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The relationship between interior office space and employee health and well-being – a literature review

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ABSTRACT

Health is a trending topic in the office market, yet scientific research on healthy offices is scattered. This study undertakes a systematic literature review on the relationship between the interior space of offices and physical, psychological and social well-being. The review identifies the characteristics of interior office space that have been studied in relation to employee health, and outlines the empirical evidence. Of 2816 papers in the database, 50 addressed the relationship between interior office space and health and did so based on six features: layout, furniture, light, greenery, controls and noise. Evidence on the relationship between interior space and health has accumulated only within a few topics. On the one hand, open-plan offices, shared rooms and higher background noise are negatively related to health. On the other hand, positive relationships are found between physical well-being and aspects that encourage physical activity; between physical/psychological well-being and (day)light, individual control and real/artificial greenery; and between social well-being and small shared rooms. In measuring health, physical well-being is predominant. Similarly, studies have predominantly aimed to prevent health problems rather than enhance health. Overall, the related research is in a nascent stage. Further research is required to verify claims about healthy offices.

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Health; well-being; workplace design; interior design; interior space; office

Introduction

What is a healthy office? One might think of fresh air, daylight and ergonomic furniture, since computer work increases musculoskeletal issues, such as neck, shoulder and lower back pain (IJmker et al., 2007; Janwantanakul, Pensri, Jiamjarasrangsri, & Sinsongsook, 2008). Research on sick building syndrome has shown that poor indoor air quality due to toxins, contamination or inadequate ventilation could lead to a variety of physical health complaints. However, there are other side effects related to mental health, stress and burnout, which have become a main occupational disease for office workers (Van der Molen et al., 2018). According to the World Health Organization (WHO, 2006, p. 1), health is 'a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity'. Thus, a healthy office could be defined as a workplace that at least does not harm employees' well-being, and ideally, actively supports it.

This study analyses the relationship between interior office space and employee health by undertaking a systematic literature review. The interior space comprises individual workstations or desks and their surroundings, or the whole inner space of the office building, as opposed to the architectural outer shell and technical installations. The design of interior space includes the use of spatial elements, lighting, surface finishes, furnishings and accessories to realize the required functional and desired visual quality (Ching & Binggeli, 2004). For example, wall openings enable the passage of people, light, heat and sound; window treatments temper sunlight; and height and surface qualities of the ceiling affect acoustics and light. Elements of interior space are more frequently and easily changed than technical installations and building construction, thereby providing quicker wins to adjust the physical working environment.

Even though well-being is a trending topic in the real estate industry (Groen, Jylhä, & Van Sprang, 2018; Hanc, McAndrew, & Ucci, 2019; World Green Building Council, 2014), in discussions concerning interior space it often goes unnoticed (Smith, Metcalfe, & Lommerse, 2012). Meanwhile, the evolution of cellular offices into

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more open workspaces has triggered an ongoing debate on the presumed negative health effects of open-plan offices, and organizations have become more concerned about the contribution of interior space to their business goals. This challenges designers of interior space to consider both aesthetic and strategic perspectives (Haddad, 2014).

Certainly, for well-being, space matters. Following the job demands – resources theory (Bakker & Demerouti, 2017; Demerouti, Bakker, Nachreiner, & Schaufeli, 2001), the characteristics of the interior space can be a demand, for instance by causing environmental stress, as well as a resource, for instance by facilitating relaxation and social cohesion. In general, environmental stressors increase physiological arousal (Berlyne, 1960), cause stimulation overload (Cohen, 1980) and evoke coping strategies, such as social withdrawal (Folkman, Lazarus, Gruen, & DeLongis, 1986). Meanwhile, opportunities to adjust the environment mediate the experience of environmental stress (Barnes, 1981), and according to the attention restoration theory (Kaplan, 1995), green spaces aid recovery from environmental stress. In summary, a well-designed interior space can compensate for job demands and poor design can undermine job resources. Since a predominance of demands relative to resources predicts burnout (Bakker, Demerouti, & Sanz-Vergel, 2014; Hakanen, Schaufeli, & Ahola, 2008), this underlines the importance of a health-supporting office space.

Previous reviews addressing interior space in offices focus on specific outcomes (Ilies, Aw, & Pluut, 2015) or specific features (De Croon, Sluiter, Kuijer, & Frings-Dresen, 2005; Engelen et al., 2019; Richardson et al., 2017); alternatively, they lack transparency in their methods (Groen et al., 2018; Rashid & Zimring, 2008; World Green Building Council, 2014). This review covers the entire interior office space and uses a wide perspective on employee health defined earlier in this section. The main research questions of this review are as follows. (1) What features of interior space in offices are studied in relation to employee health? (2) How are these features of interior space related to employee health?

Method

This review followed the guidelines of systematic literature reviews as presented by PRISMA (Moher et al., 2015) to make the reporting transparent.

Search strategy

To find the relevant papers, the multi-disciplinary citation databases of Scopus and Web of Science Core Collection were used as search engines. Several test searches were conducted by two reviewers (A and B) in October–November 2017 to find a comprehensive search strategy for the review. Because terms referring to interior office space, such as 'office' and 'workplace' are used in multiple contexts in the literature (e.g. an office can be a doctor's consulting room or the workspace of a knowledge worker), it became apparent that the initial database needed to include a broad sample of papers for subsequent manual review. To establish the initial database of papers, the same search terms were used in both citation databases in December 2017 and later updated in April 2019. In both citation databases, each of the six search terms referring to

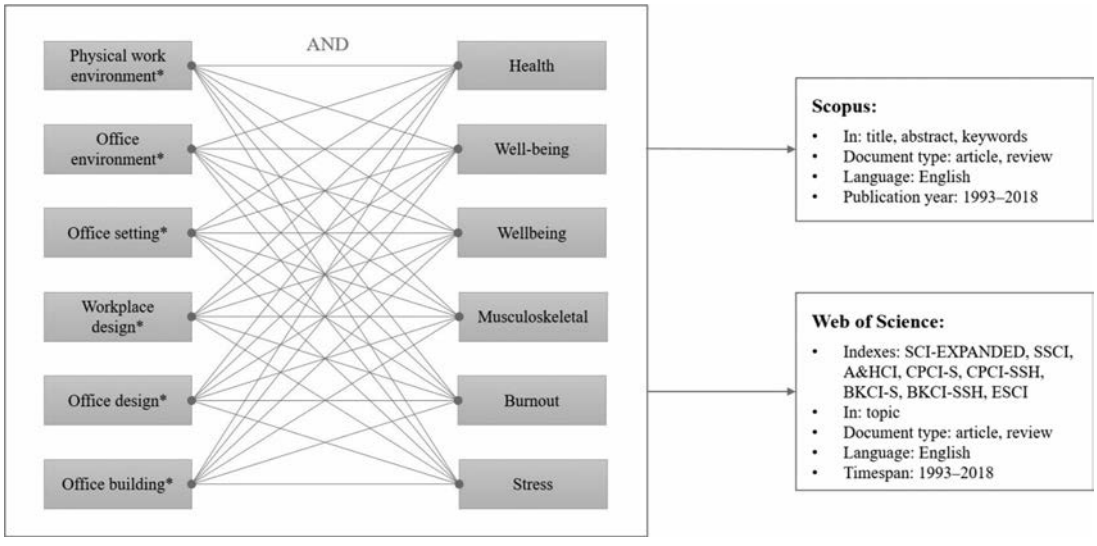

Figure 1. Search strategy.

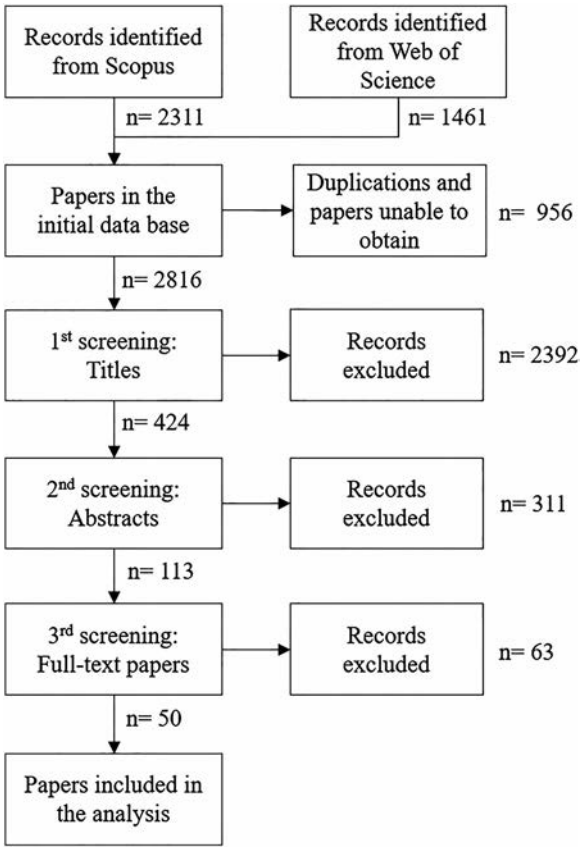

Figure 2. Overview of the screening process.

interior space was searched for in combination with each of the six search terms referring to health (see Figure 1), resulting in 2816 papers forming the initial database.

Study selection

The initial database was screened and reviewed in three phases (Figure 2).

