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The business case for a healthy office; a holistic overview of relations between office workspace design and mental health

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ABSTRACT

The role of the physical workspace in employee mental health is often overlooked. As a (mentally) healthy workforce is vital for an organisation's success, it is important to optimise office workspace conditions. Previous studies on the effects of the physical workspace on mental health tended to focus on the effects of a specific element of the physical workspace on one or only a few mental health indicators. This study takes a more holistic approach by addressing the relationship of physical workspace characteristics with ten broad indicators of work-related mental health. Results of a systematic review of empirical evidence show that many aspects of (day)light, office layout/design, and temperature and thermal comfort have been proven to be related to many mental health indicators. Less tacit workspace characteristics (e.g., noise, use of colours) have been explored too, but so far have only been related to a few mental health indicators.

Practitioner summary: The absence of holistic insights regarding the empirical proof of the effects of workspace design on employee mental health prevents a clear business case for workplace investments. This paper presents a content analysis of existing studies and shows how seven elements of workspace design relate to 10 mental health indicators.

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1. Introduction

Due to the growing number of people experiencing burnout-related mental health issues from stressors, such as work pressure (CBS 2020; TNO 2019), there is an increasing societal interest in mental health in the work environment (Hanc, McAndrew, and Ucci 2019). A large share of employers acknowledges the value of their employees' mental health. Approximately 40% of these employers also take precautions for dealing with mental health-related issues (e.g., coaching, health-checks, yoga classes) (Pas, Busch, and Proper 2014). However, one of the potential contributors to health, the physical workspace (Chadburn, Smith, and Milan 2017; Cobaleda Cordero, Babapour, and Karlsson 2019; Thatcher and Milner 2014), is not considered very often. In the past, corporate real estate strategies and investments were often solely based on short-term cost reductions and efficiency (Lindholm and Leväinen 2006; Singer, Bossink, and Vande Putte 2007), '*Business cases are constructed to outline the rationale and justification for a change, secure support and resources from leadership, and provide understanding about how a change in practice will yield an economic return on investment.*' (Linton et al. 2019, p. 2). For mental health outcomes of an improved physical workspace, such a business case remains unclear.

Apart from official mental disorders, mental health is a much broader concept regarding a person's entire functioning (Harvard Health Publishing 2008; WHO 2004). The field of positive health refers to it as '*a state of well-being that goes beyond the mere absence of disease or illness*' (Seligman 2008 p. 3). So, besides pathogenic work-related mental health issues, such as *stress, sleep quality, mood, fatigue,* or a general lack of *well-being,* and diagnosable mental disorders, such as

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depression and *burnout*, this WHO definition suggests that salutogenic indicators should be included as well for a holistic approach to mental health and well-being at work. Studies with a salutogenic approach have hinted for example at self-assessed *productivity* (Bringsén et al. 2012) and *concentration* (Ruohomäki et al. 2015). In addition, *engagement* has been put forward as the positive opposite of burnout on a continuum (Leiter and Maslach 2016). Based on such a broader approach to mental health at work, Bergefurt et al. (2022) used these ten indicators (in italics above) to identify 133 studies on mental health outcomes related to the physical office workspace in their scoping review. They concluded that research on relationships between physical workspace characteristics and these ten potential mental health indicators, tends to focus on the effects of a specific element of the physical workspace on one or only a few mental health indicators; an overview of findings is missing.

Increased mental health in the workplace will not only result in lower absenteeism rates and decreased healthcare costs (Cooper and Dewe 2008; Muldavin, Miers, and McMackin 2017), but also has the potential to affect other important business key performance indicators. For example, pleasant and comfortable settings increase cognitive capacity by reducing feelings of stress and pressure and improving an individual's mood (Isen 2001). Such increased cognitive capacity allows employees to quickly adapt to new situations and switch between tasks more easily, enhancing flexibility (Miner and Glomb 2010). Also, as indicated by Isen (2001), more positive emotions and a better mood provide individuals with more cognitive space to generate new ideas and support creativity, improving an employee's innovativeness. Furthermore, improvements in employee productivity and concentration and reductions in employee stress levels are expected to increase organisational performance too (Baird 2017; Obuobisa-Darko 2020; van der Voordt 2016) and, in turn, may lead to higher levels of customer satisfaction (Amaratunga and Baldry 2003; Taris 2006). So, the value of employee mental health for a business case on organisational performance is clear. But what about the value of workspace design investments to improve employee mental health?

1.1. Aims and objectives

One of the main reasons that withhold an organisation from investing in the physical workspace to support employees' mental health is the absence of insights into the effectiveness of such investments (Pas, Busch, and Proper 2014). Because of the specialised and focussed approach in existing studies on physical workspace and mental health (e.g. Appel-Meulenbroek, Clippard, and Pfnür 2018; Riba Sagar, Parikh, and Greden Editors 2019; Watson 2018), a holistic overview of the empirically demonstrated relationships between the two is currently missing. While Bergefurt et al. (2022) have identified existing empirical evidence, they only analysed these 133 studies on the theories, measures, and indicators that were used. They did not, however, analyse their content to identify empirically demonstrated effects of space on mental health. Therefore, the aim of the current paper is to create an overview of the potential effects of the physical office workspace on these ten mental health indicators. It does so by analysing the 133 papers that were already systematically selected by Bergefurt et al. (2022) on the gathered proof for implementing changes in each separate physical workspace element. Other systematic reviews that have been published on healthy workspaces identified far less studies (Forooraghi et al. 2020; Colenberg et al. 2021, respectively, reviewed 18 and 50 papers), as they used general search terms, such as 'office' or 'workspace design' thereby overlooking more detailed studies on, for example, noise or light. Jensen and Van der Voordt (2019) did include such search terms, but only reviewed works in four journals, thus also missing out on a lot of the empirical evidence.

