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The physical office workplace as a resource for mental health – A systematic scoping review

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ABSTRACT

Previous studies indicated a potential influence of physical workplace characteristics (e.g. light, noise, air quality) on employees' mental health (e.g. stress, fatigue, or mood). Until recently, most workplace-context research had a pathogenic instead of a salutogenic orientation. In this systematic scoping review (PRISMA) ten indicators of mental health are taken as a starting point, including both mental well-being and -illness. This provides a more holistic exploration of methods, measures, and employee-workplace theories that explain how physical workplace resources promote employees' mental health. The directions of these relationships are also observed. Results show that some workplace characteristics are studied with many validated measures, while others appear less diverse or so far lack approaches with objective measures. Results show that some indicators of mental health (e.g. concentration, and stress) have frequently been related to indoor environmental quality (IEQ) (e.g. light and daylight), while others (e.g. burnout, engagement, and depression) have received less attention in relation to the physical workplace (especially to biophilia, views, look and feel). This review identifies important avenues for future research, potential objective and subjective measures for employee mental health in relation to the office workplace and calls for a more holistic approach to mental health at work.

1. Introduction

In 1996, the World Health Organization published the results of the first Global Burden of Disease study. This study indicated that mental illness was, and still is, one of the main disease burdens worldwide. Mental illness is considered as a worldwide public health issue [1], that can be approached with a pathogenic or salutogenic orientation [2]. In the western world, the pathogenic approach is mainly used, whereby the focus lies on determining mental disease and curing people who suffer from such diseases. Keyes [1] argued that a viable alternative to the pathogenic approach is the salutogenic approach, which focusses on the promotion of mental well-being in addition to the reduction of mental illness. The absence of mental illness and the presence of high mental well-being leads to flourishing, and together these aspects refer to positive mental health [3]. Mental health at work includes more than only the absence or presence of mental diseases; it also includes health-promoting or motivational factors [4]. According to the WHO, mental health can be defined as *"a state of well-being in which every individual realizes his or her own potential, can cope with the normal stresses of life, can work productively and fruitfully, and is able to make a contribution to his or her community"* [5, p. 10]. However, as several authors (e.g. Refs. [4,6,7]) have indicated, until recently, such an inclusive salutogenic approach has not been applied to the workplace context. Earlier workplace research mainly focused on negative outcomes, such as illnesses, risks and sick leave [7]. The emergence of the salutogenic approach and the positive psychology movement (defined as *"the study of the conditions and processes that contribute to the flourishing or optimal functioning of people"* [[8], p. 104]) demands a more holistic approach in research with both positive and negative mental health indicators related to the workplace.

Previous studies that explored well-being and mental health in the workplace context found heterogeneity in the use of these terms across different research fields [9]. Some studies have already tried to systematically review literature on the relationship between interior office space and employees' well-being, but they only used general terms to describe the workplace, such as 'office', 'workplace design' or 'architecture'. Therefore, they only identified 18 papers [4] or 50 papers [10], missing works on detailed studies of, for example, noise or light that do not use these terms. Others did include such studies, but only reviewed works in four journals [11]. Such studies have identified that most

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papers in their review focussed on the relationship between one physical workplace characteristic and health instead of a more holistic approach of the physical workplace [11]. This indicates that measurements of healthy physical workplace characteristics have, until today, not been identified holistically to fully evaluate the workplace's impact on employees' mental health and well-being.

The physical work environment consists of all objects and stimuli that employees encounter in their work [12]. Roskams and Haynes argued in this regard that *"the workplace environment is a complex psychophysical system encompassing not only the objective physical stimuli within the workplace but also the ways in which these stimuli are subjectively perceived by the individual occupants"* [6, p. 142]. The effect of the physical workplace on employees' mental health thus depends on individuals' psychological and physiological responses to physical workplace characteristics [13]. As Sander et al. [12] explained, employees' reactions to the physical work environment can be assessed by their cognitive, emotional and relational responses to the whole office environment or to specific characteristics. These characteristics can be divided into resources (i.e. salutogenic) and demands (i.e. pathogenic), based on the way they might affect employees' mental health [6]. While salutogenic workplace characteristics could improve positive aspects of employees' mental health, such as their productivity, engagement or recovery from stress, environmental demands could cause an increase in negative outcomes, including stress [6].

The present paper therefore aims to demonstrate the broad impact of the physical office on employees' mental health from a holistic perspective. First, it introduces ten indicators of mental health, namely well-being, stress, depression, engagement, burnout, concentration, fatigue, mood, sleep quality and productivity, that even go beyond the definition of the WHO [5]. These indicators include both mental illness indicators (e.g. depression, burnout, fatigue) and salutogenic mental well-being indicators (e.g. mood, productivity, engagement, concentration). Although productivity does not depend on individuals' mental state only (also supervisor support, equipment, and much more), philosophical researchers do claim that "*positive mental health is good mental functioning, meaning that a healthy human mind is one that performs certain designated functions*" [6, p. 6]. As performance is considered an important component of human flourishing and included in the WHO definition of mental health, perceived productivity has been included as a salutogenic indicator. Then, previous research is systematically reviewed to identify the used methodologies, measures, employee-workplace theories, and the direction of significant relationships between a broad range of physical office environment measures and all these mental health indicators. These insights could be used by future researchers to expand current knowledge about the influence of physical workplace characteristics on employees' mental health through more complete approaches and a careful selection of appropriate measures. This knowledge could then be used in practice by workplace managers worldwide to develop workplace strategies to support their employees' mental health more optimally.

2. Indicators of mental health

The (mis)match between individual resources and environmental demands could define an individual's mental health. As Roskams and Haynes [6] proposed in their extension of the well-known Job Demands-Resources Model [15] (i.e. the Environmental Demands-Resources model), two underlying psychological processes can be identified, namely a health-depleting process and a motivational process. The health-depleting process (i.e. mismatch) is initiated by environmental demands (i.e. pathogenic) that could cause both short-term reversible consequences and long-term irreversible consequences for employees' mental health [14]. Short-term, reversible consequences include the experience of stress or fatigue [16,17], where fatigue has been defined as a feeling of tiredness or exhaustion due to insufficient sleep or to longer periods of stress [18]. As a result of short-term fatigue, people are unable to concentrate or focus attention on their job [19]. Employees can no longer direct their cognitive resources to one single object or goal and cannot adequately meet their job demands [20,21].

While short-term work fatigue is reversible (i.e. it can dissapear after a period of rest), long-term fatigue is irreversible, and can lead to sick leave and work disability [20]. Long-term fatigue involves extreme tiredness (i.e. the lack of energy), and reduced functional capacity (i.e. the lack of engagement in activities) [22]. Consequently, long-term fatigue might affect people's sleep quality and their well-being [23], and could also lead to reduced productivity (i.e. *"the relationship between forecast and executed work"* [24, p. 217]) and increased burnout complaints [16,17]. Some authors (e.g. Ref. [25]) have measured burnout by two components, namely exhaustion and disengagement from the job, while others (e.g. Ref. [26]) have argued that burnout consists of emotional exhaustion, depersonalization and lack of personal accomplishment. Feelings of exhaustion, caused by high environmental demands, could contribute to reduced job effort, productivity and engagement [17]. Other long-term consequences of high environmental demands include feelings of depression [27].

While the health-depleting process is initiated by environmental demands (i.e. pathogenic), the motivational process is initiated by environmental resources (i.e. salutogenic) that could contribute to short-term consequences, such as a positive mood, and long-term consequences, such as work engagement [17,28]. Mood can be described as a feeling with varying intensity and duration, with no specific cause or direction [29,30]. Positive affect (e.g. feeling happy, joyful and pleasant) and negative affect (e.g. feelings of depression, unhappiness, anger and anxiety) describe mood states that can be used to understand how one feels [31,32]. Both positive and negative affect, as well as cognitive evaluations of life (i.e. life satisfaction) describe hedonic/subjective well-being (i.e. positive human functioning) [33]. In contrast, eudaimonic aspects of well-being concern positive human functioning, such as purpose in life, self-acceptance and autonomy [34]. Seligman [35] argued that well-being requires both hedonic and eudaimonic components, namely positive emotion, relationships, meaning, accomplishment, and engagement. Work engagement can, in addition, be defined as a positive, fulfilling state of well-being at work [36], which consists of three dimensions, namely vigour (i.e. high levels of energy), dedication (i.e. sense of inspiration or pride) and absorption (i.e. high levels of concentration and being engrossed in work) [37]. Engaged individuals are highly involved in professional activities which enhances a sense of contribution or efficacy to the job [38]. So, as an extension of the WHO definition [5], ten indicators of mental health in the office workplace are introduced: well-being, stress, depression, engagement, burnout, concentration, fatigue, mood, sleep quality and productivity.