In the first phase, reviewer A scanned the titles to exclude the irrelevant papers. The second phase was undertaken based on the abstracts by the same reviewer to further identify relevant and non-relevant papers. In the third phase, the papers were categorized based on the identified office features. The initial categories were later further developed to summarize the research results. The full papers were divided among five reviewers (reviewers A–E) based on the above-mentioned categories for independent review. This review phase was led and instructed by reviewers A and B. The engagement of multiple reviewers allowed to jointly decide whether a paper should be included or excluded when needed. In each phase, all reviewers used the same eligibility criteria (presented in Table 1). Through this selection process, 50 papers were included.

Information extraction

A standardized template was developed and tested by reviewers A and B to extract the information from the papers. The template included six parts: (1) paper identification information; (2) used research strategy and methods; (3) data collection information; (4) information of the studied office environment; (5) independent and dependent variables regarding office and health and (6) related results. In some papers, other dependent variables were also studied, but for this review only results related to health and well-being were reported. All reviewers (A–E) used the same templates and the review process was instructed and managed by reviewers A and B. After the third phase, a quality appraisal was performed using the standardized forms developed by the Centre for Evidence Based Management based on six types of research. The main conclusions of these appraisals were used, when needed, in the analysis phase.

Analysis strategy

The analysis was performed in two stages corresponding with the two research questions. First, content analysis was used to collect, group and regroup the studied features of interior office space, following the instructions of Krippendorff (2004), Miles and Huberman (1994) and Tuomi and Sarajärvi (2012). The same process was followed for the studied health aspects. Second, the paper's findings of the relationship between interior office space and aspects of health

Table 1. Inclusion and exclusion criteria used in the selection of papers.

Inclusion criteria	Exclusion criteria
Setting: administrative office buildings or office floors	Setting: other environments, such as doctor's offices or factories
Empirical studies and systematic reviews	Theoretical papers, reviews of technology, position papers, etc.
Clear description of methods and measures	Data-collection process or analysis not transparent
Dependent variable(s), including measures of actual or perceived physical, psychological or social well-being	Dependent variable(s) not directly measuring health, such as job satisfaction, motivation and productivity
Independent variable(s), including measures of actual or perceived interior space, comprising spatial characteristics and arrangements, lighting, surfaces, furniture and accessories	Independent variables not relating to interior space, but rather, for example, to building construction, technical installations, facility services, behavioural interventions or technologies
Subjects being office workers in general, knowledge workers or clerical workers	Subjects being blue collar workers, special needs groups, the elderly, etc.

and well-being were summarized, feature-wise and paper by paper. Based on this, conclusions were drawn about the focus of the existing research on interior office space, and the resulting evidence for its relationship with employee health.

Results

Characteristics of studies

The papers show that the relationship between interior office space and employee health is an upcoming research area; 40 of the 50 included papers were published within the past decade and 27 of them within the past 5 years. The vast majority of the studies were performed within one country, most of them in Europe. There are no clear differences in scope between the areas. The papers are scattered across the literature of different disciplines.

In most papers, it is unclear for which office type the data are collected: open-plan, cellular or combination; and allocated workstations or flexible use. Most (39) of the papers concern field studies, 8 are lab studies, 1 comprises both and 2 are reviews. The two most frequently applied research designs are cross-sectional (15 papers), comparing groups at a single point in time and controlled field studies (13 papers). The remaining studies are categorized as either prospective (pre- and post-test), longitudinal (one pre-test and at least two post-tests) or systematic literature review. The methods used vary widely, and not every paper reports effect sizes.

Identified features of interior office space

The most frequently studied features of interior space are layout and specific furniture, covering half of the included papers (Figure 3). The others concern light, greenery, control and noise. Although the search strategy includes physical well-being as well as psychological and social well-being, the features are predominantly related to physical aspects of health (Figure 3).

Next, the identified features of interior space are presented in detail, followed by a summary analysis.

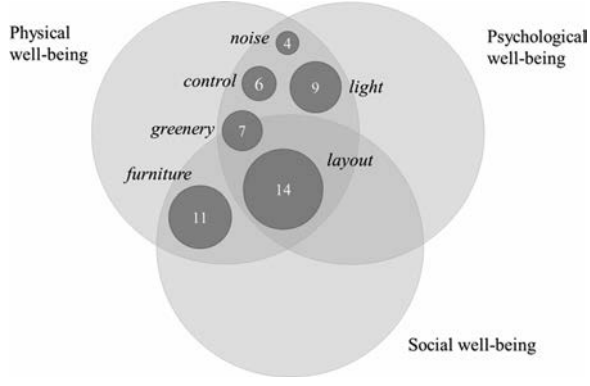

Figure 3. Number of papers on the identified features of interior office space and their health focus.

Layout

Office layout refers to the physical office space and arrangement of objects within (Lee, 2010). The included papers studied office layout at the following two levels (Table 2): (1) individual workspaces and their physical openness and size; and (2) arrangement of spaces within the office building. In these studies, the individual workspace is referred to as an office, room, cubicle or bench.

At the level of the individual workspace, the influence of layout is studied by comparing health measures of workers in two or more types of workspaces. As a main finding, these studies show differences between open-plan workspaces and smaller rooms, predominantly to the disadvantage of open-plan workspaces (Morrison & Macky, 2017; Pejtersen, Allermann, Kristensen, & Poulsen, 2006; Pejtersen, Feveile, Christensen, & Burr, 2011); only cubicles are worse (Lindberg et al., 2018). Open-plan offices, variously defined, are associated with higher sick leave (Bodin Danielsson, Chungkham, Wulff, & Westerlund, 2014), lower levels of both physical and psychological well-being (e.g. Bodin Danielsson, Bodin, Wulff, & Theorell, 2015; Haapakangas, Hongisto, Varjo, & Lahtinen, 2018), and deterioration of co-worker relations (Brennan, Chugh, & Kline, 2002). Duncan et al. (2015), Engelen et al. (2017) and Engelen, Dhillon, Chau, Hespe, and Bauman (2016) find positive results for open-plan offices, but these are limited to physical well-being and related to less sitting time. The activity-based working (ABW) environment is experienced more positively than open-plan or enclosed workspaces (Engelen et al., 2016; Foley, Engelen, Gale, Bauman, & Mackey, 2016; Meijer, Frings-Dresen, & Sluiter, 2009). Although these studies are limited by small samples and the absence of a control group, the findings are remarkable, because ABW also includes open-plan workspaces. Three longitudinal studies show that some effects occur only in the long term (Meijer et al., 2009), people do not get used to negative effects (Brennan et al., 2002), and positive effects disappear when moving back to the old situation (Foley et al., 2016).

Regarding 'size' of the workspace, which refers to the number of intended occupants or desks, four studies

Table 2. Papers addressing office layout and health.

Paper	Studied interior space variable	Type of study (*n*) (response)	Major findings related to health and well-being
Jaakkola and Heinonen (1995)	Shared vs. single room	Cross-sectional ($n = 968$) (resp. = 71%)	Workers sharing rooms had more colds in the past 12 months than those in single rooms had (OR 1.35, 95%CI 1.00–1.82).
Morrison and Macky (2017)	Own office, shared 2–3-person, open-plan, other	Cross-sectional ($n = 1000$) (recruited)	Employees in open-plan offices reported more negative interpersonal relationships ($p = .023$), distrust ($p = .010$), and uncooperative behaviour ($p = .003$). Sharing an office with one or two others was best for co-worker friendships ($p = .013$).
Pejtersen et al. (2011)	Single room, shared 2-person, shared 3–6-person, open-plan >6-person.	Cross-sectional ($n = 2403$) (resp. = 62%)	Occupants in 2-person rooms reported 50%, those in 3–6-person rooms 36%, and those in open-plan offices 62% more days of sickness absence per year than occupants of single rooms did ($p < .001$).
Pejtersen et al. (2006)	Single room, shared 2-person, shared 3–6-person, open-plan 7–28-person, or >28-person.	Cross-sectional ($n = 2301$) (resp. = 72%)	In open-plan offices, occupants complained more about noise than those in single rooms did (60% vs. 6%), about cramped space (32% vs. 5%), about unpleasant odour (17% vs. 7%), eye/nose/throat irritations (14–27% vs. 7–10%), headaches (25% vs. 10%) and fatigue (21% vs. 8%) (all $p < .001$).
Bodin Danielsson et al. (2015)	7 types: single, shared room (2–3-person), open-plan S/M/L, flex- or combi-office	Cross-sectional ($n = 5229$) (resp. = 57%)	Reported noise disturbance was much higher ($p < .001$) in open-plan offices (44–60%) than in single offices (16–20%) and shared rooms (33%). High effect sizes. Noise disturbances increased the occurrence of workplace conflicts but were only one explanatory factor.
Bodin Danielsson et al. (2014)	7 types: single, shared room (2–3-person), open-plan S/M/L, flex-, or combi-office	Prospective ($n = 1852$) (resp. = 57%)	Employees in traditional open-plan offices had higher risk of short sick leave (OR 1.82, $p < .01$ to OR 1.92, $p < .05$) than did those in single offices. Long sick leave was more common for men in flex-offices (OR2.56, $p < .05$), and for women in large open-plan offices (OR2.14, $p < .05$).
Brennan et al. (2002)	Traditional vs. open-plan offices	Longitudinal ($n = 21$)	After relocating to open-plan office, employees experienced more environmental stressors ($F(2,40) = 25.06$, $p < .01$, $\eta^2 = .56$) and were less satisfied with team member relations ($F(2,40) = 11.74$, $p < .01$, $\eta^2 = .37$). This did not change between 4 weeks and 6 months after the move.
Lindberg et al. (2018)	Workspace type	Longitudinal ($n = 231$)	Mood sampling and heart rate recording during 3 days showed workers using open benches perceived 10% less stress (B-0.27, 95%CI −0.54 – −0.02) than did those in cubicles, but physiological stress did not differ. There were no differences between private rooms and open benches.
Haapakangas et al. (2018)	Open-plan vs. private rooms, number of quiet rooms	Prospective ($n = 129/206$)	After relocation to open-plan offices, distraction (visual, noise, crowding and lack of speech privacy) increased (r 0.47/0.58, $p < .001$); stress increased only in the office building with few quiet rooms (r 0.28, $p = .0006$).
Meijer et al. (2009)	Rooms for two vs. task-oriented office	Longitudinal ($n = 138$)	The task-oriented office (ABW), including new chairs, had no or limited effects on work-related fatigue and health. In the long term, it had positive effects on perceived general health (62.0–65.9, $p = .006$) and musculoskeletal complaints (33–22%, $p = .021$).
Foley et al. (2016)	Activity-based working (ABW) vs. open-plan	Longitudinal ($n = 88/24$)	The ABW environment reduced low back pain (OR2.0, 95%CI 1.1–3.7, $p < .01$) and self-reported sedentary behaviour.
Duncan et al. (2015)	Spatial characteristics	Cross-sectional ($n = 5531$) (resp. = 12%)	In the open-plan office, greater local connectivity and co-worker visibility were associated with more sedentary breaks and lower body mass index ($p < .001$).
Engelen et al. (2017)	Floor space, desk types, distances, stair characteristics	Prospective ($n = 188$)	In the new, 'active design' building (more light, less noise, larger distances to bathroom and kitchen, sit–stand desks available and open central staircase with daylight and views), workers sat less, stood more and reported less lower back pain (2.3–2.1, $p = .036$) than in the 14 former buildings.
Engelen et al. (2016)	Floor space, sit–stand desks, distances, stair characteristics	Prospective ($n = 34$)	In the new buildings (same characteristics as above-mentioned), workers sat less, stood more and reported less lower back pain (2.5–1.7, $t = -2.53$, $p < .01$) than in the former four buildings.