The present study, therefore, fills an important research gap by analysing the systematically collected 133 papers in such a way that an overview can be provided of how different quality levels of physical workspace characteristics have been proven to affect different mental health indicators. Such an overview can be used to support healthy office business case development and to identify gaps for future research.

2. Methods

Bergefurt et al. (2022) used PRISMA guidelines to select these 133 papers from an initial database of 3695 papers, based on several eligibility criteria. Detailed information about the selection procedure can be found in Bergefurt et al. (2022). The current study adds a content analysis of the same articles. Data was extracted from each paper on general paper information (e.g. author, year, journal), the research design, time horizon, and methods, number of buildings in the study, layout of the office(s), physical workplace characteristics, mental health indicators, and the direction and

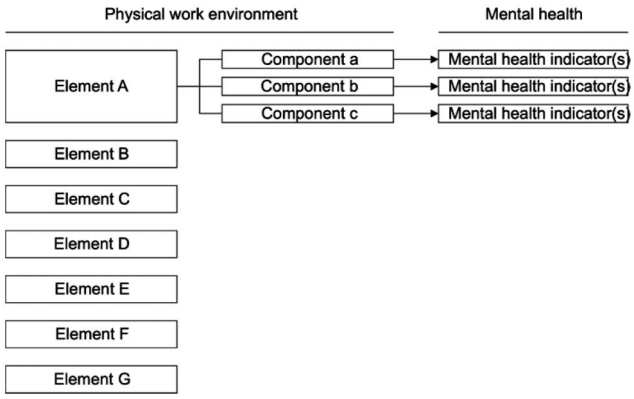

Figure 1. Division of physical workspace elements and components related to mental health indicators.

significance of relationships between physical workspace characteristics and mental health indicators.

Next, the elements of the physical workspace (e.g. *Temperature and Thermal Comfort*) and their components [e.g., *room temperature (°C)* and *relative humidity (%)*] that were empirically tested (see Figure 1), were extracted from each study. Per element, relationships of the associated components with the ten mental health indicators are gathered (positive, negative, curvilinear, no effect). Various studies also reported percentages for possible effect sizes that were measured (e.g., 3% increase in productivity). Last, the design quality levels of the different components were allocated to three categories (insufficient, sufficient, and optimal) based on the empirical findings in the papers that indicated thresholds for component values that positively or negatively affected mental health indicators. These three categories allow to identify optimisation possibilities and their potential for a positive business case based on mental health outcomes. As this study is a review of literature, no ethical approval was necessary.

3. Results

The offices studied in the papers regarded open plan offices ($n = 64$ studies), cellular offices ($n = 39$), shared offices ($n = 20$), combi offices ($n = 4$), and activity-based offices ($n = 14$). Overall, 97% of the studies used a survey, with 50% using a longitudinal approach (with one pre-test and at least two post-tests). Several studies combined the use of a survey with a field experiment, as field experiments were used in 30% of the papers. Sample sizes ranged from 7 to 25,947 respondents, with an average of 887 ($SD = 2832$) and from 1 to 191 different office buildings ($M = 11$, $SD = 25$).

The journals that the papers were published in (see Supplementary Material) give some indication of the research fields. On the hand, there were 17 journals that could be said to stem from the field of building sciences (with 49 studies) and six journals (with 29 studies) from the field of ergonomics, facilities, and real estate. Regarding mental health, many of these studies focussed on the salutogenic indicators of productivity and concentration. The building's science journals appear more focussed on indoor environmental qualities (IEQ: temperature, air, lighting, and noise), whereas the ergonomics, facilities, and real estate journals additional include office layout and design. On the other hand, there were many journals included with the main focus on people instead of the spaces, from the field of medicine and health (12 journals with 21 studies) and psychology and behaviour (four journals with 17 studies). These studies seem a bit more focussed on pathogenic indicators, especially stress. Regarding workspaces, again the IEQ elements are studied most here. Five journals (with six studies) are nature focussed, mainly on relating biophilia to stress. Eight journals (with 11 studies) were hard to assign to a specific field.

3.1. Office layout and office design

The workspace element 'office layout and office design' considers components related to the physical and functional settings of the workspace as well as its design (Al Horr et al. 2016). Its ten components (see Table 1) are shown to have significant relationships with most mental health indicators, but not (yet) with mood, depression, or fatigue. All components have been related to perceived productivity, and most to stress and well-being as well. Contrary to most other workspace elements, measured changes in mental health have not yet been indicated in percentages. In general, mostly perceptive measures of satisfaction are used to measure the layout, but five studies included an objective metric (e.g., workspace size).

Regarding office type (related to five mental health indicators), three main categories are distinguished: private offices, group offices, and open plan offices. The private office relates most positively—in comparison to the open plan office—to *well-being* and *sleep quality* (Bodin Danielsson and Bodin 2008), *productivity*, *concentration,* and reduced *stress* levels (Di Blasio et al. 2019; Haapakangas, Hallman, et al. 2018; Lindberg et al. 2018; Seddigh et al. 2014; Wiik 2011). The strength of the relationships of group office with these mental health

Table 1. Office layout and design and mental health indicators.

