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Occupant Satisfaction in LEED and BREEAM-Certified Office Buildings

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ABSTRACT: Green certification schemes, such as LEED in US and BREEAM in UK, are contributing to promote the sustainability agenda in the design and operation of office buildings. However, the role of rating tools towards improved workplace experience is still much debated. Previous work by the authors provided evidence that LEED rating per se does not significantly and substantively influence occupant satisfaction with indoor environment qualities, although tendencies showed that LEED-certified buildings were more effective in delivering satisfaction in open spaces rather than in enclosed offices, and in small rather than in large buildings. This paper investigates occupant satisfaction in BREEAM-rated office buildings in UK. User responses were collected by cross-sectional questionnaires and point-in-time surveys administered while physical measurements were taken. Consistent with earlier work, the results showed that BREEAM certification does not have a significant and practically-relevant effect on building and workspace satisfaction, although tendencies revealed that occupants of non-BREEAM buildings were more satisfied with visual privacy and air quality than users of BREEAM-rated workspaces. Lower satisfaction was detected in BREEAM buildings for occupants having spent more than 24 months at their workplace. These results support previous findings, suggesting further research on the sustained benefits of green certification over time.

Keywords: Occupant Satisfaction; BREEAM; LEED; Post-Occupancy Evaluation; Indoor Environmental Quality.

INTRODUCTION

In December 2015, at the UN Conference of Parties in Paris, almost 200 nations set the goal to “*accelerate the reduction of global greenhouse gas emissions*” (COP21, 2015), pushing carbon neutrality and energy efficiency at the core of the building industry’s environmental, social, and economic sustainability agenda. These targets reinforce the prominent role that rating tools such as the *Leadership in Energy and Environmental Design* (LEED) in US and the *Building Research Establishment Environmental Assessment Method* (BREEAM) in UK are assuming at a global level. However, although these certification schemes embrace a wide range of environmental issues, there is a risk that a major emphasis given to energy consumption may prioritise attention with respect to occupants’ health and satisfaction with Indoor Environmental Qualities (IEQ).

Particularly in the workplace, users’ IEQ satisfaction has been associated to their comfort, well-being, and self-estimated job performance (Frontczak et al., 2012). Considering that occupants greatly impact on buildings’ energy use (Janda, 2011), a vast body of research has studied the influence of physical parameters of the indoor environment on user perception (Frontczak & Wargocki, 2011), and the contribution of environmental rating tools on occupant satisfaction. Among many others (e.g., Singh et al., 2010; Baird et al., 2012; Newsham et al., 2013), previous research by the authors (Altomonte & Schiavon, 2013; Schiavon & Altomonte 2014) analysed a subset of the Center for the Built Environment (CBE, UC Berkeley) survey database

featuring 21,477 responses from 144 buildings (of which 65 were LEED-rated) to investigate if LEED certification leads to higher, equal, or lower occupant satisfaction, and to study the impact on workspace experience of factors that are distinct from conventional IEQ parameters. The results showed that occupants of LEED-rated buildings were equally satisfied with the building, workspace, and several indicators of IEQ than users of non-LEED offices. These outcomes were independent of gender, age, office type, spatial layout, distance from windows, building size, work type, and working hours. However, evidence was detected for LEED-rated buildings to be more effective in delivering satisfaction in open rather than in enclosed offices, and in small rather than in large buildings. Also, tendencies suggested that occupants of LEED buildings might be more satisfied with air quality and more dissatisfied with amount of light, and that the positive values of certification might decrease with time.

Although research has furthered knowledge on the impact that certification systems have on occupant satisfaction, with relatively few exceptions (e.g., Leaman and Bordass, 2007) studies have been mostly conducted either in US or in Canada, using datasets obtained from buildings rated by LEED. Conversely, the contribution of other rating tools such as BREEAM to workplace experience has been largely unexplored.