3. Method

For this systematic scoping review the PRISMA (Preferred Reporting Items for Systematic reviews and Meta-Analyses) guidelines were used. PRISMA supports authors to report the results of systematic reviews and meta-analyses in a complete and transparent way. The PRISMA checklist can be used to improve the transparency of the review process [39]. This section introduces the eligibility assessment to select the sample of studies that was deduced from the initial database of papers.

3.1. Search strategy

Reviewed papers were generated from the multi-disciplinary citation database Scopus. Papers were selected based on combinations of terms referring to the physical office environment and mental health aspects in either the title, abstract or keywords (see Fig. 1). For the physical office characteristics, seven of the eight categories as introduced by Al Horr et al. [40] were used, namely office layout and design, light and

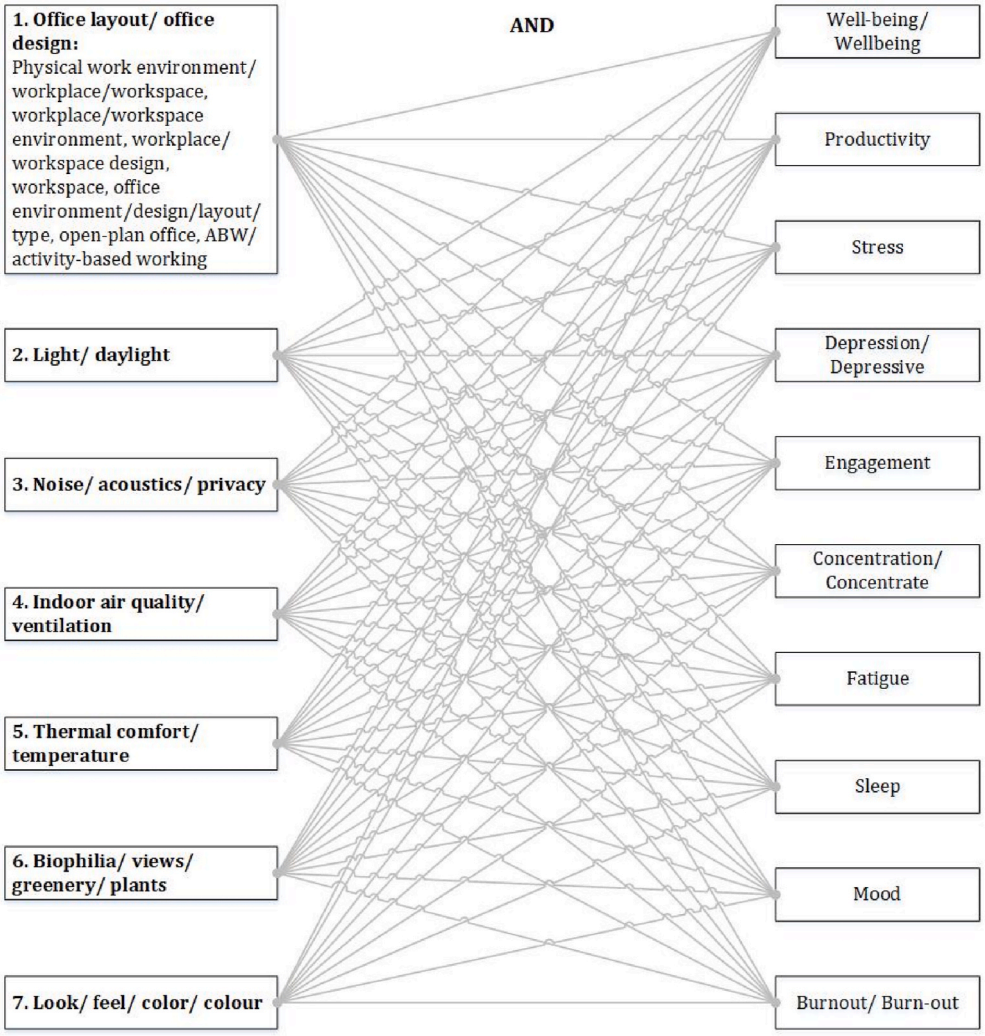

Fig. 1. Search strategy.

daylight, noise, acoustics and privacy, indoor air quality and ventilation, thermal comfort and temperature, biophilia, views, greenery and plants, and look, feel and colours. The category 'Location and amenities' was not included since it does not refer to the physical workplace itself but to its surroundings. The terms referring to the physical office environment were combined with each of the ten mental health indicators introduced in the previous section. For the physical workplace terms in categories 2–7, the word 'office' was added, to ensure records to be related to the office environment. For example, a search term would be; 'light' AND 'depression' AND 'office'.

Only articles written in English and published between 1990 and 2020 were selected. Articles written before 1990 were excluded, because office environments underwent substantial developments. During the 1990s, new technology interventions promoted the development of new and modern office types [41]. Paper searches were conducted between March and December 23rd, 2020, initially resulting in 3695 papers.

3.2. Study selection

The initial database was screened and reviewed in three phases (see Fig. 2). During all three screening phases eligibility criteria were used. The eligibility assessment was performed by the first author, who screened the papers based on inclusion and exclusion criteria which were set by all authors of this article. Studies were included if they: (1) reported one of the physical workplace characteristics (left side of Fig. 1); (2) were conducted in an office environment with adults (also including laboratory settings that mimic an office workplace); (3) measured a specific outcome related to mental health (right side of Fig. 1); (4) were empirical studies, including longitudinal, prospective and cross-sectional designs; and (5) had full-text articles available in English. Papers were excluded if they; (1) were performed in a hospital, school, factory or other space not being/mimicking an office environment; (2) did not measure a specific outcome related to mental health; (3) were theoretical papers, (technology) reviews or proceedings; or (4) were not fully available in English.

Duplicates and papers unable to retrieve were deleted, which resulted in 3497 papers. In the first screening phase, the titles were scanned to exclude irrelevant papers, which decreased the list to 862 eligible papers. Papers with unclear titles were not initially excluded. The abstracts of these papers were read in the second screening phase, which led to the exclusion of another 436 papers, unrelated to the physical office environment. In the third phase, the full text of the remaining 426 papers was read, which led to the exclusion of another 293 papers. These papers were mainly deleted because the described research methods were not transparent, could not be reproduced or because the mental health indicators mentioned in the abstracts were not further investigated in the full article. The remaining 133 papers were screened again by all authors to ensure they met all the eligibility criteria, which they did. All authors also checked whether important