	Insufficient	Sufficient	Optimal	Stress	Well-being	Burnout	Mood	Sleep quality	Depression	Engagement	Fatigue	Concentration	Productivity
Office type	Open plan office	Group office	Private office	–	+			+				+	+
Workspace use	Dedicated seating		Flexible seating	–									+
Concentration spaces/breakout rooms	No		Yes	–	+							+	+
Vitality zones/aspects	Not present		Present	–		–		+		+			+
Easy access to facilities	No		Yes										+
Separated refreshment areas	No		Yes									+	+
Cluster size	>20 people	6–20 people	2–5 people	–	+					+			+
Cluster separation	No	Visual or acoustic	Visual and acoustic							+			+
Decorative elements	Not present		Present		+								+
Workspace adjustability	Not adjustable		Adjustable										+

indicators lies in between those of the two other office types. Besides office layout design, flexible use of individual workspaces relates more positively to *productivity* (Candido, Chakraborty, and Tjondronegoro 2019; Haapakangas, Hallman, et al. 2018; Haynes, Suckley, and Nunnington 2017; Kim et al. 2016) and *stress* levels (MacHe, Servaty, and Harth 2020) than dedicated seating.

In addition to the office layout in its entirety, the availability of concentration spaces and breakout rooms also relates to higher *productivity* (Di Blasio et al. 2019; Haynes, Suckley, and Nunnington 2017; Kim et al. 2016; Rasheed, Khoshbakht, and Baird 2019; Wiik 2011), better *concentration, less stress* (Haapakangas, Hongisto, et al. 2018; Seddigh et al. 2014) and higher overall *well-being* (Davis, Leach, and Clegg 2020). Similarly, vitality zones and active elements (e.g., exercise balls, standing desks, table tennis tables, lounge chairs, etc.) reduce *stress* and *burnout*-related symptoms (Coffeng et al. 2014; Engelen et al. 2017). Engelen et al. (2017) also reported an increase in *sleep quality*, *productivity,* and *engagement* for such components. On top of that, people in workspaces with easy access to facilities that support them in their everyday tasks perceive higher *productivity* (Groen et al. 2019). Candido et al. (2019) and Haynes, Suckley, and Nunnington (2017) call for a clear separation of refreshment areas from workspaces as these areas cause distractions that negatively affect employee *productivity* and *concentration*.

The number of occupants and how they are spread over the office are also relevant layout components. In general, a larger number of occupants has adverse effects on *productivity* and *well-being* (Bodin Danielsson and Bodin 2008; Herbig, Schneider, and Nowak 2016). Di Blasio et al. (2019) and Rasheed, Khoshbakht, and Baird (2019) suggested a division of workspaces in clusters of 2–5 employees with acoustic and visual separations between the different clusters to enhance *engagement* and *productivity*. Clusters of 6–20 employees are found to negatively affect *productivity* and result in more difficulties in *concentrating* on tasks and increases in *stress* as well as decreased *well-being* (Di Blasio et al. 2019; Seddigh et al. 2014). Open office spaces that accommodate over 20 employees have the most negative effects on these mental health indicators (Di Blasio et al. 2019; Rasheed, Khoshbakht, and Baird 2019).

Last, the implementation of decorative elements (art, natural elements, furniture, colours, photos, etc.) also positively relates to employee *well-being* (Cobaleda Cordero, Babapour, and Karlsson 2019; Wiik 2011) and *productivity* (Candido et al. 2019; Fassoulis and

Alexopoulos 2015). In addition, the freedom to adjust the workspace to personal preferences (e.g., furniture, decoration) relates to higher workspace satisfaction and increased *productivity* (Candido, Chakraborty, and Tjondronegoro 2019; Fassoulis and Alexopoulos 2015).

3.2. Look, feel, and color

The element Look, feel and colour of the workspace refers to aesthetic components as well as textures and colours (Al Horr et al. 2016). So far, it seems that only room colour has been studied in relation to mental health, without percentual indications of such effects (see Table 2). Room colour is associated with *productivity* (Kwallek et al. 1997; Kwallek, Soon, and Lewis 2007; Poursafar, Rodrigues, and Sriram 2019), *mood* (Kwallek et al. 1997; Tonello 2004), and *stress* (Hsiao, Hsiao, and Wang 2013; Lee et al. 2018). Despite minor differences between personality types, predominantly white and blue colours are found to have the most positive effects (Poursafar, Rodrigues, and Sriram 2019). Both objective measures (e.g., colour intensity and saturation) and subjective measures have been used, but the objective ones were only included in two studies.

3.3. Biophilia, greenery, views, and plants

Regarding natural elements of the workspace, four components of plants and outside views have been studied (see Table 3). Hähn, Essah, and Blanusa (2021) showed that a small number of plants (1–3) per employee or desk is most beneficial for *productivity*, *concentration,* and *stress*, in line with earlier studies (e.g., Smith and Pitt 2009). A higher number of plants (>3) might be perceived as chaotic or busy, and reduces feelings of comfort in the workspace, which negatively relates to *productivity* and *stress*, although to a lesser extent than having no plants at all. In comparison to workspaces without indoor vegetation, the implementation of 1–3 plants per desk or employee is expected to result in increased *productivity* (3–15%), *concentration* (10–20%) (Hähn, Essah, and Blanusa 2021; Nieuwenhuis et al. 2014; Smith and Pitt 2009) and a reduction in *stress* symptoms (4–8%) (Bjornstad, Patil, and Raanaas 2015; Gray and Birrell 2014; Smith and Pitt 2009; Toyoda et al. 2020). Furthermore, the implementation of indoor vegetation relates to increased *well-being* (Thomsen, Sønderstrup-Andersen, and Müller 2011) and slight reductions in *depression* rates (Kim et al. 2011). Plants should be placed in the direct office environment for improvements in

Table 2. Look, feel, and color and mental health indicators.

