buildings

Review

Indoor Environmental Quality and Comfort in Offices: A Review

Virginia Isabella Fissore *, Silvia Fasano, Giuseppina Emma Puglisi, Louena Shtrepi and Arianna Astolfi

Department of Energy, Politecnico di Torino, 10129 Turin, Italy; s.fasano.95@gmail.com (S.F.); giuseppina.puglisi@polito.it (G.E.P.); louena.shtrepi@polito.it (L.S.); arianna.astolfi@polito.it (A.A.)
* Correspondence: virginia.fissore@polito.it

Abstract: People spend about 90% of their time in closed spaces such as residential and office environments, and indoor environmental quality (IEQ) has effects on their health, well-being, overall comfort and work productivity. The IEQ domains (i.e., thermal, acoustic, visual and indoor air quality) are able to influence office users' work day and even cause the onset of diseases. This review aims at investigating IEQ in offices and the multidomain combined effects on occupants' overall comfort. Studies published between 2016 and 2022 were summarized, focusing on four research questions formulated to deepen the knowledge on (i) IEQ perception and evaluation, (ii) IEQ indexes and parameters, (iii) factors that influence comfort perception and (iv) IEQ and comfort representation in space and time. For these research questions, a total of 29, 19, 10 and 9 studies, found on the Scopus database through a keywords search, were considered, respectively. The studies were included only if they appraised a multidomain approach. The results obtained for each research question reveal that: (i) Post-Occupancy Evaluation (POE) surveys are often applied to understand how occupants perceive IEQ, and in-field monitoring based on low-cost sensors is implemented more and more to acquire IEQ data, (ii) a set of indexes and parameters for IEQ assessment is not standardized yet, although some parameters are commonly used, (iii) personal factors like age and gender, and contextual factors like workstation location and office type, influence occupants' comfort perception and (iv) dashboards are used to allow office end-users to visualize the indoor conditions of the environment.

Keywords: indoor environmental quality; overall comfort; office; health; well-being; work productivity; personal factors; contextual factors

Citation: Fissore, V.I.; Fasano, S.; Puglisi, G.E.; Shtrepi, L.; Astolfi, A. Indoor Environmental Quality and Comfort in Offices: A Review. *Buildings* **2023**, *13*, 2490. https://doi.org/10.3390/buildings13102490

Academic Editors: Chi-Chung Lee, Kin Wai Tsang, Asiri Umenga Weerasuriya, Yaohan Li and Xuelin Zhang

Received: 3 August 2023
Revised: 22 September 2023
Accepted: 25 September 2023
Published: 30 September 2023

1. Introduction

Indoor environmental quality (IEQ), which accounts for the thermal, acoustic, visual and indoor air quality (IAQ) domains, is a remarkably investigated topic in the recent literature due to the time that people spend indoors [1]. According to the European Commission, people spend about 90% of their time in closed spaces and most of the time at work [2,3]; thus, research focuses on the influence of IEQ on occupants' overall comfort, well-being, health and work productivity in offices [4].

The assessment of indoor environmental conditions is therefore of fundamental importance and is usually based on two methodologies, i.e., in-field monitoring of IEQ parameters and indexes and occupants' subjective feedback collection [5].

Traditionally, measurements of IEQ parameters were performed by means of independent devices and mainly consisted of spot measurements with high costs and invasiveness in the monitored environment [6]. This methodology has changed through the years thanks to the use of low-cost sensors within the IoT framework, and nowadays it is possible to perform intensive, long-term monitoring campaigns [7]. The design of continuous IEQ monitoring systems, through the implication of wireless sensor network and cloud software platforms, allows one to monitor, continuously and simultaneously, the thermal, acoustic, lighting and air quality domains [3,5]. Standards and building certification schemes define parameters and indexes to be monitored to assess thermal, acoustic and visual conditions and indoor air quality in offices. Nevertheless, a set of parameters or a universally recognized index deemed to be effective for IEQ assessment is not available yet. Standards, e.g., EN 16798-1:2019 [8], ANSI/ASHRAE 55:2017 [9], ISO 7730:2005 [10], ISO 3382-3:2022 [11], ISO 22955:2021 [12], NF S31-080 [13], EN 17037:2018 [14] and EN 12464-1:2021 [15], establish threshold values which are used as guidelines by designers to achieve indoor habitability. Building certification schemes provide a set of parameters and their thresholds as well, with the aim of ensuring building acceptability and occupants' health and well-being, becoming a useful guide for the selection of parameters to be monitored for IEQ assessment. As Wei et al. [16] state in their review, most of the building certification schemes were developed for the evaluation of many building aspects (e.g., energy, use of materials, water, etc.). The WELL Building Standard was mainly devoted to the health and quality of life of building occupants, and recently, LEED and BREEAM also expanded their credit structure, considering social and economic well-being, safety and security.

Nevertheless, it has been proven that not all the occupants consider themselves satisfied with IEQ conditions even when the physical requirements are met [17]. Occupants' comfort is defined as the status in which people feel a sensation of well-being and satisfaction, and it deals with the space that surrounds the human body and its perception. Moreover, one's feeling about oneself in relation to the surrounding environment defines well-being, and if physiological, psychological and social needs are satisfied, individual well-being tends to be high [18]. For this reason, to investigate IEQ perception and users' satisfaction with indoor environmental conditions, the Post-Occupancy Evaluation (POE) method is applied, which includes questionnaires to be submitted to the end-users [4,19]. Nevertheless, the reliability of subjective responses could be altered by factors that influence occupants' comfort perception [17], such as contextual, physiological and personal factors. The main contextual factors are building orientation, view toward the outside, workstation location [20], office typology and occupancy hours [21]. The main personal factors are age, gender [22], place of residence [21], culture and past experiences [17]. Occupants' level of control over the building systems and indoor environmental conditions at their workstation affects their comfort perception too [23].

Many POE survey tools in the past were developed as benchmarks for future POE studies, e.g., among others, the UK Building Use Studies (BUS), the Australian Building Occupants Survey System Australia (BOSSA), the Dutch Work Environment Diagnosis Instrument (WODI) and the American model developed by the Center of the Built Environment (CBE) [4,19].

Thanks to the information and communication technology and the use of portable computers, tablets and smartphones, it is now possible to continuously collect occupants' subjective feedback. However, a unique methodology universally recognized and applied is not available yet [24]. As a step forward in the collection of subjective feedback, occupants can be provided with information on real-time monitored IEQ conditions, and a comparison between objective and subjective data can be performed through the new technologies [6].

Questionnaires represent a useful tool also for the broader detection of office occupants' self-assessed productivity and health, since they allow for a personal recording of building-related health symptoms (e.g., tired or strained eyes, headache, cough, etc.) caused by bad indoor environmental conditions [25]. In 1983, the World Health Organization first defined the concept of Sick Building Syndrome (SBS), when causes and consequences were not widely investigated yet, ventilation rates in buildings were limited and emissions from buildings materials were high. The symptoms of SBS (e.g., eyes, nose, throat and skin irritation and neurotoxic health problems) affect building occupants in relation to the time they spend indoor and are related to personal and environmental variables [26]. Therefore, both physical monitoring and consequent interventions and actions for workers' well-being and health are needed for the prevention of building-related symptoms [25].

Work productivity is also demonstrated to be affected by IEQ depending on the occupants' demographics, the type of office and the type of work tasks to be performed [27]. Thermal comfort, indoor air quality, visual comfort, acoustics and office layout are key factors affecting occupants' productivity [28]. A study was conducted to analyze the interconnections between IEQ and attitudinal, social and demographic factors and their influence on productivity belief. The results demonstrate that IEQ satisfaction, country of residence, thermal comfort, perceived possibility of controlling indoor environmental features and proneness in sharing these controls are the strongest positive predictors of the productivity belief [21].

Four research questions are released in this review and shown in Table 1 with the keywords used for the review searching process. The four research questions were formulated based on a primary knowledge of IEQ to deeply investigate the main factors contributing to this theme. The final aim was the development of a system, named PROMET&O (PROactive Monitoring for indoor EnvironmenTal quality & cOmfort), including a low-cost multisensor device, a questionnaire to assess the occupants' comfort perception, personal and behavioral factors and a dashboard for data visualization [29].

Table 1. Research questions and keywords used for the literature review. The questions are related to offices.

N	Research Question	Keywords
RQ1	How is IEQ perceived and evaluated?	Multidimensional comfort, overall comfort, IEQ, discomfort, cross-modal effect, combined effect, office, workplace, work environment
RQ2	What are the main IEQ indexes and parameters?	IEQ index, IEQ parameter, office, work environment
RQ3	What are the main contextual and personal factors that influence the comfort perception?	IEQ, indoor environmental quality, indoor environment, office, workplace, work environment, contextual variable, contextual factor, psychosocial factor, context
RQ4	How are IEQ and comfort represented in space and time?	Indoor environmental quality, comfort, user interface, platform, interface, data representation, data visualization, office

The relationship between IEQ and its perception, i.e., the influence it has on human beings, was considered the first factor to be investigated. IEQ is assessed for different reasons (e.g., the correlation with energy consumptions, with occupant behavior, with building automation and control systems, etc.), but one of the major concerns is the relationship with occupants' comfort, well-being and health. These different reasons determine different methodologies for IEQ evaluation; however, it almost always encompasses the measurement and calculation of the parameters and indexes of the four domains (thermal, visual, acoustic and IAQ). Due to the lack of a standardized procedure, a further goal of this review (addressed in the first and second research questions) was to understand how this problem is tackled in the current literature in terms of methodologies, devices, time required, parameters and indexes assessed.

In the third research question, the main personal and contextual factors, to be analyzed when performing an in-field campaign of IEQ and comfort perception assessment, are investigated.

The fourth research question was formulated with the aim of acknowledging the way IEQ is communicated to the end-users of the environment. For this reason, studies presenting a single IEQ index, able to resume the environmental conditions and presenting a smart solution for IEQ conditions and overall comfort reporting to the end-user were searched for. The final aim was to identify, if present, the common points to define a final methodology for IEQ representation in space and time.

2. Materials and Methods

This work aims at summarizing the state of the art about IEQ in office buildings and its effects on occupants' overall comfort. Studies published between 2016 and 2022 are summarized, focusing on the abovementioned four research questions. In the following subsections, the process followed for the literature search and the selection of records is described.

The searching method applied in this review followed the rules of the "Preferred Reporting Items for Systematic Reviews and Meta-Analyses" (PRISMA) [30]. It is based on detecting documents using specific keywords combined by means of the Boolean operators. These keywords appeared in the title, abstract or keywords of the searched documents. Table 1 shows the keywords for each of the four research questions, which were based on a general literature survey [1,31,32].

The search process was carried out with the Scopus search engine. Once the records responding to the first step of the selection based on the keywords were collected, inclusion and exclusion criteria were defined for the further selection. As inclusion criteria, keywords were searched only in articles published between 2016 and 2020, and the papers had to be written in English. Articles out of topic or not related to indoor environmental quality and comfort were excluded, and, after reading the text, other studies were excluded if they were not in compliance with the research purposes. Additional research on the Scopus database was conducted for each research question with the same methodology mentioned above to add the papers published between 2021 and 2022. For each research question, studies found with the searches of the other research questions but considered relevant were also included.

2.1. Literature Search Outcomes for the Four Research Questions

A total of 641, 106, 703 and 295 records were found on the Scopus database for the four research questions, respectively. After the application of the inclusion and exclusion criteria, a total of 15, 6, 4 and 2 studies were then analyzed for the four topics, respectively. Through the additional research conducted following the same methodology but limited to years 2021 and 2022, a total of 1, 6 and 1 studies were included, respectively, in the first, second, and fourth research questions. The search was also conducted for the third research question, but no significant studies were found. Additionally, 13, 7, 6 and 6 studies were included in the first, second, third and fourth research questions from the results of the other research questions. Details on the literature search outcomes are reported in the following paragraphs, where the four research questions are labeled as RQ1, RQ2, RQ3 and RQ4, respectively.

2.1.1. RQ1—"How Is IEQ Perceived and Evaluated?"

Figure 1 shows the study-selection process followed for the first research question, "How is IEQ perceived and evaluated?". The literature search brought 641 results, lowered to 490 by applying the document typology limitation to articles. A further reduction to 166 records was applied by excluding the documents not published between 2016 and 2020 and the documents not written in English. After the screening of their title and abstract, only 21 out of 166 were considered to be relevant to the research question. Particularly, 146 were excluded because they were related to other research fields, such as the medical, psychosocial, nursing and management fields. After the full text reading, 6 records were further excluded because they did not present a multidomain approach (n = 5) and because they were not carried out in offices (n = 1). Finally, only 15 of the available studies on IEQ perception and evaluation in offices were used. Only 1 study published between 2021 and 2022 was added, and 13 studies were added from the second (n = 9), third (n = 2) and fourth (n = 2) research questions, for a total of 29 studies analyzed.