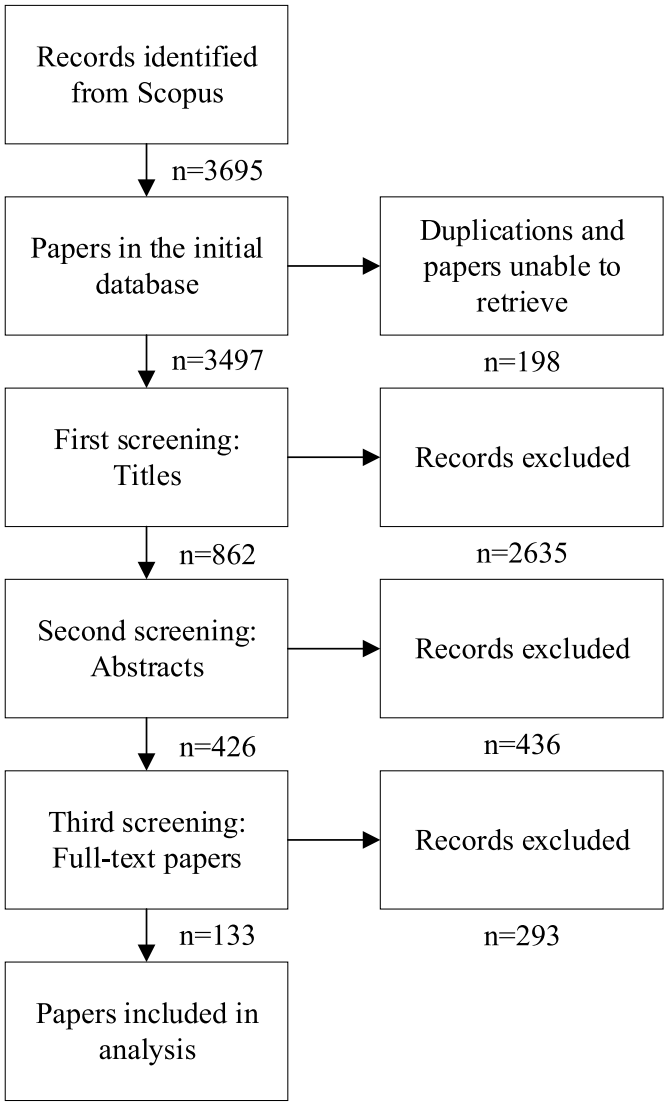

Fig. 2. Screening process overview.

contributions to the field of mental health in the office environment were missing in the remaining database.

3.3. Data synthesis and analysis strategy

A data collection sheet was developed to extract information from the 133 papers. Information was extracted from each included paper on (1) general paper information (i.e. country, journal, year of publication, office type); (2) the research approach, time horizon and methods; (3) the size of the sample and the number of buildings or offices included in the study; (4) the layout of the office environment in which the study was conducted; (5) the physical workplace characteristics that were included; (6) the mental health indicator that was measured in the study; and (7) the direction of the relationship between the physical office characteristic and the mental health indicator.

The synthesized data were analysed content-wise in Excel, by first counting the number of studies that used a specific type of research approach, time horizon or method, mental health indicator, and physical office characteristic, and calculating the average sample size and the number of buildings/offices included. Then, the measures of the mental health indicators and physical office characteristics were divided into objective and subjective, and in different research strategies. In addition, the direction of the relationships between physical office characteristics and mental health indicators were identified. Based on all findings, conclusions and recommendations for future research were drawn.

4. Results

4.1. General paper information

The 133 studies were performed in 33 different countries; mainly in the USA (15.8%), UK (12.1%), Canada (10.5%), Sweden (8.3%), Australia (6.0%) and the Netherlands (5.3%). Only five studies included multiple countries, both in Europe and in the USA. The papers were published in 52 different journals: particularly in *Building and Environment* (11.3%), *Journal of Corporate Real Estate* (6.8%), *Journal of Environmental Psychology* (6.0%), and *Lighting Research and Technology* (6.0%).

Although the link between workplace design and mental health has been studied throughout the 30-year search period, there is a clear rise of interest in the last few years (see Fig. 3). Furthermore, the mean sample size of the papers' data-collections equals 887, with 7 people (a study of a lab-mimic of an office workplace) being the lowest and 25,947 (an online survey of office workers) being the highest. The mean number of office buildings being studied equals 11, with 1 being the lowest and 191 being the highest.

Only 56% of the studies indicated the office type at which data were collected. When classified according to Bodin Danielsson and Bodin [42], most of those studies (86.5%) looked at open-plan offices. Another 52.7% looked at cellular offices, followed by studies on shared room offices (27.0%). Only 18.9% of the studies looked at flex offices (open-plan offices with free seating and back-up space for concentrated tasks and meetings), and 5.4% combi-offices (similar to flex offices, but with dedicated seating [30]). Because in some studies two office types were compared, the summed percentage is higher than 100%.

4.2. Methodologies used

The research methodologies used in the papers were categorized according to the layers of the Research Onion (see Ref. [43]). The layers of the onion provide a detailed description of the stages of a research process, namely the time horizon, the methodological choice, and the research strategy. The time horizon describes the time that is needed to complete the research. The methodological choice layer describes the nature of the techniques and procedures that are chosen by the researcher to perform the study, which can be quantitative or qualitative. The research strategy layer of the onion defines how the researcher intends to perform the study [43].

The time horizon layer consists of longitudinal research, prospective research, and cross-sectional research. A longitudinal approach, that includes one pre-test and at least two post-tests [10], has been used in 49.6% of the reviewed papers. In 10.5% of the studies a prospective time horizon was used, meaning that one pre-test and one post-test were performed [10]. The remaining 39.8% of the studies used a cross-sectional approach, in which a particular phenomenon at a particular time is observed [43].

The methodological choice layer of the onion is divided in quantitative, qualitative, and mixed method approaches. Most studies (88.7%) used a quantitative approach, in which data are analysed using statistical methods. Only 3.0% had a qualitative approach, and 8.3% a mixed method approach.

The research strategy layer is divided in experiments, interviews, and surveys. In experiments, causal links between variables are studied [43]. Three types of experiments were distinguished: field experiments, laboratory experiments, and natural experiments. Field experiments were performed in 30.1% of the papers, to test hypotheses by manipulating an independent variable [44]. A laboratory setup was used in 10.5% of the papers. According to Festinger and Katz [45], in a laboratory experiment

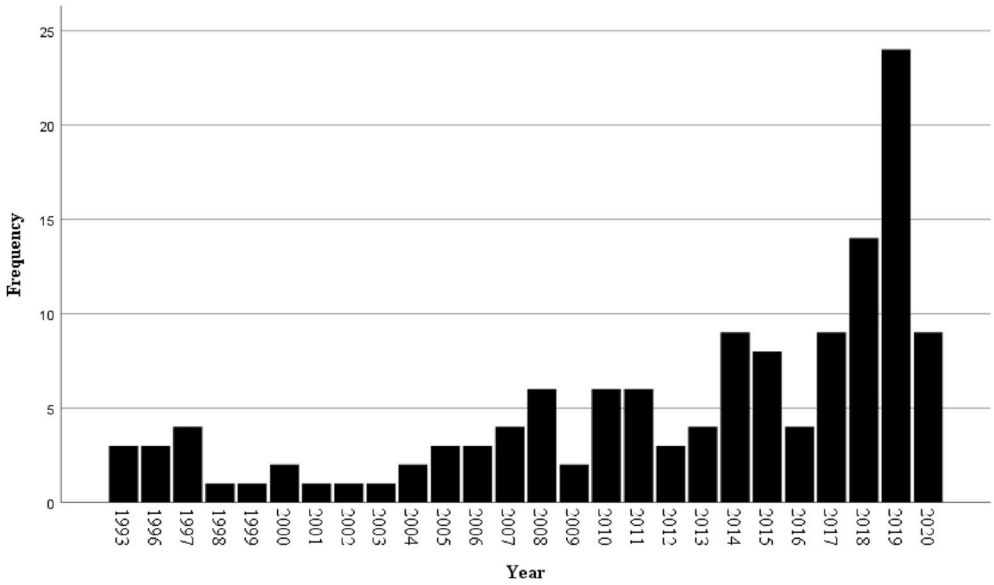

Fig. 3. The year of publication.

the environmental conditions can be controlled, and the variables studied can either be controlled or manipulated. In 5.3% of the studies a natural experiment was performed. Natural experiments are conducted in everyday environments, in which the experimenter observes the randomly occurring comparison of a treatment group with a control group. In these experiments, the experimenter has limited control over the independent variable [44,46]. Most studies (97%) used a survey, which allows the collection of quantitative data that can be analysed quantitatively to observe the significance of relationships between variables [43]. Another 8.3% of the studies used interviews between two or more people to gather qualitative data [43].

4.2.1. *Physical workplace characteristics*

Fig. 4 shows the frequency of the physical workplace characteristics that have been addressed in the studies. Many studies focused on light and daylight (54.9%), indoor air quality and ventilation (36.8%), and noise, acoustics, and privacy (36.8%). Less studies focused on biophilia and views (20.3%) and look and feel (9.0%). Subjective measures were used most frequently (see Fig. 4). Subjective measures include individual perceptions that could change continuously, while objective measures are independent of individuals' perceptions or social phenomena [43]. Some studies used both, especially when studying indoor environmental quality aspects (e.g. light and daylight, or noise, acoustics, and privacy).

