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Creating Office Spaces in the Mediterranean. The importance of well-being, health and performance of office users

Diseño de oficinas en el Mediterráneo. La importancia del bienestar, la salud y el rendimiento de los usuarios

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ABSTRACT

Recent research has studied the influence of office buildings indoor environment quality (IEQ) on employees' well-being, health and performance. However, it seems that it has not been explicitly explored what are the appropriate environmental conditions to different work patterns that coexist in these spaces. This paper presents results of an empirical research, based on the synchronized measurements of different IEQ parameters (i.e., noise, lighting and temperature), and well-being, health and performance of 71 employees in twelve office spaces in the Valencian Community along three periods, considering winter and summer conditions. Findings of the first winter period data, suggest the existence of different ideal parameters for different levels of task complexity (one of the dimensions that characterizes work patterns) in the Mediterranean climate; and open new avenues of research to build up a specific Smart and Sustainable Offices (SSO) model and further systemic design-support tools.

Keywords: smart and sustainable offices, employees' well-being, indoor environment quality, IEQ, work patterns, task complexity, employees' performance, health, Mediterranean climate.

RESUMEN

Estudios previos han investigado la influencia de la calidad del ambiente interior (CAI) de las oficinas en el bienestar, salud y rendimiento de los empleados. Sin embargo, no parecen haberse explorado explícitamente cuáles son las condiciones ambientales apropiadas para los diferentes patrones de trabajo que conviven en estos espacios. Este artículo presenta los resultados de un estudio empírico, basado en mediciones sincronizadas de diferentes parámetros CAI (i.e., ruido, iluminación y temperatura), y el bienestar, la salud y el rendimiento de 71 empleados ubicados en doce espacios de oficinas de la Comunidad Valenciana durante tres periodos, considerando invierno y verano. Estos resultados referentes al primer invierno monitorizado, sugieren la existencia de diferentes parámetros óptimos asociados a diferentes niveles de complejidad de la tarea para el clima mediterráneo; y abren nuevas vías de investigación para establecer un modelo de Oficinas Inteligentes y Sostenibles (SSO) y desarrollar herramientas de apoyo al diseño y la gestión de las mismas.

Palabras clave: *oficinas sostenibles, bienestar de los empleados, calidad ambiental CAI, patrones de trabajo, complejidad de la tarea, rendimiento de los empleados, salud, clima mediterráneo.*

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1. INTRODUCTION

Office environments are meant to be cradles for innovation and productivity. In studying and analysing work environment, compulsory normative and major number of research studies report instead on negative effects of offices on employees such as sick leave due to physical conditions (1, 2). As a result, designers mainly focus on how to plan offices that mitigate these adverse consequences. Thus, little attention is paid to positive aspects of office environment, as how the office environment can stimulate well-being and performance, and enable sustained work engagement for individuals, as a key aspect to promote productivity (3, 4).

Improving office environments in order to stimulate employee performance and well-being is one of the challenges that many organizations attempt to address especially today, after 2008 financial crisis. On the other side, the environmental impact of the built environment is still a big challenge in Europe, even with EPBD (2010) and EED (2013) EU Directives running. Designing workplaces that support individuals to experience well-being and sustain work engagement while reducing energy consumption remains a challenge for organizations, designers and organizational psychologists.

Smart and Sustainable Offices (SSO) pan European initiative addresses this challenge. The main SSO goal is to provide work environments that positively affect users and reduce overall costs while reducing energy consumption, as stated in Climate KIC web description. The SSO hypothesis behind is that by improving physical working conditions it can improve productivity and innovation processes without increasing energy consumption. In order to define a SSO valid model, first step was testing the relationships between the offices indoor environment quality (IEQ) parameters, energy consumption and employees' well-being, health and performance by carrying out empirical study in different climates, in different seasons, and in real case scenarios.

Based on data of several companies in Spain, this paper presents the results of an empirical study in the Mediterranean climate. The purpose of this paper is to gain more insight into the optimal ranges of the IEQ parameters in office spaces considering the type of work and the climate. To this end, the relationships between the IEQ parameters (specifically, noise, lighting and temperature) and employees' well-being, health and performance have been further analyzed (Figure 1).

Rational

The economic crisis has forced to some organizations to reduce resources such as space or energy consumption, affecting negatively to the psychological well-being of employees and decreasing employees' performance (5, 6). On the other hand, organizations are increasingly seeking to increase productivity in order to get competitive advantage and the smart specialization that Europe is looking for (7, 8).

Previous research confirms that there is a direct relationship between the IEQ of office environments and the occupants' health and well-being (9, 10, 11, 12, 13). Some of these studies also suggest that improving health and well-being conditions at work may increase performance, which is related to benefits for the organization in terms of less sick leave absences and higher work engagement, motivation, job satisfaction, staff retention, among others (13, 14, 15).

Four factors are widely considered to characterize the acceptability of an indoor environment: indoor air quality (IAQ), noise, lighting and thermal comfort (16). In order to assess comfort and health conditions, international organization and research institutions have developed standards to define the acceptable ranges of the main IEQ parameters (6, 17, 18, 19). In particular, problems of IAQ are recognized as important risk factors for human health (20). Due to the importance for the public health protection, national and international organizations (WHO, European Environment Agency, etc.) are dealing with it in detail. Additionally, it is being studied by experts on toxic properties and effects of pollutants (20, 21). From a broader perspective than health, this preliminary study is based on the three following IEQ factors: noise, lighting and thermal comfort, although IAQ main parameters were also monitored to verify that were within the established ranges. The values set out in the European standard EN 15251: 2007 for the parameters of these three factors are shown in Table 1.