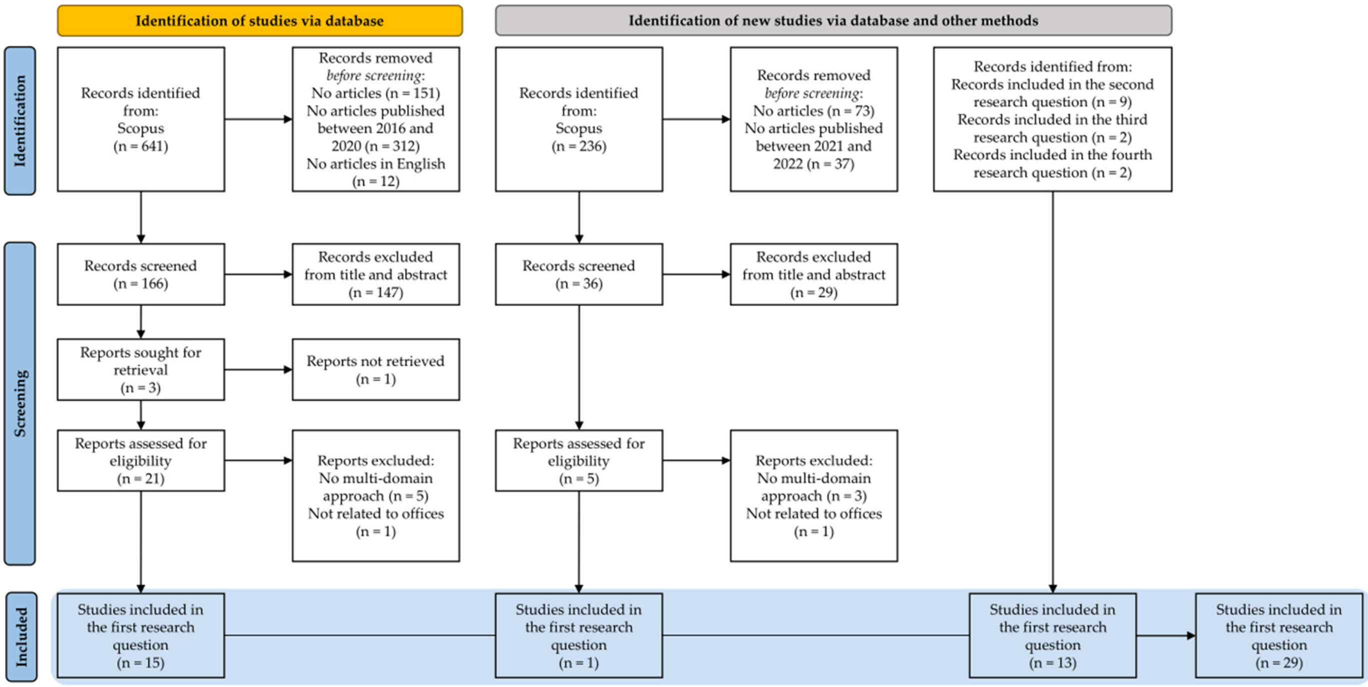

Figure 1. Flowchart of the selection process followed to determine the studies published between 2016 and 2022 deemed inherent and complying to the research question "How is IEQ perceived and evaluated?".

2.1.2. RQ2—"What Are the Main IEQ Indexes and Parameters?"

Figure 2 shows the study-selection process followed for the second research question, "What are the main IEQ indexes and parameters?". The literature search brought 106 results, lowered to 68 by applying the document typology limitation to articles. A further reduction to 45 records was applied by excluding the documents not published between 2016 and 2020. After the screening of their title and abstract, only 19 out of 45 were considered to be relevant to the research question. After reading the full text, 13 records were further excluded because they were not related to the four IEQ domains' parameters and indexes or because they did not present a multidomain approach. Finally, only 6 of the available studies on IEQ indexes and parameters to assess office environments were used. Additionally, 6 studies published between 2021 and 2022 were added and 7 studies from the first (n = 5) and fourth (n = 2) research questions were added, for a total of 19 studies analyzed.

2.1.3. RQ3—"What Are the Main Contextual and Personal Factors That Influence the Comfort Perception?"

Figure 3 shows the study-selection process followed for the third research question, "What are the main contextual and personal factors that influence the comfort perception?". The literature search brought 703 results, lowered to 371 by applying the document typology limitation to articles. A further reduction to 160 records was applied by excluding the documents not published between 2016 and 2020. After the screening of their title and abstract, only 17 out of 160 were considered to be relevant to the research question. Particularly, 143 were excluded because they were related to the medical field, chemical field or computer science field or because they did not present a multidomain approach. After reading the full text, 13 records were further excluded because they did not present a multidomain approach or were off topic. Finally, only 4 of the available studies on contextual and personal factors influencing comfort perception were used. No studies published between 2021 and 2022 were added, since the research conducted on the Scopus database did not bring significant results on the topic. In the end, 6 studies from the first research question were added, for a total of 10 studies analyzed.

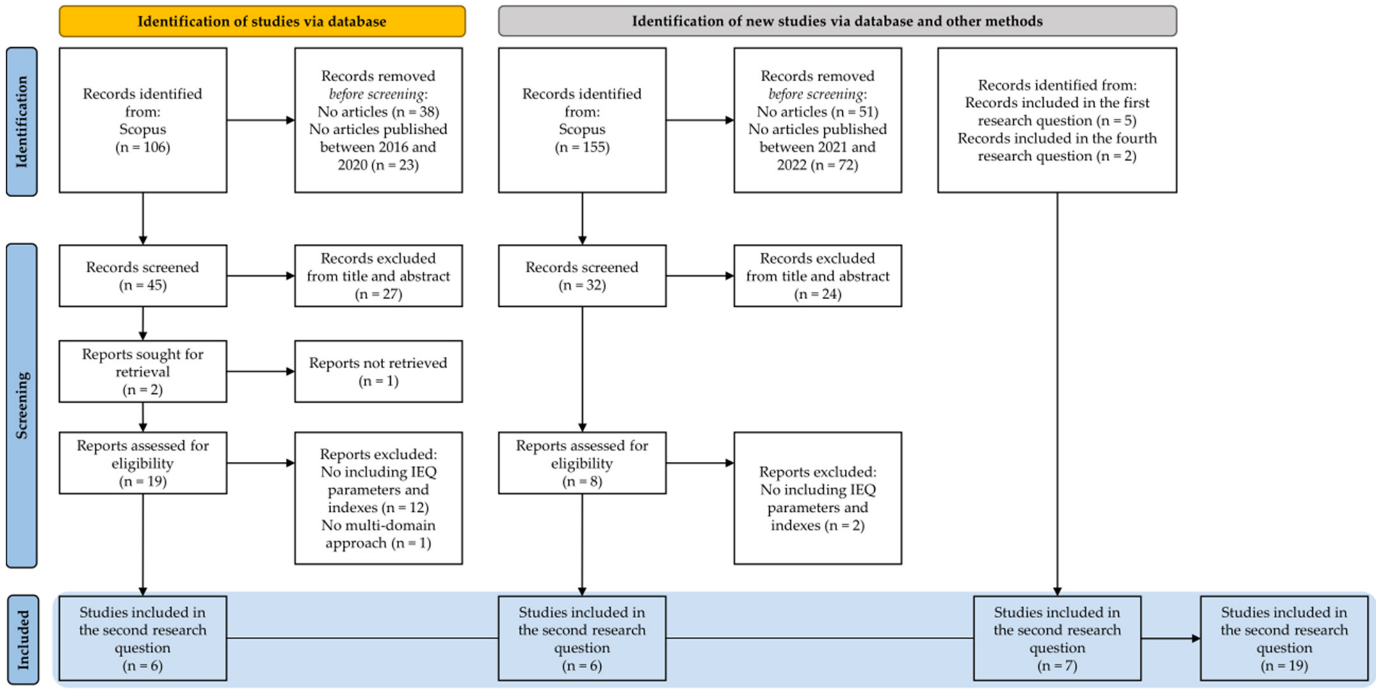

Figure 2. Flowchart of the selection process followed to determine the studies published between 2016 and 2022 deemed inherent and complying to the research question "What are the main IEQ indexes and parameters?".

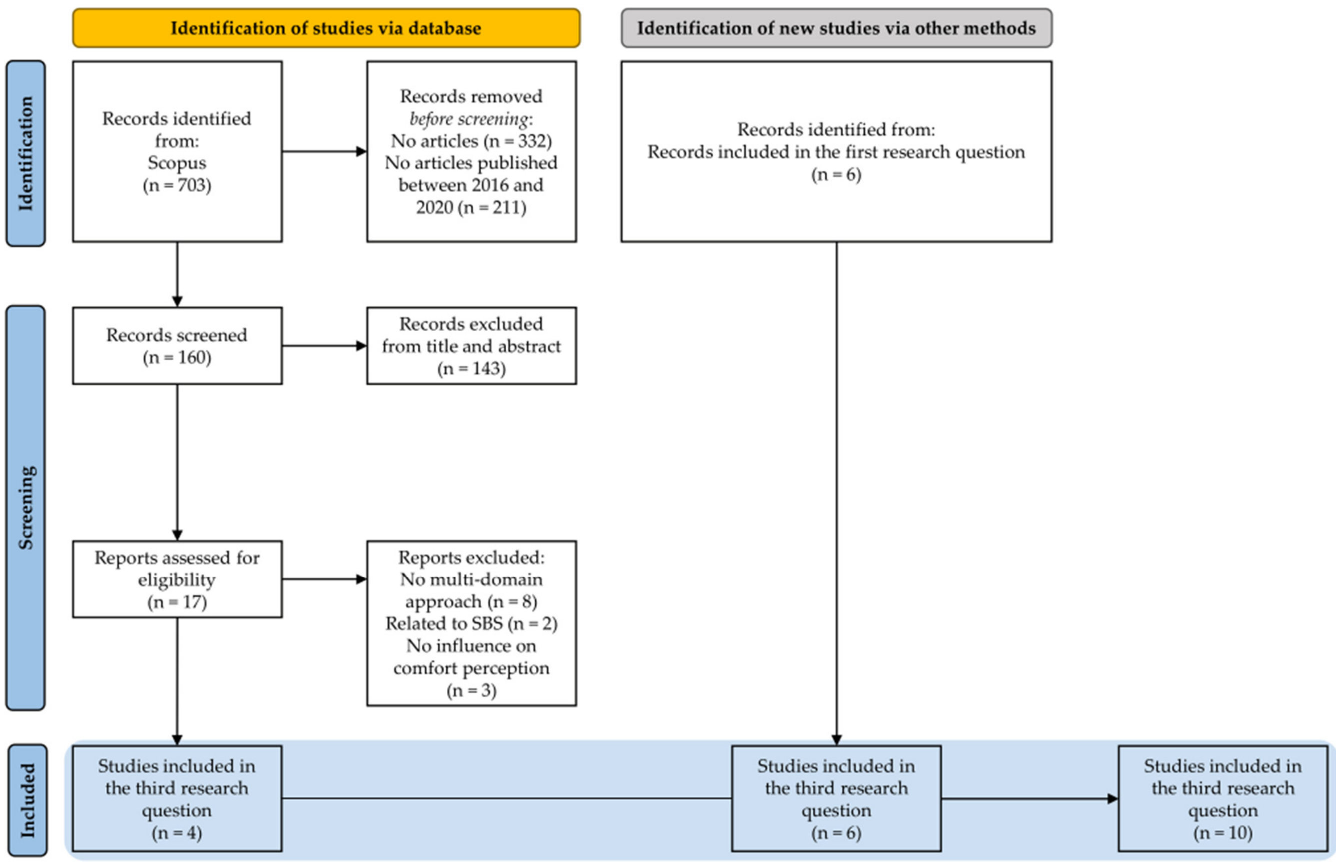

Figure 3. Flowchart of the selection process followed to determine the articles published between 2016 and 2022 deemed inherent and complying to the research question "What are the main contextual and personal factors that influence the comfort perception?".

2.1.4. RQ4—"How Are IEQ and Comfort Represented in Space and Time?"

Figure 4 shows the study-selection process followed for the fourth research question, "How are IEQ and comfort represented in space and time?". The literature search brought 295 results, lowered to 138 by applying the document typology limitation to articles. A further reduction to 51 records was applied by excluding the documents not published between 2016 and 2020 and the documents not written in English. After the screening of their title and abstract, only 6 out of 51 were considered to be relevant to the research question. Particularly, 45 were excluded because they were related to the medical field or chemical field or did not present a multidomain approach. After reading the full text, 4 records were further excluded because they were considered to be off topic. Finally, only 2 of the available studies on IEQ and comfort representation in space and time were used. Additionally, 1 study published between 2021 and 2022 was added, and 6 studies from the first (n = 1) and second (n = 5) research questions were added, for a total of 9 studies analyzed.