	Insufficient	Sufficient	Optimal	Stress	Well-being	Burnout	Mood	Sleep quality	Depression	Engagement	Fatigue	Concentration	Productivity
Room color	Dark colors	Neutral colors	Blue and white colors	–			+						+

Table 3. Biophilia, greenery, views, and plants and mental health indicators.

	Insufficient	Sufficient	Optimal	Stress	Well-being	Burnout	Mood	Sleep quality	Depression	Engagement	Fatigue	Concentration	Productivity
Number of plants	No plants	>3 plants per desk	1–3 plants per desk	−8%					−			+20%	+15%
Plant placement	No plants	Office or breakout rooms	Office and breakout rooms	−									
Visual contact to the outdoors	No visual contact	<100% of workspaces	100% of workspaces		+		+	+		+			
Views	No visual contact	Neutral views	Pleasant views	−4%									+

productivity and *concentration*; not just in breakout rooms and refreshment areas (Hähn, Essah, and Blanusa 2021). On the other hand, removing plants from the latter spaces leads to an increase in *stress* symptoms among employees.

Regarding views, workspaces where employees can look outside, are related to better *sleep quality*, better *mood*, and higher ratings of overall *well-being* (Dreyer et al. 2018; Newsham et al. 2013). According to Meir et al. (2019), pleasant views (e.g., of nature) increase *productivity* and reduce feelings of *fatigue*. Shin (2007) observed a 4% reduction in *stress* symptoms after employees moved towards windows that offered forest views. The studies on plants mostly used quantitative metrics (8 studies), but the studies on views were all using subjective quality assessments.

3.4. Temperature and thermal comfort

Also for this workspace element four components are identified, including temperature, humidity, personal control, and satisfaction (see Table 4). Studies on optimal workspace temperatures vary between 18 and 25 °C (Kim et al. 2018; Park and Gotoh 1993; Valančius and Jurelionis 2013), based on seasonal and topographical differences. Generally speaking, temperatures within the range of 20–24 °C are considered optimal (Kekäläinen et al. 2010; Newsham et al. 2013; Wiik 2011), with adjustments of one or two degrees depending on the type of season and location-specific climate (Fassoulis and Alexopoulos 2015). Office environments that deviate from this bandwidth, particularly in terms of higher room temperatures negatively affect *productivity* and *concentration* (Kekäläinen et al. 2010; Menzies et al. 1997; Reynolds et al. 2001; Valančius and Jurelionis 2013), *stress* (Kim et al. 2018), *fatigue* (Kekäläinen et al. 2010; Menzies et al. 1997; Reynolds et al. 2001), *sleep quality* and *mood* (Newsham et al. 2013), and *well-being* (Wiik 2011). Generally, improvements of over 20% are measured when these components were optimised.

The relative humidity is considered optimal between 40 and 55% (Bourbeau, Brisson, and Allaire 1997; Razjouyan et al. 2020; Wiik 2011), again with possible seasonal and geographical adjustments (Fassoulis and Alexopoulos 2015; Park and Gotoh 1993). Values below or above this range are associated with decreased *productivity* (Candido, Chakraborty, and Tjondronegoro 2019; Wiik 2011), difficulties *concentrating* on tasks (Mendell et al. 2008; Menzies et al. 1997), increased *stress* levels up to 22% (Razjouyan et al. 2020), poor *sleep quality* (Newsham et al. 2013; Razjouyan et al.

Table 4. Temperature and thermal comfort and mental health indicators.

	Insufficient	Sufficient	Optimal	Stress	Well-being	Burnout	Mood	Sleep quality	Depression	Engagement	Fatigue	Concentration	Productivity
Room temperature	<18 or >25 °C	18–20 or 25 °C	20–24 °C	−	+		+ +	+ +		+ +	−20%	+26%	+30%
Relative humidity	<30 or >60%	30–60%	40–55%	−22%							−	+	+ +
Personal control over thermal conditions	No		Yes										+ +
Satisfaction with thermal conditions	PPD >15%	PPD 6–15%	PPD <6%										+30%

2020), negative *mood* (Newsham et al. 2013) and higher *fatigue* (Bourbeau, Brisson, and Allaire 1997; Mendell et al. 2008).

More specifically, Gupta, Howard, and Zahiri (2020a, 2020b) note that high levels of satisfaction with thermal comfort could improve *productivity*. A widely used scale to measure satisfaction with the thermal climate is the Predicted Percentage Dissatisfied (PPD) rate, which indicates the percentage of dissatisfied employees. According to EN ISO 7730, this value should optimally be below 6% with an acceptable upper limit of 15% (Valančius and Jurelionis 2013). In addition, in comparison to offices without personal control, employees in offices with individually controllable thermal conditions are on average up to 85% more satisfied with the thermal comfort, which enhances employee *productivity* (D'Oca et al. 2018). Many studies ($n = 24$) used objective measures to identify either temperature and/or relative humidity, although also 24 studies only used subjective measures of comfort and satisfaction.