But, are these ranges universally applicable across all building types, climates, and populations? (22). According to Frontczak and Wargocki's reviews (2011), there are some key aspects linking overall satisfaction with IEQ, such as the type of job and the country of origin, which have not been pondered by standards. Other aspects such as the level of education, the psychosocial atmosphere at work and time are also

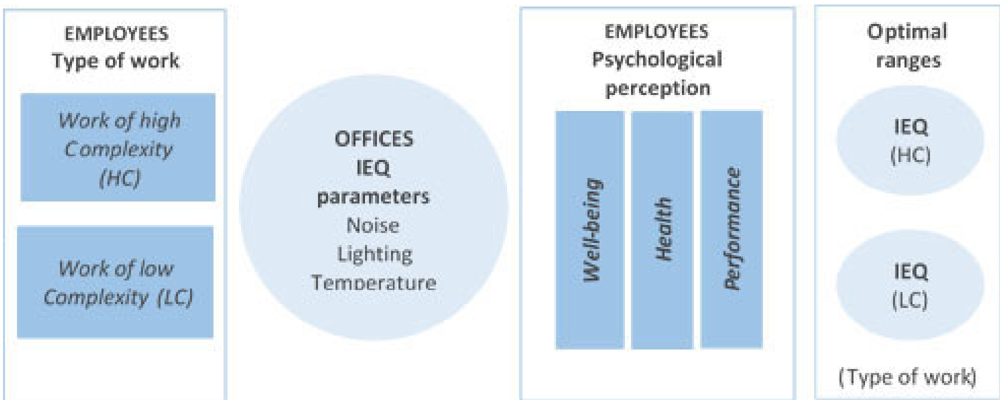

Figure 1. Conceptual model for the study of IEQ optimal ranges in warm climate offices according to the type of work.

Table 1. Recommended criteria for noise, lighting and thermal comfort in EN 15251:2007.

IEQ factor	Parameter	Value
Noise comfort	Maximum sound pressure level for offices	45 dBA
Lighting comfort	Maintained illuminance at working areas	500 lux
Thermal comfort (winter season)	Operative temperature range for environments of category I*	21-23 °C
	Operative temperature range for environments of category II**	20-24 °C

* Category I: high level of expectation, spaces occupied by very sensitive and fragile persons.
** Category II: normal level of expectation for new buildings and renovations.

important and have not been studied enough in the built environment field (10).

Focus on the type of job, the characterization of different work patterns is especially valuable for the purposes of designing work environments in a way that better suit these work patterns facilitating and contributing to the effective and efficient work (23, 24). However, the role that the work patterns may have in the relationship between working conditions and well-being, health and work performance has not been sufficiently studied yet (25).

Focus on the country of origin, specifically the climate zone, previous studies on adaptive thermal comfort confirm that people's expectations and preferences may differ depending on the location of the buildings due to people's adaptation to different climates and cultures (5, 22). In recent years both the American Society of Heating, Refrigerating and Air-conditioning Engineers guideline and European standards have incorporated these cultural specifications in line with the research carried out in this area (22, 26, 27). Apart from that, very little research has used this approach due to lack of research on this field in real case scenarios (6).

Furthermore, several researches have also been identified the variability of the IEQ parameters as an important aspect in determining the acceptability of the indoor environment. In relation to noise variability, studies of noise evaluation in landscaped offices found that temporal variability of noise is one of the factors that most affected the response of workers (28, 29). Moreover, Knez and Hygge (2002) stated that discomfort increases over time in the silent condition and decreases when subjects are exposed to irrelevant noise produced by speech (30, 31). According to the effects of lighting variability, de Kort and Smolders (2010) research on dynamic lighting revealed that office workers are more satisfied with dynamic lighting condition than with static condition. However, workers reported fewer disturbances of artificial lighting in the static condition (32). These studies focus on lighting control systems. Several empirical studies have found that individual control of environmental office conditions has positive effects on workers' performance (33, 34, 35).

Therefore, there are significant influences between the IEQ parameters and their variation with well-being, health and performance of employees, but there is a gap on their relationship with the type of job and climate (10). In order to fill in this gap and to achieve one of the Smart and Sustainable Office model definition described before, in this paper the relationships between the main parameters of three IEQ factors (i.e., noise, lighting and thermal comfort) and employees' well-being, health and performance are studied in real case scenarios, considering the potential influence of the type of work and the specificity of Mediterranean climate.

2. METHODOLOGY

2.1. Study cases

2.1.1. Study design

The study was carried out in twelve office spaces inside four different office buildings in the Valencian Community along three periods, considering winter and summer conditions. The results of this paper derive from winter 2015, the first monitoring period (T1).

The 12 offices were classified into two type of spaces: open-plan office and private office spaces. For the measurement campaign, open-plan offices included workstations in collective spaces and department rooms, which were used by non-management employees. They contained computer terminals, technical equipment and employees who usually spend more than 75 per cent of their time in this space. The private office spaces were separated rooms used by executive managers and operational managers. These spaces contained more than one workstations and had a direct physical relation with the general office area. The type of work was included through the task complexity, one of the dimensions that characterizes the work patterns. It is important to remark that the Occupational Information Network (O*NET) distinguishes four types of work activities occurring on multiple jobs: information input, mental processes, work output, and interaction with others. Soriano et al. (2015) point out that the former activities can be best described by two dimensions: task complexity, which integrates the first three activities and can be defined as the degree of requirement of the task to the executor regarding the processing of the information involved (36), and interaction with people: whether the work activity is being held with clients or with co-workers (25). Due to limitations regarding the sample size, the present study only analyzes task complexity.

