.

Taken together, this study establishes a new paradigm for objectively investigating the behavioural, well-being and health consequences of built environments, and it provides, for the first time, empirical evidence for associations between office workstation type, physical activity, and objective and subjective stress responses both at and outside of the office. These findings have important implications, as economic forces and the changing nature of work patterns are driving more and more office spaces towards open designs.[34] This is the first study to show that open bench seating may be an unrecognised positive factor in promoting physical activity levels at work. Given the importance of physical activity to health, the fact that office workstation type may influence how much people move at work should not be overlooked in the health field.

Limitations and interpretation

Because this is an observational study, we cannot confirm a causal relationship between office workstation type and physical activity, nor confirm causal relationships for any other significant paths in our model. Importantly, we verified that participants in the study did not self-select but instead were assigned to consistent office workstation types based on location and organisation. While we controlled for relevant variables such as certain demographics, perceived stress and work type in the statistical models, there may be other contributing factors to these findings. For instance, because of the sample size, we were limited in the number of variables that we could include in the SEM. We prioritised modelling variables such as BMI, age, gender and work type over other factors such as ethnicity and education level.

Office workstation size, materiality, appearance, ambient environmental characteristics, common workspace availability and work culture differences may vary systematically among participants. Such factors should be considered in future research. For instance, the total area allocated to office workstations tends to differ by design between the three office workstation types. In our sample, 97.9% of open bench seating workstations were under 36 square feet in area, 96.9% of cubicles were between 36 and 64 square feet in area, and 95.2% of private offices were at least 100 square feet in area. Since workstation type and size tend to be related, the effect of workstation type on physical activity and stress apart from any possible effect of workstation size cannot be disentangled in this study. Moreover, the distribution of office workstation type was closely tied to study site. To account for this, we recruited participants from a variety of work types within each site (table 2) and statistically accounted for these characteristics. However, ultimately, the natural inability to fully insulate workstation effects from influences of clustering of workstations by building or departments remains a limitation.

We also explored the relationships of several other characteristics of the built environment on physical activity and stress responses. For instance, we were interested in investigating the effect of window views to nature and the office workstation distance to windows on other variables, but the limited amount of available data for these two variables prevented inclusion in our model. There are many more workplace design features that may help explain differences in levels of observed physical activity, including circulation patterns, the availability of informal meetings spaces and the accessibility of stairwells.

In this study we have only used SDNN measures to represent HRV. While previous studies suggest a high correlation between SDNN and other HRV measures, other metrics provide a different window into the stress response. When the root mean square of successive differences, a stronger indicator of parasympathetic activity, is used in the SEM analysis, the link between physical activity at the office and stress response outside the office is not present (see online supplementary table A and supplementary figure A). This may be due to the fact that SDNN represents both sympathetic and parasympathetic activity,[35] but further analyses, which are beyond the scope of this paper, are needed to clarify this.

Little empirical evidence exists on the mechanism by which office workstation type can affect physical activity, yet this finding suggests an important potential health benefit of open bench seating that must be weighed against other office space design trade-offs.

Workers tend to rate private offices as more desirable than other office workstation types,[16] but there may be other consequences when compared with open bench seating arrangements. For instance, valuable, impromptu conversations may be an unintended benefit to this design strategy, as well as improved communication and an increased awareness of others.[14] It is possible that the open nature of a space leads to increased physical activity by encouraging interaction and mobility, including movement to spaces designed for unplanned meetings and phone calls, when available. Individuals in open bench seating may also be more aware of others and more dependent on shared services (eg, meeting rooms, printing and filing areas, social spaces) than those in private offices.

Similarly, there may be unintended trade-offs between cubicles and open bench seating. Past research has shown that workers in cubicles tend to report higher levels of visual privacy compared with those in open bench seating, yet this pattern does not hold for perceived auditory privacy. In fact, there is evidence that workers in cubicles report less auditory privacy compared with workers in open bench seating.[16] It is possible that because there is less of a visual connection between workers in cubicles, people in cubicles may be less aware of the presence of other workers

nearby and thus less sensitive to the impact on others when they engage in conversations and phone calls.[15 16] It is possible that this greater awareness of others enhances physical activity and encourages better sound etiquette.

While the relationship between physical activity patterns and built environment design elements is rarely simple and often contains cultural elements,[36] this study suggests that in some cases, design modifications may be employed to overcome the negative health impact features of different types of office workstations. To explore potential mechanisms for behavioural changes associated with office design characteristics, we are currently investigating the relationship between sound levels, types of work tasks and office workstation type. Moreover, the process employed to transition workers to new office workstation types may influence workers' perceptions. There is evidence that the process of engagement with both management and individual workers, to effectively understand needs and communicate design intent before a move, may increase subsequent satisfaction levels and achievement of design goals.[37 38] Communicating the health implications of different office workstation types to future occupants may also help transitions.

The results of this study are an important step towards establishing best practices and guidelines for office design and operations. There are ongoing and accelerating trends towards reducing dedicated individual workspace in offices in order to save rental and other overhead costs, and to reduce environmental impacts of underutilised space. The US federal government in particular views reduction and consolidation of office space as a critical cost-saving measure as indicated by the recent passage of the Federal Property Management Reform Act of 2016.[39]

While many US government programmes are not informed by research,[40] the US General Services Administration seeks to use the best research available to shift the focus of occupational health programmes from risk avoidance to health promotion. Indeed, the current study's methodology can be applied to other types of office workspaces and to other building types, such as healthcare and education settings. Doing so will help to better understand how the behaviour and health of millions of people are affected by the built environment in which they spend so much of their lives. The findings of this study suggest that features of office design may play a role in office workers' levels of physical activity. While further interventional research is required to better understand the related mechanisms, this study can inform designers' thinking about how office design elements might encourage physical activity and potentially even reduce levels of stress, thus facilitating a healthier lifestyle.

Author affiliations
[1]College of Medicine, Institute on Place, Wellbeing & Performance, University of Arizona, Tucson, Arizona, USA
[2]INSITE Center for Business Intelligence and Analytics, Department of MIS, Eller College of Management, University of Arizona, Tucson, Arizona, USA
[3]Office of Federal High-Performance Buildings, US General Services Administration, Washington, District of Columbia, USA
[4]Michael E DeBakey Department of Surgery, Baylor College of Medicine, Interdisciplinary Consortium on Advanced Motion Performance (iCAMP), Houston, Texas, USA
[5]Center for Innovations in Quality, Effectiveness and Safety, Houston, Texas, USA
[6]LMI, Tysons, Virginia, USA
[7]Department of Psychology, University of Arizona, Tucson, Arizona, USA
[8]Aclima, San Francisco, California, USA

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