In response, this paper offers preliminary analysis of occupant satisfaction with the building, workspace, and several IEQ parameters in BREEAM-rated office buildings recently built at a University in the UK, and

compares occupant responses with those provided by users of non-BREEAM certified buildings similar in age, function, size, and location. In addition, this paper explores how factors unrelated to conventional measures of environmental quality might affect IEQ satisfaction in BREEAM and non-BREEAM buildings. Consistent with earlier studies, responses were collected via cross-sectional (transversal) questionnaires based on the CBE survey (Zagreus et al., 2004). The information gathered was also supported by point-in-time (right-now) surveys administered while physical measurements were taken.

METHOD

The BREEAM Programme

There are globally more than 500,000 BREEAM certified developments in 72 countries, and more than 2 million buildings have been registered for assessment since the scheme was launched in 1990 (BRE, 2016). The BREEAM system awards credits in: Energy; Health and Wellbeing; Innovation; Land Use; Materials; Management; Transport; Waste; Water; and, Pollution. BREEAM encompasses both mandatory and optional credits. It is, however, a flexible system that can ‘trade’ credits in different categories, while always setting minimum standards in essential areas. The Health and Wellbeing category weighs 15% of the total score attainable, and assigns credits to aspects such as: visual comfort, indoor air quality, thermal comfort, acoustic performance, etc. Rating benchmarks go from *Unclassified* (<30), to *Pass* (≥30), *Good* (≥45), *Very Good* (≥55), *Excellent* (≥70) and *Outstanding* (≥85).

Building Selection

The criteria for the selection of buildings in this study required them to be comparable in terms of size, age of construction, function, etc., and to be certified – or having applied for certification – with the BREEAM system. This was meant to ensure that differences in the data could be associated primarily to the certification, and that no other physical factor affected the assessment.

Four buildings were chosen for this preliminary study, all hosting office-type activities. The buildings all included private, shared, and open-plan workspaces and laboratories, had 3-4 floors, a size from 3,000 to 3,200 m², were built between 2011 and 2012, and all belonged to a University in the United Kingdom. Two buildings were certified by BREEAM (respectively, *Outstanding* and *Excellent*), while two failed to achieve the targeted *Excellent* BREEAM rating, and lower certification was not pursued since two mandatory credits were found not to be achievable. The BREEAM-rated buildings received, respectively, 7 and 9 out of the targeted 12 credits in the Health and Wellbeing category.

Data Collection

Transversal online questionnaires were electronically sent to the occupants of the selected buildings, featuring

general questions about participants’ gender, age, time spent in the building and at their current workspace, the nature of their work, the location of the workspace, its orientation, proximity to windows, and spatial layout (i.e., private office, shared office, cubicle, open space). The questionnaire also asked occupants to rate – on a Likert scale ranging from *very dissatisfied* (-3) to *very satisfied* (+3) with a neutral midpoint (0) – their satisfaction with: building; workspace; ease of interaction; cleanliness; amount of light; colours and textures; amount of space; visual comfort; air quality; visual privacy; noise; temperature; and, sound privacy. Further questions asked participants if the quality of their workspace either enhanced or interfered with their ability to get their job done, and lastly, finished with an open section providing subjects with the opportunity to add any comments on their workspace and building.

Right-now surveys were distributed while occupants were at their workplace and physical measurements of environmental parameters were taken. The survey collected information on satisfaction with luminous, acoustic, and thermal conditions, and perceived control over these, and offered participants opportunity to give comments on the characters of their workspace. While the survey was filled, the following measurements were recorded by calibrated instruments: temperature (dry bulb, globe, and surface); relative humidity; air velocity; vertical and horizontal illuminance; sound levels.

Table 1 summarizes the *datasets* used in this study.

Table 1: Description of the datasets

Occupant responses	BREEAM	Non-BREEAM	Total
Online questionnaires	63	58	121
Right-now surveys	48	33	82
Total	111	91	203

To perform a statistically robust comparison, the two independent groups of responses needed to be not only homogenous in terms of location, size, function and year of construction of the buildings (BREEAM and non-BREEAM), but also similar in sample size. In addition, several non-environmental factors – “*factors unrelated to environmental quality that influence whether indoor environments are considered to be comfortable*” (Frontczak & Wargocki, 2011) – were considered, since earlier research had revealed that they might affect satisfaction (Schiavon & Altomonte, 2014). The two groups (BREEAM and non-BREEAM) were found to be also comparable in terms of distribution of responses based on: gender; age; time spent in the building and at the workspace; distance from windows; spatial layout.