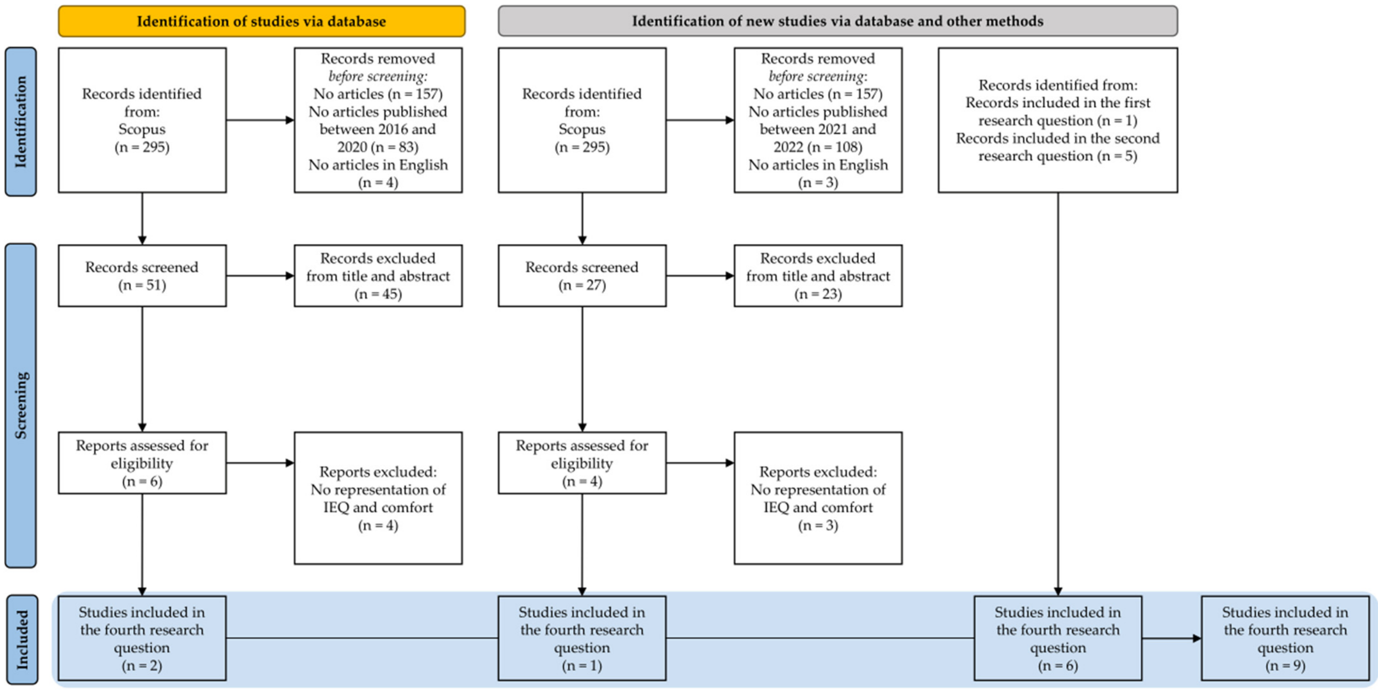

Figure 4. Flowchart of the selection process followed to determine the articles published between 2016 and 2022 deemed inherent and complying to the research question "How are IEQ and comfort represented in space and time?".

3. Results

Table 2 resumes the most meaningful information of the contents collected from all the analyzed studies.

Table 2. Summary of the contents collected from the studies (Ref) included in review. The following information is provided: location; study period; number of office or buildings (NO/NB); questionnaire details, i.e., questionnaire typology (QT), questionnaires sent (QS), questionnaires valid (QV), response rate (R), support used (S), number of questions (NQ); IEQ monitoring details, i.e., devices used (D), method used (M), that is, long-term monitoring (LM) or spot measurement (SM), and parameters and indexes assessed (P/I).

Ref	Location	Study Period	NO/NB	IEQ Evaluation								
				Questionnaire						IEQ Monitoring		
				QT	QS	QV	R	S	NQ	D	M	P/I
[3]	University of Warwick		1 O				-			Multisensor	LM	T_a, RH, E, CO_2, CO, PM2.5, PM10, TVOC, SPL
[4]	Downtown Los Angeles	2017	1 O	Customized COPE		110		Paper	30	IEQ cart “e-BOT” and hand-held sensors	SM	T_a, T_r, RH, V_a, E, UGR, CO_2, PM, TVOC, SPL
	City of Irvine		1 O			79						
[5]							-			SAMBA	LM	T_a, T_{mr}, RH, V_a, E, CO_2, CO, TVOC, CH_2O, SPL
[6]	China	2020	63 B			2425		Online, mobile		Multisensor	LM	T_a, RH, E, CO_2, PM2.5
[19]	Minnesota	2009–2019	41 B	SPOES		2836		Online	29		-	
[21]	Brazil, Italy, Poland, Switzerland, United States, Taiwan		6 B			2537		Online			-	
[22]	University of Southern California		9 B	Customized COPE					29	IEQ cart	LM and SM	T_a, T_r, RH, V_a, E, CO_2, PM, TVOC, SPL
	City of Los Angeles		5 B									
[23]	8 European Countries	October 2011–May 2012	167 B			7441	41%	Online			-	
[27]	South of China	December 2015–March 2016	19 B			231	87%				-	
[33]	Huaqiao University, China	September 2017	13 O			62	82.2%			Independent devices	SM	T_a, RH, E, U_o, SPL, L_{min}, L_{max}, L_{10}, L_{50}, L_{90}, CO_2, CH_2O, PM2.5, PM10
			12 O			63						
[34]	Turin	April–May 2017			4424	502	11%	Online	37		-	
	Perugia				2991	405	14%					
	Renden				1598	253	16%					
[35]	Eastern Washington State	2018	1 B		180	57	31.7%	Online, photovoice survey	60		-	
[36]	Australia		4 O	BOSSA Time-Lapse		465					-	
			5 O			656						
[37]	Australia		61 O	BOSSA Time-Lapse		8827		Online	31		-	
[38]	Canada	June–July 2018	23 B			170		Interviews	24		-	
[39]				BOSSA Time-Lapse and BOSSA Snap-Shot				Online	31	BOSSA Nova cart	SM	T_a, T_g, RH, V_a, E, CO_2, CO, TVOC, CH_2O, SPL

Table 2. *Cont.*

Ref	Location	Study Period	NO/NB	IEQ Evaluation								
				Questionnaire						IEQ Monitoring		
				QT	QS	QV	R	S	NQ	D	M	P/I
[40]	Netherlands	October 2016	1 B			173		Online		Wireless sensor infrastructure	LM	T_a, RH, E, CO_2
	United Kingdom	November 2016	1 B			288						
[41]						-				Independent devices	LM and SM	ΔCO_2, T_a, RH, T_{mr}, V_a, PMV, PD, DR, DF, $U_{0,surr}$, $U_{0,back}$, R_{surr}, R_{back}, $L_{i,w}$, $L_{i,s}$, T, STI, B, EF
[42]		2003–2014	64 O	Customized COPE				Paper and online		NEAT cart, independent devices	LM and SM	T_a, T_r, RH, V_a, E, UGR, CO_2, CO, PM2.5, PM10, TVOC, acoustic quality
[43]	Tsinghua University in Beijing, China	November 2016	1 O			441		Online		Independent devices	Test (2 h)	T_a, T_g, RH, E, CO_2, $L_{p,B}$
[44]	Singapore	September 2014–December 2016	4 B	POE		115	73.7%	Tablet		Independent devices	LM	CO_2, T_a, RH
			4 B			113	85.6%					
			6 B			139	72.9%				SM	E, CO, CH_2O, PM2.5, outdoor ACR
[45]	Guangzhou, China	April–May 2014	1 O			91				Independent devices	SM	T_a, RH, V_a, E, CO_2, PM10, CH_2O, SPL
[46]	National University of Singapore	April–May 2019	2 B					Mobile		Independent sensors	LM	T_a, RH, E, CO_2, TVOC, SPL
[47]	Auckland, New Zealand	October 2020–January 2021	5 B		257	52	20%	Online			-	
[48]	Al Ain, United Arab Emirates	December 2019–February 2020	9 O	POE						Independent devices	LM and SM	T_a, RH, E, CO_2, PM2.5, PM10, TVOC, SPL
[49]	Novi Sad, Serbia	August 2020	1 O		34	34	100%	Paper		ENVIRA Prototype	LM	T_a, T_g, T_{mr}, V_a, RH, PMV, PPD, E, CO_2, PM2.5, TVOC, SPL, p_b
			1 O		36	35						
[50]	Southern, Central and Northern Europe	April 2019–March 2020	6 B			-				Independent sensors	LM and SM	T_a, ventilation rate, RH, E, DF, CO_2, PM2.5, CH_2O, benzene, radon, SPL
[51]	Putrajaya, Kuala Lumpur	May–August 2019	1 B	BUS	174	112	64%			Independent devices	LM	T_a, V_a, RH, E, CO_2, TVOC, SPL
	Shah Alam, Kuala Lumpur		1 B									
[52]	Budapest	November 2019–January 2020	1 O			216		Online		Independent devices	SM	T_a, T_r, V_a, RH, E, CO_2, SPL

3.1. RQ1—"How Is IEQ Perceived and Evaluated?"

To answer the question on how IEQ is perceived by office occupants, the first step is to search for the methodologies used to acquire their subjective feedback on their comfort perception. The Post-Occupancy Evaluation (POE) method was introduced in the 1960s for this purpose [19]. POE surveys were introduced not only to understand occupants' overall comfort, but also as tools for the assessment of indoor conditions to further evaluate, overall, the building performance after it has been built and occupied [22,39,48]. Thus, a POE survey requires more data (e.g., building properties and IEQ data) that are collected through in-field IEQ measurements [4,19] to further ascertain the consistency of subjective feedback.

Among the analyzed studies within the first research question, the evaluation of IEQ is entrusted both to office occupants' feedback (obtained through their answer to surveys) and to in-field monitoring of IEQ parameters in 14 out of 29 studies [4,6,22,33,40,42–46,48,49,51,52]. A total of 10 studies performed only an IEQ perception analysis campaign [19,21,23,27,34–38,47], 3 studies performed only an in-field IEQ measurement campaign [3,41,50], 1 study presents the BOSSA tool for IEQ perception and evaluation [39] and 1 study presents the development of the SAMBA tool for IEQ monitoring [5].

A total of 25 studies assessed the comfort perception, and the results reveal that 16% of them found visual comfort to be the most satisfying domain, 1 study (4%) found IAQ to be the most satisfying domain and the other 80% did not provide this information. On the other side, the most unsatisfying domain is the acoustic one in 24% of the studies, followed by the thermal domain and IAQ (16%). Furthermore, the acoustic domain has the highest correlation with work productivity and health.

The results reveal that temperature is the most unsatisfying aspect of thermal comfort, followed by air movement and humidity. Concerning acoustic comfort, verbal noise, ability to limit undesired sounds, sound privacy, noise level, nonverbal noise, quietness and noise from the inside are the most-complained-about aspects. Artificial lighting, amount of daylighting and glare are the most unsatisfying aspects of visual comfort. Concerning IAQ, ventilation, followed by freshness, stuffy or fresh air and odor are the aspects complained about the most by office occupants.

As presented in Table 2, many typologies of questionnaires were applied in the analyzed studies. Some of them used already developed questionnaires, e.g., the COPE (Cost-effective Open-Plan Environment), the SPOES (Sustainable Post-Occupancy Evaluation Surveys), the BOSSA Time-Lapse and the BOSSA Snap-Shot, while others used customized questionnaires. A total of 16% of the studies used paper-based questionnaires, 56% used online surveys and 1 study used the photovoice application (4%). Among the studies that used an online survey, 21% used a mobile device to administer it, 14% used a tablet, 7% used a computer and the other studies did not specify this information.

All the questionnaires presented a different number of questions, but 68% of these were based on a seven-point Likert scale; 20% on a five-point Likert scale; 8% on a four-point Likert scale; and 4% on a three-point Likert scale, a nine-point Likert scale, a continuous visual analogue scale spanning from −100 to +100, a scale from 0 to 100 and open-ended questions.

As shown in Table 3, for what concerns thermal comfort, the perception of the overall thermal environment is the most surveyed aspect (in 60% of the studies), followed by satisfaction with temperature (52%), air movement (20%), humidity (16%), too hot/too cold temperature, temperature variation and temperature of the surfaces surrounding the person (8%), temperature stability, windows position and cold feet (4%). Concerning visual comfort, 60% of the questionnaires asked about satisfaction with the overall lighting environment, 32% about satisfaction with natural lighting and 24% with artificial lighting. A total of 28% asked about lighting level; 16% about direct glare, visual privacy and view outside; and 12% about glare in the computer screen, light for computer work, glare from sun, glare from artificial lighting and shading. Only 8% asked about amount of electric lighting, reflected light and access to daylight. A total of 4% asked about light for paper-based tasks.

The overall acoustic environment satisfaction was assessed by 44% of the papers, whereas 40% assessed the noise level; 20% the satisfaction with sound privacy; 16% with verbal noise; and 12% with outside noise, noise from building systems and noise from inside. Only 8% assessed nonverbal noise and unwanted interruptions, and 4% assessed noise disturbance, noise distraction, quietness and noise sources. The greatest part of the studies (80%) asked about general satisfaction with IAQ, and only a few asked more detailed questions on IAQ domain: 32% asked about ventilation, 28% about odor, 20% about humid/dry air and 16% about stuffy or fresh air and freshness.