Well-being, health and performance information were collected using diary studies from a sample of 71 employees, differentiated into two groups according to the task complexity. Simultaneously, physical IEQ parameters were measured by specific equipment located in the workstations of the twelve offices monitored. Data were analyzed through multiple regressions and optimal ranges definition, according to the type of work: of high/low complexity. The empirical study design is shown in Figure 2.

2.1.2. Office building selection and sample

The office buildings selected were owned/occupied by different companies that cover the main business activities demanding office space according to available information on the Spanish economy (37-39): Technological Institute of Ceramics (ITC) and Valencia Institute of Building (IVE) representing services sector, ACTIU-Furniture Manufacturer (AC-

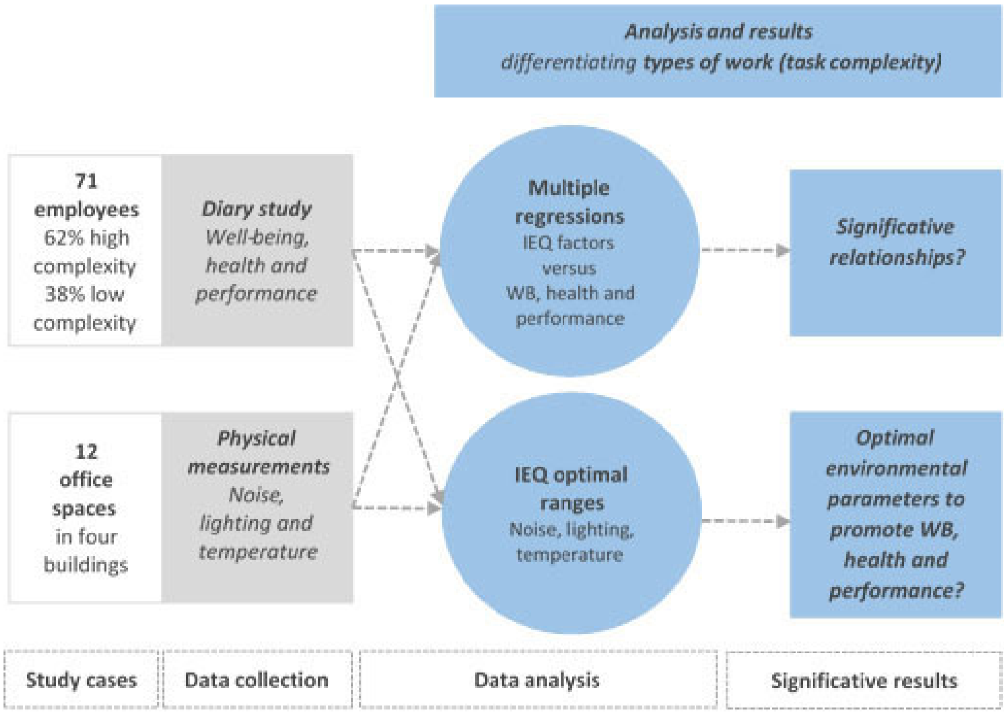

Figure 2. Study design.

TIU) representing offices associated to the industry sector, and University Jaume I (UJI) representing offices associated to the public sector. Each of them provided three office spaces occupied by a minimum of 2 employees and a maximum of 6, with a total number of 71 monitored employees. The participants ranged in age from 23 to 61 years (M=39.61). Their occupational category was: 29.5% "technician", 27.9% "highly-qualified professional", 27.9% "administrative work", and 4.9% "manager". The total sample was split in two groups considering two types of task complexity, with a single-item scale using a dichotomous response scale: 27 participants (38%) informed to have a work of low complexity and 44 (62%) informed to have a work of high complexity.

2.2. Data collection

The data collection in period T1 lasted four weeks, one week per building from Tuesday to Friday, while Monday was used to change equipment between one building and the following to be monitored. Data was collected by using specific equipment for measuring the main IEQ parameters that may affect employees' well-being, health and performance, as well as diaries that aimed at capturing a dynamic dimension of the variables of interest as explained in the introduction.

The 71 workers filled out the diary studies to assess employees' subjective well-being, occurrence of health symptoms and performance. These diary studies were filled out twice a day for four consecutive days, providing a total of 568 data collection points in T1, as explained in section 2.2.2. On the same days, the IEQ data were gathered in the offices as described in section 2.2.1. Both data sources were matched.

2.2.1. Physical environment measurements: IEQ parameters

Noise, lighting and temperature parameters were measured by using the same equipment, a multi-measuring device for workplace analysis BAPPU-evo provided by ELK GmbH Ingenieurbüro für Elektronik. BAPPU-evo was outfitted with the software and storage location needed to record all measured values with a granularity of 5 minutes, being also able to transmit the data stored to a computer and evaluate it with BAPPU software.

If possible, this specific device was located in an empty desk or close to a busy desk (Figures 3, 4) in order to simulate as much as possible those indoor environmental conditions that were affecting workers. The installation of equipment was performed always by the same people in all the buildings to improve reproducibility and data quality.

The acoustic and lighting environment were measured directly by BAPPU-evo. The noise level (class 2 in accordance with DIN EN 61672-1) in dBA was used as the parameter to evaluate the acoustic environment, while the quantity of light in lux was used as the parameter to evaluate the lighting environment.

However, the thermal environment was not measured directly by using the above-mentioned device BAPPU-evo, but it was necessary to apply the procedure explained right after to calculate it. The parameter used to evaluate the thermal environment was the operative temperature. BAPPU-evo is able to measure different parameters, such as air and globe temperature, relativity humidity and air speed. These parameters allowed us to calculate the radiant temperature by using the calculation method established by EN ISO 7726:2002, based on the Fanger method (2). Finally, the operative temperature was estimated as the arithmetic mean between the mean radiant temperature and the air temperature considering that the air speed measured was always lower than 0.2 m/s (40).