Statistical Analysis

The analysis of *online questionnaires* initially consisted in calculating descriptive statistics (e.g., mean, median, standard deviation, interquartile ranges) of votes of satisfaction with the building, workspace, and IEQ

parameters in BREEAM and non-BREEAM buildings. Data inspection (N= 121) (Q-Q plots and Kolmogorov-Smirnov tests) revealed non-normal distribution of statistical values, thus violating one of the assumptions for the adoption of parametric tests. Since data had an ordinal character, the statistical significance (NHST, null hypothesis significance testing) of the differences in median votes of satisfaction between groups (ΔM_{dn} , BREEAM minus non-BREEAM) were tested with a two-tailed non-parametric Wilcoxon rank sum test (using the SPSS package). Individual responses were considered in the analysis instead of average building values. This was to avoid loss of information (variance) considering that, at the building level, the sample size was small. Results were declared statistically significant when the probability that a difference could have arisen by chance was below 5% ($p \leq 0.05$). However, one of the limitations of NHST is that the p -value depends on the sizes of both the sample and the influence tested. Hence, the mean ranks for each group were determined, and the effect size was calculated for each comparison using the equation: $Effect\ size = (Z\text{-score})/\sqrt{N}$, where the Z-score was provided by the Wilcoxon tests, and N was the number of observations (Field, 2013). The effect size – i.e., the standardised size of the difference between groups – provided a reliable estimator to infer whether the difference detected had practical relevance, and was calculated by equivalence with the Pearson's r coefficient. In interpreting the outcomes, benchmarks were used for small, moderate, and strong effect sizes ($r \geq 0.20$, 0.50, and 0.80, respectively) (Ferguson, 2009). Values of $r < 0.20$ were considered negligible, and therefore not providing any substantive (i.e., practically relevant) effect. The same method of analysis was used for consideration of *non-environmental factors*.

To correlate physical measurements with responses to the *right-now surveys*, the Jonckheere-Terpstra (J-T) test was used (N= 82). J-T tests are rank-based non-parametric tests that require independent groups divided into ranked orders to search for statistically significant trends between (continuous or ordinal) independent and dependent variables. Dependent variables were measured at the ordinal level based on 7-point Likert scales (e.g., from *no discomfort* to *a lot of discomfort*). In this case, the effect size measured both the magnitude and the directionality of the trend, i.e. whether there was a direct or inverse relationship (positive or negative effect) between variables. For lighting and noise, physical readings were directly used in statistical analysis. For thermal sensation, since buildings were not free-running, measures of dry bulb temperature, humidity, air speed, and mean radiant temperature (derived from globe temperature), were combined with estimations of metabolic rate and clothing levels to determine the Predicted Mean Vote (PMV), which was calculated via the online CBE Thermal Comfort Tool (comfort.cbe.berkeley.edu) (Schiavon et al., 2014).

RESULTS

Satisfaction in BREEAM and non-BREEAM offices

Table 2 provides overall differences (N=121) in mean (ΔM) and median (ΔM_{dn}) votes of satisfaction between BREEAM (BRE) and non-BREEAM offices (n-BRE), their statistical significance (NHST), mean ranks of independent groups, and effect sizes (r) of differences. Values in bold italic are statistically significant ($p < 0.05$) and have substantive magnitude of effect ($r \geq |0.20|$).