Table 3. Summary of the surveyed subfactors for each IEQ domain in the studies (Ref) included in the first research question.

IEQ Domain	Subfactors	Ref
Thermal comfort	Overall thermal environment	[6,19,21,27,33–36,38,43,45,47,49,51,52]
	Temperature	[4,19,21–23,27,33,39,40,42,44,46,51]
	Air movement	[19,21,23,42,44]
	Humidity	[19,27,33,44]
	Too hot/too cold temperature	[23,48]
	Temperature variation	[23,48]
	Surfaces' temperature	[23,48]
	Temperature stability	[51]
	Windows are too close/far from me	[21]
	Cold feet	[48]
Visual comfort	Overall lighting environment	[4,6,21,23,27,33–36,42–45,47,51]
	Natural lighting	[20,26,30,35,37,40,46,53]
	Lighting level	[37,39,44,46,48,49,52]
	Artificial lighting	[19,23,28,33,38,51]
	Direct glare	[22,23,35,48]
	Visual privacy	[35,37,42,44]
	View to outside	[21,37,39,48]
	Glare in the computer screen	[4,21,42]
	Amount of daylighting	[20,22,35]
	Light for computer work	[4,22,42]
	Glare from sun	[4,42,51]
	Glare from artificial light	[4,42,51]
	Shading	[37,39,52]
	Reflected light	[22,48]
	Amount of electric lighting	[19,21]
	Access to daylight	[37,39]
	Light for paper-based tasks	[42]
Acoustic comfort	Overall acoustic environment	[6,19,21,23,27,33,34,43,45,47,51]
	Noise level	[35,37–40,44,46,48,49,52]
	Sound privacy	[35,37,39,42,44]
	Verbal noise	[4,23,42,51]
	Outside noise	[21,23,51]
	Noise from building systems	[4,21,23]
	Noise from inside	[21,24,51]
	Nonverbal noise	[23,42]
	Unwanted interruptions	[37,39]
	Noise disturbance	[33]
	Noise distraction and privacy	[36]
	Quietness	[28]
	Noise sources	[28]
IAQ perception	Overall air quality	[4,6,19,21–23,28,33–37,39,42–45,47,49,51]
	Ventilation/air velocity	[21,22,28,33,37,39,48,52]
	Odor	[21,23,38,42,48,51,52]
	Humid/dry air	[23,37,39,48,51]
	Stuffy or fresh air	[21,23,28,48]
	Freshness	[28,33,39,51]

Figure 5 shows the weight of each domain in the IEQ survey calculated considering the number of questions for each domain over the total number of questions. The mean weight of the thermal domain, calculated as mean of its weight in each analyzed study, is 23%. The visual domain has a mean weight of 32%, the acoustic domain of 23% and the IAQ of 22%. This means that visual comfort is, so far, considered to have the greatest role on IEQ evaluations, while IAQ results in the lowest weight, which may be due to the complexity of the possible variables to be accounted for.

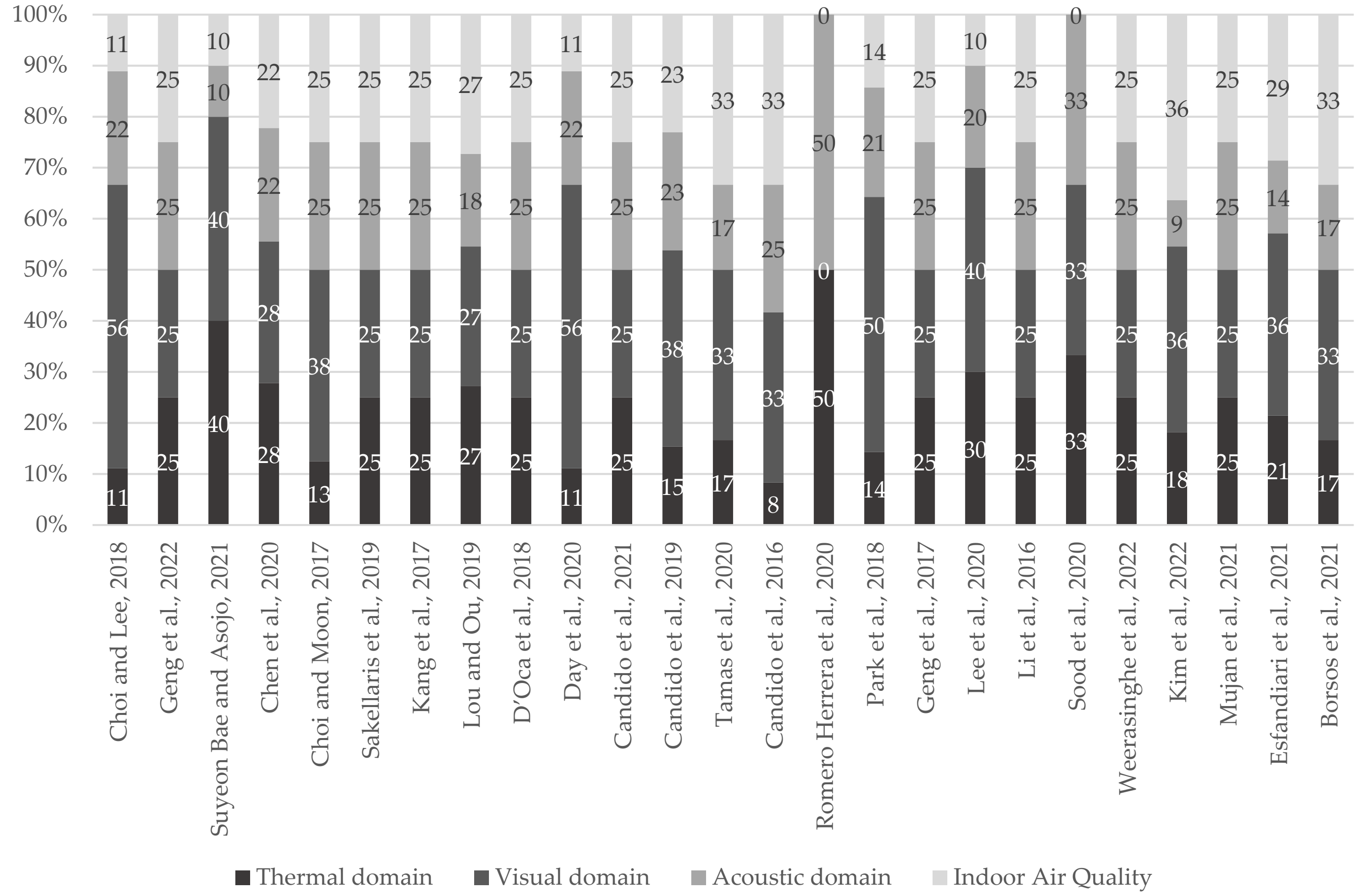

Figure 5. Weight in percentage for thermal domain, visual domain, acoustic domain and indoor air quality over overall IEQ calculated considering the number of questions asked for each domain in the questionnaires submitted in the analyzed studies [4,6,19,21–23,27,33–40,42–49,51,52].

From the analyzed studies, a summary of the most frequently asked questions not related to IEQ is presented in Table 4. Questions have been categorized by the authors. Gender and age are the most frequently asked factors (48% of the studies), followed by perceived productivity and access to thermostats (44%); control over light (36%); overall comfort, job category and view outside (28%).

Table 4. Summary of the surveyed factors and subfactors not belonging to the four IEQ domains and assessed through the questionnaires in the studies (Ref) included in the first research question.

Surveyed Factors	Subfactors	Ref
Workspace	Personal space	[27,33,36,38]
	Amount of personal space	[4,22,39,42,44]
	Connection to the outdoor environment	[36,37,39]
	Building maintenance	[19,36,37,39]
	Overall layout	[23,27,33,35–37]
	View outside	[4,22,23,35,37,39,42]
	Overall appearance (aesthetics)	[19,37,39,42]
	Cleanliness	[19,37,39,42,51]
	Overall furnishings	[19,27,35,51]
	Adjustability of furnishings	[19,35,37,39]
	Office type	[21,42,47,51]
	Enclosure of the work area	[4,22,42]
	Indoor environment	[22,44]

Table 4. *Cont.*

Surveyed Factors	Subfactors	Ref
Health	Perceived health	[36,37,39,51]
	Headache	[23,44,48]
	Stuffy/runny nose	[23,44,48]
	Sleepiness	[23,44,48]
Time spent at work	Hours per week in work area	[19,21,34,36,42]
	Overall years spent in the building	[19,38,48,51]
Personal	Gender	[4,19,21,27,34,36,37,42,47–49,51]
	Age	[4,19,21,27,34,36,37,42,47–49,51]
	Job category	[4,21,34,36,37,42,48]
Control	Personal control	[21,35–37,44]
	Access to thermostats	[4,21–23,34,35,37–39,47,48]
	Control over ventilation	[23,37,39,47,48]
	Control over shade from the sun	[21,23,34,35]
	Control over light	[21,23,34,35,37–39,47,48]
	Control over noise	[23,38,47]
	Operable windows	[21,34,35]
Perceived productivity		[4,21,23,27,33,34,36,37,39,42,51]
Level of privacy		[4,19,22,23]
Alterability of physical conditions		[4,35,42]
Overall comfort		[23,34,37–40,51]
IEQ		[4,21,35,42,43,49]

Table 2 also shows how IEQ is evaluated through in-field monitoring campaigns. A total of 6 studies declared they performed both long-term monitoring and spot measurements [22,41,42,44,48,50], whereas 6 studies performed only long-term monitoring [3,6,40,46,49,51], 4 studies performed only spot measurements [4,22,45,52], 1 study presents the SAMBA tool [5] and 1 study presents the BOSSA tool for IEQ monitoring [39]. A total of 53% of the studies used independent devices for specific parameters to be monitored, 37% used a specific kind of multisensor to measure simultaneously thermal, acoustic, visual and air quality parameters. These devices were either a low-cost portable device [3], the IEQ cart "e-BOT" [4], IEQ cart [22], NEAT (National Environmental Assessment Toolkit) cart developed by the Center for Building Performance and Diagnostics (CBPD) at Carnegie Mellon University [42], the BOSSA Nova cart [39], the SAMBA tool [5], a wireless sensor infrastructure [40], a multisensor [6] or the ENVIRA prototype [49]. The 11% of the studies used both single devices and a multisensor. The IEQ indexes and parameters used to assess IEQ through in-field monitoring will be better analyzed in RQ2.

Furthermore, 32% of the studies used low-cost sensors, 47% used accurate devices and 21% did not declare this information.

3.2. RQ2—"What Are the Main IEQ Indexes and Parameters?"

A total of 19 studies on IEQ parameter and index monitoring were analyzed, as described in Section 3.1, and Table 5 resumes the main indexes and parameters assessed by each study. Concerning thermal comfort, air temperature is monitored by all the studies, relative humidity by 95%, air velocity by 53%, predicted mean vote and predicted percentage of dissatisfied by 32%, globe temperature and radiant temperature by 21%, mean radiant temperature by 16% and draught risk by 5%. Illuminance is the most monitored parameter of visual comfort, since 100% of the studies chose to monitor it. It is then followed by unified glare rating (21%); daylight factor (16%); luminance (11%); and illuminance uniformity, ratio of the minimum illuminance to the average illuminance on the immediate surrounding area, ratio of the minimum illuminance to the average illuminance on the background area, ratio of the visual task discomfort glare to the average discomfort glare in the immediate surrounding area and ratio of the visual task discomfort glare to the average discomfort glare on the background area (5%). To assess acoustic conditions of the environment, sound pressure level is monitored by 74% of the studies; reverberation time by 11%; and background noise level, sound pressure level of winter air conditioning, sound pressure level of summer air conditioning, statistical sound levels and speech transmission index by 5%. Concentration of carbon dioxide is monitored by 100% of the analyzed studies to evaluate the air quality. Particulate matter 2.5 is monitored by 53% of the studies; total volatile organic compounds and particulate matter 10 by 42%; formaldehyde by 32%; concentration of carbon monoxide by 16%; concentration of benzene by 12%; and ventilation rate, concentration of radon, volatile organic compounds and relative humidity by 5%.

Figure 6 shows the weight of each domain on overall IEQ calculated considering the number of parameters assessed for each domain in the analyzed studies. The mean weight of the thermal domain, calculated as mean of its weight in each analyzed study, is 37%. The visual domain has a mean weight of 17%, the acoustic domain of 11% and the IAQ domain of 35%. This means that the thermal domain is considered to be the one that mainly influences the IEQ conditions, while the acoustic is the less assessed one in the analyzed studies through in-field monitoring. This could be due to the number of variables to be considered when evaluating the acoustic quality of an environment, especially in open-plan offices, where controlling noise sources is often not easy or even not possible.