3.5. Noise, acoustics, and privacy

Literature on noise, acoustics, and privacy distinguishes four components of noise disturbance, that is mainly related to *fatigue*, *concentration*, and *productivity* (see Table 5). In accordance with ISO 3382-3 standards, background noise levels should not exceed 48 dB (Haapakangas, Hallman, et al. 2018; Kaarlela-Tuomaala et al. 2009; Lou and Ou 2019; Seddigh et al. 2015). Moreover, Wiik (2011) advised to set a limit of 35 dB for quiet areas intended for cognitively demanding tasks. Workspaces exceeding these standards are expected to negatively affect mental health, specifically regarding *productivity* (Di Blasio et al. 2019; Fassoulis and Alexopoulos 2015; Wiik 2011), *concentration* (Di Blasio et al. 2019; Reynolds et al. 2001; Roskams et al. 2019; Seddigh et al. 2015), *stress* (Leather, Beale, and Sullivan 2003; Seddigh et al. 2015), *fatigue* (Kaarlela-Tuomaala et al. 2009; Park and Gotoh 1993; Perrin Jegen and Chevret 2017; Reynolds et al. 2001), and *depression* (Zhang, Kang, and Jiao 2012). In addition, low-frequency noise (below 20 Hz, mostly caused by climate systems or office equipment; Tesarz et al. 1997) results in difficulties *concentrating* and increased levels of *fatigue* for those sensitive to it (Burt 1996; Tesarz et al. 1997). Higher general satisfaction with acoustics also positively affects *productivity* (Chadburn, Smith, and Milan 2017; Lou and Ou 2019; Wiik 2011).

Table 5. Noise, acoustics, and privacy and mental health indicators.

	Insufficient	Sufficient	Optimal	Stress	Well-being	Burnout	Mood	Sleep quality	Depression	Engagement	Fatigue	Concentration	Productivity
Background noise	Exceeding limits		Workspace <48 dB	–					–		–	+	+3%
			Quiet areas <35 dB										
Satisfaction with acoustical quality	Dissatisfied employees		Satisfied employees									+	
Low frequency noise	Present		Absent								–4%		
Speech privacy	STI > 0.6	STI 0.3–0.6	STI 0.0–0.3		+							+	+

Besides noise, speech privacy—the (in)ability to listen to conversations of co-workers—correlates with *concentration*, *productivity,* and *well-being* as well (Candido, Chakraborty, and Tjondronegoro 2019; Fassoulis and Alexopoulos 2015; Haapakangas, Hongisto, et al. 2018). In total, 15 studies included objective and subjective measurements, 4 only objective ones (e.g. sound levels), and 30 studies only measured subjective perceptions.

3.6. Indoor air quality and ventilation

Research on the air quality and ventilation element distinguishes six components, which again are mainly related to fatigue, concentration, and productivity (see Table 6). ASHRAE standards for CO_2 (1000 ppm) are considered as a baseline and upper acceptable limit (Haghighat and Donnini 1993; Wiik 2011). Increased levels lead to a loss in *productivity* of 4–12% for concentrations between 1000 and 1400 ppm and 14–24% for concentrations >1400 ppm, compared to the 1000 ppm baseline scenario (Gupta, Howard, and Zahiri 2020a, 2020b). In addition, Lu et al. (2015) reported a 16% increase in *fatigue* and a slight decrease in the ability to *concentrate* per 100 ppm increase in CO_2. Through higher blood pressure, increased *stress* levels have been measured as well (Kim et al. 2018). Similar to CO_2 levels, ASHRAE standards are used to study the effects of changes in formaldehyde (limit: 100 $\mu g/m^3$) and total volatile organic compounds (TVOC) concentrations (Candido et al. 2019; Hedge, Erickson, and Rubin 1996; Lou and Ou 2019; Lu et al. 2015). For every 100 ppm increase in TVOC concentrations, *fatigue* increased by 2% (Lu et al. 2015). Similarly, *fatigue* increases with higher concentrations of formaldehyde (Hedge, Erickson, and Rubin 1996; Kim et al. 2011).

Besides measuring air components, a ventilation rate of at least 8 L/s/person is found to be both optimal in terms of *productivity* and satisfaction (Candido, Chakraborty, and Tjondronegoro 2019; Fassoulis and Alexopoulos 2015; Meir et al. 2019). According to Meir et al. (2019), *productivity* increases by 1.7% for each 2-fold increase in ventilation rate when increasing from 1 to 8 L/s/person. The suboptimal air supply is also related to higher levels of *fatigue* (Bourbeau, Brisson, and Allaire 1997; Meir et al. 2019) and difficulties *concentrating* (Meir et al. 2019). Similar to thermal conditions, individually controllable ventilation systems show positive relations with mental health, with up to 15% higher *productivity* levels (Menzies et al. 1997), less *fatigue*, and a higher ability to *concentrate*

Table 6. Indoor air quality and ventilation and mental health indicators.