Table 3. Papers addressing office furniture and health.

Paper	Studied interior space variable	Type of study (*n*) (response)	Major findings related to health and well-being
Karakolis and Callaghan (2014)	Sit–stand desk	Systematic review ($n = 14$)	Reduced trend in discomfort (e.g. lower back) for sit–stand work compared with sit-only work. Alternating between sitting and standing may lead to higher wrist discomfort.
Robertson et al. (2013)	Sit–stand desk combined with training	Controlled lab study ($n = 22$)	The trained group facing mandatory standing periods had less visual ($p < .05$) and musculoskeletal ($p < .01$) symptoms than did the minimally trained group without mandatory standing.
Carr et al. (2016)	Long-term access to sit–stand desks	Cross-sectional ($n = 69$) (recruited)	Employees with sit–stand desks sat less and stood more than did those without, but their cardio-metabolic risk factors did not differ.
Graves et al. (2015)	Availability of sit–stand desk	Controlled field study ($n = 47$)	Use of sit–stand desk decreased sitting time and beneficially changed cholesterol ($p = .049$). There were no changes in musculoskeletal pain.
Healy et al. (2013)	Sit–stand desk accompanied by coaching	Controlled field study ($n = 43$)	Sitting time decreased and standing time increased, but there were no significant musculoskeletal or cardio-metabolic health outcomes except for improved blood glucose level in the intervention group.
Torbeyns et al. (2016)	Bike desks	Controlled field study ($n = 38$)	Fat percentage decreased (36.6–34.4%, $p < .05$) among workers who had to use a bike desk. There were no significant changes in other health parameters (e.g. aerobic fitness, perceived musculoskeletal problems, fatigue and relationship with colleagues).
Roossien et al. (2017)	Smart chair with/ without feedback signal	Longitudinal ($n = 45$)	The feedback signal about sitting posture led to small or non-significant changes in sitting behaviour and musculoskeletal discomfort.
Van Niekerk et al. (2012)	Adjustable chair	Systematic review ($n = 5$)	Adjustable chairs with appropriate training hold the most promise in reducing musculoskeletal pain among workers who must sit for prolonged periods.
Robertson et al. (2009)	Adjustable chair and ergonomics training	Controlled field study ($n = 216$)	Ergonomics training with and without an adjustable chair led to lower musculoskeletal risk ($p < .05$).
Amick et al. (2012)	Adjustable chair and ergonomics training	Controlled field study ($n = 184$)	Workers who received a highly adjustable chair and office ergonomics training had reduced vision-related symptoms ($p < .01$) for at least 12 months. The training-only group did not differ from the control group.
Grooten et al. (2017)	Dynamic/conventional chair/standing desk	Controlled field ($n = 15$) and lab study ($n = 13$)	There were no differences in comfort between experimental conditions in the field and in the lab.

show that the larger the size, the more health complaints workers report. This is related to either bacterial contamination (Jaakkola & Heinonen, 1995) or stress caused by the presence of other people, such as noise (Bodin Danielsson et al., 2015; Pejtersen et al., 2006) and feeling cramped (Pejtersen et al., 2006).

At the level of the whole office building, the influence of layout is studied by collecting data from employees before and after they moved to a new office building designed to stimulate physical activity (Engelen et al., 2017, 2016). Stimulating features regarding layout included larger distances from workspace to communal facilities and a central position for the staircase. Combined with the other features of the new office, including furniture, light and noise, the new layout is associated with less back pain. The decreased back pain could have resulted from the decreased sitting and increased standing time of the employees, which is found in both studies, although the authors do not statistically test this relationship. Since the employee's walking time does not change, it seems plausible that the decreased back pain was influenced by the new furniture rather than the new layout.

In summary, working in open workspaces with six or more occupants tends to have a negative relationship with well-being if there are no enclosed workspaces to divert to, as provided by ABW environments. The actual impact on physical health remains unclear, because these studies all rely on self-reporting.

Furniture

The reviewed papers analyse the health-supporting capacity of the following two types of furniture (Table 3): (1) ergonomic furniture designed to fit the user's body or to stimulate alternating working postures, and thereby reduce musculoskeletal or visual discomfort while sitting (e.g. Robertson, Ciriello, & Garabet, 2013; Roossien et al., 2017; Van Niekerk, Louw, & Hillier, 2012) and (2) activating furniture to stimulate physical activity or reduce sitting time (e.g. Carr, Swift, Ferrer, & Benzo, 2016; Graves, Murphy, Shepherd, Cabot, & Hopkins, 2015).

Ergonomic, adjustable chairs reduce discomfort (Amick et al., 2012; Robertson et al., 2013; Van Niekerk et al., 2012), although this is not solely attributed to the use of the furniture, because it is often accompanied by ergonomics training. The provision of tactile feedback from smart chairs (Roossien et al., 2017) does not prove to be effective in decreasing discomfort or improving physical health.

Activating furniture is found to have few or mixed health effects despite reducing static sitting time. The furniture studied includes sit–stand workstations, being desks adjustable to the appropriate height to work seated or standing up, and a bike desk, which is a workstation with an exercise bike instead of an office chair. The experiments with this furniture show that their use leads to beneficial changes in blood pressure (Graves

Table 4. Papers addressing light in the office and health.

Paper	Studied interior space variable	Type of study (*n*) (response)	Major findings related to health and well-being
Van Duijnhoven et al. (2018)	Light levels on work surface	Longitudinal ($n = 46$)	Overall, subjective alertness did not correlate with light levels – only six participants showed significant reactions. Multiple confounders were identified.
Thayer et al. (2010)	Light levels on work surface (among other elements)	Controlled field study ($n = 60$)	The 40 participants working in the traditional office (less light: 235 vs. 375 lux, less access to window views, poorer air quality and more low frequency noise) had higher physiological stress responses (heart rate variability $p < .01$; cortisol $p < .001$) than the 20 participants in the modern office.
Lamb and Kwok (2016)	Perceived light level (combined with noise and thermal comfort)	Cross-sectional ($n = 114$) (resp. n.a.)	The most positive mood was reported in association with a comfortable light level ($p < .05$). The more environmental stressors workers perceived (light, noise and temperature), the greater the reported use of painkillers ($p < .05$). Stressors negatively affected mood and increased headaches and feeling 'off'.
Fostervold and Nersveen (2008)	Direct vs. indirect lighting	Controlled field study ($n = 64$)	Varying proportions of direct and indirect lighting did not affect perceived musculoskeletal or eye problems, mood, anxiety or depression.
Veitch et al. (2008)	Lighting quality	Controlled lab studies ($n = 151/80$)	Participants who perceived their office lighting as of higher quality rated the space as more attractive. As a result, they were in a more pleasurable mood and reported less overall discomfort.
Boubekri et al. (2014)	Workstations with or without windows	Cross-sectional ($n = 49$) (recruited)	Workers in workplaces where daylight was >2% of the outdoor illuminance slept 46 min more per night ($p < .05$) and reported better overall sleep quality ($p = .05$) and more vitality (+16%, $p = .004$). There were no differences in self-reported physical or social function, bodily pain or general health.
Bjørnstad et al. (2016)	Amount of sunlight	Cross-sectional ($n = 565$) (resp. = 40%)	More indoor nature contact, including sunlight, in the primary workspace was associated with fewer subjective health complaints and sickness absence, and more organizational support (all $p < .001$).
De Kort and Smolders (2010)	Dynamic vs. static lighting	Controlled field study ($n = 83$)	No significant differences between static and dynamic lighting in a monthly alternating scheme were found in perceived need for recovery, vitality, alertness, headache and eyestrain, mental health, or sleep quality.
Viola et al. (2008)	Blue-enriched white light vs. white light	Controlled field study ($n = 94$)	Blue-enriched white lighting (17,000 K) had better effects on daytime alertness ($P < .0001$) and sleepiness ($p = .0001$), positive mood ($p < .0001$), irritability ($p = .004$), eye discomfort ($p = .002$), and night-time sleep quality ($p = .016$) than white light (4000 K) did. No effects on headaches were found.