Table 2: Descriptive and inferential statistics (N= 121)

Variable	ΔM	ΔM_{dn}^{NHST}	Mean Rank BRE	Mean Rank n-BRE	Effect Size (r)
Building overall	-0.66	0.00 n.s.	55.83	66.61	-0.16
Workspace	-0.60	0.00 n.s.	55.75	66.70	-0.16
Ease of interaction	-0.23	0.00 n.s.	58.78	63.41	-0.07
Cleanliness	-0.29	0.00 n.s.	58.21	64.03	-0.08
Amount of light	-0.48	0.00 n.s.	57.17	65.16	-0.12
Colours & textures	-0.16	0.00 n.s.	59.26	62.89	-0.05
Amount of space	-0.66	0.00*	55.10	67.41	-0.18
Visual Comfort	-0.55	-1.00 n.s.	56.30	66.10	-0.14
Air Quality	-0.93	-1.00**	52.17	70.59	-0.27
Visual Privacy	-0.70	0.00*	54.48	68.09	-0.20
Noise	-0.62	-1.00 n.s.	55.79	66.66	-0.16
Temperature	-0.45	-1.00 n.s.	56.33	66.08	-0.14
Sound Privacy	-0.53	-1.50*	54.91	67.61	-0.18

*** $p \leq 0.001$ =highly significant; ** $p \leq 0.01$ = significant; * $p \leq 0.05$ = weakly significant; n.s.= not significant; $r < |0.20|$ = negligible; $|0.20| \leq r < |0.50|$ = small; $|0.50| \leq r < |0.80|$ = moderate; $r \geq |0.80|$ = strong

Analysis of descriptive statistics for both groups revealed positive mean (M) and median (Mdn) scores of satisfaction with the building (BRE: M= 0.56, Mdn = 1.00; n-BRE: M= 1.22, Mdn= 1.00) and the workspace (BRE: M= 0.52, Mdn= 1.00; n-BRE: M= 1.12, Mdn= 1.00). For most IEQ parameters, satisfaction votes showed positive or neutral mean and median values, except for visual (BRE: M= -0.29, Mdn = 0.00; n-BRE: M= 0.41, Mdn= 0.00) and sound privacy (BRE: M= -0.84, Mdn = -2.00; n-BRE: M= -0.31, Mdn= -0.50).

The inferential tests showed that users of BREEAM and non-BREEAM buildings had equal satisfaction with the building (ΔM_{dn} = 0.00 n.s., r = -0.16) and the workspace (ΔM_{dn} = 0.00 n.s., r = -0.16), as per the non-statistically significant differences and the effect sizes of non-relevant magnitude. For all other IEQ parameters, the inferential results showed that BREEAM-rated buildings had equal or lower median satisfaction scores (ΔM_{dn} values always zero or negative) than non-BREEAM buildings, although the differences detected were mostly not statistically or practically significant, with the exception of satisfaction with air quality, visual and sound privacy, and amount of space. Satisfaction with air quality showed the highest significant median difference with an effect size of practical relevance (BRE: M= 0.14, Mdn = 0.00; n-BRE: M= 1.07, Mdn= 1.00; ΔM_{dn} = -1.00**, r = -0.27). This suggests a higher occupant satisfaction with air quality in buildings not

certified by BREEAM. Consideration of visual privacy detected higher satisfaction in non-BREEAM buildings, as denoted by a statistically significant difference and an effect size of substantive relevance (BRE: $M = -0.29$, $Mdn = 0.00$; n-BRE: $M = 0.41$, $Mdn = 0.00$, $\Delta Mdn = 0.00^*$, $r = -0.20$). Finally, results for satisfaction with amount of space (BRE: $M = -0.56$, $Mdn = 1.00$; n-BRE: $M = 1.22$, $Mdn = 1.00$; $\Delta Mdn = 0.00^*$, $r = -0.18$) and sound privacy (BRE: $M = -0.84$, $Mdn = -2.00$; n-BRE: $M = -0.31$, $Mdn = -0.50$, $\Delta Mdn = -1.50^*$, $r = -0.18$) revealed tendencies for a marginally higher satisfaction in non-BREEAM buildings, this being supported by weakly significant differences in median scores, but with effect sizes at the borderline of practical relevance.