	Insufficient	Sufficient	Optimal	Stress	Well-being	Burnout	Mood	Sleep quality	Depression	Engagement	Fatigue	Concentration	Productivity
CO_2 concentration	>1400 ppm	1000–1400 ppm	<1000 ppm	–							−16%	+	+24%
Formaldehyde concentration	Exceeding limits		ASHRAE standards								–		
TVOC concentration	Exceeding limits		ASHRAE standards								−2%		
Ventilation rate	<1L/s/person	1–8 L/s/person	>8 L/s/person								–	+	+5%
Personal control of IAQ	No		Yes								–	+	+15%
Satisfaction with IAQ	Dissatisfied employees		Satisfied employees				+	+			−70%	+70%	+12%

(Haghighat and Donnini 1999; Menzies et al. 1997). Overall satisfaction with the indoor air quality appears positively related to improved *sleep quality* and a more positive *mood* (Newsham et al. 2013) as well, in addition to the already mentioned mental health indicators. A 12% decrease in *productivity* is observed when air is rated 'stuffy' instead of 'fresh' (Gupta, Howard, and Zahiri 2020a, 2020b). The perceived freshness of air also affects *concentration* and *fatigue* (Haghighat and Donnini 1999; Hedge, Erickson, and Rubin 1996; Reijula and Sundman-Digert 2004). Besides such subjective perceptions of the air quality, 25 studies also included objective metrics (e.g., CO_2 levels, air speed).

3.7. Light and daylight

The workspace elements light and daylight focus on both artificial and natural lighting conditions in the workspace with nine different components (see Table 7). Light exposure is a key component in an individual's health as it is the main influencer of circadian rhythm (Aries, Beute, and Fischl 2020; Figueiro et al. 2019). Disruptions in this biological rhythm due to insufficient light exposure are associated with 30% poorer *sleep quality* and increased *fatigue* (Figueiro et al. 2019; Zhang et al. 2020), negative *mood* (Figueiro et al. 2019), and reduced *productivity* and *concentration* (Aries, Beute, and Fischl 2020; Figueiro et al. 2019). Furthermore, increased scores on circadian stimulus with daylight led to 5–10% *stress* reductions (Figueiro et al. 2017), increased *well-being* (Borisuit et al. 2015; Boubekri et al. 2014; Cobaleda Cordero, Babapour, and Karlsson 2019) and a 20% reduction in feelings of *depression* (Figueiro et al. 2017). Employees prefer exposure to daylight over artificial light (Borisuit et al. 2015; Day et al. 2019; Maierova et al. 2016), indicating a general preference for daylight in the workspace. It can be expected though that not all workspaces can be spaced within the proximity of windows which results in insufficient daylight exposure. For such workspaces, skylights appear a suitable solution as opposed to conventional electric lighting to improve *mood* by 10% and decrease *stress* levels (Canazei et al. 2017). A negative effect of direct daylight exposure is the occurrence of glare, which reduces visual comfort and therewith negatively affects *mood* (Borisuit et al. 2015), *fatigue*, and *productivity* (Aries, Veitch, and Newsham 2010; Fostervold and Nersveen 2008). To avoid glare, it is advised to reduce direct sunlight penetration by applying shading to the windows (Boubekri et al. 2020). Choi et al. (2019)

Table 7. Light and daylight and mental health indicators.

	Insufficient	Sufficient	Optimal	Stress	Well-being	Burnout	Mood	Sleep quality	Depression	Engagement	Fatigue	Concentration	Productivity
Daylight exposure	CS < 0.15 or <2%	CS 0.15–0.30	CS > 0.3 or 2–6%	−10%	+		+	+30%	−20%		–		+
Skylights (only if insufficient daylight exposure)	Conventional lighting		Use of skylights	–			+10%						
Glare	Present		Absent				+				–		+
Shading	No shading	Blinds	Dynamic glazing				+25%				−29%	+13%	+22%
Direct and indirect lighting	Only direct		Direct and indirect		+								
Correlated colour temperature	<3000K	3000–6500 K	>6500 K	–			+	+	–		−27%	+37%	+19%
Illuminance	<500lx	500–750 lx	>750 lx				+	+			–		+
Personal control	No		Yes		+		+						
Satisfaction with lighting conditions	Dissatisfied employees		Satisfied employees		+		+			+			+

report an increase in *productivity* (21.7%), the ability to *concentrate* (12.7%), *mood* (25.3%), and a decrease in *fatigue* (29.4%) after implementation of dynamic glass instead of conventional manual shading (blinds). Additionally, to avoid glare, it is recommended to implement a lighting design that uses both direct and indirect lighting as these lighting systems are also found to positively affect employee *well-being* (Fostervold and Nersveen 2008).

Besides daylight, artificial light variations are studied, such as colour and illuminance. High correlated colour temperature (CCT) levels (>6500 K) refer to blue-white, bright, and cool colours and lower levels (<3000 K) to lower light levels and warmer yellow colours (Zhu et al. 2019). Studies found a 19.4% increase in *productivity*, 36.8% increase in *concentration*, and 26.9% decrease in feelings of *fatigue* after increasing CCT values from 2900 to 17,000 K (Mills, Tomkins, and Schlangen 2007). Furthermore, high levels of CCT lead to improved *sleep quality* and *mood* (Borisuit et al. 2015; Maierova et al. 2016; Partonen and Lönnqvist 2000; Tonello et al. 2019; Viola et al. 2008), reduced *stress* levels (Maierova et al. 2016; Tonello et al. 2019) and reduced feelings of *depression* (Partonen and Lönnqvist 2000) compared to dim light environments (<3000 K). Higher workspace illuminance levels (in lux) improve *sleep quality* (Boubekri et al. 2020; Kozaki et al. 2012), *mood* (Aries, Beute, and Fischl 2020; Tonello 2004; Zhu et al. 2019), *fatigue* (van Duijnhoven et al. 2018; Zhu et al. 2019) and *productivity* (Boubekri et al. 2020; Candido, Chakraborty, and Tjondronegoro 2019; Newsham et al. 2005). Standards on illuminance levels differ per country and range between 300 and 500 lx for the lowest acceptable limits (Zhang et al. 2020). However, illuminance levels of 500 lx are not fully optimal, as various studies show more positive results for even higher illuminance levels. Regarding *sleep quality*, Kozaki et al. (2012) indicate that, compared to 500 lx, *sleep quality* increases with levels of 750 lx. Positive effects of illuminance levels on productivity also do not occur until 750 lx (Boubekri et al. 2020; Candido, Chakraborty, and Tjondronegoro 2019; Newsham et al. 2005). In terms of *mood*, it is even found that illuminance levels of 800–1200 lx are associated with more positive moods compared to 200–500 lx conditions (Aries, Beute, and Fischl 2020; Tonello 2004; Zhu et al. 2019).