Table 5. Summary of the indexes and parameters of thermal, acoustic, visual and indoor air quality domains used to assess IEQ in the studies (Ref) included in the second research question.

IEQ Domain	Indexes and Parameters	Ref
Thermal domain	Air temperature	[3–6,22,33,39–46,48–52]
	Relative humidity	[3–6,22,33,39–46,48–51]
	Air velocity	[4,5,22,39,41,42,45,49,51,52]
	Predicted mean vote	[5,6,41,43,49,51]
	Predicted percentage of dissatisfied	[6,22,41,43,49,52]
	Globe temperature	[5,39,43,49]
	Radiant temperature	[4,22,42,52]
	Mean radiant temperature	[5,41,49]
	Draught risk	[41]
Visual domain	Illuminance	[3–6,22,33,39–46,48–52]
	Unified glare rating	[4,22,41,42]
	Daylight factor	[41,50,52]
	Luminance	[41,42]
	Illuminance uniformity	[33]
	Ratio of the minimum illuminance to the average illuminance on the immediate surrounding area	[41]
	Ratio of the minimum illuminance to the average illuminance on the background area	[41]
	Ratio of the visual task discomfort glare to the average discomfort glare in the immediate surrounding area	[41]
	Ratio of the visual task discomfort glare to the average discomfort glare on the background area	[41]

Table 5. *Cont.*

IEQ Domain	Indexes and Parameters	Ref
Acoustic domain	Sound pressure level	[3–5,22,33,39,42,45,46,48–52]
	Reverberation time	[41,52]
	Background noise level	[22,43]
	Sound pressure level of winter air conditioning	[41]
	Sound pressure level of summer air conditioning	[41]
	Statistical sound levels (L_{10}, L_{50} and L_{90})	[33]
	Speech transmission index	[41]
Indoor Air Quality	Carbon dioxide	[3–6,22,33,39–46,48–52]
	Particulate Matter 2.5	[3,4,6,22,33,42,44,48–50]
	Total volatile organic compounds	[3,5,22,39,42,48,49,51]
	Particulate Matter 10	[3–5,23,33,42,45,47]
	Formaldehyde	[5,33,39,44,45,50]
	Carbon monoxide	[3,5,39,42,44]
	Benzene	[50]
	Ventilation rate	[50]
	Radon	[50]
	Volatile organic compounds	[46]
	Relative humidity	[50]

Furthermore, air temperature, illuminance and carbon dioxide are the only parameters assessed by all the analyzed papers, while for the acoustic domain, the most assessed parameter is the sound pressure level, which is assessed only by 74% of the studies.

IEQ Indexes in International Standards

Starting from the results of this research question, further research was carried out about IEQ indexes related to thermal, acoustic, visual and indoor air quality domains set in international standards.

ISO 3382-3:2022 [11] and NF S31-080 [13] for acoustic comfort provide values for different office types. Standard EN 12464-1:2021 [15] for visual comfort is organized in tasks, because each activity requires a different level of lighting conditions.

Table A1 shows indexes selected from international standards divided in the four IEQ domains. Three typologies of workplaces were identified: single office, shared office (from two to five people) and open-plan offices. The indexes and parameters included for thermal quality are predicted mean vote, predicted percentage of dissatisfied, room operative temperature, relative humidity and air velocity. Noise levels, reverberation time, insulation, spatial decay and distraction distance are the indexes evaluated for the acoustic domain. For the visual domain, it is necessary to differentiate between electric lighting and natural lighting: levels of illuminance, unified glare rating, illuminance uniformity and color rendering index are assessed for electric lighting, whereas daylight factor and dynamic indexes such as spatial daylight autonomy, annual sunlight exposure and daylight glare probability are used to evaluate natural lighting. Concentrations of carbon dioxide, carbon monoxide, formaldehyde, particulate matter, ozone, radon and nitrogen dioxide are defined for IAQ.

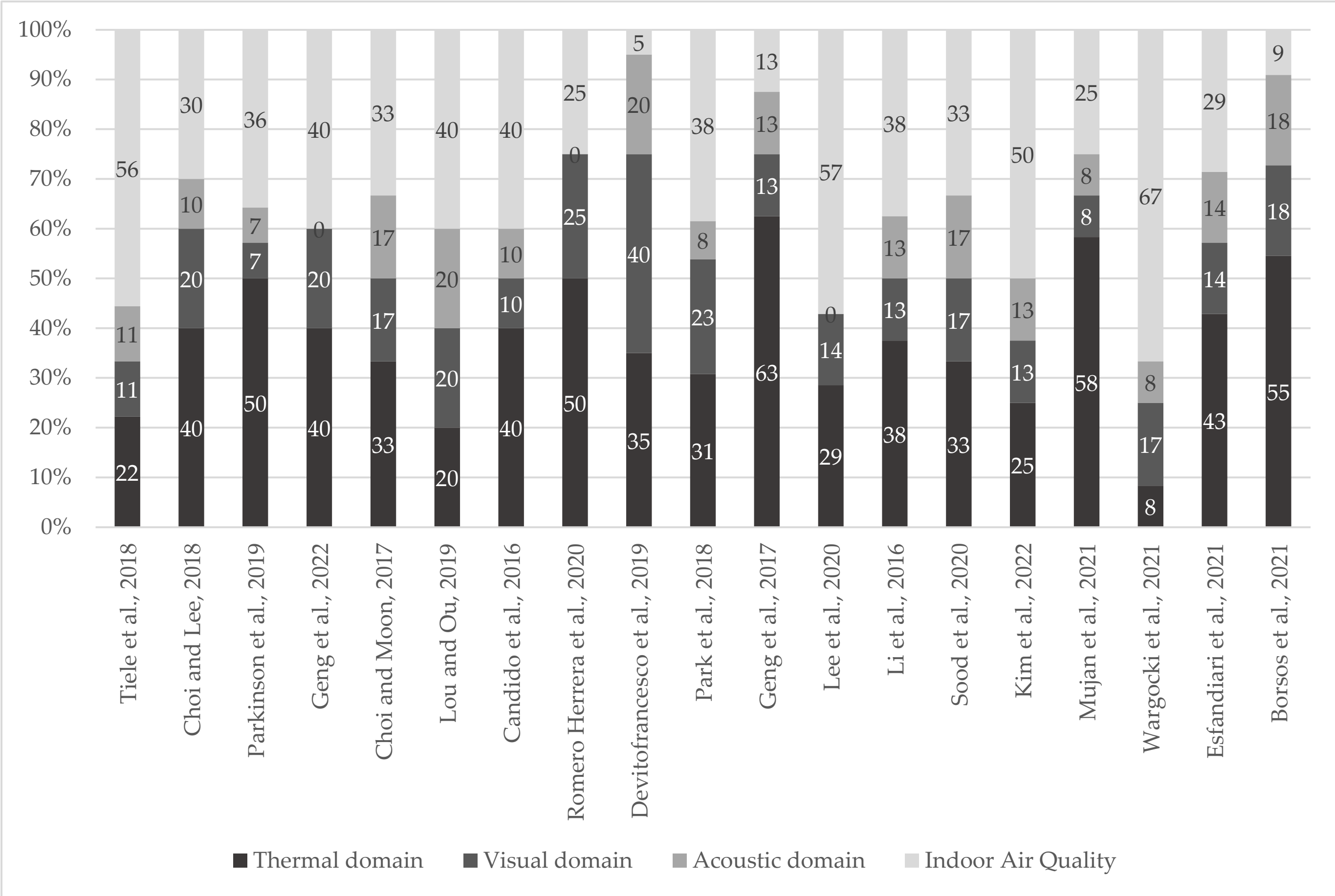

Figure 6. Weight in percentage for thermal domain, visual domain, acoustic domain and indoor air quality over overall IEQ calculated considering the number of parameters assessed for each domain in the analyzed studies [3–6,22,33,39–46,48–52].

3.3. RQ3—"What Are the Main Contextual and Personal Factors That Influence the Comfort Perception?"

Occupants' perception of IEQ is influenced by factors not strictly related to thermal, acoustic, visual and IAQ domains. The findings of the research reveal that occupants' personal control over the indoor environment and over building systems (e.g., thermostats, windows and electric lighting) have a high correlation with overall comfort [23,35]. Furthermore, access to nature, daylight and outdoor environment should be ensured to reduce stress and improve positive mood and wellness of office workers [36,53].

Tables 6 and 7 resume, respectively, the main contextual factors and personal factors that in the analyzed studies are found to influence the occupants' comfort perception. Concerning the contextual factors, personal space has been found to affect overall comfort, whereas the office typology affected overall comfort in one study and only the visual comfort in another study due to the different levels of control on electric lighting conditions. However, the authors of that study declared that a larger sample size is needed to confirm this result, since Bonferroni correction showed that this result was not significant [35].

The workstation location is found to affect overall comfort perception, thermal comfort and visual comfort. Work typology is found to affect thermal and acoustic comfort. Two studies revealed that occupants' control on building systems influences the overall comfort perception, while one study showed it influences mainly visual comfort. Work area aesthetics, adaptation of the work area, furnishings, cleanliness, amount of interruptions, season, area ratio of window to floor and privacy influence the overall comfort perception.

Table 6. Summary of the contextual factors that influence the comfort perception identified in the analyzed studies (Ref) included in the third research question.

Contextual Factor	Affected Domain	Ref
Personal space	Overall comfort	[33]
Office typology	Overall comfort Visual comfort Acoustic comfort	[33] [35] [27]
Workstation location	Overall comfort Thermal comfort Visual comfort	[27] [22] [22]
Work typology	Thermal comfort Acoustic comfort	[33] [27,33]
Occupants' control on building systems	Overall comfort Visual comfort	[23,38] [35]
Work area aesthetics	Overall comfort	[37]
Adaptation of the work area	Overall comfort	[37]
Furnishing	Overall comfort	[19,37]
Cleanliness	Overall comfort	[19,37]
Amount of interruptions	Overall comfort	[37]
Season	Overall comfort	[4]
Area ratio of window to floor	Visual comfort	[33]
Privacy	Overall comfort	[19]

Table 7. Summary of the personal factors that influence the comfort perception identified in the analyzed studies (Ref) included in the third research question.

Personal Factor	Affected Domain	Ref
Gender	Thermal comfort Visual comfort Acoustic comfort	[4,22,27,34] [23] [4]
Age	Thermal comfort Visual comfort Acoustic comfort	[23] [4,23,28] [28]
Birthplace	Thermal comfort Visual comfort Acoustic comfort	[28] [28] [28]

Concerning the personal factors that influence comfort perception, in the analyzed studies, three factors have been assessed: gender, age and birthplace. Gender was found to influence thermal comfort by 4 studies and visual and acoustic comfort by 1 study. Age was found to influence visual comfort in 3 studies and thermal and acoustic comfort in 1 study. Only 1 study showed that birthplace had an influence on thermal, visual and acoustic comfort.

3.4. RQ4—"How Are IEQ and Comfort Represented in Space and Time?"

To answer this research question, a total of 9 studies [3,5,6,40,41,46,49,50,52] were analyzed, as summarized in Table 8. In all the analyzed studies, an in-field monitoring campaign was performed to collect data about the real conditions of the working space. In 67% of the studies, an IEQ index was calculated, starting from the monitored parameters. In one study, a simulation tool was also used to define the value of some specific indexes used for the calculation of the IEQ index. Each study presents a specific methodology for the calculation of the IEQ index, that comprehends parameters' threshold definition and weighting scheme of each parameter and comfort domain (thermal, visual, acoustic, air quality). A total of 33% of the studies, among the 6 that calculated the IEQ index [3,5,6,41,49,50], chose to define it through a percentage value, 33% chose to represent it through a caption (e.g., "good", "average", "poor") and a percentage value, 17% represented it by the use of colors (e.g., green, yellow, red) and a percentage value and, finally, 17% represented it with numbers. Furthermore, 56% collected occupants' feedback to obtain data on their perception of the indoor environment. Among them, 60% asked the occupants for feedback directly through a developed dashboard, 11% asked for it through a paper-based survey and 11% did not specify this information.

Table 8. Summary of the contents of the studies (Ref) included in the fourth research question. The following information is provided: parameters and indexes used for the calculation of the IEQ index; parameters rating; IEQ index, occupants' feedback collection; represented data; support tool used for data representation; end-users of the developed tool.