Influence of non-environmental factors

Gender. Inferential tests showed that gender did not significantly affect differences in satisfaction with the building and workspace in BREEAM and non-BREEAM buildings. Analysis of other IEQ variables revealed that median satisfaction votes provided by males were usually higher than females both in BREEAM and non-BREEAM buildings, and were positive for almost all IEQ parameters except for sound and visual privacy. However, no statistically significant differences were detected when comparing satisfaction scores given by males in BREEAM and non-BREEAM buildings. Conversely, consideration of female votes detected practically significant higher satisfaction with temperature, air quality, amount of space, visual and sound privacy, in buildings not rated by BREEAM.

Age. Analysis of age groups (under 30, 30-40, 41-50, over 50) did not show significant differences between BREEAM and non-BREEAM buildings. However, substantive effect sizes ($r \geq |0.20|$) were detected for several comparisons, suggesting that age might have an effect on satisfaction, although the sample size may not have allowed detection of statistical significance.

Time spent in the building. For people who spent less than 12 months in their building, the median votes of satisfaction were consistently positive, except for temperature in BREEAM-certified buildings (6-12 months: $Mdn = -0.50$). For occupants who spent over 24 months in their building, inferential tests detected in non-BREEAM offices a statistically significant and practically relevant higher satisfaction with workspace ($\Delta Mdn = -2.00^{**}$, $r = -0.38$), cleanliness ($\Delta Mdn = 0.00^*$, $r = -0.30$), visual comfort ($\Delta Mdn = 0.00^*$, $r = -0.28$), amount of space ($\Delta Mdn = -2.00^*$, $r = -0.33$), air quality ($\Delta Mdn = -2.00^{**}$, $r = -0.40$), noise ($\Delta Mdn = -2.00^{**}$, $r = -0.35$), temperature ($\Delta Mdn = -1.00^*$, $r = -0.33$), visual privacy ($\Delta Mdn = -2.00^{***}$, $r = -0.46$) and sound privacy ($\Delta Mdn = -1.00^{**}$, $r = -0.34$). An analogue tendency was detected for satisfaction with the building, although such difference had a substantive effect size ($r = -0.27$), but it was not statistically significant ($p > 0.05$). Similar trends of relevant but not significant effect sizes could be found

for higher satisfaction with noise ($r = -0.25$) and sound privacy ($r = -0.36$) in non-BREEAM offices for users having occupied their building for 12-24 months.

Time spent at the workspace. Participants who spent over 24 months at their workstation in a non-BREEAM building expressed higher satisfaction with cleanliness ($\Delta Mdn = -1.00^*$, $r = -0.39$), amount of space ($\Delta Mdn = -2.00^*$, $r = -0.37$), visual privacy ($\Delta Mdn = -2.00^{**}$, $r = -0.49$) and sound privacy ($\Delta Mdn = -2.00^*$, $r = -0.36$). Similar tendencies were detected, for this category of users, for satisfaction with workspace ($r = -0.28$), visual comfort ($r = -0.33$), air quality ($r = -0.23$), noise ($r = -0.32$) and temperature ($r = -0.22$). These differences were marginally non-significant, yet supporting a trend for higher IEQ satisfaction in non-BREEAM buildings.

Distance from windows. Median votes of satisfaction provided by occupants whose workstation was within 4.6 m from a window were invariably higher than those expressed by users sitting far from the perimeter across the two groups of buildings. Users sitting further than 4.6 m from a window expressed higher satisfaction with building, workspace, and almost all IEQ parameters in non-BREEAM buildings. All differences detected were significant and with an effect size of relevant magnitude.