Last, the ability to individually control lighting conditions relates to *mood* (Newsham et al. 2005; Veitch and Newsham 2000) and *well-being* (Veitch et al. 2008; Veitch and Newsham 2000). It should be noted that, as indicated by Day et al. (2019), the ability to control

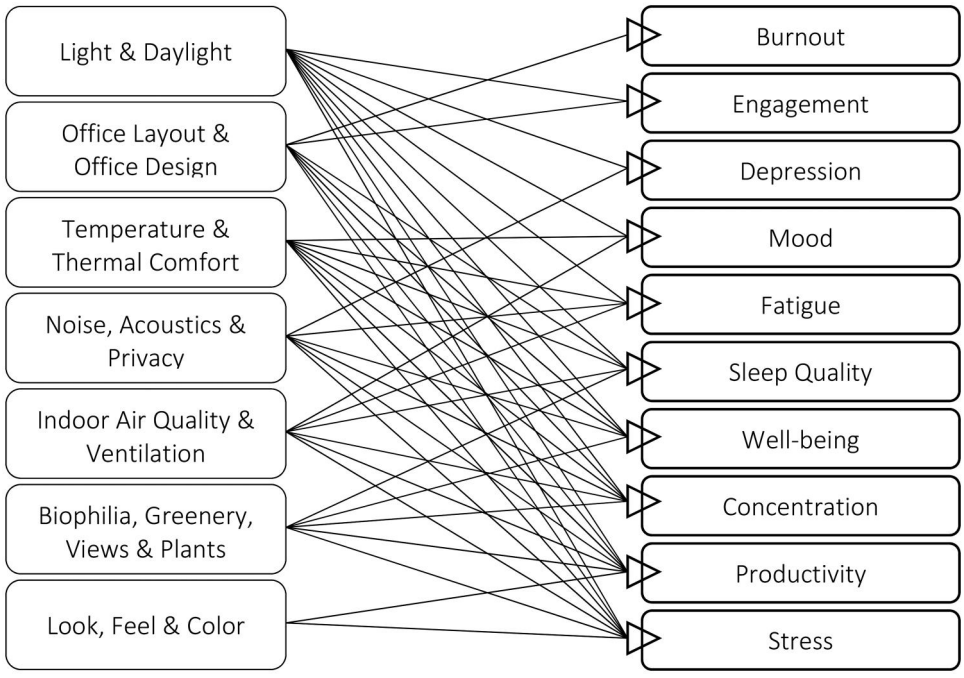

Figure 2. Overview empirical relationships.

workspace lighting appears to be more important than actually having to adjust the lighting. Furthermore, the positive effects of this aspect were only significant for situations where lighting conditions are not satisfactory (Veitch and Newsham 2000), indicating that personal control is only beneficial when workspace lighting conditions are rated insufficient. Moreover, personal control over the lighting conditions is the main predictor of overall satisfaction with workspace lighting (Day et al. 2019; Newsham et al. 2005, 2013; Veitch, Stokkermans, and Newsham 2013; Veitch and Newsham 2000), which positively correlates with employee *productivity* (Day et al. 2019; Lou and Ou 2019) *mood* (Veitch et al. 2008, Veitch, Stokkermans, and Newsham 2013), *well-being* (Veitch et al. 2008) and *engagement* (Veitch, Stokkermans, and Newsham 2013). Lighting research is a well-developed discipline, which is also reflected in the metrics that are used; 42 studies used at least some objective metrics (e.g. luminance, CCT) *vs.* 33 studies that were purely focussed on subjective metrics.

4. Discussion, implications, and limitations

The aim of this paper was to provide a holistic overview of the proven effects of office workspace design on mental health indicators. The 133 scientific studies that are analysed in this paper, differ in location, sample size, and office and organisation type, resulting in a broad selection of workspaces under study. This study is the first in providing such an overview with a pathogenic and salutogenic set of mental health indicators. Its results show that 'the physical workspace' relates to all mental health indicators with at least one of the seven physical workspace elements (see Figure 2). Figure 2 also makes clear that none of the physical workspace elements have empirically demonstrated relationships with all ten mental health indicators, although (day)light has been related to all except burnout. The detailed tables in the results section show that some workspace elements are related to mental health through different components (e.g., office layout/design, 10 components; (day)light, 9 components), while others seem to have more straightforward relations (e.g., look, feel, and colour, 1 component). This might indicate that the relationships of these latter physical workspace elements are either less complex or that there might just be a lack of research attention for these relationships so far. For example, office lighting has been a field of study for much longer than biophilia or interior design; especially in relation to employee (mental) health.