Table A (see Appendix) indicate that a large variety of objective and subjective measures were used for IEQ characteristics (e.g. thermal comfort and temperature), while a smaller variety of objective measures was used for the more 'tacit' workplace characteristics (i.e. office layout, looks and feel, and biophilia and views outside). These characteristics were more frequently measured subjectively, although some studies also used objective measures (e.g. work area per person [47], number of plants [48], or colour intensity [49]). Objective measures are usually obtained through building sensors or wearable/actigraphy devices (e.g. Refs. [50,51]). Sensors are used to obtain continuous measurements of ambient conditions, including relative humidity, carbon dioxide level, particulate matter, indoor air temperature, and illuminance levels (e.g. Refs. [51,52]). Actigraphy devices could be used to measure the amount and duration of light illuminance (e.g. Refs. [53,54]). Both sensors and

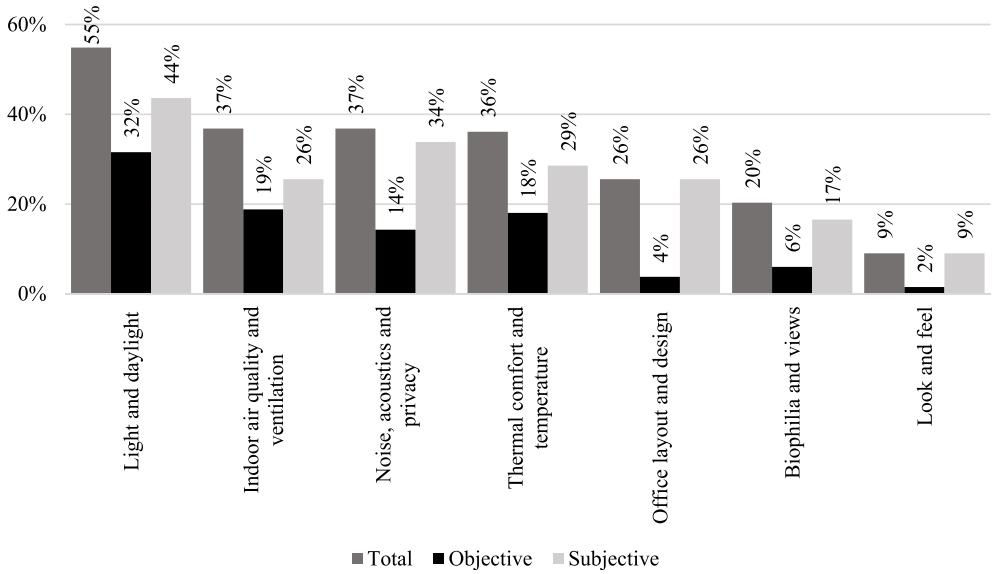

Fig. 4. The frequency of physical workplace characteristics.

wearables are frequently applied in field and laboratory experiments.

Fig. 5 divides the studies according to research strategy. It shows that laboratory experiments have been performed relatively frequently for the characteristic light and daylight (15.1%), while field experiments have more often been performed for the characteristic biophilia and views (29.6%). Overall, surveys have been used most frequently for all physical workplace characteristics. Examples of frequently used surveys include WODI [55–57], BUS [58–63] or BOSSA [64,65].

4.3. Indicators of mental health

Fig. 6 shows how often the mental health indicators were addressed. It indicates that productivity was measured most frequently (42.1%), followed by concentration (26.3%), stress (24.8%) and sleep quality (24.8%). Table B (see Appendix) shows that most mental health indicators were measured subjectively, by asking participants about their experience, feelings, or satisfaction. In line with this, Fig. 7 adds that for all mental health indicators, surveys were used most frequently. In surveys, reoccurring, validated measurement scales could be used, such as the Positive and Negative Affect State (PANAS) (e.g. Refs. [50,66]), Copenhagen Psychosocial Questionnaire (COPSOQ) (e.g. Refs. [67,68]), Pittsburgh Sleep Quality Index (PSQI) (e.g. Refs. [69,70]) and Karolinska Sleepiness Scale (e.g. Refs. [71,72]). However, in other surveys no validated measurement scales were used (e.g. Refs. [73–75]). Although Table B shows that there are several scales for the mental health indicators, only some of these scales were applied by more than one author. The internal validity of such scales is questionable, and should therefore be checked before applying them in new research [76].

In some studies, mental health indicators were measured objectively, such as physiological stress, task performance or sleep patterns (see Table B). The exposure to stress could cause physiological changes in the human body, such as increased heart rate or blood pressure [77]. These physiological changes can be measured by pulse rates [78], skin conductance level, or skin conductance response (i.e. measure of emotional or sympathetic responses) [50]. Performance measures consist of quantitative measurements that could be used to determine mental, cognitive and visual aspects of work [79], such as typing tasks [79,80], Stroop tests (i.e. report colour of target word) [66,72], or proofreading tasks (i.e. identify spelling errors in text paragraphs) [60,81]. Sleep patterns are identified based on people's heart rate, respiration rate, and movement. With these measures, people's total sleep time, sleep onset (i.e. when an individual falls asleep), sleep onset latency (i.e. time to fall asleep), bedtime, or wake time are calculated [50]. These measures could be used in experimental setups. Fig. 7 shows that field experiments were addressed relatively frequently for burnout (66.7%), sleep quality (57.6%), and fatigue (41.2%). Laboratory experiments were performed relatively often for mood (29.6%), engagement (28.6%) and depression (23.1%). Natural experiments and interviews were, overall, less often applied.

4.4. Direction of relationships between physical workplace characteristics and mental health indicators

Table 1 indicates the number of studies that addressed a specific physical workplace characteristic in combination with an indicator of mental health. Since some papers discussed multiple mental health indicators or physical workplace characteristics, the sum of the total number of papers (most right column and bottom row) is higher than 133. While almost half of the studies included measures of productivity, especially in relation to indoor air quality and ventilation, thermal comfort and temperature, and office layout and design, only a few studied depression, engagement, or burnout in relation to the physical work environment.

Table C (see Appendix) shows the expected directions of relationships between the physical workplace characteristics and mental health indicators. The authors of this paper did not attempt to provide a full overview of all directions of relationships and effect sizes but aimed to provide first insights of these directions that were described in the reviewed papers. Upward arrows indicate increased mental well-being or illness (i.e. increased productivity, concentration, stress, sleep quality, mood, well-being, fatigue, depression, engagement and burnout), and downward arrows indicate reduced mental well-being or illness. The zero indicates that a relationship is insignificant.

First, for light and daylight it was found that increased exposure to daylight could increase employees' productivity, sleep quality, mood, and reduce fatigue. As Boubekri et al. [70] argued, it is important to optimize the access to daylight to increase employees' mental health. Next to increased daylight, previous research also showed that increased illuminance, higher circadian stimulus (CS) values (i.e. the effectiveness of a light source in providing circadian stimulus [82]) and increased correlated colour temperature (CCT) values (i.e. cooler colours [83]) could increase employees' productivity, concentration, sleep quality,

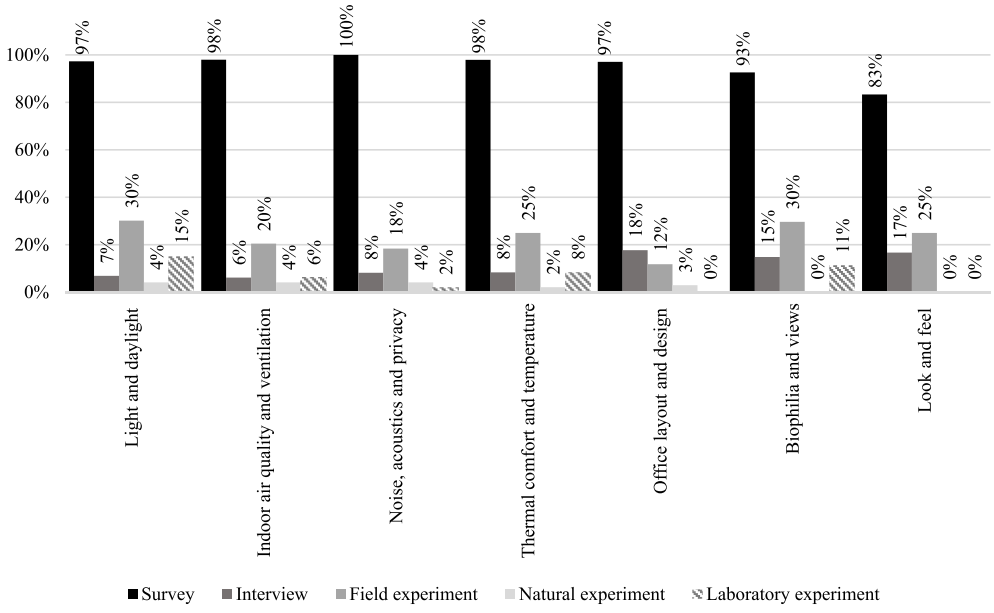

Fig. 5. The frequency of research strategies per physical office characteristic.