Spatial layout. Median votes of satisfaction from occupants of enclosed offices (private and shared) were positive in both BREEAM and non-BREEAM buildings. For these layouts, inferential tests did not detect statistically significant differences, even if effect sizes of practical relevance suggested higher satisfaction in non-BREEAM buildings. For users of cubicles, votes varied depending on IEQ parameter, but differences were consistently not significant. Conversely, significant and substantive higher satisfaction with building ($\Delta Mdn = -1.50^{***}$, $r = -0.50$), workspace ($\Delta Mdn = -2.00^{***}$, $r = -0.49$), amount of light ($\Delta Mdn = -2.00^*$, $r = -0.31$), visual comfort ($\Delta Mdn = -2.00^*$, $r = -0.33$), amount of space ($\Delta Mdn = -1.00^{**}$, $r = -0.40$), air quality ($\Delta Mdn = -2.50^{***}$, $r = -0.53$), noise ($\Delta Mdn = -2.00^{***}$, $r = -0.53$), temperature ($\Delta Mdn = -2.00^{**}$, $r = -0.39$), visual privacy ($\Delta Mdn = -1.00^*$, $r = -0.37$), and sound privacy ($\Delta Mdn = -2.50^{***}$, $r = -0.60$) was expressed by occupants of open spaces in non-BREEAM certified buildings.

Right-now surveys and physical measurements

Light. In BREEAM offices, no significant and relevant relationships were detected between measured vertical and horizontal illuminance (natural and artificial), users' description of lighting availability, perceived level of control, and discomfort. Conversely, in non-BREEAM buildings, direct associations were detected between self-reported lighting availability and horizontal ($p = 0.01^{**}$, $r = 0.43$) and vertical illuminance (facing screen ($p = 0.03^*$, $r = 0.38$), facing occupant ($p = 0.002^{**}$, $r = 0.53$)). Direct trends were also found in non-BREEAM offices between reported control over natural lighting and horizontal ($p = 0.02^*$, $r = 0.39$) and vertical facing

occupant ($p = 0.004^{**}$, $r = 0.51$) illuminance. Similar results were obtained for control over artificial lighting and horizontal ($p = 0.02^{*}$, $r = 0.39$) and vertical facing occupant ($p = 0.03^{*}$, $r = 0.38$) illuminance. Inverse relationships were found in non-BREEAM buildings between discomfort from natural and artificial lighting, and horizontal ($p = 0.05^{*}$, $r = -0.33$; and, $p = 0.01^{**}$, $r = -0.43$) and vertical facing occupant ($p = 0.03^{*}$, $r = -0.39$; and, $p = 0.001^{***}$, $r = -0.55$) illuminance.

Sound. A significant and relevant direct relationship was found between users' sensitivity to noise and the measured decibel levels in BREEAM buildings ($p = 0.002^{**}$, $r = 0.44$). This trend was, however, not detected in non-BREEAM buildings. In terms of perceived control over noise, an inverse relationship appeared between users' responses and sound levels in BREEAM offices ($p = 0.01^{**}$, $r = -0.37$), while a direct trend was found in non-BREEAM buildings ($p = 0.02^{**}$, $r = 0.39$).

Thermal sensation. A highly significant and substantive direct relationship was detected between users' description of their thermal sensation and the calculated PMV in BREEAM-certified buildings ($p = 0.000^{***}$, $r = 0.51$). This trend was also substantiated by the results in non-BREEAM buildings, although at lower significance and magnitude ($p = 0.01^{**}$, $r = 0.44$).

DISCUSSION

Comprehensive analysis of the data from the transversal questionnaires led to infer that BREEAM rating *per se* does not influence satisfaction with building, workspace, and several IEQ parameters. However, occupants of non-BREEAM buildings expressed a statistically significant and practically relevant higher satisfaction with air quality and visual privacy. Tendencies also suggested that users of non-BREEAM offices might be more satisfied with sound privacy and amount of space.

These results are consistent with previous research by the authors (Altomonte & Schiavon, 2013), where LEED rating was found to not substantively affect satisfaction with the building and the workspace. Also, in line with earlier studies, satisfaction with air quality, noise, visual and sound privacy corresponded to the lowest detected mean and median scores in BREEAM buildings. Issues related to lack of visual and acoustic privacy are recurrent in green-buildings research, likely due to the incentive towards the design of open spaces that may enhance natural ventilation and deeper daylight penetration. However, studies on LEED-rated buildings detected higher satisfaction with air quality (Newsham et al., 2013; Zagreus et al., 2004), a result not supported by this study. This might be explained by the mandatory credits for indoor air quality being required for LEED certification but not compulsory for BREEAM rating.