Technical characteristics of the different sensors BAPPU-evo used to perform the measures are defined in Table 2.

Figure 3. IEQ equipment in an ACTIU open-plan office.

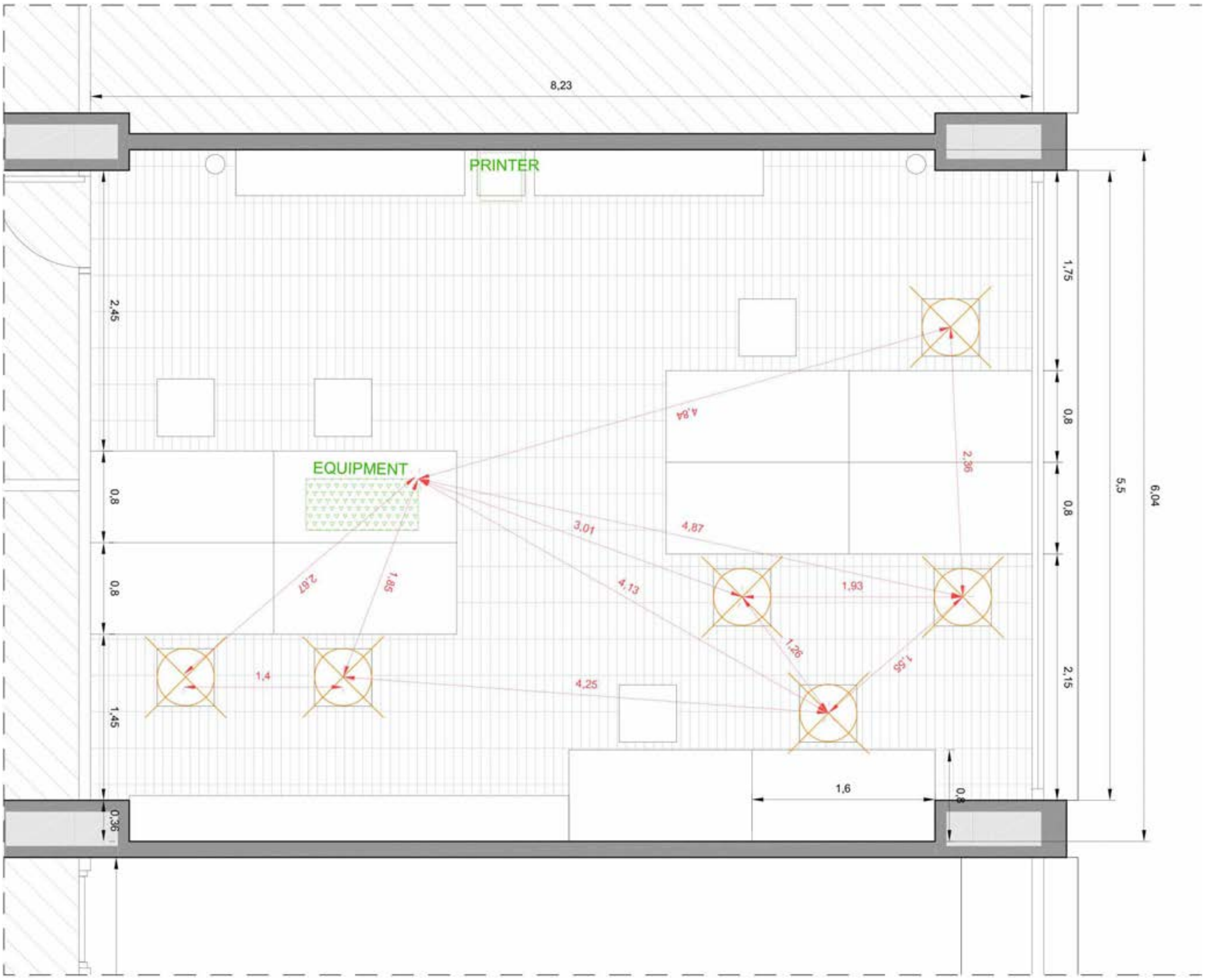

Figure 4. IEQ equipment and space distribution in an IVE open-plan office.

Table 2. Technical characteristics of BAPPU-evo sensors.

Type of parameter	Parameter	Technical characteristics			
		Measurement range	Tolerance	Sensor	Resolution
Noise	Noise level (class 2 in accordance with DIN EN 61672-1)	30 to 110 dBA	+/- 1.0 dBA (at 1Khz) inherent noise < 25 dBA	Precision electret condenser microphone	0.1 dBA
Lighting	Illuminance level (class C in accordance with DIN 5032-7)	50-30,000 lux	V-Lambda adjustment 7.5%. Cos-accurate evaluation 4%. Linearity 3%	Silicon photo-element adapted spectral sensitivity	1 lux
Temperature	Air temperature	-20…50 °C	+/- 0.5 ºC	PT 1000 Sensor	0.1 °C
	Globe temperature	0…70 °C	+/- 0.5 °C	Integrated temperature semiconductor sensor	0.1 °C
	Relative humidity	10…90%	+/- 4% r.H.	Capacitive humidity sensor	0.1%
	Air speed	0.0…5 m/sec	+/- 10% f. MV. +/-3 Digit	Thermo-anemometer	0.01 m/sec

2.2.2. Diary study data collection

In the diary study a set of different self-report scales were used to assess three work indicators: employees' subjective well-being, occurrence of health symptoms and performance (see Appendix 1).