Ref	Parameters and Indexes	Parameters Rating	IEQ Index	Occupants' Feedback	Represented Data	Support Tool	End-Users
[3]	T_a, RH, CO, CO_2, TVOC, PM2.5, PM10, E, SPL	Good, average, poor, bad	Percentage		IEQ indicator, IEQ score and warnings	Low-power OLED display on the external case	Researchers, enthusiasts, everyday users
[5]	T_a, RH, T_g, V_a, SPL, E, TVOC, CH_2O, CO, CO_2	Good (green), fair (yellow), poor (red)	Percentage		Real-time averages, compliance times, recent histories, alerts, noncompliant parameters, IEQ rating	IEQ Analytics web service (online data visualization)	Building owners, facility managers, tenants, building occupants
[6]	T_a, RH, E, CO_2, PM	Percent of measurement results within the compliance range in the last hour	Percentage based on specific weighting scheme	Perceptions or level of satisfaction with each IEQ factor	Data visualization and downloads	Web platform and mobile interface	Professionals and data analysts
					Real-time and historical data of IEQ parameters, their ratings, overall IEQ and suggestions for users	Mobile interface	Building occupants
[40]	T_a, RH, CO_2, E, movement			Pleasantness, thermal comfort, sound level	Real-time temperature value of the selected sensor box, occupants' pleasantness and thermal sensation votes	Compi app: web-based mobile app also accessible via a web browser	Office employees
[41]	ΔCO_2, T_a, RH, T_m, V_a, PMV, PPD, DR, DF, $U_{0,surr}$, $U_{0,back}$, R_{surr}, R_{back}, $L_{i,w}$, $L_{i,s}$, T, STI, B, EF	Score attributed according to a predefined benchmark scale and weight	Score in a four-option range evaluation (−1, 0, 3, 5)		Indoor thermal comfort, indoor air quality, visual comfort, acoustic quality, electromagnetic pollution, overall level of environmental quality		Owner, manager, building customer
[46]	T_a, RH, SPL, E, CO_2, TVOC, presence			Temperature, light, noise levels	Information about the room and real-time values of temperature, humidity and noise	Spacematch platform: web-based mobile application	Office employees
[49]	T_a, T_g, T_r, V_a, RH, E, CO_2, PM2.5, TVOC, SPL, p_b		Integration of IEQ parameters through derivation of their weighting coefficients	Perception of IEQ evaluated using a paper-based survey	Single domain indexes and IEQ index displayed visually using gauges, real-time values of IEQ parameters and their graphical representation	User-friendly smartphone application	Building occupants
[50]	T_a, ventilation rate, RH, E, DF, CO_2, PM2.5, CH_2O, benzene, radon, SPL	Green, yellow, orange, red color	Roman numerals from I (high quality level) to IV (low quality level)		Quality of the thermal environment, acoustic environment, indoor air, luminous environment and overall level of IEQ		
[52]	T_a, T_r, V_a, RH, E, CO_2, SPL			Odors, ventilation, noises and sounds, shielding, lighting and thermal conditions	Thermal comfort, CO_2, visual comfort and acoustic comfort of each workstation		Office occupants

A total of 56% of the 9 studies included in this research represented the data on a developed dashboard, 11% directly over the multisensor and 33% did not specify this information. The represented data are in 9% of the studies only the IEQ index; in 22% the IEQ index and the value of each domain; in 22% the IEQ index and the value of each monitored parameter; and in 11% the IEQ index, the value of each domain and the value of each monitored parameter. A total of 11% represented only the temperature value, and 22% represented only the monitored parameters. Furthermore, 22% represented the occupants' subjective comfort perception obtained from their feedback. A total of 44% of the studies also provided additional information (e.g., specific warnings in case of exceeding the established threshold for a single parameter, suggestions about the monitored parameters or more information about the monitored environment) while 56% did not.

4. Conclusions and Future Perspectives

This literature review summarizes studies published between 2016 and 2022 to investigate IEQ in offices and the multidomain combined effects on occupants' overall comfort. Four research questions have been formulated to better investigate (i) IEQ perception and evaluation, (ii) IEQ indexes and parameters, (iii) factors that influence the comfort perception and (iv) IEQ and comfort representation in space and time. In this section, the main conclusions outreached from the analysis of the selected studies for each research question are listed.

4.1. RQ1—"How Is IEQ Perceived and Evaluated?"

The first research question of this review aimed first at analyzing the way the indoor environmental conditions are perceived by office building occupants and how their perception is investigated in terms of the mainly used support tool, questionnaire typology, number of questions, rating scale and most frequently asked questions for each IEQ domain. The results demonstrate that in the included studies, (i) 56% administered online surveys and 16% paper-based questionnaires, (ii) different typologies of questionnaires were used (POE, COPE, SPOES, BOSSA Time-Lapse, BOSSA Snap-Shot and customized questionnaires) with different numbers of questions, (iii) the most frequently asked questions for each domain are overall thermal environment and temperature, overall lighting environment and natural lighting, overall acoustic environment and noise level, and overall air quality and ventilation, and (iv) 68% of the administered questionnaire was based on a seven-point Likert scale. Furthermore, visual comfort is usually the most satisfying domain, while acoustic comfort is the most unsatisfying and has the highest correlation with work productivity and health.

A further aim of the first research question was to understand the way IEQ is assessed. Among the selected studies, 14 out of 29 performed the IEQ evaluation both through occupants' feedback collection and in-field monitoring of IEQ parameters. Concerning the IEQ monitoring, the aim of the review was to acquire knowledge on the devices used and the way the monitoring is conducted. The results demonstrate that (i) 32% of the studies used low-cost sensors, 47% used accurate devices, the others did not provide this information, and that (ii) 53% used independent sensors or accurate devices, 37% used prototypes that combine multiple accurate devices or low-cost sensors in a single body and 11% used both.

4.2. RQ2—"What Are the Main IEQ Indexes and Parameters?"

The main indexes and parameters monitored using the aforementioned devices to assess IEQ were analyzed and included in the second research question. The aim was to understand how many and which parameters need to be monitored to define the conditions of an indoor environment. The results reveal two main findings. First, the thermal domain is the one with a higher number of monitored parameters with respect to the other domains, while the acoustic domain is the less assessed one. This is considering both number of monitored parameters and number of studies that assessed it, as air temperature, illuminance and carbon dioxide are the only parameters assessed by all the analyzed studies. For the acoustic domain, the most assessed parameter is the sound pressure level, which is assessed by 74% of the studies. Second, the two most assessed parameters or indexes for each domain in the analyzed studies are air temperature and relative humidity, illuminance and unified glare rating, sound pressure level and reverberation time, carbon dioxide and PM2.5.

4.3. RQ3—"What Are the Main Contextual and Personal Factors That Influence the Comfort Perception?"

The reliability of subjective responses on comfort perception obtained through questionnaires was the object of investigation. There are many factors found in the literature that were proven to influence occupants' comfort perception, such as contextual and personal factors. From the studies included in this review, a list of contextual factors was defined, but (i) most of them were found to have influence over one or more aspects of comfort by only one study and (ii) among them, work typology, occupants' control on building systems, furnishings and cleanliness are the only factors found to influence comfort by more than one study. Concerning personal factors, the performed analysis revealed that (i) gender is the most influencing factor on thermal comfort and (ii) age is the most influencing factor on visual comfort.

4.4. RQ4—"How Are IEQ and Comfort Represented in Space and Time?"

The fourth research question was formulated to find out how, in the recent literature, the IEQ and comfort are represented in space and time in an effective and user-friendly way. The main outcomes reveal that 67% of the studies included in the fourth research question defined a new IEQ index, and this is represented in 33% of the studies through a percentage value, in 33% through a caption and a percentage value, in 17% through the use of colors and a percentage value and, finally, in the other 17%, through numbers. A total of 56% of the studies also collected subjective feedback and, among them, 60% collected feedback directly through a developed dashboard. A total of 56% of the studies showed the data in the developed dashboard.

4.5. Future Perspectives

The standards on thermal comfort, acoustic comfort, visual comfort and indoor air quality often provide parameters and indexes threshold values to avoid a discomfort condition. Only some standards, such as EN 16798-1:2019 [8] and NF S31-080 [13], provide a subdivision into categories, allowing different quality levels to be achieved in the indoor environment. In recent years, building certification schemes have given specific attention to comfort factors through scores assignment to each domain. The French acoustics standard NF S31-080 [13] defines parameters and indexes values for three different performance ranges, overcoming the concept of comfort as risk avoidance. In this way, different flexible comfort ranges are provided: the "standard" level, the "efficient" level and the "highly efficient" level. This is a qualitative definition related to office activities based on the different typologies of tasks and workplaces. These comfort ranges may allow the setting of indoor environmental conditions in relation to occupants' needs and office tasks, and the satisfaction of customers' requests through office design. However, as result of this review, it can be stated that to reach the maximum expected level of comfort, it is not sufficient that all the parameters and indexes of the four domains, identified as contributing to the indoor environmental quality definition, comply with the highest range. In fact, there are contextual and personal factors that greatly influence the occupants' comfort perception. The influence of these factors determines an uncertainty that can only find expression with the assessment of the occupants' perceived comfort. Furthermore, the occupants' actions aimed at satisfying personal comfort expectations impact the energy consumption of office buildings. For this reason, an optimal design that appraises IEQ and occupants' perception could ensure their health, well-being and comfort and support energy savings.

The IEQ perception and the multidomain effect on occupants' comfort is a field still to be investigated. The implementation of a methodology able to appraise the relationship between IEQ, occupants' comfort, personal and contextual factors and energy consumption is fostered. Occupants' engagement toward a more proactive behavior is needed, especially in the post-COVID-19 era, in which more attention is paid to office design, with regards to safety, health and a new office-working concept.

Author Contributions: Conceptualization, V.I.F., S.F., G.E.P., L.S. and A.A.; methodology, V.I.F., S.F., G.E.P., L.S. and A.A; formal analysis, V.I.F., S.F. and A.A.; writing—original draft preparation, V.I.F. and S.F.; writing—review and editing, V.I.F., G.E.P., L.S. and A.A.; supervision, G.E.P., L.S. and A.A. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by the national action program in the framework of the REACT EU Initiative: Programma Operativo Nazionale (PON) Ricerca e Innovazione 2014–2020 REACT EU Percorsi di dottorato su tematiche green e sui temi dell'innovazione D.M. 1061 del 10/08/2021.

Data Availability Statement: Data available on request from the authors.

Acknowledgments: The authors would like to thank Giorgia Spigliantini, Anna Pellegrino, Stefano Paolo Corgnati, Marco Carlo Masoero, Vincenzo Corrado, C2R Energy Consulting S.r.l. and Italgas.

Conflicts of Interest: The authors declare no conflict of interest.

Abbreviations

ACR	Air Change Rate
B	magnetic induction mean value
BOSSA	Building Occupants Survey System Australia
BREEAM	Building Research Establishment Environmental Assessment Method
BUS	Building Use Studies
CBE	Center of the Built Environment
CBPD	Center for Building Performance and Diagnostics
COPE	Cost-effective Open-Plan Environment
D	Devices used
DF	Daylight Factor
DR	Draught Risk
E	illuminance
EF	Electrical Field level
GM	Green Mark
I	Indexes assessed
IAQ	Indoor Air Quality
IEQ	Indoor Environmental Quality
IoT	Internet of Things
L_{10}	sound pressure level tenth percentile
L_{50}	sound pressure level fiftieth percentile
L_{90}	sound pressure level ninetieth percentile
LEED	Leadership in Energy and Environmental Design
$L_{i,w}$	sound pressure level of winter air–conditioning
$L_{i,s}$	sound pressure level of summer air–conditioning
LM	Long-term Monitoring
L_{min}	minimum sound pressure level
L_{max}	maximum sound pressure level
$L_{p,B}$	background noise level
M	Method used
NB	Number of Buildings
NEAT	National Environment Assessment Toolkit
NO	Number of Offices
NQ	Number of Questions
OLED	Organic Light-Emitting Diode
P	Parameters assessed
p_b	barometric pressure
PD	Percentage of Dissatisfied

PM	Particulate Matter
PMV	Predicted Mean Vote
POE	Post-Occupancy Evaluation
PPD	Predicted Percentage of Dissatisfied
PRISMA	Preferred Reporting Items for Systematic Reviews and Meta-Analyses
QS	Questionnaires Sent
QT	Questionnaire Typology
QV	Questionnaires Valid
R	Response rate
R_{back}	ratio of the visual task discomfort glare to the average discomfort glare on the background area
RH	Relative Humidity
R_{surr}	ratio of the visual task discomfort glare to the average discomfort glare in the immediate surrounding area
S	Support used
SAMBA	Sentient Ambient Monitoring of Buildings in Australia
SBS	Sick Building Syndrome
SM	Spot Measurement
SPL	Sound Pressure Level
SPOES	Sustainable Post-Occupancy Evaluation Surveys
STI	Speech Transmission Index
T	reverberation time
T_a	air temperature
T_g	globe temperature
T_{mr}	mean air temperature
T_r	radiant temperature
TVOC	Total Volatile Organic Compounds
UGR	Unified Glare Rating
U_o	illuminance uniformity
$U_{0,surr}$	ratio of the minimum illuminance to the average illuminance on the immediate surrounding area
$U_{0,back}$	ratio of the minimum illuminance to the average illuminance on the background area
V_a	air velocity
WHO	World Health Organization
WODI	Work Environment Diagnosis Instrument

Appendix A

Table A1. IEQ parameters and indexes and their thresholds defined by standards. Parameters and indexes are divided in the four IEQ domains (thermal, acoustic, visual and indoor air quality) and in three office typologies (single office, shared office and open-plan office).