4.1. Implications for research and practice

Especially *stress*, *productivity*, and *concentration* have been proven to relate to the physical workspace in various ways and could thus be taken up in a workspace design intervention business case. Employee *productivity* research dominates this set of papers on mental health and workplace design, just like

organisational outcome measurement is often driven by performance. It still seems to be the holy grail of workplace research and the most sought-after approach to support a business case for investing in the office environment. This is despite the fact that it is hard to measure the individual productivity of knowledge workers and there are no existing validated scales to do so. Future research should focus on the measurement of productivity first, or at least prove that perceived productivity correlates strongly with objective measurements, before using it as a dependent variable. Stress on the other hand is one of the most often reported mental health-related problems in the workplace (Cartwright and Cooper 1997; Teasdale 2006) and can be assessed with a variety of validated measures. Attention for stress in physical workspace design studies (e.g. Vischer and Wifi 2017) and in the workspace management practice has been increasing too. Given the evidence found in this review for a variety of relationships between stress and productivity with elements of the physical workspace, a design intervention would have much potential to increase mental health indicators. Together with *fatigue*, studies on these indicators have also more often been able to provide percentages of improvements (although there are still differences between studies), which is in line with the often-quantitative approach of business cases in practice. In comparison, very few studies are available on *burnout, engagement*, and *depression* in relation to the physical workspace, and so far only links with light, layout, and acoustics have been shown. Therefore, the extent to which these mental health indicators are affected by the physical workspace is still less clear and more research is needed.

Especially improvements in *(day)light, layout design*, and *thermal comfort* have been shown to contribute to many different mental health indicators. Previously, Wiik (2011) already found that satisfaction with these workspace elements results in higher levels of *productivity*. The current study adds that these workspace elements may have an impact beyond mere productivity on a large amount of mental health indicators. Another contribution of this study to the existing literature, are the three identified value categories for each workspace component that can be used to support (identification of) improvement potential in existing buildings and future building designs. These insights can be used by workplace managers to understand how office design could be optimised to improve employees' mental health. In more traditional IEQ fields, such findings are already incorporated in standards (ISO, ASHRAE on noise, lighting, air, etc.), but for the spatial design and more decorative elements, this is not yet the case. This study can provide valuable input to create such standards. So, as a roadmap for future research, we suggest to first create validated scales to measure some of the ten mental health indicators that currently lack this. Perhaps some of them are so highly intercorrelated, that one general mental health scale could be developed. Next, the relationships in Figure 2 that are not yet present (or only studied a few times) deserve more research attention. In addition, a critical shortcoming of many studies is that they do not map the actual physical space in much detail (in terms of e.g., configuration, how it is used, etc.). This makes it difficult to discover with review studies like this one, whether certain effects might be limited to certain contexts. So, future studies must include more objective descriptions of the research context as well. Barriers to perform such studies are, amongst others, the increasing reluctance of office organisations (and their workers) to participate in extensive surveys, and the tightening of ethical and data protection regulations in universities, especially regarding studies on people's (mental) health.

4.2. Limitations

The current study has some limitations. First, the magnitudes of effects presented in this study are subject to subjective (e.g., personal preferences) and situational (e.g., local climate) factors and, thus, cannot be fully generalised. Effects can differ per person, for example, effects of light colour temperatures vary due to an individual's sensitivity to (bright) light (Maierova et al. 2016; Tonello et al. 2019), and also room colour perception is based on stimulus screening ability (e.g., the ability to block or neglect irrelevant aspects of the environment (Kwallek, Soon, and Lewis 2007). On top of that, some effects are expected to decrease over time as a result of familiarity and adapting to the workspace (Kwallek, Soon, and Lewis 2007). For some workspace elements, these individual differences are more pronounced than for others, so further research on the working of each workspace element's mechanism is warranted.

The optimal levels of all the workspace components should also be interpreted with care because of possible interrelations between components and even between elements, which this review has not incorporated. For example, CCT of artificial light can be dominant over daylight exposure (Mills, Tomkins, and

Schlangen 2007; Zhang et al. 2020), light can influence how office temperatures are perceived (Kompier et al. 2020), and office layout obviously relates to perceived noise and acoustics (Lee 2010). Moreover, current workspace quality levels could become outdated over time due to new research findings or the introduction of new technologies and should thus frequently be re-evaluated. Last, implementation costs of workspace interventions fell beyond the scope of this study but are essential to support decision-making regarding the prioritisation of interventions when optimising the physical workspace.

Since this study is the first in providing a detailed, holistic overview of physical workspace interventions in relation to mental health, its outcomes should be (cross)validated. Case studies are needed in which the identified workspace components are jointly monitored in combination with mental health measurements. Additionally, besides the physical workspace, mental health is also affected by for example organisational culture and leadership within an organisation (Adler et al. 2014; Garcia et al. 2017). It is therefore important to gain insights into the extent to which mental health can be improved by interventions in the physical workspace in comparison to interventions targeting psychosocial work factors. It would also be valuable for future research to conduct a similar analysis as the one presented in this study, but with a focus on the mental health—organisational performance relationship and combine these findings to substantiate the potential of physical workspace interventions for organisational effectiveness. Hopefully, this will eventually result in a perception of physical workspace interventions as a valuable investment rather than an expense.

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