The first indicator, employee subjective well-being is differentiated into *hedonic well-being* and *eudemonic well-being*. *Hedonic well-being,* is considered the extent to which a person experiences positive emotions (e.g., happiness), negative emotions (e.g., anxiety, frustration) and flow at work. *Eudemonic well-being,* is defined as the activity "worthwhileness", that is, the employee's conviction that the activities carried out right now are worthwhile and useful to other people, have greater meaning and serve to a higher purpose.

The second indicator, the *occurrence of health symptoms,* is based on the existence of health symptoms due to one's work environment. Employees had to rate their symptoms in the moment of responding the diary study (e.g., fatigue, headache).

Finally, performance is also differentiated into two dimensions: in-role state performance and extra-role state performance. In-role state performance is considered the perception of one's fulfilment of requirements of the job (e.g.,I have been fulfilling all the requirements for my job). Extra-role state performance means the extent to which a person is showing additional effort at work although it is not necessarily expected from him/her in their job description (e.g., I've voluntarily done more than was required of me).

2.3. Data analysis

2.3.1. Multiple regressions

Multiple regressions have been carried out to examine the associations between the IEQ parameters (noise level in dBA, quantity of light in lux and operative temperature) operationalized both as the arithmetic mean and the variability (i.e., standardized deviation), and employees responses such as well-being (i.e., positive emotions, negative emotions, flow, and activity worthwhileness), health-related symptoms, and performance (i.e., in-role and extra-role performance), in groups of two different levels of task complexity (i.e., work of high complexity and of low complexity), using MPlus 7.1 software (32). Prior to the analysis, the variables were checked for collinearity.

To integrate IEQ data in the database used to develop multiple regressions, the arithmetic mean and standardized deviation of each IEQ parameter was calculated, considering all the values collected within the period comprised between the previous 30 minutes before the completion of the diary study by each person in the sample, and the moment of the diary study completion. This interval was considered to be an adequate representation of the environmental characteristics in the offices during the time respondents took to fill out the diaries, which could be perceived by them as the current situation in their office.

2.3.2. Optimal ranges

To obtain the optimal ranges, groups of people who scored high (the highest 33 percentile) on in-role performance, extra-role performance and positive emotions at the same time were considered. They were differentiated into two different levels of complexity: people who performed complex tasks (N=44) and those who performed simple tasks (N=27). The minimum, maximum and mean noise, lighting and temperature levels were calculated (with SE and SD) in these two groups to obtain the ranges and means of the characteristics when people performing well and feeling positive emotions (Table 4).

3. RESULTS

3.1. Descriptive statistics

The description of the variables assessed in this study is showed in Table 3. The average score on the measures of negative emotions and health symptoms were 1.97 and 1.77, respectively. These results suggest that the general level of both variables is quite low. The average levels of physical conditions: noise, lighting and operative temperature (equal to 53.37 dBA, 557.98 lux and 23.21 ºC, respectively), can be considered as normal levels for conditioned workspaces.

3.2. Relationships between environmental characteristics and well-being, health and performance in simple and complex task samples

Results of the multiple regressions are showed in Table 4.

Table 3. Descriptive statistics for the variables of interest in the current study.

Variables	Mean	SD	Min	Max
Noise	53.37	3.18	44.35	61.03
Lighting	557.98	208.14	71.33	1302.83
Temperature	23.21	1.50	19.62	26.83
Positive emotions	4.31	1.25	1.00	7.00
Negative emotions	1.97	0.95	1.00	5.43
Flow	5.25	1.20	1.00	7.00
Activity worthwhileness	4.99	1.25	1.00	7.00
Health symptoms	1.77	0.80	1.00	5.75
In-role	5.93	0.93	1.00	7.00
Extra-role	5.18	1.39	1.00	7.00

Notes. SD = Standard Deviation; Min = Minimum; Max = Maximum.

Table 4. Multiple regression analysis between environmental characteristics and well-being, health and performance in high and low task complexity.

IEQ parameters		Task complexity	Subjective well-being				Health symptoms	Performance	
			Hedonic		Eudemonic				
			Positive emotions	Negative emotions	Flow	Activity worth-whileness		*In-role*	Extra-role
Noise	Mean	High	-0.01	0.05	-0.18*	-0.14	0.01	-0.18*	-0.07
		Low	0.01	-0.18	-0.10	-0.19*	0.21*	-0.14	0.05
	SD	High	-0.09	0.07	-0.23**	-0.17*	0.15*	-0.10	-0.09
		Low	-0.18*	0.05	-0.25**	-0.09	0.01	-0.07	-0.04
Lighting	Mean	High	-0.21**	0.06	-0.31**	-0.18*	0.52**	-0.11	0.05
		Low	0.07	-0.09	-0.02	0.07	-0.12	0.04	0.18*
	SD	High	-0.05	0.01	-0.09	0.11	0.23**	0.11	-0.03
		Low	0.06	-0.14	0.03	0.17*	-0.14	0.12	0.12
Temperature	Mean	High	0.03	0.12	0.07	0.08	-0.04	0.01	0.07
		Low	0.16	-0.05	0.17*	0.13	0.04	0.09	0.02
	SD	High	0.02	-0.02	0.01	0.25**	0.06	0.20**	-0.08
		Low	0.04	-0.22**	-0.02	-0.11	-0.01	0.03	0.08

Notes: *p < 0.05; **p < 0.01 ; SD = Standard Deviation.