In terms of non-environmental factors, *gender* did not affect differences in satisfaction with building and workspace in BREEAM and non-BREEAM offices, although males generally expressed higher median votes

of IEQ satisfaction than females. These findings are consistent with Schiavon & Altomonte (2014), Kim & de Dear (2013), Frontczak et al. (2012), who also found males to be more satisfied with their workspace. In line with Frontczak & Wargocki (2011), *age* could not be correlated to significant differences in IEQ satisfaction.

Inferential tests revealed that median votes of satisfaction tended to decrease with the increase in *time spent in the building* and *at the workspace*, this being particularly evident in BREEAM-rated offices. In fact, users who spent more than 24 months in BREEAM buildings expressed statistically significant and practically relevant lower satisfaction with their workspace and several IEQ parameters than occupants of non-BREEAM buildings. These results are consistent with the findings of Schiavon & Altomonte (2014), who concluded that users of LEED-rated offices having spent less than a year at their workplace had higher satisfaction than users who occupied their building for more than 12 months. In this context, Singh et al. (2010) suggested that perceived IEQ satisfaction might be higher immediately after moving into a new green building, hence leading to query the sustained value of green certification on users' satisfaction over time.

Results related to consideration of *distance from windows* and *workspace type* are in line with the findings of Leder et al. (2016), who stated that access to a window positively affects workspace experience and suggested that IEQ satisfaction is higher in enclosed offices, a result supported by our findings. Indeed, the spatial layout had considerable influence on the difference in satisfaction in BREEAM and non-BREEAM buildings, although, contrary to previous results (Schiavon & Altomonte, 2014), occupants of open workspaces showed to be significantly and substantively more satisfied with almost all IEQ parameters in buildings not certified by BREEAM. This could be explained by considering the results of right-now surveys combined with physical measurements.

In terms of *lighting*, in fact, no significant or relevant relationship was detected between measured levels of illuminance, users' assessed perception of the luminous environment, and their reported degree of control over it in BREEAM buildings. Conversely, direct associations were found between perceived luminous qualities and measured parameters in non-BREEAM buildings. These findings led to hypothesise that occupants' lack of control over their lighting conditions in BREEAM offices – particularly in open-plan workspaces – might have resulted in a luminous perception that is effectively detached from fluctuations in illuminance levels and, ultimately, led to lower satisfaction with environmental qualities. Instead, awareness of personal control over luminous levels was present in non-BREEAM buildings, allowing users to directly intervene at the occurrence of temporary visual discomfort, and enhancing feelings of comfort even with highly variable levels of illumination.

Similarly, a direct relationship was found between *sound levels* and reported perception of noise, and an inverse influence was detected between measured acoustic parameters and perceived control over noise, in BREEAM buildings. This suggests that users of BREEAM offices might be particularly sensitive to sound compared to non-BREEAM buildings. To remind that lower satisfaction with noise and sound privacy was especially evident for people having occupied their BREEAM-rated workplace for more than 24 months, or whose workstation was located further than 4.6m from a window (this being often the case in an open layout).

Finally, a stronger direct relationship was detected between occupants' *thermal sensation* and the PMV in BREEAM buildings. This suggests that occupants of BREEAM-rated workspaces were particularly sensitive to changes in their thermal environment, as also confirmed by analysis of the open comments provided by participants who often related their dissatisfaction with temperature particularly to a lack of control.

In summary, as already advocated by Newsham et al. (2013), Kim & de Dear (2013), and Schiavon & Altomonte (2014), the findings of this study confirm that the BREEAM rating system – as well as other certification schemes such as LEED – might benefit from balancing the criteria that directly address issues of visual, acoustic, and thermal performance, with proper design solutions and strategies that are conducive to perceived privacy, control, and proxemics.