et al., 2015) and blood glucose level (Healy et al., 2013); other physical health parameters do not change. Results regarding musculoskeletal or visual comfort using this furniture are mixed: a positive relationship is found in two studies (Karakolis & Callaghan, 2014; Robertson et al., 2013), and a negative in one (Karakolis & Callaghan, 2014), while in three studies (Graves et al., 2015; Healy et al., 2013; Torbeyns et al., 2016) there is no relationship found.

The relationship between the furniture intervention and participants' health is measured by changes in anthropometrics (Torbeyns et al., 2016), physiological parameters (e.g. Carr et al., 2016; Healy et al., 2013) or self-reported health (e.g. Grooten et al., 2017; Roossien et al., 2017). Except for Torbeyns et al. (2016), these studies do not address psychological or social well-being.

Light in the workspace

Both natural and artificial light in the office, spread through wall openings, translucent materials and reflection on polished and light-coloured surfaces, result in a certain amount and quality of light in the individual workspace.

The results of the papers are summarized in Table 4. The papers show that adequate light levels and quality contribute to both physical well-being and better mood (Lamb & Kwok, 2016; Thayer et al., 2010; Veitch, Newsham, Boyce, & Jones, 2008; Viola, James, Schlangen, & Dijk, 2008), but not to alertness (Van Duijnhoven, Aarts, Rosemann, & De Kort, 2018), and that more daylight enhances sleep quality (Bjørnstad, Patil, & Raanaas, 2016; Boubekri, Cheung, Reid, Wang, & Zee, 2014). Dynamic lighting with variation of colour temperature during the day (De Kort & Smolders, 2010), and different proportions of direct and indirect light (Fostervold & Nersveen, 2008) do not impact health.

Greenery

In seven of the included papers, contact with nature is assumed to have beneficial effects on human beings, based on, for example, the air-cleaning ability of plants and studies of patient recovery. The studies related to this topic in offices are limited to views from the workspace on greenery – both real and artificial (Table 5).

Table 5. Papers addressing office greenery and health.

Paper	Studied interior space variable	Type of study (*n*) (response)	Major findings related to health and well-being
Bjørnstad et al. (2016)	Amount of indoor/outdoor nature contact	Cross-sectional (*n* = 565) (resp. = 40%)	More indoor nature contact in the primary workspace (plants or flowers, windows to the outdoors, sunlight, unobstructed views, and nature elements in view) was associated with fewer subjective health complaints and sickness absence and more organizational support (all $p < .001$). Small effect sizes.
Fjeld (2000)	Open office with vs. without plants	Controlled field study (*n* = 51)	Self-reported cough (−37%, $p < .05$), fatigue (−30%, $p < .01$), and dry throat and skin (−23%, $p < .05$) were lower for offices with plants. There was no difference in headaches, feeling heavy headed, nausea, irritated eyes or nose or mental health.
Evensen et al. (2015)	Plants vs. comparable inanimate objects	Controlled lab study (*n* = 85)	Environmental enrichment with either plants or objects at the computer workstation increased fascination ('restorative potential'), but self-reported restoration was not affected by plants, objects or window view.
Qin et al. (2014)	Plants: different sizes, colours and amount of scent	Controlled lab study (*n* = 16)	Physiological stress measures showed little difference. Participants preferred offices with plants, especially green, slightly scented and small plants.
Kahn et al. (2008)	Nature views through glass or plasma window vs. blank wall	Controlled lab study (*n* = 90)	Nature view through glass window: more rapid heart rate recovery (restoration) from low level physical stress ($p = .045$). Aplasma windows (artificial view) was not more restorative than a blank wall was.
Xue et al. (2016)	Nature views	Cross-sectional (*n* = 413) (resp. n.a.)	There were no differences in health concerns between workers with and without visual connections from the workstation to outdoor green spaces.
Kweon et al. (2008)	Posters, abstract art and/or nature posters	Controlled lab study (*n* = 210)	Increased proportions of nature paintings decreased the state of anger ($\beta = -.20$, $p < .05$) and stress ($\beta = -.31$, $p = .0009$).

The presence of both real and artificial greenery shows mixed results, but none of them are negative. Regarding real plants in the workspace, field studies find a positive influence on health (Bjørnstad et al., 2016; Fjeld, 2000) but lab studies do not (Evensen, Raanaas, Hagerhall, Johansson, & Patil, 2015; Qin, Sun, Zhou, Leng, & Lian, 2014).

For real outdoor nature views, two studies find positive (Bjørnstad et al., 2016; Kahn et al., 2008) and one study finds no health benefits (Xue, Gou, & Lau, 2016). In lab studies testing the health effect of artificial nature views, a positive effect is found for nature posters (Kweon, Ulrich, Walker, & Tassinary, 2008); nature views on a plasma display window have no health effect (Kahn et al., 2008). Overall, the reviewed papers provide only limited evidence that greenery in the workspace has a positive impact on health and no evidence that greenery has a negative impact on health.

Individual control

The research on interior space and health extends to tangible options for office workers to control their physical work environment. The following two types of control are addressed (Table 6): (1) the possibility of adjusting the conditions of the workspace (Bluyssen, Aries, & Van Dommelen, 2011; Boerstra et al., 2015; Joines et al., 2015; Knight & Haslam, 2010; Toftum, 2010) and (2) personalization of the workstation (Wells, 2000). Both control types are found to have a positive relationship with psychological well-being, and to a lesser extent, physical well-being.

The findings also show that actual control of one aspect of the environment leads to perceived control of other aspects (Boerstra et al., 2015; Toftum, 2010). The studies on individual control emphasize physical well-being although perceived control is an important psychological factor in reducing stress (Spector & Jex, 1998). Owing to the small number of studies, their mostly cross-sectional design and mixed results, this review cannot present strong evidence that the control types investigated enhance health.

Office noise

The characteristics of the interior office space, including spatial arrangements, room dimensions and finishing materials, influence noise by absorption or reflection of sound waves. In this review, only papers that present measurements using acoustic parameters are included, since (dis)satisfaction with noise does not tell how the noise is related to characteristics of interior space (Table 7).

The reviewed papers indicate that high levels of background noise and speech intelligibility in the workplace negatively affect both physical and psychological well-being. A higher sound level causes higher self-rated fatigue (Jahncke, Hygge, Halin, Green, & Dimberg, 2011), disturbance and annoyance (Schlittmeier & Liebl, 2015). Shafiee Motlagh, Golmohammadi, Aliabadi, Faradmal, and Ranjbar (2018) find that a higher sound level slightly increases physiological stress, but Jahncke et al. (2011), using other indicators for physiological stress (see Table 7), do not find this effect.

Sound absorption lowering the sound level from 47 to 45 dB decreases perceived disturbance and stress (Seddigh, Berntson, Jönsson, Danielson, & Westerlund, 2015). Schlittmeier and Liebl (2015) indicate that

Table 6. Papers addressing individual control and health.

Paper	Studied interior space variable	Type of study (n) (response)	Major findings related to health and well-being
Wells (2000)	Workspace personalization	Cross-sectional ($n = 338$) (resp. = 51%)	Indirect relationship: personalization is correlated with satisfaction with physical work environment (r 0.226, $p < .001$) and job satisfaction (r 0.434, $p < .001$), which is correlated with physical and psychological well-being (r 0,266, $p < .001$).
Knight and Haslam (2010)	Managerial control of office space	Cross-sectional ($n = 288$/ 1643) (resp. = 35%)	Both studies indicate that lack of involvement in layout changes ($p < .01$) and individual control of temperature ($p < .01$) are moderately associated with physical and psychological well-being ($p < .001$).
Joines et al. (2015)	Adjustable task lighting	Controlled field study ($n = 95$)	Using the adjustable task lights had significant benefits for musculoskeletal ($p = .011$–$.041$) and visual ($p = .005$–$.043$) comfort. No negative results on health were found.
Bluyssen et al. (2011)	Control of lighting, noise, sun shading, ventilation, temperature	Cross-sectional ($n = 5732$) (resp. n.a.)	The perceived amount of control was positively associated with overall comfort ($p < .001$). Control of sun shading had a stronger relationship with overall comfort ($p < .001$) than control of noise, ventilation or temperature.
Toftum (2010)	Opening windows	Cross-sectional ($n = 1272$) (resp. n.a.)	In buildings with opening windows, occupants experienced more opportunities for control. The degree of perceived control had a greater influence on heavy heads, headaches, and irritated eyes (all $p < .05$) than the ventilation mode per se.
Boerstra et al. (2015)	Personal desk fan controlled by self or other	Controlled lab study ($n = 23$)	In the self-control condition, which was preferred by the subjects, perceived control of temperature, air movement, ventilation, light and noise was higher. No differences in thermal comfort and intensity of nose/throat/ eye irritation, headache or fatigue were observed.