Focus on noise in work of high complexity, noise is negatively associated with flow and in-role performance, while variation in noise is negatively associated with flow and activity worthwhileness and positively associated with health-related symptoms. In work of low complexity, noise is negatively associated with activity worthwhileness and positively associated with health-related symptoms, while variation in noise is negatively associated with positive emotions and flow.

Lighting is negatively associated with positive emotions, flow and activity worthwhileness as well as positively associated with health-related symptoms in work of high complexity; and positively associated with extra-role performance in work of low complexity. Moreover, variation in lighting is positively associated with activity worthwhileness in work of low complexity as well as positively associated with health-related symptoms in work of high complexity.

Finally, temperature is positively associated with flow in work of low complexity. Variation in temperature is positively associated with activity worthwhileness and in-role performance in work of high complexity, and negatively associated with negative emotions in work of low complexity.

3.3. Optimal ranges for high and low tax complexity work environment

With these preliminary results, one step forward has been trying to find out the optimal ranges for the IEQ factors in offices considering the level of the task complexity (Table 5).

Focus on work of high complexity, results showed that employees present high performance and high well-being in significantly lower noise and significantly higher lighting than employees who develop work of low complexity. Focus on work of low complexity, results showed that employees present high performance and high well-being in significantly higher noise and significantly lower lighting than employees who develop work of high complexity.

Table 5. Optimal ranges of characteristics in high-performing employees with positive-emotions.

Physical characteristics	Task complexity	*Min*	*Max*	*M*	*SE*	*SD*	*F*
Noise	**High**	44.91	61.03	52.65	0.43	2.86	4.00*
	Low	48.70	60.30	54.08	0.59	3.06	
Lighting	**High**	293.83	994.50	581.29	21.53	142.79	7.99**
	Low	289.33	843.00	490.54	21.11	109.67	
Temperature	**High**	21.48	26.16	23.43	0.16	1.07	1.57
	Low	20.20	26.16	23.06	0.26	1.36	

Notes. Min = Minimum; Max = Maximum; M = Mean Score; SE = Standard Error of Mean; SD = Standard Deviation; F = significance of the difference in mean scores of environmental characteristics between low complexity and high complexity. *p < 0.05; ** p < 0.01.

The optimal ranges are graphically described in the figures below.

4. DISCUSSION

The aim of this study was to investigate the relationships between noise, lighting and temperature (i.e., three IEQ parameters) and employees' well-being, health and performance for different levels of task complexity (i.e., work of high complexity and work of low complexity) in the Mediterranean context. The results of the multiple regressions in Section 3 revealed significant and different pattern of individuals' responses in both levels of the task complexity, which led to deeply study their respective optimal ranges.

How far is noise affecting offices' employees' wellbeing, health and performance?

Regarding the office space description, during the interval of 30 minutes before the completion of each diary study the noise level ranged from 44.35 dBA to 61.03 dBA (Table 3). According to Optimal ranges (Table 5), the highest performance and positive emotions with the acoustic environment occurred when the noise level was below 61.03 dBA in the case of work of high complexity and below 60.30 dBA in the case of low complexity (Figure 5). The fact that both results are over the maximum recommended value for international offices standards is noteworthy, and open a new question: is the determination of the most appropriate acoustic environment affected by climate and employees culture?

In relation to the optimal ranges, the multiple regressions analysis presented in Table 4 reinforce the need to set maximum limits. According to multiple regressions, the acoustic environment in terms of noise level is negatively associated with well-being and performance and positively associated with health-related symptoms.

Findings also showed minimum noise levels in the optimal ranges (Table 5 and Figure 5) for both work of high complexity (44.91 dBA) and work of low complexity (48.70 dBA), which seem to show the preference of employees for being exposed to a certain level of noise rather than being in a silent condition.

In general, these results offer support for considering different noise optimal ranges based on the type of work, with higher minimum values for work of low complexity than for work of high complexity.

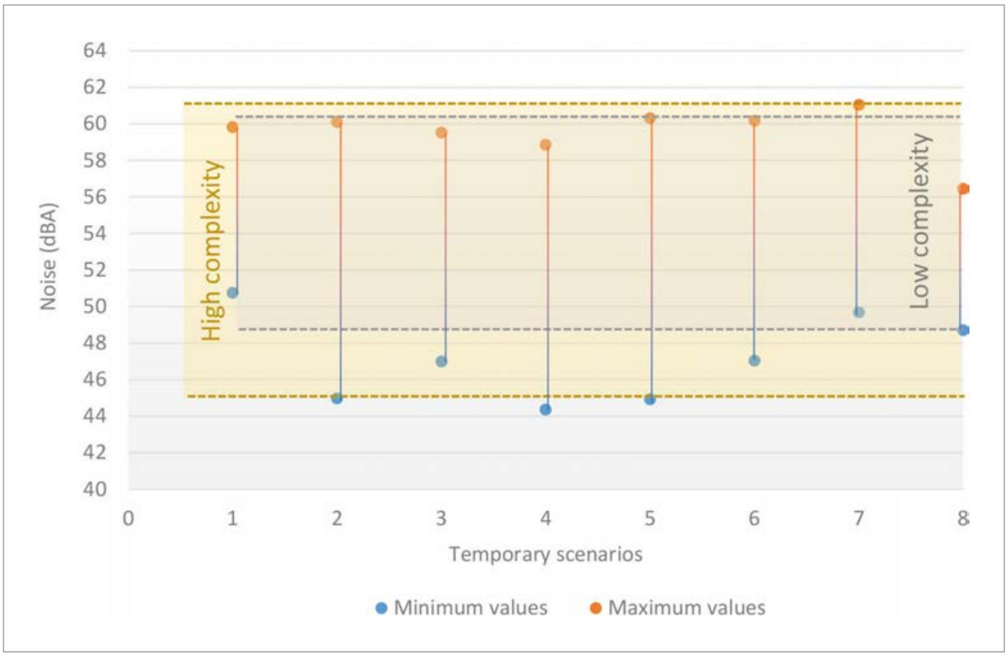

Figure 5. Values of noise measured and optimal ranges for work of high and low complexity.