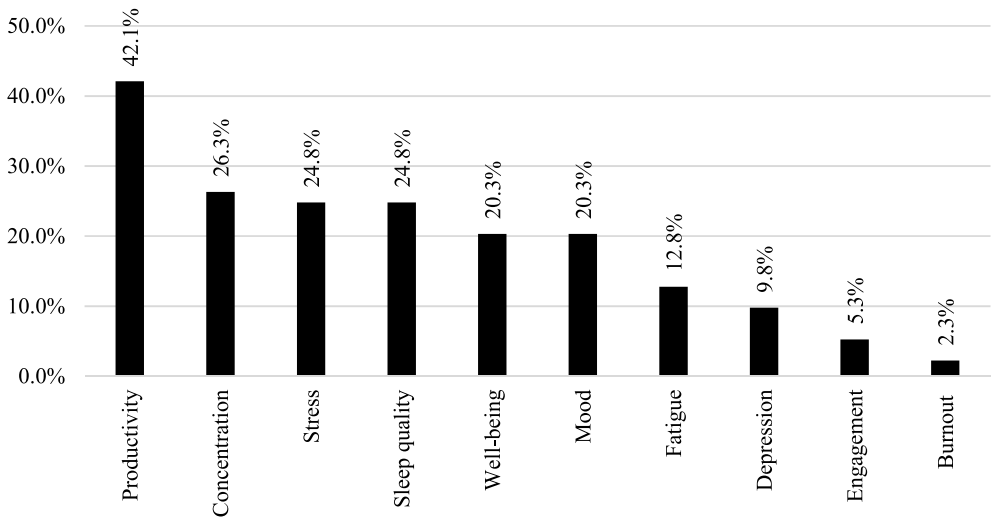

Fig. 6. The frequency of measuring mental health indicators.

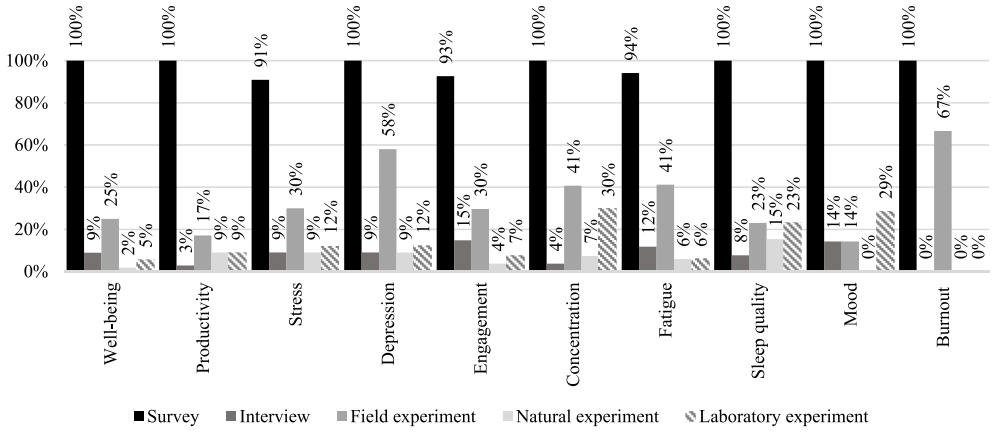

Fig. 7. The frequency of research strategies per mental health indicator.

Table 1
Physical workplace characteristics vs. mental health indicators.

	Productivity	Concentration	Stress	Sleep quality	Mood	Well-being	Fatigue	Depression	Engagement	Burnout	Nr. of papers
Light and daylight	26	13	11	28	23	6	5	9	3	0	73
	35.6%	17.8%	15.1%	38.4%	31.5%	8.2%	6.8%	12.3%	4.1%	0.0%	
Indoor air quality and ventilation	29	14	7	7	4	6	10	2	2	0	49
	59.2%	28.6%	14.3%	14.3%	8.2%	12.2%	20.4%	4.1%	4.1%	0.0%	
Noise, acoustics and privacy	28	16	11	7	5	10	5	4	4	1	49
	57.1%	32.7%	22.4%	14.3%	10.2%	20.4%	10.2%	8.2%	8.2%	2.0%	
Thermal comfort and temperature	31	12	4	9	4	5	7	3	2	0	48
	64.6%	25.0%	8.3%	18.8%	8.3%	10.4%	14.6%	6.3%	4.2%	0.0%	
Office layout and design	24	7	6	2	1	5	0	3	4	2	34
	70.6%	20.6%	17.6%	5.9%	2.9%	14.7%	0.0%	8.8%	11.8%	5.9%	
Biophilia and views	12	6	10	3	3	6	1	4	3	0	27
	44.4%	22.2%	37.0%	11.1%	11.1%	22.2%	3.7%	14.8%	11.1%	0.0%	
Look and feel	7	1	2	0	3	2	1	0	0	0	12
	58.3%	8.3%	16.7%	0.0%	25.0%	16.7%	8.3%	0.0%	0.0%	0.0%	
Nr. of papers	56	35	33	33	27	27	17	13	7	3	

mood, well-being and reduce fatigue, depression, and stress. Both daylight and artificial light contribute to individuals' daily light exposure, which could enhance their mental health [71]. Table C also indicates that most studies used CO_2 concentration and ventilation rate as indicators of the indoor air quality and ventilation. Suboptimal air quality and ventilation conditions could reduce individuals' productivity, concentration, and increase stress and fatigue. As Reijula and Sundman-Digert [84] pointed out, issues of indoor air quality should be

considered, since they could negatively affect people's (mental) health.

Furthermore, Table C shows that the characteristic noise, acoustics, and privacy was measured by the background noise and acoustic privacy at the office. Increased background noise and reduced acoustic privacy were related to reduced productivity, concentration, well-being, and increased stress and fatigue. Although employees prefer to work in a vibrant work environment [85,86], disturbing background noise (e.g. ringing phones or conversations) could negatively influence individuals' mental health (e.g. Refs. [85,87]). For thermal comfort and temperature, it was found that temperatures below or above 20–24 °C and a relative humidity below or above 40–55% could decrease an individual's productivity, concentration, sleep quality, mood, and well-being, and increase fatigue and stress. For example, Jamrozik et al. [88] found that too cold office temperatures were uncomfortable and hindered employees to work (e.g. difficulties with typing).

For office layout and design, it was found that private offices could stimulate productivity and concentration and reduce stress, while open-plan offices could reduce productivity and concentration and increase stress (e.g. Refs. [55,89,90]). Furthermore, activity-based working (ABW) (where employees can switch between workplaces that are designed for specific activities and tasks [65]) might increase productivity and well-being and reduce stress. Candido et al. [91] argued that ABW strategies could promote employees to perform their tasks in suitable environments, that also suit their personal preferences with regard to IEQ factors such as light, noise and temperature. Furthermore, plants in the office and the satisfaction with views outside were mainly used as indicators of biophilia and views. The presence of plants could increase employees' productivity, concentration, and well-being, and could reduce stress and depression. However, some studies (e.g. Ref. [92]) indicated that too many plants were perceived as chaotic and uncomfortable, and should therefore be prevented. Views outside, specifically natural outdoor views, could increase productivity and reduce fatigue and stress. Finally, blue and white room colours were found to have a small positive effect on productivity, mood and stress. However, as Kwallek et al. [49] pointed out, the effect size of colour depends on individuals' stimulus screening ability (i.e. ability to block or neglect irrelevant aspects of the environment) and should therefore be considered with care.