Table 7. Papers addressing noise and health.

Paper	Studied interior space variable	Type of study (n) (response)	Major findings related to health and well-being
Jahncke et al. (2011)	Sound level, high vs. low	Controlled lab study ($n = 47$)	More yawning ($F(2,32) = 6.25$, $p < .01$) in the high noise condition (51 dBA) vs. low noise condition (12–39 dBA) was observed. There were no reliable noise effects on stress hormone levels.
Schlittmeier and Liebl (2015)	Sound level, speech intelligibility	Controlled lab study ($n = 74$)	Perceived disturbance and annoyance were lower if background sound level and speech intelligibility were diminished. Background sound (35/55 dBA) was significantly more disturbing than silence was (25 dBA).
Shafiee Motlagh et al. (2018)	Sound level, speech intelligibility	Longitudinal ($n = 104$)	Physiological stress increased (skin conductance $r = 0.069$, $p < .001$; respiratory rate $r = 0.120$, $p < .05$) at higher noise levels, moderated by working experience. Speech transmission index had no impact.
Seddigh et al. (2015)	Sound absorption (baseline/better/ worse)	Controlled field study ($n = 117$)	Perceived disturbances and cognitive stress in the open-plan office were lower in the condition with enhanced sound absorption ($p < .05$).

lowering the sound level might not solve noise problems; instead, it is the combination of a high sound level and high speech intelligibility that causes disturbance.

The four papers addressing noise indicate that acoustic qualities of office space affect health (Jahncke et al., 2011; Schlittmeier & Liebl, 2015; Seddigh et al., 2015; Shafiee Motlagh et al., 2018). However, only one of the papers explicitly analyses the relationship between health, actual acoustics and the components of the office space design.

Summary analysis

Table 8 summarizes the features of interior office space studied in the reviewed papers, and the relationships of these features with employee's physical, psychological and social well-being.

The findings of the relationship between interior office space and health are threefold. First, as Table 8 shows, open-plan offices, shared rooms and higher background noise are the only features found to negatively affect health. Second, the other features analysed in the papers more often improve health than do nothing for health. Third, positive relationships with health are reported for all features of interior space. Features that encourage physical activity, including sit–stand and bike desks, and increased distances to communal facilities, are found to have a positive relationship with physical well-being. Similarly, the increase of (day)light and individual control and the presence of plants and outdoor views show positive results for both physical and psychological well-being. Small shared rooms support social well-being.

Table 8 shows that interior office space is analysed rather as individual workspace (openness, size, furniture, light levels and acoustics) than wider interior space (e.g. meeting areas, staircases or the arrangement of workspaces and workstations). Within the individual workspace, both spatial characteristics (e.g. openness, size and distances) and presence of objects (e.g. furniture,

Table 8. Summary of the relation between interior office space and health.

		Physical well-being											Psychological well-being					Social well-being	
		sickness absence	Physiological stress indicators	Cardio-metabolic risk factors / fat	Musculo-skeletal issues	Skin/ eye/ nose/ throat irritation	Tiredness/ fatigue/ alertness	Headache/ nausea/ dizziness	Visual comfort	Thermal comfort	Unpleasant odour	Overall comfort	Sleep quality/ duration	Self-rated health/ vitality	Perceived stress	Mood/ depression/ anxiety	General annoyance/ anger	Noise annoyance/ disturbances	Crowding/ privacy	Interpersonal relations	Perceived organizational support
	Workspace openness/size																				
Layout	Shared vs. single room[1,2,3]	–				–														+	
	Open-plan[2,4,5,6,7,8,9]	–		+		–	–	–	–		–				–			–	–	–	
	Activity-based (mix)[10,11]				+		0							±							
	Open bench vs. cubicle[12]		0												+						
	Open bench vs. private[12]		0												0						
	Distance to facilities																				
	Dist. to bathroom/ kitchen [13, 14]			+	(+)																
Furniture	*Activating desks*																				
	Sit–stand desk [15, 16, 17, 18, 19, 20]			+/0	+/–				+			0		0							
	Bike desk [21]			+	0		0													0	
	Ergonomic chairs																				
	Feedback chair [22]				0																
	Adjustable chair[20,23,24,25]				(+)				(+)			0									
	Natural light																				
Light	Amount of daylight[26,27]	(+)											+	+		(+)					
	Electrical lighting																				
	Light level/ quality[13,14,28,29,30,31]		(+)		(+)		0	(+)				+				+					
	Dynamic lighting[32]							0	0				0	0		0					
	Indirect lighting[33]				0				0							0					
	Blue-enriched light[34]							0	+				+			+					
Greenery	*Real nature*																				
	Plants[26,35,36,37]	(+)	+/0			+/0	+	0				+	(+)	+		(+)					(+)
	Outdoor nature views[26,40]		+											(+)		(+)				(+)	
	Artificial nature																				
	Artificial nature views[38,39]		0												+		+				
	Options for adjustment																				
Control	Climate controls[41,42,43,44]					+/0	+/0	+/0		+		+		+							
	Adjustable task lighting[46]				+				+					0							
	Identity marking																				
	Personalization[45]													+		+					
Noise	Background noise level[13,14,47,48,49]		0/–		(–)		–										–				
	Speech intelligibility[48,49]		0														+				
	Sound absorption[50]														+		+				

+ Better health, – worse health; 0 no relationship; () result in combination with other design features; [grey color] result of >1 study.

[1] Jaakkola and Heinonen (1995); [2] Morrison and Macky (2017); [3] Pejtersen et al. (2011); [4] Bodin Danielsson et al. (2014); [5] Bodin Danielsson et al. (2015); [6] Brennan et al. (2002); [7] Pejtersen et al. (2006); [8] Duncan et al. (2015); [9] Haapakangas et al. (2018) [10] Meijer et al. (2009); [11] Foley et al. (2016); [12] Lindberg et al. (2018); [13] Engelen et al. (2017); [14] Engelen et al. (2016); [15] Karakolis and Callaghan (2014); [16] Robertson et al. (2013); [17] Carr et al. (2016); [18] Graves et al. (2015); [19] Healy et al. (2013); [20] Grooten et al. (2017); [21] Torbeyns et al. (2016); [22] Roossien et al. (2017); [23] Van Niekerk et al. (2012); [24] Robertson et al. (2009); [25] Amick et al. (2012); [26] Bjørnstad et al. (2016); [27] Boubekri et al. (2014); [28] Van Duijnhoven et al. (2018); [29] Thayer et al. (2010); [30] Lamb and Kwok (2016); [31] Veitch et al. (2008); [32] De Kort and Smolders (2010); [33] Fostervold and Nersveen (2008); [34] Viola et al. (2008); [35] Fjeld (2000); [36] Evensen et al. (2015); [37] Qin et al. (2014); [38] Kahn et al. (2008); [39] Kweon et al. (2008); [40] Xue et al. (2016); [41] Toftum (2010); [42] Boerstra et al. (2015); [43] Bluyssen et al. (2011); [44] Knight and Haslam (2010); [45] Wells (2000); [46] Joines et al. (2015); [47] Jahncke et al. (2011); [48] Schlittmeier and Liebl (2015); [49] Shafiee Motlagh et al. (2018); [50] Seddigh et al. (2015).

plants, controls and acoustic tiles) are measured, forming the designer's palette, as well as the qualities resulting from the design (light, views, perceived control and noise). The features of interior space are often either studied in relative isolation (only 7 of the 50 papers cover more than one of the features in the left column) or all at once (results in brackets), without analysing their mutual relationship or ranking their influence on health.

Regarding health, Table 8 shows that the studies emphasize physical health symptoms, and pay less attention to psychological and especially social well-being. In addition, psychological well-being is measured in a more general way (mood, general annoyanceand stress) than physical well-being ('how is your back/wrist/head/nose/throat/sleep?'), while the measures for social well-being are not yet mature. The studies predominantly focus on ways to prevent and reduce health problems, such as ergonomic furniture to reduce discomfort, better lighting to reduce headaches, and sound absorption to reduce annoyance, and pay less notice to features that may enhance health, for example, real and artificial daylight to increase night sleep, nature contact as a means to recover from stress and personalization as a means to enhance well-being.

Discussion and conclusion

Strengths and limitations

This study brings together empirical research on the relationship between interior office space and employee health and well-being published in the past 26 years. The strengths of this review are its wide scope and systematic approach to the collection and screening of the literature. Its limitations include its restriction to peer-reviewed journal papers in two databases. Future research should expand the scope to cover other types of publications, such as doctoral dissertations and other scientific reports, as well as the use of more specific databases, such as PsycINFO and PubMed.