Regarding the variation in noise, the results in Table 4 showed that variation in noise decreases overall well-being. Specifically, it is negatively associated with flow in both levels of task complexity, positive emotions in the case of work of low complexity and activity worthwhileness in the case of work of high complexity, and it is positively associated with health-related problems in the case of work of high complexity. This result is also in line with other studies (previously analyzed in Rational), that point out the temporal variability of noise as one of the factors that most affects the workers' response.

Does optimal lighting enlighten your work?

With regard to the office space description, during the period of the diary study the light level (illuminance) ranged from 71.33 lux to 1302.83 lux (Table 3). According to Optimal ranges (Table 5), the highest performance and positive emotions with the lighting environment occurred when the light level was between 294 lux and 995 lux in the case of work of high complexity and between 289 lux and 843 lux in the case of work of low complexity (Figure 6). Therefore, the more complex the work is, the higher light level is needed.

According to multiple regressions (Table 4), values surpassing the upper limits (995 lux) are associated with less positive emotions, flow, activity worthwhileness and more health-related problems in the case of work of high complexity. Differences between the mean values of the optimal ranges for each type of work, 581 lux and 491 lux (Table 5), have also been found, that reinforce how light levels may have influence on well-being and performance depending on the type of work (3). Regarding the minimum light levels, the values for both types of work are similar, 289 and 294 lux.

All these results would provide guidance for the design of the lighting system in the offices. One measure to be implemented could be that the individual lighting system was controlled independently of the general system. The latter could provide 300 lux, the minimum limit found of the optimal ranges, and employees could have individual lighting in their workstation to provide at least 200-300 lux. Thereby they could control both the level and directionality of lighting to suit to their personal needs or those motivated by a change of activity, and obtain positive effects on their performance. Additionally, having different controls for individual and general lighting would benefit the energy efficiency, given the possibility to reduce the energy consumption when the workstations are not occupied.

Finally, regarding the variation in lighting, the results in Table 4 showed that variation in lighting is positively associated with activity worthwhileness in work of low complexity, but it is also associated with health-related problems in work of high complexity. These findings are in line with previous research of de Kort and Smolders, analyzed in Rational.

Is there a way to end up with the eternal conflict of the temperature level in office spaces?

With regard to the office space description, during the interval of 30 minutes before the completion of each diary study the operative temperature ranged from 19.62 °C to 26.83 °C (Table 3). According to Optimal ranges (Table 5), the highest performance and positive emotions with the thermal environment occurred when the operative temperature was between 21.48 °C and 26.16 °C in the case of work of high complexity and between 20.20 °C and 26.16 °C in the case of low complexity (Figure 7). Although there are different values in each optimal range of temperature in Table 3 (F= 1.57), these differences are not statistically significant.

The results of the minimum temperature might resemble those established in the European standard in winter for different categories: 21 °C for environments of category I, which could be assimilated to work of high complexity, and 20 °C for environments of category II, which could be assimilated to work of low complexity. However, the maximum temperature values of this study are much higher than those set out in the standard, which may indicate that office employees in warm climates are less tolerant to low temperatures.

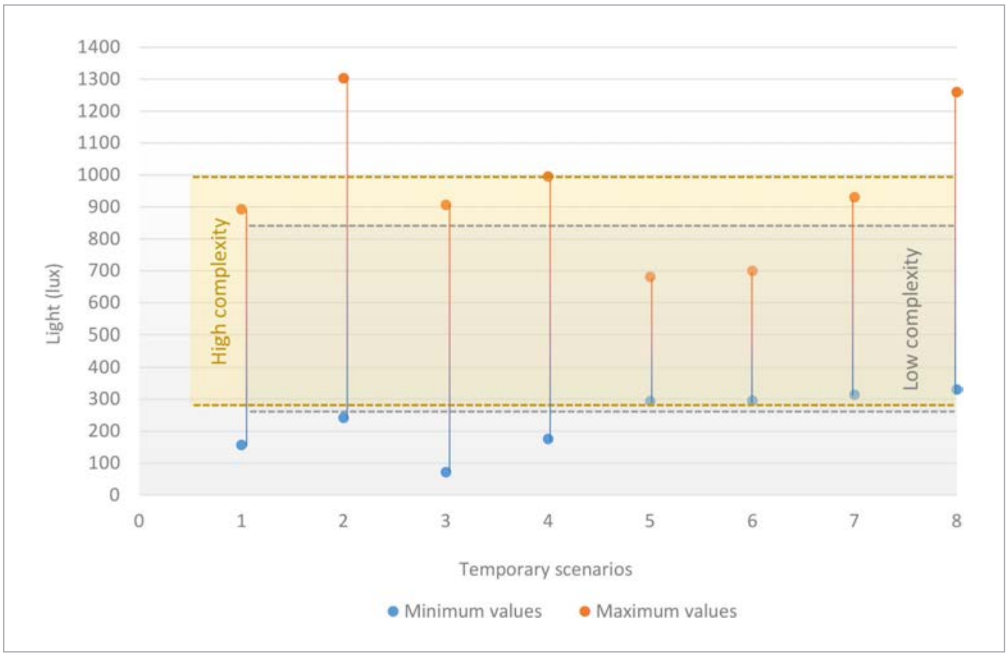

Figure 6. Values of lighting measured and optimal ranges for work of high and low complexity.