4.5. Workplace theories

Table D (see Appendix) shows the workplace theories, models and frameworks that were found in the included studies. Theories can be used to explain or examine how a workplace element affects an outcome [93]. Previously, different theories, models and frameworks were introduced to explain comparable relationships between workplace elements and outcomes. However, theories have not been used sufficiently, and might therefore not clearly depict "the complexity of the entire employee-workplace ecosystem" [94, p. 653]. The following subdivision in theories describing the employee-workplace relationships was made. First, person-environment theories relate to the (mis)fit between the environment and the individual. While a high-quality work environment could promote mental well-being, a suboptimal work environment could lead to stress [95]. Next, several theories explained the relationship between job demands and -resources. Job resources might buffer the negative effects of job stress due to high job demands, and might also affect engagement, exhaustion and productivity [67]. Furthermore, several arousal theories explained that the presence of others could create arousal that is necessary for individuals' performance of routine tasks, while too much arousal could decrease performance of more complex tasks [96]. In addition, natural theories explained the influence of natural elements in the work environment, that could restore individuals' attention on the job [59]. Finally, two remaining theories were found, that were not classified. While the Broaden-and-build Theory focuses on the cumulative positive effect of emotions on health [97], the Self-determination Theory explains how competence, autonomy, and relatedness help to explain individuals' engagement [97].

5. Discussion

This systematic scoping review identified 133 papers that discussed the relationships between the physical office environment and mental health. The results indicated that most papers addressed the traditional indoor environmental quality (IEQ) aspects, such as light, noise, indoor air quality and temperature, and that the more 'tacit' aspects of the work environment, such as views outside, biophilia and look and feel (including colours) were addressed less frequently. In general, IEQ studies have a longer history in healthy buildings research [98,99]. For instance, all eight reviewed papers that were written before 2000 addressed indoor air quality and ventilation and five of them addressed thermal comfort and temperature. Only one contribution that was written before 2000 addressed look and feel (i.e. colours) [100], while there were no papers of this age that addressed biophilia, greenery, or views outside. Although these 'tacit' aspects have not been explored as much yet, they can have a significant influence on mental health. For instance, Kaplan [101] argued that the experience of natural environments can help to mitigate or recover from stress. Flowers and green plants in an office can lead to improved mood and reduced feelings of stress [102,103]. One of the few studies that addressed look and feel showed that the shapes, colours and textures of an office could affect employees' productivity and mood [100]. Thus, current research field could be advanced by exploring the possible effects of these 'tacit' aspects (e.g. natural colours, plants, flowers, natural views outside) on mental health in more depth.

The limited number of studies that have investigated mental health indicators, such as burnout and engagement, while also considering physical workplace characteristics indicate specific research gaps (e.g. look and feel – engagement, depression and burnout, or light and daylight – burnout) for follow-up research. However, the influence of physical workplace characteristics on depression, engagement, and burnout might be small or indirect. As Appel-Meulenbroek et al. [104] indicated, workplace characteristics (incl. distractions and office comfort) are indirectly related to burnout and engagement, mediated by situational factors (incl. overload, recognition and control). This study, which was published after the screening process of current review was completed, confirms the expectation that engagement and burnout depend on social workplace characteristics, management style, organisational culture or on personal/personality characteristics (e.g. Ref. [105]). For instance, engagement depends on employees' social work context, including their feelings of psychological safety, status, and interactions with colleagues or supervisors [106]. Burnout and engagement depend on employees' personality, with neurotic employees being more likely to experience burnout complaints, and conscientious employees being more likely to be highly engaged [106]. Therefore, future studies could explore whether the relationship between physical workplace characteristics and mental health indicators is moderated by personal- or social workplace characteristics.

This paper has also systematically reviewed research approaches used to identify the relationships between physical workplace characteristics and indicators of mental health. Results confirm that the vast majority of workplace-related research has been conducted in traditional Western countries (e.g. USA, UK, Sweden, and the Netherlands) and findings might thus not be valid for other parts of the world. There is a clear tendency towards longitudinal research that allows the comparison between pre- and post-change. Almost all studies used surveys, which might be plausible, considering that mental health is based on human perceptions and feelings, which could best be measured through surveys [107].

More surprisingly, eight laboratory experiments were found, which investigated artificial light or daylight in relation to mood. Although it might be easier to adapt lighting conditions under highly controlled

laboratory conditions, only temporary light effects can be measured [108,109] and changes in mood might be caused by experimental stimuli rather than by lighting conditions [110]. As Jamrozik et al. [51] have recommended, a living lab experiment (i.e. real-world office environment that is occupied by employees for a longer period) can be a viable alternative to laboratory and field experiments, in which people's reactions (including health outcomes) to different environmental conditions can be examined. Another alternative would be to design three-dimensional virtual office environments that could simulate interactive real-life environments. VR allows people to experience a simulated world and to interact with it. VR experiments allow the real-time measurement of participants' psychological and physiological responses to certain situations [111]. Future research could explore whether living lab experiments or VR experiments are viable alternatives to study the influence of the physical office environment on employees' mental health. In addition, the use of objective instead of subjective physical office measures should be promoted, to guarantee a more sophisticated comparison between research outcomes.

Finally, first insights in the direction of relationships between physical workplace characteristics and indicators of mental health were explored. It was found that exposure to daylight and artificial light, optimal CO_2 concentration and ventilation rate, a balanced background noise and sufficient acoustic privacy, temperature and relative humidity within acceptable boundaries, the ABW strategy, plants and natural views outside, and white and blue colours on the walls were all, to some extent, related to indicators of mental health. As an extension of the WHO and salutogenic perspective [1,4], the current study provided first insights in how the work environment should best be designed to promote recovery from mental illness (e.g. work stress) and mental well-being in a holistic way. These insights can be used by workplace managers to optimize workplace strategies to promote mental health.

5.1. Strengths and limitations

The strengths of this review include the systematic approach that was chosen, which supports reporting results in a transparent way. In addition, the use of a data collection sheet with eligibility criteria ensures that all relevant papers were systematically reviewed, and irrelevant papers were discarded. As a result, a transparent overview of the relevant papers remained. The contribution of this paper is threefold, by 1) identifying important avenues for future research, 2) providing lists of objective and subjective measures of employee mental health in relation to their office workplace, and 3) calling for a more holistic approach to mental health combining a salutogenic and pathogenic standpoint. Clearly, the office workplace has been shown to affect employee mental health from both these standpoints and it would thus be interesting to study more holistically how the full workplace-employee mental health mechanism can be optimised.

It should be noted that each of the studies has been performed in a specific context (e.g. country, office, and sample) and can therefore not easily be compared or copied to a different context. These context-specific aspects should be considered, to be able to decide how relevant the findings are for the setting at hand and whether the results can be generalized. As the context is not always clearly reported, this review could not make context-specific inferences. In addition, the quality of the included studies has not been assessed, which means that the identified research gaps cannot be linked to the research quality. Also, this systematic review provided only first insights into the direction of relations between mental health indicators and the physical work environment and did not include effect sizes of these relationships.

Last, to minimize the number of hits during the search period, only empirical studies (i.e. longitudinal, prospective, and cross-sectional designs) were selected, while theoretical papers, reviews, and proceedings have been left out. Search terms might also have limited the papers that were found. For instance, search terms such as sunlight or natural environment might also have resulted in valuable contributions (e.g. Refs. [112,113]). It is therefore possible that some relevant studies were not included in the current review. In addition, a salutogenic approach might call for an unlimited number of positive mind aspects, that could not all be included here. For example, job satisfaction might be considered but was not included, for its extensive research field which would have 'clouded' the insights in the currently used more health-related indicators.