Implications

As a practical implication, the study provides support for workplace managers, interior designers, architects and corporate real estate managers, for instance, as input for verbalizing and testing assumptions about the expected effect of a design. As Haddad (2014, p. 284) states: 'Every design is a hypothesis but unlike scientific researches the design hypotheses are rarely expressed in projects'. Although the studies surveyed in the literature review overall lack the numbers, consistency and robustness to draw firm conclusions, they provide some directions for achieving health-supporting interior space. First, it seems that open-plan offices should be avoided, although it is not yet clear to what extent the number of occupants, spatial density and openness are related to health complaints. Furthermore, to support employee health, interior office space preferably should feature sit–stand desks, plants and sufficient (day)light. Providing employees with sit–stand desks have been shown to have a positive impact on employees' physical well-being. Although the positive health impact of viewing plants and nature in the workplace needs confirmation in large field experiments, thus far, the research shows that employees appreciate plants and feel better around them (Fjeld, 2000; Smith & Pitt, 2009). The positive influence of greenery and daylight is consistent with studies on biophilic design (Gillis, Gatersleben, Gillis, & Gatersleben, 2015) and green space (Gilchrist, Brown, & Montarzino, 2015). Above all, this review contributes to the debate on healthy offices by strengthening the evidence-based discussion.

For scientific scholars, this study contributes to a collective basis for research on interior office space to form a more united and mature research domain. The review brings together examples from different disciplines on useful research designs and instruments. It serves as a comprehensive reference source for further research in the area and provides a basis for a common language between disciplines, which helps research on the work environment to develop as a multi-disciplinary field, as proposed by Appel-Meulenbroek, Clippard, and Pfnür (2018).

Recommendations for future research

First, future research should aim to deepen understanding of the relationship between interior office space and employee well-being. One open-ended question is what combination of conditions causes negative experience of open-plan offices. Based on the work of Wohlers and Hertel (2017), future research could investigate how a well-designed ABW environment could minimize health risks and maximize health benefits. Regarding the impact of noise, future research should measure objective as well as subjective noise, and connect this to design features reducing actual noise, such as sound-absorbing wall and floor finishes and partitions, as well as options for controlling or escaping noise.

In addition to the purpose of reducing office workers' stress, future research on interior office space should address positive design, strategies to enhance their well-being by facilitating restoration, relatedness and health-supporting behaviour. After all, several features

of interior space have been shown to affect social interaction and relationships (Khazanchi, Sprinkle, Masterson, & Tong, 2018; Sailer & McCulloh, 2012), and the presence of natural elements contributes to recovery from stress (Gillis et al., 2015). Creating obvious, easy and attractive opportunities for physical activity, relaxation and positive social interaction may stimulate desired behaviour through 'nudging' (Thaler & Sunstein, 2008). In the included papers, this was limited to furniture and walking distances, but there may be other features that also nudge health-related behaviour, for instance, attractive staircases (Swenson & Siegel, 2013), visual communication (Kwak, Kremers, Van Baak, & Brug, 2007) and the placement of food and drinks (Arno & Thomas, 2016; Kroese, Marchiori, & De Ridder, 2016). For an effective application of nudges, more research is needed on the long-term effects and the conditions for lasting habits (Lally, Van Jaarsveld, Potts, & Wardle, 2010).

Conclusion

This research identified a lack of strong evidence in the literature on the relationship between interior office space and individuals' well-being, specifically psychological and social well-being. The features studied include layout, furniture, light, greenery, individual control and noise. Future research not only should expand on the features of interior space and health aspects, but also should aim to develop a collective vocabulary, increase methodological strength and work toward holistic models. Developing taxonomies for interior space in offices and psychological and social well-being could contribute to transdisciplinary collaboration and progress of the field. A wider use of observational and physiological measures, validated self-report measures and longitudinal designs would add to the rigour. Including more moderating and mediating variables, and performing multivariate and multilevel analyses could yield insights into the complex interaction of people and environment. This would help office space research to mature and contribute to a more solid foundation for evidence-based design of healthy offices.

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References

Amick, B. C., Menéndez, C. C., Bazzani, L., Robertson, M., DeRango, K., Rooney, T., & Moore, A. (2012). A field intervention examining the impact of an office ergonomics training and a highly adjustable chair on visual symptoms in a public sector organization. *Applied Ergonomics*, *43*(3), 625–631.

Appel-Meulenbroek, R., Clippard, M., & Pfnür, A. (2018). The effectiveness of physical office environments for employee outcomes: An interdisciplinary perspective of research efforts. *Journal of Corporate Real Estate*, *20*(1), 56–80. doi:10.1108/JCRE-04-2017-0012

Arno, A., & Thomas, S. (2016). The efficacy of nudge theory strategies in influencing adult dietary behaviour: A systematic review and meta-analysis. *BMC Public Health*, *16*(1), 676. doi:10.1186/s12889-016-3272-x

Bakker, A. B., & Demerouti, E. (2017). Job demands-resources theory: Taking stock and looking forward. *Journal of Occupational Health Psychology*, *22*(3), 273–285. doi:10.1037/ocp0000056

Bakker, A. B., Demerouti, E., & Sanz-Vergel, A. I. (2014). Burnout and work engagement: The JD–R approach. *Annual Review of Organizational Psychology and Organizational Behavior*, *1*(1), 389–411. doi:10.1146/annurev-orgpsych-031413-091235

Barnes, R. D. (1981). Perceived freedom and control in the built environment. In J. H. Harvey (Ed.), *Cognition, social behavior, and the environment* (pp. 409–422). Hillsdale, NJ: Erlbaum.

Berlyne, D. E. (1960). *McGraw-Hill series in psychology. Conflict, arousal, and curiosity*. New York: McGraw-Hill Book Company. doi:10.1037/11164-000

Bjørnstad, S., Patil, G. G., & Raanaas, R. K. (2016). Nature contact and organizational support during office working hours: Benefits relating to stress reduction, subjective health complaints, and sick leave. *Work*, *53*, 9–20. doi:10.3233/WOR-152211

Bluyssen, P. M., Aries, M., & Van Dommelen, P. (2011). Comfort of workers in office buildings: The European HOPE project. *Building and Environment*, *46*(1), 280–288. doi:10.1016/J.BUILDENV.2010.07.024

Bodin Danielsson, C., Bodin, L., Wulff, C., & Theorell, T. (2015). The relation between office type and workplace conflict: A gender and noise perspective. *Journal of Environmental Psychology*, *42*, 161–171. doi:10.1016/j.jenvp.2015.04.004

Bodin Danielsson, C., Chungkham, H. S., Wulff, C., & Westerlund, H. (2014). Office design's impact on sick leave rates. *Ergonomics*, *57*(2), 139–147. doi:10.1080/00140139.2013.871064

Boerstra, A. C., Te Kulve, M., Toftum, J., Loomans, M. G. L. C., Olesen, B. W., & Hensen, J. L. M. (2015). Comfort and performance impact of personal control over thermal environment in summer: Results from a laboratory study. *Building and Environment*, *87*, 315–326. doi:10.1016/J.BUILDENV.2014.12.022

Boubekri, M., Cheung, I. N., Reid, K. J., Wang, C.-H., & Zee, P. C. (2014). Impact of windows and daylight exposure on overall health and sleep quality of office workers: A case-control pilot study. *Journal of Clinical Sleep Medicine*, *10* (06), 603–611. doi:10.5664/jcsm.3780

Brennan, A., Chugh, J. S., & Kline, T. (2002). Traditional versus open office design. *Environment and Behavior*, *34*(3), 279–299. doi:10.1177/0013916502034003001

Carr, L. J., Swift, M., Ferrer, A., & Benzo, R. (2016). Cross-sectional examination of long-term access to sit–stand desks in a professional office setting. *American Journal of Preventive Medicine*, *50*(1), 96–100. doi:10.1016/J.AMEPRE.2015.07.013

Ching, F. D. K., & Binggeli, C. (2004). *Interior design illustrated* (2nd ed.). Hoboken, NJ: Wiley & Sons.

Cohen, S. (1980). Aftereffects of stress on human performance and social behavior: A review of research and theory. *Psychological Bulletin*, *88*(1), 82–108. doi:10.1037/0033-2909.88.1.82

De Croon, E. M., Sluiter, J. K., Kuijer, P. P. F. M., & Frings-Dresen, M. H. W. (2005). The effect of office concepts on worker health and performance: A systematic review of the literature. *Ergonomics*, *48*(2), 119–134. doi:10.1080/00140130512331319409

De Kort, Y., & Smolders, K. (2010). Effects of dynamic lighting on office workers: First results of a field study with monthly alternating settings. *Lighting Research & Technology*, *42*(3), 345–360. doi:10.1177/1477153510378150

Demerouti, E., Bakker, A. B., Nachreiner, F., & Schaufeli, W. B. (2001). The job demands-resources model of burnout. *Journal of Applied Psychology*, *86*(3), 499–512.