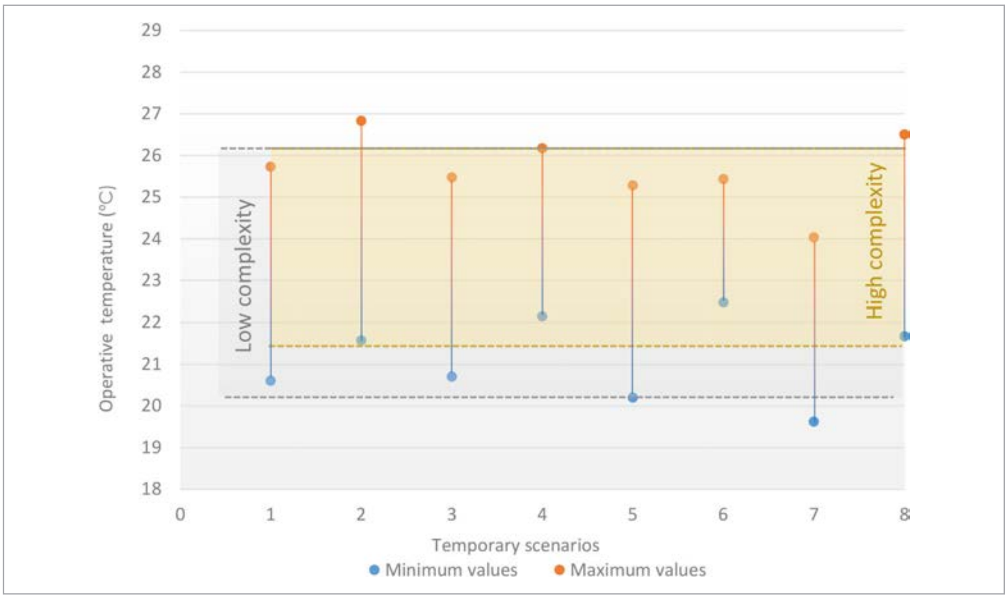

Figure 7. Values of operative temperature measured and optimal ranges for work of high and low complexity.

5. CONCLUSIONS AND NEXT STEPS

The present study offers preliminary findings in Mediterranean climates for considering several associations between the three IEQ parameters measured (i.e., noise, lighting, and temperature) and employee's well-being, health-related symptoms, and performance, in two types of work in offices: work of low complexity and work of high complexity.

Physical characteristics of the indoor environment in offices (i.e., noise, lighting and temperature) are associated with some dimensions that define well-being, health and performance, being these associations different depending on the task complexity. In general, employees who perform more complex tasks need more restrictive indoor environment conditions than those who perform simple tasks. Additionally, the effects of variations in temperature, noise and lighting have also been observed to have a significant influence on employees' well-being, health and performance. Examples of these results are the different ranges of noise and lighting obtained for work of high and low complexity, when people performing well and feeling positive emotions. The optimal ranges of noise were reported between 44.9 dBA and 61.0 dBA for work of high complexity and 48.7 dBA and 60.3 dBA for work of low complexity; the optimal ranges of lighting, between 294 lux and 994 lux for work of high complexity and 289 lux and 843 lux for work of low complexity. In relation to the optimal ranges of temperature, findings of this study showed differences statistically non-significant in this parameter.

Important preliminary results have been obtained, which will be completed with the analysis of the data collected in the two remaining monitoring periods (T2 and T3). In addition, future research can be carried out by widening the sample of participants, investigating with other dimensions of work patterns, and work patterns themselves, and monitoring offices in different climates apart from the Mediterranean zone.

This paper could serve as an important starting point to research on the optimal values of the IEQ parameters for different levels of task complexity. As a result, these values could be implemented both in the designing phase of smart and sustainable offices and in the operation phase, being the potential outcome an office design guide and other office design support-tools where the optimal ranges would be integrated as preliminary design requests for architects and designers to turn current standard office spaces into smart and sustainable offices.

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APPENDIX 1

The subjective well-being is differentiated into the current research perspectives: the hedonic approach which defines well-being in terms of pleasure attainment and pain avoidance, and the eudemonic approach which defines well-being in terms of the degree to which a person is fully functioning (41).

Hedonic well-being has been measured with 13 items using a response scale from 1 (not at all) to 7 (very much): assessing positive emotions (3 items; Cronbach's alpha coefficient was 0.81.), self-efficacy (1 item), negative emotions (7 items; Cronbach's alpha coefficient was 0.89.) and flow (2 items) (42, 43). Eudemonic well-being has been measured with a 3-item scale (42) and using a response scale from 1 (not at all) to 7 (very much). Cronbach's alpha coefficient was 0.84.

The occurrence of health symptoms is a list of symptoms (e.g., headaches, difficulties concentrating) adapted from Andersson, 1998 (44). Cronbach's alpha coefficient was 0.83.

Finally, the performance is differentiated into two dimensions: in-role state performance and extra-role state performance, following Katz (1964) who raised the issue of the distinction between extra-role and in-role behaviours (45).

In-role state performance was measured using a 3-item sub-scale developed by Xantopolou et al., 2009 (46, 47) with a response scale from 1 (not at all) to 7 (very much), considering in-role behaviour as behaviours that are recognized by formal reward systems and are part of the requirements as described in job descriptions. Cronbach's alpha coefficient was 0.75. xtra-role state performance was measured using a 3-item subscale developed by Xantopolou et al., 2009 (46, 47) and using a response scale from 1 (not at all) to 7 (very much). Cronbach's alpha coefficient was 0.77.

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