6. Conclusion

This systematic scoping review has listed current empirical research on physical workplace characteristics and employees' mental health. The study has outlined that most physical workplace characteristics have been studied in relation to all ten mental health indicators. However, important research gaps remain, especially with regard to the more "tacit" workplace characteristics. Researchers could benefit from this study because of its overview of research gaps that could be addressed and measures that could be used, while workplace managers in practice are informed about potential workplace design characteristics that they might not have been aware of.

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Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix

Table A
Measures physical workplace characteristics.

Objective measures		Subjective measures	
Office layout and office design			
- Categorization office layout	- [58,85,96,114–117]	- Satisfaction with layout/workplace	- [47,55–57,119–121]
- Work and storage size	- [47]	- Satisfaction with number/diversity/ functionality workplaces	- [47,55–57,65,90,95,122–127]
- Area per person	- [47,118]	- Perceived influence of workplace on productivity	- [85,114,115,124,128–131]
		- Perception workplace	- [42,132–136]
Light and daylight			
- Illuminance			

(*continued on next page*)

Table A (*continued*)

Objective measures		Subjective measures	
	- [47,50,51,53,64,69–71,74,77,79,80,82,83,97,108,110,114,132,137–153]	- Satisfaction with light (amount, glare, reflections, contrast, distribution)	- [56,57,64,65,80,95,119,123,125,126,132,139,141,157–162]
- Glazing area	- [114]	- Perception of light (brightness, glare, reflections, distribution, colour)	- [47,58,60,69,72,83,97,135,140,142,143,146,163–170]
- Luminance	- [74,79,108,110,132,143,145]	- Perceived influence of light on productivity	- [57,81,114,115,128–131,139]
- Circadian system/stimulus	- [82,148,154]	- Satisfaction with (access to) daylight	- [64,125,126,161,162]
- Correlated Colour Temperature (CCT)	- [50,51,70,81–83,110,138,142,147,150,155]	- Light quality	- [79,110,158]
- Light level/intensity	- [54,70,115,156]	- Perceived naturalness of light	- [50,171]
- Colour Rendering Index (CRI)	- [69,70,81,108,110,142,145,155]	- Perceived comfort level of light	- [62,63,141,142]
- Irradiance	- [69,74,108,142,149]	- Appraisal of light	- [79,152,153,155]
- Spectral light composition	- [142]		
Noise, acoustics, and privacy			
- Background sound level	- [114,134,172]	- Satisfaction with acoustics	- [47,55,56,73,132,160,178]
- Sound pressure level	- [47,64,68,73,87,97,132,143,151,173–177]	- Satisfaction with (auditory, visual, sound) privacy	- [55,56,65,90,95,125,132,162]
- Reverberation time	- [177]	- Complaints about noise	- [84]
- Decay rate of speech	- [134,172]	- Perception of noise	- [48,58,60,63,64,143,173,174]
- Distraction distance	- [172]	- Perception of sound	- [164,177]
- Ambient noise level	- [73,174]	- Perception of sound privacy	- [48,64]
- Radius of comfort	- [68]	- Noise annoyance/disturbance (different sources)	- [47,68,72,73,75,87,89,119,126,134,161,167,170,173]
- Noise type	- [51]	- Satisfaction with noise	- [57,62,65,95,123,125,126,159,162]
		- Satisfaction with sound/acoustical quality	- [119,172]
		- Perceived influence of privacy on productivity	- [114,130,131]
		- Perceived influence of annoyance on productivity	- [89,114]
		- Perceived influence of noise on productivity	- [57,75,115,130,131]
		- Interference acoustical privacy	- [120]
		- Appraisal of noise	- [97]
		- Noise sensitivity	- [172]
Indoor air quality and ventilation			
- Ventilation rate	- [103,164,179]	- Satisfaction with indoor climate	- [56]
- Carbon dioxide	- [47,52,60,61,64,66,103,115,132,137,143,176,179–185]	- Environmental problems (draught, dry, stuffy air)	- [84,167,170,181]
- Carbon monoxide	- [64,132,143,176,179,183]	- Satisfaction with air quality	- [62–65,95,123,125,126,160–162]
- Ozone	- [64,143]	- Perception of air quality	- [60,61,119,121,143,168,180,187]
- Total volatile organic compounds	- [64,143,179,181,183–185]	- Perception of ventilation	- [47,60,168]
- Air velocity	- [143,179,183]	- Perception of freshness	- [47]
- Air speed	- [64,179]	- Perceived influence of ventilation on productivity	- [114,128–130,161]
- Formaldehyde	- [47,137,179,185]	- Perceived influence of air quality (dryness, dust, smell) on productivity	- [164]
- Ventilation type	- [185,186]	- Satisfaction with ventilation	- [132,162]
- PM10, PM2.5	- [47,52,97,115]	- Appraisal of dust	- [97]
Thermal comfort and temperature			
- Temperature	- [47,51,52,60,61,64,66,103,114,115,132,137,143,146,151,156,164,176,179–185,187–189]	- Satisfaction with indoor climate	- [56]
- Relative humidity	- [47,52,60,61,66,103,114,115,132,137,143,146,156,164,176,179,183–185,189]	- Satisfaction with temperature	- [42,46,57,63,95,115,119,120,123,125,126,139,161,166,181]
		- Perception of temperature	- [36,58,61,167]
		- Thermal comfort/sensation/acceptability/preference	- [60–62,64,65,72,128,129,132,143,159,160,164,170,180,187,189]
		- Satisfaction with humidity	- [47,115,125,161]
		- Perceived influence of temperature on productivity	- [128–131]
		- Acceptability temperature	- [181]
Biophilia, views, greenery and plants			
- Visual contact to outdoors	- [114,190]	- Satisfaction with (access) views outdoors	- [40,43,48,51,71,77,116,126,128]
- Absence/presence of plants	- [59,92,121]	- Satisfaction with absence/presence plants	- [115,121,167,192]
- Number of plants	- [48,59,92,121,191]	- Connectedness to nature	- [108,193,194]
- Open/closed shades	- [51]	- Quality of views outdoors	- [158]
- Type of plants	- [48,78]	- Plant preference	- [48]
Look, feel and colours			
- Colour intensity	- [49,100]	- Satisfaction with aesthetics interior	- [50,52,71,73,159]

(*continued on next page*)

Table A (*continued*)

Objective measures		Subjective measures	
- Colour chroma (i.e. the perceived strength of a surface colour)	- [49,100]	- Satisfaction with aesthetics exterior	- [56,65]
- Colour saturation	- [49,100]	- Perception/preference of colours and textures	- [86,130,152,163,195]

Table B
Measures mental health.