Duncan, M. J., Short, C., Rashid, M., Cutumisu, N., Vandelanotte, C., & Plotnikoff, R. C. (2015). Identifying correlates of breaks in occupational sitting: A cross-sectional study. *Building Research & Information*, *43*(5), 646–658. doi:10.1080/09613218.2015.1045712

Engelen, L., Chau, J., Bohn-Goldbaum, E., Young, S., Hespe, D., & Bauman, A. (2017). Is active design changing the workplace? A natural pre-post experiment looking at health behaviour and workplace perceptions. *Work*, *56*, 229–237. doi:10.3233/WOR-172483

Engelen, L., Chau, J., Young, S., Mackey, M., Jeyapalan, D., & Bauman, A. (2019). Is activity-based working impacting health, work performance and perceptions? A systematic review. *Building Research & Information*, *47*(4), 468–479. doi:10.1080/09613218.2018.1440958

Engelen, L., Dhillon, H. M., Chau, J. Y., Hespe, D., & Bauman, A. E. (2016). Do active design buildings change health behaviour and workplace perceptions? *Occupational Medicine*, *66*(5), 408–411. doi:10.1093/occmed/kqv213

Evensen, K. H., Raanaas, R. K., Hagerhall, C. M., Johansson, M., & Patil, G. G. (2015). Restorative elements at the computer workstation. *Environment and Behavior*, *47*(3), 288–303. doi:10.1177/0013916513499584

Fjeld, T. (2000). The effect of interior planting on health and discomfort among workers and school children. *HortTechnology*, *10*(1), 46–52. doi:10.21273/HORTTECH.10.1.46

Foley, B., Engelen, L., Gale, J., Bauman, A., & Mackey, M. (2016). Sedentary behavior and musculoskeletal discomfort are reduced when office workers trial an activity-based work environment. *Journal of Occupational and Environmental Medicine*, *58*(9), 924–931. doi:10.1097/JOM.0000000000000828

Folkman, S., Lazarus, R. S., Gruen, R. J., & DeLongis, A. (1986). Appraisal, coping, health status, and psychological symptoms. *Journal of Personality and Social Psychology*, *50*(3), 571–579. doi:10.1037/0022-3514.50.3.571

Fostervold, K., & Nersveen, J. (2008). Proportions of direct and indirect indoor lighting — The effect on health, well-being and cognitive performance of office workers. *Lighting Research & Technology*, *40*(3), 175–200. doi:10.1177/1477153508090917

Gilchrist, K., Brown, C., & Montarzino, A. (2015). Workplace settings and wellbeing: Greenspace use and views contribute to employee wellbeing at peri-urban business sites. *Landscape and Urban Planning*, *138*, 32–40. doi:10.1016/J.LANDURBPLAN.2015.02.004

Gillis, K., Gatersleben, B., Gillis, K., & Gatersleben, B. (2015). A review of psychological literature on the health and well-being benefits of biophilic design. *Buildings*, *5*(3), 948–963. doi:10.3390/buildings5030948

Graves, L. E. F., Murphy, R. C., Shepherd, S. O., Cabot, J., & Hopkins, N. D. (2015). Evaluation of sit-stand workstations in an office setting: A randomised controlled trial. *BMC Public Health*, *15*(1), 1145. doi:10.1186/s12889-015-2469-8

Groen, B. H., Jylhä, T. E., & Van Sprang, H. (2018). Healthy offices: An evidence-based trend in facility management? In S. Nenonen, A. Salmisto, & V. Danivska (Eds.), *Proceedings of the 1st transdisciplinary workplace research conference*. Tampere: Tampere University of Technology, Laboratory of Civil Engineering, Construction Management and Economics.

Grooten, W. J. A., Äng, B. O., Hagströmer, M., Conradsson, D., Nero, H., & Franzén, E. (2017). Does a dynamic chair increase office workers' movements? Results from a combined laboratory and field study. *Applied Ergonomics*, *60*, 1–11. doi:10.1016/J.APERGO.2016.10.006

Haapakangas, A., Hongisto, V., Varjo, J., & Lahtinen, M. (2018). Benefits of quiet workspaces in open-plan offices – evidence from two office relocations. *Journal of Environmental Psychology*, *56*, 63–75. doi:10.1007/s40857-018-0143-x

Haddad, R. (2014). Research and methodology for interior designers. *Procedia - Social and Behavioral Sciences*, *122*, 283–291. doi:10.1016/j.sbspro.2014.01.1343

Hakanen, J. J., Schaufeli, W. B., & Ahola, K. (2008). The job demands-resources model: A three-year cross-lagged study of burnout, depression, commitment, and work engagement. *Work & Stress*, *22*(3), 224–241. doi:10.1080/02678370802379432

Hanc, M., McAndrew, C., & Ucci, M. (2019). Conceptual approaches to wellbeing in buildings: A scoping review. *Building Research & Information*, *47*(6), 767–783. doi:10.1080/09613218.2018.1513695

Healy, G. N., Eakin, E. G., LaMontagne, A. D., Owen, N., Winkler, E. A. H., Wiesner, G., … Dunstan, D. W. (2013). Reducing sitting time in office workers: Short-term efficacy of a multicomponent intervention. *Preventive Medicine*, *57*(1), 43–48. doi:10.1016/J.YPMED.2013.04.004

IJmker, S., Huysmans, M. A., Blatter, B. M., Van der Beek, A. J., Van Mechelen, W., & Bongers, P. M. (2007). Should office workers spend fewer hours at their computer? A systematic

review of the literature. *Occupational and Environmental Medicine*, *64*(4), 211–222. doi:10.1136/oem.2006.026468

Ilies, R., Aw, S. S. Y. Y., & Pluut, H. (2015). Intraindividual models of employee well-being: What have we learned and where do we go from here? *European Journal of Work and Organizational Psychology*, *24*(6), 827–838. doi:10.1080/1359432X.2015.1071422

Jaakkola, J. J. K., & Heinonen, O. P. (1995). Shared office space and the risk of the common cold. *European Journal of Epidemiology*, *11*(2), 213–216. doi:10.1007/BF01719490

Jahncke, H., Hygge, S., Halin, N., Green, A. M., & Dimberg, K. (2011). Open-plan office noise: Cognitive performance and restoration. *Journal of Environmental Psychology*, *31*(4), 373–382. doi:10.1016/J.JENVP.2011.07.002

Janwantanakul, P., Pensri, P., Jiamjarasrangsri, V., & Sinsongsook, T. (2008). Prevalence of self-reported musculoskeletal symptoms among office workers. *Occupational Medicine*, *58*(6), 436–438. doi:10.1093/occmed/kqn072

Joines, S., James, T., Liu, S., Wang, W., Dunn, R., & Cohen, S. (2015). Adjustable task lighting: Field study assesses the benefits in an office environment. *Work*, *51*(3), 471–481. doi:10.3233/WOR-141879

Kahn, P. H., Friedman, B., Gill, B., Hagman, J., Severson, R. L., Freier, N. G., … Stolyar, A. (2008). A plasma display window? The shifting baseline problem in a technologically mediated natural world. *Journal of Environmental Psychology*, *28*(2), 192–199. doi:10.1016/J.JENVP.2007.10.008

Kaplan, S. (1995). The restorative benefits of nature: Toward an integrative framework. *Journal of Environmental Psychology*, *15*(3), 169–182. doi:10.1016/0272-4944(95)90001-2

Karakolis, T., & Callaghan, J. P. (2014). The impact of sit–stand office workstations on worker discomfort and productivity: A review. *Applied Ergonomics*, *45*(3), 799–806. doi:10.1016/J.APERGO.2013.10.001

Khazanchi, S., Sprinkle, T. A., Masterson, S. S., & Tong, N. (2018). A spatial model of work relationships: The relationship-building and relationship-straining effects of workspace design. *Academy of Management Review*, *43*(4), 590–609. doi:10.5465/amr.2016.0240

Knight, C., & Haslam, S. A. (2010). Your place or mine? Organizational identification and comfort as mediators of relationships between the managerial control of workspace and employees' satisfaction and well-being. *British Journal of Management*, *21*(3), 717–735. doi:10.1111/j.1467-8551.2009.00683.x

Krippendorff, K. (2004). *Content analysis: An introduction to its methodology* (2nd ed.). Thousand Oaks, CA: Sage.

Kroese, F. M., Marchiori, D. R., & De Ridder, D. T. D. D. (2016). Nudging healthy food choices: A field experiment at the train station. *Journal of Public Health*, *38*(2), e133–e137. doi:10.1093/pubmed/fdv096

Kwak, L., Kremers, S. P. J., Van Baak, M. A., & Brug, J. (2007). A poster-based intervention to promote stair use in blue- and white-collar worksites. *Preventive Medicine*, *45*(2–3), 177–181. doi:10.1016/J.YPMED.2007.05.005

Kweon, B.-S., Ulrich, R. S., Walker, V. D., & Tassinary, L. G. (2008). Anger and stress: The role of landscape posters in an office setting. *Environment and Behavior*, *40*(3), 355–381. doi:10.1177/0013916506298797

Lally, P., Van Jaarsveld, C. H. M. M., Potts, H. W. W. W., & Wardle, J. (2010). How are habits formed: Modelling habit formation in the real world. *European Journal of Social Psychology*, *40*(6), 998–1009. doi:10.1002/ejsp.674

Lamb, S., & Kwok, K. C. S. (2016). A longitudinal investigation of work environment stressors on the performance and wellbeing of office workers. *Applied Ergonomics*, *52*, 104–111. doi:10.1016/J.APERGO.2015.07.010

Lee, Y. S. (2010). Office layout affecting privacy, interaction, and acoustic quality in LEED-certified buildings. *Building and Environment*, *45*(7), 1594–1600. doi:10.1016/J.BUILDENV.2010.01.007

Lindberg, C. M., Srinivasan, K., Gilligan, B., Razjouyan, J., Lee, H., Najafi, B., … Sternberg, E. M. (2018). Effects of office workstation type on physical activity and stress. *Occupational and Environmental Medicine*, *75*(10), 689–695. doi:10.1136/oemed-2018-105077

Meijer, E. M., Frings-Dresen, M. H. W., & Sluiter, J. K. (2009). Effects of office innovation on office workers' health and performance. *Ergonomics*, *52*(9), 1027–1038. doi:10.1080/00140130902842752

Miles, M. B., & Huberman, M. A. (1994). *Qualitative data analysis: An expanded sourcebook* (2nd ed.). Thousand Oaks, CA: Sage.