Parameter/Index and Reference Standard		Single Office	Shared Office	Open-Plan Office
Thermal domain				
Predicted mean vote (PMV) * [-] EN ISO 7730:2005 [10]	Category A	−0.2 < PMV < +0.2	−0.2 < PMV < +0.2	−0.2 < PMV < +0.2
	Category B	−0.5 < PMV < +0.5	−0.5 < PMV < +0.5	−0.5 < PMV < +0.5
	Category C	−0.7 < PMV < +0.7	−0.7 < PMV < +0.7	−0.7 < PMV < +0.7
Predicted percentage of dissatisfied (PPD) * [%] EN ISO 7730:2005 [10]	Category A	PPD < 6	PPD < 6	PPD < 6
	Category B	PPD < 10	PPD < 10	PPD < 10
	Category C	PPD < 15	PPD < 15	PPD < 15
Operative temperature (T_{op}) [°C] EN ISO 7730:2005 [10]	A (summer)	24.5 ± 1.0		24.5 ± 1.0
	A (winter)	22.0 ± 1.0		22.0 ± 1.0
	B (summer)	24.5 ± 1.5		24.5 ± 1.5
	B (winter)	22.0 ± 2.0		22.0 ± 2.0
	C (summer)	24.5 ± 2.5		24.5 ± 2.5
	C (winter)	22.0 ± 3.0		22.0 ± 3.0

Table A1. *Cont.*

Parameter/Index and Reference Standard		Single Office	Shared Office	Open-Plan Office
Relative humidity (RH) [%] EN 16798-1:2019 [8]		$25 \leq RH \leq 60$		$25 \leq RH \leq 60$
Air velocity (V_a) [m/s] EN ISO 7730:2005 [10]	A (summer) A (winter) B (summer) B (winter) C (summer) C (winter)	0.12 0.10 0.19 0.16 0.24 0.21		0.12 0.10 0.19 0.16 0.24 0.21
Acoustic domain				
Total noise level (L_{50}) [dB(A)] NF S31-080:2006 [13]	Standard level Efficient level Highly efficient level	$L_{50} \leq 55$ $35 \leq L_{50} < 45$ $30 < L_{50} < 35$	$L_{50} \leq 55$ $35 \leq L_{50} < 45$ $30 < L_{50} < 35$	$L_{50} \leq 55$ $40 < L_{50} < 45$ $40 < L_{50} < 45$
—External noises ($D_{nT,A,tr}$) [dB] NF S31-080:2006 [13]	Standard level Efficient level Highly efficient level	$D_{nT,A,tr} \geq 30$ $D_{nT,A,tr} \geq 30$ and $L_{50} \leq 35$ dB(A) $D_{nT,A,tr} \geq 30$ and $L_{50} \leq 30$ dB(A)	$D_{nT,A,tr} \geq 30$ $D_{nT,A,tr} \geq 30$ and $L_{50} \leq 35$ dB(A) $D_{nT,A,tr} \geq 30$ and $L_{50} \leq 30$ dB(A)	$D_{nT,A,tr} \geq 30$ $D_{nT,A,tr} \geq 30$ and $L_{50} \leq 35$ dB(A) $D_{nT,A,tr} \geq 30$ and $L_{50} \leq 30$ dB(A)
—Equipment noise NF S31-080:2006 [13]	Standard level Efficient level Highly efficient level	$L_{Aeq} \leq 45$ dB(A) $Lp \leq NR\ 33$ $Lp \leq NR\ 30$ (permanent) and $L_{max} \leq 35$ dB(A) (intermittent)	$L_{Aeq} \leq 45$ dB(A) $Lp \leq NR\ 33$ $Lp \leq NR\ 30$ (permanent) and $L_{max} \leq 35$ dB(A) (intermittent)	$L_{Aeq} \leq 45$ dB(A) $NR\ 35 \leq Lp \leq NR\ 40$ $Lp \leq NR\ 33$ (permanent) and $L_{max} \leq 35$ dB(A) (intermittent)
Reverberation time (T_r) [s] NF S31-080:2006 [13]	Standard level Efficient level Highly efficient level	/ $T_r \leq 0.7$ $T_r \leq 0.6$	$T_r \leq 0.6$ $T_r \leq 0.6$ $T_r \leq 0.5$	$T_r \leq 0.8$ $0.6 < Tr < 0.8$ $T_r \leq 0.6$
Reverberation time (T_r) [s] ISO 22955:2021 [12]				$Tr \leq 0.5$ $Tr \leq 0.8$ at 125 Hz
Impact noise L'_{nTw} [dB] NF S31-080:2006 [13]	Standard level Efficient level Highly efficient level	$L'_{nTw} \leq 62$ $L'_{nTw} \leq 60$ $L'_{nTw} \leq 58$	$L'_{nTw} \leq 62$ $L'_{nTw} \leq 60$ $L'_{nTw} \leq 58$	$L'_{nTw} \leq 62$ $L'_{nTw} \leq 60$ $L'_{nTw} \leq 58$
Insulation from internal airborne noise ($D_{nT,A}$) [dB] NF S31-080:2006 [13]	Standard level Efficient level Highly efficient level	$D_{nT,A} \geq 35$ $D_{nT,A} \geq 40$ $D_{nT,A} \geq 45$	$D_{nT,A} \geq 35$ $D_{nT,A} \geq 40$ $D_{nT,A} \geq 45$	$D_{nT,A} \geq 30$ $D_{nT,A} \geq 35$ $D_{nT,A} \geq 40$
Spatial decay NF S31-080:2006 [13]	Standard level Efficient level Highly efficient level			2 dB. If decay not applicable: $T_r \leq 1.2$ s 3 dB. If decay not applicable: $T_r \leq 1.0$ s 4 dB. If decay not applicable: $T_r \leq 0.8$ s
Spatial decay ISO 3382-3:2022 [11]				7 dB
Spatial decay ISO 22955:2021 [12]				>6 dB
Distraction distance [m] ISO 3382-3:2022 [11]				5
Visual domain—electric lighting				
Illuminance in working areas (E) [lx] EN 16798-1:2019 [8]		500		500

Table A1. *Cont.*

Parameter/Index and Reference Standard		Single Office	Shared Office	Open-Plan Office
Illuminance on the task area (E) [lx] * EN 12464-1:2021 [15]	T1	300	300	300
	T2	500	500	500
	T3	750	750	750
	T4		300	300
	T5	200	200	200
	T6	500	500	
Unified glare rating (UGR) [-] * EN 12464-1:2021 [15]	T1	UGR ≤ 19	UGR ≤ 19	UGR ≤ 19
	T2	UGR ≤ 19	UGR ≤ 19	UGR ≤ 19
	T3	UGR ≤ 16	UGR ≤ 16	UGR ≤ 16
	T4		UGR ≤ 22	UGR ≤ 22
	T5	UGR ≤ 35	UGR ≤ 35	UGR ≤ 35
	T6	UGR ≤ 19	UGR ≤ 19	
Illuminance uniformity (U) [-] * EN 12464-1:2021 [15]	T1	U ≥ 0.4	U ≥ 0.4	U ≥ 0.4
	T2	U ≥ 0.6	U ≥ 0.6	U ≥ 0.6
	T3	U ≥ 0.7	U ≥ 0.7	U ≥ 0.7
	T4		U ≥ 0.6	U ≥ 0.6
	T5	U ≥ 0.4	U ≥ 0.4	U ≥ 0.4
	T6	U ≥ 0.6	U ≥ 0.6	
Color rendering index (CRI) [-] * EN 12464-1:2021 [15]	T1	CRI ≥ 80	CRI ≥ 80	CRI ≥ 80
	T2	CRI ≥ 80	CRI ≥ 80	CRI ≥ 80
	T3	CRI ≥ 80	CRI ≥ 80	CRI ≥ 80
	T4		CRI ≥ 80	CRI ≥ 80
	T5	CRI ≥ 80	CRI ≥ 80	CRI ≥ 80
	T6	CRI ≥ 80	CRI ≥ 80	
Visual domain—natural lighting				
Daylight factor (DF) [%] EN 17037:2018 [14]		DF > 2	DF > 2	DF > 2
Spatial daylight autonomy (sDA) [%] * IES_LM-83-12 [54]	Nominally accepted	sDA > 55	sDA > 55	sDA > 55
	Preferred	sDA > 75	sDA > 75	sDA > 75
Annual sunlight exposure (ASE) [%] * IES_LM-83-12 [54]	Nominally accepted	ASE < 7	ASE < 7	ASE < 7
	Clearly acceptable	ASE < 3	ASE < 3	ASE < 3
Daylight glare probability (DGP) [-] * EN 17037:2018 [14]	Daylight glare mostly not perceived *	DGP ≤ 0.35	DGP ≤ 0.35	DGP ≤ 0.35
	Daylight glare perceived not disturbing *	0.35 < DGP ≤ 0.4	0.35 < DGP ≤ 0.4	0.35 < DGP ≤ 0.4
	Daylight glare often disturbing	0.4 < DGP ≤ 0.45	0.4 < DGP ≤ 0.45	0.4 < DGP ≤ 0.45
	Daylight glare intolerable	DGP ≥ 0.45	DGP ≥ 0.45	DGP ≥ 0.45
Indoor air quality				
Carbon dioxide (CO_2) concentration above outdoors for nonadapted persons [ppm] * EN 16798-1:2019 [8]	Category I	550	550	550
	Category II	800	800	800
	Category III	1350	1350	1350
	Category IV	1350	1350	1350
Carbon monoxide (CO) [mg/m^3] * EN 16798-1:2019 [8]	15 min mean	≤100	≤100	≤100
	1 h mean	≤35	≤35	≤35
	8h mean	≤10	≤10	≤10
	24 h mean	≤7	≤7	≤7
Formaldehyde [$\mu g/m^3$] * EN 16798-1:2019 [8]	30 min mean	≤100	≤100	≤100

Table A1. *Cont.*

Parameter/Index and Reference Standard		Single Office	Shared Office	Open-Plan Office
Particulate matter (PM2.5) [μg/m^3] * EN 16798-1:2019 [8]	24 h mean	≤25	≤25	≤25
	Annual mean	≤10	≤10	≤10
Particulate matter (PM10) [μg/m^3] * EN 16798-1:2019 [8]	24 h mean	≤50	≤50	≤50
	Annual mean	≤20	≤20	≤20
Ozone (O_3) [μg/m^3] * EN 16798-1:2019 [8]	8 h mean	≤100	≤100	≤100
Radon (Rn) * EN 16798-1:2019 [8]		100 Bq/m^3 (sometimes 300 mg/m^3, country-specific)	100 Bq/m^3 (sometimes 300 mg/m^3, country-specific)	100 Bq/m^3 (sometimes 300 mg/m^3, country-specific)
Nitrogen dioxide (NO_2) [μg/m^3] * EN 16798-1:2019 [8]	1 h mean	≤200	≤200	≤200
	Annual mean	≤20	≤20	≤20

T1 Filing, copying, etc. T2 Writing, typing, reading, data processing, CAD workstations. T3 Technical drawing. T4 Conference and meeting rooms. T5 Reception desk. T6 Archives. * Parameters specified for the different office typologies by authors and not by standards indications.