CONCLUSIONS

The main conclusions to be drawn from this study are:

- In the dataset analysed, BREEAM rating *per se* did not significantly and substantively affect building and workspace satisfaction. This is consistent with previous research on other certification schemes such as LEED.
- Occupants of non-BREEAM buildings showed higher satisfaction with air quality than users of BREEAM-rated offices. The BREEAM scheme may benefit from stricter criteria for indoor air quality and natural ventilation in its Health and Wellbeing category.
- Significant and substantive lower IEQ satisfaction was detected in BREEAM offices for occupants having spent more than 24 months at their workplace. This is in line with previous studies, suggesting further research on the sustained benefits of green certification over time.
- The workspace type had considerable impact on the difference in satisfaction between BREEAM and non-BREEAM buildings. Improved workplace experience may benefit from a thorough consideration of the nature of office work, occupant density, perceived control, and spatial layouts from an early stage of design.

In interpreting these results, some limitations should be acknowledged. Only a narrow sample of buildings and a relatively small number of occupant responses were used for this analysis. The buildings were chosen to be as similar as possible for them to be statistically

comparable, and all belonged to a University in the United Kingdom. Also, responses were not related to the credits attained by buildings in their certification. Nevertheless, the results obtained provide important preliminary data on which further research, with larger and more varied samples, is being developed.

Far from being a criticism of LEED, BREEAM, or other rating schemes, studies such as that presented in this paper can provide evidence-based data to improve the standards achieved in green certification, whereas the emphasis given to energy should not come to the detriment of indoor environmental qualities and occupant satisfaction. As pointed out by (Allen et al., 2015), one of the strongest limitations of the research in this field is related to the frequent reliance on indirect and abstract measures, without a direct appraisal of the factors that mostly impact on users' perception. This study intended to offer a contribution in this direction.

REFERENCES

- Allen J., et al. 2015. Green buildings and health. *Curr Environ Health Rep.* 2015; 2(3): 250-258.
- Altomonte S, Schiavon S. 2013. Occupant satisfaction in LEED and non-LEED buildings. *Build Env*, 68:66-76.
- Baird G, et al. 2012. A comparison of the performance of sustainable buildings with conventional buildings. *Architectural Science Review*, 55:135-44.
- BRE. 2016. What is BREEAM. Online [Available at] <http://www.breeam.com> (Accessed February 20 2016)
- COP21, 2015. Adoption of the Paris Agreement. Paris: United Nations Framework Convention on Climate Change.
- Ferguson C.J. 2009. An effect size primer. *Professional Psychology: Research and Practice*, 40: 532-538.
- Field A. 2013. *Discovering Statistics using IBM SPSS Statistics*. London: Sage.
- Frontczak M, Wargocki P. 2011. Literature survey on how different factors influence human comfort in indoor environments. *Build Env*, 46:922-937.
- Frontczak M, et al. 2012. Quantitative relationships between occupant satisfaction and satisfaction aspects of indoor environmental quality. *Indoor Air*, 22:119-131.
- Janda K. 2011. Buildings don't use energy: people do. *Architectural Science Review*, 54: 15-22.
- Kim J, de Dear R. 2013. Workspace satisfaction. *Journal of Environmental Psychology*, 36: 18-26.
- Leaman A, Bordass, B. 2007. Are users more tolerant of 'green' buildings? *BRI*, 35(6):622-673.
- Leder S, et al. 2016. Effects of office environment on employee satisfaction: a new analysis. *BRI*, 4(1): 34-50.
- Newsham G, et al. 2013. Do 'green' buildings have better indoor environments? New evidence. *BRI*, 41(4):415-434.
- Schiavon S, Altomonte S. 2014. Influence of factors unrelated to environmental quality on occupant satisfaction in LEED and non-LEED certified buildings. *Build Env*, 77:148-159.
- Schiavon S, Hoyt T, Piccioli A. 2014. Web application for thermal comfort visualization and calculation according to ASHRAE 55, *Building Simulation* 7(4):321-334.
- Singh A, et al. 2010. Effects of green buildings on employee health and productivity. *Amer J Public Health* 100:1665-8.
- Zagreus L, et al. 2004. Listening to the occupants: a web-based indoor environmental quality survey. *Indoor Air*, 14(8):65-74.