Moher, D., Shamseer, L., Clarke, M., Ghersi, D., Liberati, A., Petticrew, M., … Stewart, L. A. (2015). Preferred reporting items for systematic review and meta-analysis protocols (PRISMA-P) 2015 statement. *Systematic Reviews*, *4*(1), 1. doi:10.1186/2046-4053-4-1

Morrison, R. L., & Macky, K. A. (2017). The demands and resources arising from shared office spaces. *Applied Ergonomics*, *60*, 103–115. doi:10.1016/j.apergo.2016.11.007

Pejtersen, J., Allermann, L., Kristensen, T. S. T. S., & Poulsen, O. M. M. (2006). Indoor climate, psychosocial work environment and symptoms in open-plan offices. *Indoor Air*, *16*(5), 392–401. doi:10.1111/j.1600-0668.2006.00444.x

Pejtersen, J. H., Feveile, H., Christensen, K. B., & Burr, H. (2011). Sickness absence associated with shared and open-plan offices — a national cross sectional questionnaire survey. *Scandinavian Journal of Work, Environment & Health*, *37*, 376–382. doi:10.2307/23064898

Qin, J., Sun, C., Zhou, X., Leng, H., & Lian, Z. (2014). The effect of indoor plants on human comfort. *Indoor and Built Environment*, *23*(5), 709–723. doi:10.1177/1420326X13481372

Rashid, M., & Zimring, C. (2008). A review of the empirical literature on the relationships between indoor environment and stress in health care and office settings. *Environment and Behavior*, *40*(2), 151–190. doi:10.1177/0013916507311550

Richardson, A., Potter, J., Paterson, M., Harding, T., Tyler-Merrick, G., Kirk, R., … McChesney, J. (2017). Office design and health: A systematic review. *New Zealand Medical Journal*, *130*(1467), 39–49.

Robertson, M., Amick III, B. C., DeRango, K., Rooney, T., Bazzani, L., Harrist, R., & Moore, A. (2009). The effects of an office ergonomics training and chair intervention on worker knowledge, behavior and musculoskeletal risk. *Applied Ergonomics*, *40*(1), 124–135.

Robertson, M. M., Ciriello, V. M., & Garabet, A. M. (2013). Office ergonomics training and a sit-stand workstation: Effects on musculoskeletal and visual symptoms and performance of office workers. *Applied Ergonomics*, *44*(1), 73–85. doi:10.1016/J.APERGO.2012.05.001

Roossien, C. C., Stegenga, J., Hodselmans, A. P., Spook, S. M., Koolhaas, W., Brouwer, S., … Reneman, M. F. (2017). Can a smart chair improve the sitting behavior of office workers? *Applied Ergonomics*, *65*, 355–361. doi:10.1016/J.APERGO.2017.07.012

Sailer, K., & McCulloh, I. (2012). Social networks and spatial configuration – How office layouts drive social interaction. *Social Networks*, *34*(1), 47–58. doi:10.1016/j.socnet.2011.05.005

Schlittmeier, S. J., & Liebl, A. (2015). The effects of intelligible irrelevant background speech in offices – cognitive disturbance, annoyance, and solutions. *Facilities*, *33*(1/2), 61–75. doi:10.1108/F-05-2013-0036

Seddigh, A., Berntson, E., Jönsson, F., Danielson, C. B., & Westerlund, H. (2015). The effect of noise absorption variation in open-plan offices: A field study with a cross-over design. *Journal of Environmental Psychology*, *44*, 34–44. doi:10.1016/J.JENVP.2015.08.004

Shafiee Motlagh, M., Golmohammadi, R., Aliabadi, M., Faradmal, J., & Ranjbar, A. (2018). Empirical study of room acoustic conditions and neurophysiologic strain in staff working in special open-plan bank offices. *Acoustics Australia*, *46*(3), 329–338. doi:10.1007/s40857-018-0143-x

Smith, A., & Pitt, M. (2009). Sustainable workplaces: Improving staff health and well-being using plants. *Journal of Corporate Real Estate*, *11*(1), 52–63. doi:10.1108/14630010910940552

Smith, D., Metcalfe, P., & Lommerse, M. (2012). Interior architecture as an agent for wellbeing. *Journal of the Home Economics Institute of Australia*, *19*(3), 2–9.

Spector, P. E., & Jex, S. M. (1998). Development of four self-report measures of job stressors and strain: Interpersonal conflict at work scale, organizational constraints scale, quantitative workload inventory, and physical symptoms inventory. *Journal of Occupational Health Psychology*, *3*(4), 356–367.

Swenson, T., & Siegel, M. (2013). Increasing stair use in an office worksite through an interactive environmental intervention. *American Journal of Health Promotion*, *27*(5), 323–329. doi:10.4278/ajhp.120221-QUAN-104

Thaler, R. H., & Sunstein, C. R. (2008). *Nudge: Improving decisions about health, wealth, and happiness*. New Haven, CT: Yale University Press. doi:10.1007/s10602-008-9056-2

Thayer, J. F., Verkuil, B., Brosschotj, J. F., Kevin, K., West, A., Sterling, C., … Sternberg, E. M. (2010). Effects of the physical work environment on physiological measures of stress. *European Journal of Cardiovascular Prevention & Rehabilitation*, *17*(4), 431–439. doi:10.1097/HJR.0b013e328336923a

Toftum, J. (2010). Central automatic control or distributed occupant control for better indoor environment quality in the future. *Building and Environment*, *45*(1), 23–28. doi:10.1016/J.BUILDENV.2009.03.011

Torbeyns, T., de Geus, B., Bailey, S., De Pauw, K., Decroix, L., Van Cutsem, J., & Meeusen, R. (2016). Bike desks in the office. *Journal of Occupational and Environmental Medicine*, *58*(12), 1257–1263. doi:10.1097/JOM.0000000000000911

Tuomi, J., & Sarajärvi, A. (2012). *Laadullinen tutkimus ja sisältöanalyysi [Qualitative research and content analysis]* (9th ed.). Vantaa: Tammi.

Van der Molen, H., Kuijer, P., De Groene, G., Bakker, J., Sorgdrager, B., Lenderink, A., … Brand, T. (2018). *Beroepsziekten in cijfers 2018 [Occupational diseases 2018]*. Amsterdam: Nederlands centrum voor beroepsziekten. Retrieved from https://www.occupationaldiseases.nl/

Van Duijnhoven, J., Aarts, M. P. J., Rosemann, A. L. P., & De Kort, H. S. M. (2018). Ambiguities regarding the relationship between office lighting and subjective alertness: An exploratory field study in a Dutch office landscape. *Building and Environment*, *142*(June), 130–138. doi:10.1016/j.buildenv.2018.06.011

Van Niekerk, S.-M., Louw, Q. A., & Hillier, S. (2012). The effectiveness of a chair intervention in the workplace to reduce musculoskeletal symptoms. A systematic review. *BMC Musculoskeletal Disorders*, *13*(145), 145. doi:10.1186/1471-2474-13-145

Veitch, J., Newsham, G., Boyce, P., & Jones, C. (2008). Lighting appraisal, well-being and performance in open-plan offices: A linked mechanisms approach. *Lighting Research & Technology*, *40*(2), 133–151. doi:10.1177/1477153507086279

Viola, A. U., James, L. M., Schlangen, L. J., & Dijk, D. J. (2008). Blue-enriched white light in the workplace improves self-reported alertness, performance and sleep quality. *Scandinavian Journal of Work, Environment & Health*, *34*(4), 297–306.

Wells, M. M. (2000). Office clutter or meaningful personal displays: The role of office personalization in employee and organizational well-being. *Journal of Environmental Psychology*, *20*(3), 239–255. doi:10.1006/jevp.1999.0166

WHO. (2006). *Constitution of the World Health Organization*. Retrieved from https://www.who.int/governance/eb/who_constitution_en.pdf

Wohlers, C., & Hertel, G. (2017). Choosing where to work at work – Towards a theoretical model of benefits and risks of activity-based flexible offices. *Ergonomics*, *60*(4), 467–486. doi:10.1080/00140139.2016.1188220

World Green Building Council. (2014). *Health, wellbeing and productivity in offices: The next chapter for green building*. Retrieved from https://www.worldgbc.org/news-media/health-wellbeing-and-productivity-offices-next-chapter-green-building

Xue, F., Gou, Z., & Lau, S. (2016). Human factors in green office building design: The impact of workplace green features on health perceptions in high-rise high-density Asian cities. *Sustainability*, *8*(11), 1095. doi:10.3390/su8111095