References

1. Schweiker, M.; Ampatzi, E.; Andargie, M.S.; Andersen, R.K.; Azar, E.; Barthelmes, V.M.; Berger, C.; Bourikas, L.; Carlucci, S.; Chinazzo, G.; et al. Review of Multi-domain Approaches to Indoor Environmental Perception and Behaviour. *Build. Environ.* **2020**, *176*, 106804. [CrossRef]
2. European Comission. *European Comission Indoor Air Pollution: New EU Research Reveals Higher Risks than Previously Thought*; European Comission: Brussels, Belgium, 2003; IP/03/1278.
3. Tiele, A.; Esfahani, S.; Covington, J. Design and Development of a Low-Cost, Portable Monitoring Device for Indoor Environment Quality. *J. Sensors* **2018**, *2018*, 5353816. [CrossRef]
4. Choi, J.H.; Lee, K. Investigation of the Feasibility of POE Methodology for a Modern Commercial Office Building. *Build. Environ.* **2018**, *143*, 591–604. [CrossRef]
5. Parkinson, T.; Parkinson, A.; de Dear, R. Continuous IEQ Monitoring System: Context and Development. *Build. Environ.* **2019**, *149*, 15–25. [CrossRef]
6. Geng, Y.; Zhang, Z.; Yu, J.; Chen, H.; Zhou, H.; Lin, B.; Zhuang, W. An Intelligent IEQ Monitoring and Feedback System: Development and Applications. *Engineering* **2022**, *18*, 218–231. [CrossRef]
7. Jayathissa, P.; Quintana, M.; Abdelrahman, M.; Miller, C. Humans-as-a-Sensor for Buildings—Intensive Longitudinal Indoor Comfort Models. *Buildings* **2020**, *10*, 174. [CrossRef]
8. *EN 16798-1*; 2019 Energy Performance of Buildings—Ventilation for Buildings. Part 1: Indoor Environmental Input Parameters for Design and Assessment of Energy Performance of Buildings Addressing Indoor Air Quality, Thermal Environment, Lighting and Acoustics. European Committee for Standardization: Brussels, Belgium, 2019.
9. *ANSI/ASHRAE 55*; 2017 Thermal Environmental Conditions for Human Occupancy. American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE): Atlanta, GA, USA, 2017.
10. *ISO 7730*; 2005 Ergonomics of the Thermal Environment—Analytical Determination and Interpretation of Thermal Comfort Using Calculation of the PMV and PPD Indices and Local Thermal Comfort Criteria. ISO: Geneva, Switzerland, 2005.
11. *ISO 3382-3*; 2012 Acoustics—Measurement of Room Acoustic Parameters. ISO: Geneva, Switzerland, 2012.
12. *ISO 22955*; 2021 Acoustics—Acoustic Quality of Open Office Spaces. ISO: Geneva, Switzerland, 2021.
13. *NF S31-080*; Acoustics—Offices and Associated Areas—Acoustic Performance Levels and Criteria by Type of Area. AFNOR: Saint-Denis, France, 2006.
14. *EN 17037*; 2018 Daylight in Buildings. European Committee for Standardization: Brussels, Belgium, 2018.
15. *EN 12464-1*; 2021 Light and Lighting—Lighting of Work Places. Part 1: Indoor Work Places. European Committee for Standardization: Brussels, Belgium, 2021.
16. Wei, W.; Wargocki, P.; Zirngibl, J.; Bendžalová, J.; Mandin, C. Review of Parameters Used to Assess the Quality of the Indoor Environment in Green Building Certification Schemes for Offices and Hotels. *Energy Build.* **2020**, *209*, 109683. [CrossRef]
17. Rasheed, E.O.; Byrd, H. Can Self-Evaluation Measure the Effect of IEQ on Productivity? A Review of Literature. *Facilities* **2017**, *35*, 601–621. [CrossRef]
18. Ong, B.L. *Beyond Environmental Comfort*; Routledge: Oxford, UK; New York, NY, USA, 2013; ISBN 9780415453684/0415453682/9780415453691/0415453690.

19. Suyeon Bae, C.S.M.; Asojo, A.O. Indoor Environmental Quality Factors That Matter to Workplace Occupants: An 11-Year-Benchmark Study. *Build. Res. Inf.* **2021**, *49*, 445–459. [CrossRef]
20. Aboulfotouh, A.K.; Tolba, O.; Ezzeldin, S. The Impact of Workspace Location and Indoor Environmental Quality on Employees' Satisfaction within Office Buildings: A Case Study in Cairo. *Indoor Built Environ.* **2020**, *31*, 2094–2114. [CrossRef]
21. Chen, C.F.; Yilmaz, S.; Pisello, A.L.; De Simone, M.; Kim, A.; Hong, T.; Bandurski, K.; Bavaresco, M.V.; Liu, P.L.; Zhu, Y. The Impacts of Building Characteristics, Social Psychological and Cultural Factors on Indoor Environment Quality Productivity Belief. *Build. Environ.* **2020**, *185*, 107189. [CrossRef]
22. Choi, J.H.; Moon, J. Impacts of Human and Spatial Factors on User Satisfaction in Office Environments. *Build. Environ.* **2017**, *114*, 23–35. [CrossRef]
23. Sakellaris, I.; Saraga, D.; Mandin, C.; de Kluizenaar, Y.; Fossati, S.; Spinazzè, A.; Cattaneo, A.; Szigeti, T.; Mihucz, V.; de Fernandes, E.O.; et al. Personal Control of the Indoor Environment in Offices: Relations with Building Characteristics, Influence on Occupant Perception and Reported Symptoms Related to the Building—The Officair Project. *Appl. Sci.* **2019**, *9*, 3227. [CrossRef]
24. Lassen, N.; Josefsen, T.; Goia, F. Design and In-Field Testing of a Multi-Level System for Continuous Subjective Occupant Feedback on Indoor Climate. *Build. Environ.* **2021**, *189*, 107535. [CrossRef]
25. Azuma, K.; Ikeda, K.; Kagi, N.; Yanagi, U.; Osawa, H. Evaluating Prevalence and Risk Factors of Building-Related Symptoms among Office Workers: Seasonal Characteristics of Symptoms and Psychosocial and Physical Environmental Factors. *Environ. Health Prev. Med.* **2017**, *22*, 38. [CrossRef]
26. Dhungana, P.; Chalise, M. Prevalence of Sick Building Syndrome Symptoms and Its Associated Factors among Bank Employees in Pokhara Metropolitan, Nepal. *Indoor Air* **2019**, *30*, 244–250. [CrossRef]
27. Kang, S.; Ou, D.; Mak, C.M. The Impact of Indoor Environmental Quality on Work Productivity in University Open-Plan Research Offices. *Build. Environ.* **2017**, *124*, 78–89. [CrossRef]
28. Al Horr, Y.; Arif, M.; Kaushik, A.; Mazroei, A.; Katafygiotou, M.; Elsarrag, E. Occupant Productivity and Office Indoor Environment Quality: A Review of the Literature. *Build. Environ.* **2016**, *105*, 369–389. [CrossRef]
29. Astolfi, A.; Carullo, A.; Fissore, V.; Puglisi, G.E.; Arcamone, G.; Shtrepi, L.; Raviola, E.; Barbaro, A.; Espinosa, G.R.; Chiavassa, P.; et al. Development and Metrological Characterization of a Multi-Sensor Device for Indoor Environmental Quality (IEQ) Monitoring. In Proceedings of the 2023 IEEE International Workshop on Metrology for Living Environment (MetroLivEnv), Milano, Italy, 29–31 May 2023; pp. 179–184.
30. Page, M.J.; McKenzie, J.E.; Bossuyt, P.M.; Boutron, I.; Hoffmann, T.C.; Mulrow, C.D.; Shamseer, L.; Tetzlaff, J.M.; Akl, E.A.; Brennan, S.E.; et al. The PRISMA 2020 Statement: An Updated Guideline for Reporting Systematic Reviews. *PLoS Med.* **2021**, *18*, e1003583. [CrossRef]
31. Frontczak, M.; Schiavon, S.; Goins, J.; Arens, E.; Zhang, H.; Wargocki, P. Quantitative Relationships between Occupant Satisfaction and Satisfaction Aspects of Indoor Environmental Quality and Building Design. *Indoor Air* **2012**, *22*, 119–131. [CrossRef]
32. Sakellaris, I.A.; Saraga, D.E.; Mandin, C.; Roda, C.; Fossati, S.; De Kluizenaar, Y.; Carrer, P.; Dimitroulopoulou, S.; Mihucz, V.G.; Szigeti, T.; et al. Perceived Indoor Environment and Occupants' Comfort in European "Modern" Office Buildings: The OFFICAIR Study. *Int. J. Environ. Res. Public Health* **2016**, *13*, 444. [CrossRef] [PubMed]
33. Lou, H.; Ou, D. A Comparative Field Study of Indoor Environmental Quality in Two Types of Open-Plan Offices: Open-Plan Administrative Offices and Open-Plan Research Offices. *Build. Environ.* **2019**, *148*, 394–404. [CrossRef]
34. D'Oca, S.; Pisello, A.L.; De Simone, M.; Barthelmes, V.M.; Hong, T.; Corgnati, S.P. Human-Building Interaction at Work: Findings from an Interdisciplinary Cross-Country Survey in Italy. *Build. Environ.* **2018**, *132*, 147–159. [CrossRef]
35. Day, J.K.; Ruiz, S.; O'Brien, W.; Schweiker, M. Seeing Is Believing: An Innovative Approach to Post-Occupancy Evaluation. *Energy Effic.* **2020**, *13*, 473–486. [CrossRef]
36. Candido, C.; Marzban, S.; Haddad, S.; Mackey, M.; Loder, A. Designing Healthy Workspaces: Results from Australian Certified Open-Plan Offices. *Facilities* **2021**, *39*, 411–433. [CrossRef]
37. Candido, C.; Chakraborty, P.; Tjondronegoro, D. The Rise of Office Design in High-Performance, Open-Plan Environments. *Buildings* **2019**, *9*, 100. [CrossRef]
38. Tamas, R.; Ouf, M.M.; O'Brien, W. A Field Study on the Effect of Building Automation on Perceived Comfort and Control in Institutional Buildings. *Archit. Sci. Rev.* **2020**, *63*, 74–86. [CrossRef]
39. Candido, C.; Kim, J.; De Dear, R.; Thomas, L. BOSSA: A Multidimensional Post-Occupancy Evaluation Tool. *Build. Res. Inf.* **2016**, *44*, 214–228. [CrossRef]
40. Romero Herrera, N.; Doolaard, J.; Guerra-Santin, O.; Jaskiewicz, T.; Keyson, D. Office Occupants as Active Actors in Assessing and Informing Comfort: A Context-Embedded Comfort Assessment in Indoor Environmental Quality Investigations. *Adv. Build. Energy Res.* **2020**, *14*, 41–65. [CrossRef]
41. Devitofrancesco, A.; Belussi, L.; Meroni, I.; Scamoni, F. Development of an Indoor Environmental Quality Assessment Tool for the Rating of Offices in Real Working Conditions. *Sustainability* **2019**, *11*, 1645. [CrossRef]
42. Park, J.; Loftness, V.; Aziz, A. Post-Occupancy Evaluation and IEQ Measurements from 64 Office Buildings: Critical Factors and Thresholds for User Satisfaction on Thermal Quality. *Buildings* **2018**, *8*, 156. [CrossRef]
43. Geng, Y.; Ji, W.; Lin, B.; Zhu, Y. The Impact of Thermal Environment on Occupant IEQ Perception and Productivity. *Build. Environ.* **2017**, *121*, 158–167. [CrossRef]

44. Lee, J.Y.; Wargocki, P.; Chan, Y.H.; Chen, L.; Tham, K.W. How Does Indoor Environmental Quality in Green Refurbished Office Buildings Compare with the One in New Certified Buildings? *Build. Environ.* **2020**, *171*, 106677. [CrossRef]
45. Li, N.; Cui, H.; Zhu, C.; Zhang, X.; Su, L. Grey Preference Analysis of Indoor Environmental Factors Using Sub-Indexes Based on Weber/Fechner's Law and Predicted Mean Vote. *Indoor Built Environ.* **2016**, *25*, 1197–1208. [CrossRef]
46. Sood, T.; Janssen, P.; Miller, C. Spacematch: Using Environmental Preferences to Match Occupants to Suitable Activity-Based Workspaces. *Front. Built Environ.* **2020**, *6*, 113. [CrossRef]
47. Weerasinghe, A.S.; Onyeizu, E.; Rotimi, J.O.B. Environmental and Socio-Psychological Drivers of Building Users' Behaviours: A Case Study of Tertiary Institutional Offices in Auckland. *J. Facil. Manag.* **2022**. [CrossRef]
48. Kim, Y.K.; Abdou, Y.; Abdou, A.; Altan, H. Indoor Environmental Quality Assessment and Occupant Satisfaction: A Post-Occupancy Evaluation of a UAE University Office Building. *Buildings* **2022**, *12*, 986. [CrossRef]
49. Mujan, I.; Licina, D.; Kljajić, M.; Čulić, A.; Anđelković, A.S. Development of Indoor Environmental Quality Index Using a Low-Cost Monitoring Platform. *J. Clean. Prod.* **2021**, *312*, 127846. [CrossRef]
50. Wargocki, P.; Wei, W.; Bendžalová, J.; Espigares-Correa, C.; Gerard, C.; Greslou, O.; Rivallain, M.; Sesana, M.M.; Olesen, B.W.; Zirngibl, J.; et al. TAIL, a New Scheme for Rating Indoor Environmental Quality in Offices and Hotels Undergoing Deep Energy Renovation (EU ALDREN Project). *Energy Build.* **2021**, *244*, 111029. [CrossRef]
51. Esfandiari, M.; Zaid, S.M.; Ismail, M.A.; Hafezi, M.R.; Asadi, I.; Mohammadi, S.; Vaisi, S.; Aflaki, A. Occupants' Satisfaction toward Indoor Environment Quality of Platinum Green-Certified Office Buildings in Tropical Climate. *Energies* **2021**, *14*, 2264. [CrossRef]
52. Borsos, Á.; Zoltán, E.S.; Pozsgai, É.; Cakó, B.; Medvegy, G.; Girán, J. The Comfort Map—A Possible Tool for Increasing Personal Comfort in Office Workplaces. *Buildings* **2021**, *11*, 233. [CrossRef]
53. Göçer, Ö.; Candido, C.; Thomas, L.; Göçer, K. Differences in Occupants' Satisfaction and Perceived Productivity in High- and Low-Performance Offices. *Buildings* **2019**, *9*, 199. [CrossRef]
54. IES Daylight Metrics Committee. *IES Spatial Daylight Autonomy (sDA) and Annual Sunlight Exposure (ASE)*; Daylight Metrics Committee. Approved Method IES LM-83-12; Illuminating Engineering Society of North America: New York, NY, USA, 2012.