Well-being		Stress	
- Perceived well-being	- [42,59,73,75,79,89,90,135,141,142,145,155,192,194]	- Self-reported job stress/perceived stress	- [50,59,73–75,89,134,137,162,164,172,182,184,194]
- Well-being relative to SBS symptoms	- [164]	- Health questionnaire – perceived stress	- [157]
- Heart rate variability	- [52]*	- Oldenburg Burnout Inventory – exhaustion	- [117]
- Warwick-Edinburgh Mental Well-Being Scale (WEM-WBS)	- [168]	- Recovery Experience Questionnaire - Detachment and relaxation after work	- [117]
- Sick Building Syndrome (SBS) questions – physical well-being	- [168]	- Workload	- [86]
- Building Use Studies (BUS)	- [63]	- Role conflict	- [86]
- Mood state – general well-being	- [108]	- Role ambiguity	- [86]
- World Health Organization Well-being Index (WHO-5)	- [178]	- Stress at Work Scale	- [190]
- Athens Insomnia Scale – sense of well-being	- [146]	- Job Stress Survey	- [50,145,193]
- Symptoms of infection diseases (SID) scale – general well-being	- [174]	- Perceived Stress Scale	- [50,82,154,167]
- Positive and Negative Affect Schedule/State (PANAS)	- [169]	- Short Form Perceived Stress Scale	- [116]
- Warr's Depression-Enthusiasm Continuum of Affective Well-Being	- [118,161]	- Copenhagen Psychosocial Questionnaire (COPSOQ) – Cognitive Stress Scale	- [67,68,96]
- Scale of Positive and Negative Experiences (SPANE)	- [95]	- Heart rate variability	- [52,77]*
- Flourishing scale	- [95]	- State-Trait Anxiety Inventory (STAI) – psychological stress	- [78]
- Short-Form 36 items (SF-36)	- [71]	- Physiological stress	- [50,77,78]*
		Pulse rate	[78]
		Skin conductance level (SCL)	[50]
		Skin conductance response (SCR)	[50]
		Salivary cortisol	[77]
		- Perceived physical stress	- [127]
		- Dundee Stress State Questionnaire	- [108]
		- Krasek's scales of job demand and decision latitude – Job strain	- [174]
Productivity		*Concentration*	
- Werkomgevingsdiagnose instrument (WODI)	- [55–57]	- Concentration difficulties/problems	- [73,75,84,87,143,158,164,166,175,179,183–186,188]
- Building Use Studies (BUS)	- [58–63]	- Werkomgevingsdiagnose instrument (WODI)	- [55]
- Building Occupant Survey System Australia (BOSSA)	- [64,65,125,126]	- Loss of concentration	- [72,89]
- World Health Organization Health and Work Performance Questionnaire	- [147]	- Need for concentration/concentration requirements	- [57,96,134,171]
- Health and Work Questionnaire	- [123]	- MM Questionnaire	- [97]
- Perceived Productivity Impact	- [130]	- Diagnostische Verfahren zu Lebensqualität und Wohlbefinden	- [108]
- Post-Occupancy Evaluation Survey	- [131]	- Subjective Symptom Questionnaire	- [145]
- Cost-effective Open-Plan Environments (COPE) survey	- [50,160]	- Activity and Work Analysis in Hospitals	- [178]
- Work Productivity and Activity Impairment Questionnaire	- [115]	- Copenhagen Psychosocial Questionnaire (COPSOQ I) – concentration requirements	- [67]
- Indoor Productivity Index	- [115]		
Productivity		Concentration	
- Perceived/self-assessed productivity	- [47,48,75,79–81,85,89,90,92,114,119,121,124,127–129,136,139,147,161,163,165,166,168,170,172,180,189,196]	- Columbia Jetlag Scale – Concentration difficulties	- [147]
- Presenteeism	- [115]	- Self-assessed concentration	- [73,121,124,147,160,172,180]
Stanford Presenteeism scale	[115]	- Workplace Questionnaire – Concentration	- [69]
NRC Post-Occupancy Questionnaire	[115]	Cognitive performance test	- [187]*
Indoor Productivity Index	[115]		
- Task performance	- [49,66,79,80,181]*		

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Table B (*continued*)

Well-being		Stress	
Typing task	[49,79,80]		
Zip code proofreading task	[49]		
Text proofreading task	[49,60]		
Timed vision test	[79,80]		
Cognitive judgements	[79,80]		
Calculation of salaries (nr. of receipts handled)	[181]		
Payment traffic (nr. of vouchers handled)	[181]		
Stroop test	[60,66,72]		
Shifting attention task	[66]		
Continuous performance test	[66]		
- Strategic Management Simulation (SMS) software	- [159]		
- Level of efficiency	- [181]		
- Perceived performance	- [133]		
Sleep quality		*Fatigue*	
- Karolinska Sleepiness Scale	- [69,71,72,82,83,141]	Indoor Air Questionnaire	- [84]
- Perceived sleep quality	- [42,149]	- Perceived fatigue	- [74,188,194]
- Sleep difficulties/sleepiness	- [51,143,156,157,189]	- Questionnaire on Experience and Evaluation of Work (QEEW) – tiredness and recovery capacity	- [157]
- Groningen Sleep Quality Scale	- [132,158]	- Sick Building Syndrome symptoms/respiratory symptoms – fatigue	- [66,145,151,156,173,175,176,179,183,185,186]
- Sleep patterns	- [159]	- Columbia Jet Lag Scale	- [147]
- Pittsburgh Sleep Quality Index (PSQI)	- [50,52,53,69,70,82,83,148,150,154]		
- Patient-Reported Outcomes Measurement Information Sleep Disturbance-Short (PROMIS) Form 8a	- [148,154]		
- Sleep logs and sleep tracking	- [86,101,108,119,134,138,161]*		
Bedtime	[50,52,54,70,138,150]		
Sleep latency	[50,52,70,138]		
Time-to-wake-up	[50,54,138,150,169]		
Time-to-get-up (sleep inertia)	[138]		
Sleep quality		Fatigue	
- Sleep logs and sleep tracking	- [86,101,108,119,134,138,161]*		
Use of alarm clock	[138]		
Total sleep time	[50,52,54,70,150]		
Sleep efficiency	[50,52,70]		
- Seasonal Pattern Assessment Questionnaire (SPAQ)	- [140,149]		
- Usual sleeping hours	- [123,144]		
- Athens Insomnia Scale	- [146]		
- Columbia Jet Lag Scale	- [147]		
- Munich Chronotype Questionnaire	- [150]		
- Epworth Sleepiness Scale	- [110,150]		
- Stanford Sleepiness Scale	- [50,66]		
Mood		*Depression*	
- Perceived mood	- [72,132,142,145,152,155,195]	- Depression	- [42,177]
- Positive and Negative Affect Schedule/State (PANAS)	- [50,66,69,74,83,148,154,169]	- Symptom Distress Checklist 90 (SCL-90)	- [140,191]
- Ecological Momentary Assessments	- [116]	- Center for Epidemiologic Studies Depression Scale (CES-D)	- [148,154]
- Positive Emotions scale	- [97]	- Mood state	- [108]
- Profile of Mood States (POMS)	- [100]	- Becks Depression Inventory (BDI)	- [83,145]
- Seasonal Pattern Assessment Questionnaire (SPAQ)	- [140]	- Warr's Depression-Enthusiasm Continuum of Affective Well-Being	- [118,161]
- Mood state	- [108]	- Patient Health Questionnaire-4 (PHQ4)	- [95]
- Mehrabian and Russell 3-Factor Mood Scale/ Pleasure-Arousal-Dominance (PAD) model	- [79–81,149]	- National Institute for Occupational Safety and Health Generic Job Stress Questionnaire (NIOSH GJSQ)	- [51]
- Oxford Questionnaire	- [160]		
- National Institute for Occupational Safety and Health Generic Job Stress Questionnaire (NIOSH GJSQ)	- [51]		
- Scale for Mood Assessment	- [110]		
- Self-Assessment Manikin (SAM)	- [141]		
Engagement		*Burnout*	
- Utrecht Work Engagement Scale (UWES)	- [115,120,172]	- Oldenburg Burnout Inventory (OLBI)	- [117]
- Dundee Stress State Questionnaire	- [108]	- Maslach Burnout Inventory General Survey (MBI-GS)	- [68,96]
- (Dis)engagement	- [121,123]		
- Cognitive appraisal, motivation, work structure	- [153]		

*Indicates objective measures.

Table C
Physical office characteristics – Mental health indicators (1/2)

Physical office	Mental health							
	Productivity		Concentration		Stress		Sleep quality	
Light and daylight		Reference						
Increased daylight exposure	↑	[65, 70, 139, 155, 165]	-	-	-	-	↑	[53, 146, 148, 149]
Reduced visual comfort	↓	[145, 158]	-	-	-	-	-	-
Increased CCT values	↑	[69, 70, 83, 147]	↑	[69, 83, 138, 147, 150]	↓	[110, 150]	↑	[69, 70]
Increased illuminance	↑	[65, 70, 80]	-	-	-	-	↑	[70, 146]
Personal control over light	↑	[47, 139]	-	-	-	-	-	-
Increased CS scores	-	-	-	-	↓	[154]	↑	[82, 154]
Insufficient light exposure	-	-	-	-	-	-	↓	[50, 82, 138]
Indoor air quality and ventilation								
Suboptimal CO_2 concentration	↓	[60, 61, 66]	↓	[60, 61]	↑	[182]	-	-
Suboptimal ventilation rate	↓	[57, 65, 156]	↓	[156, 188]	–	-	↓	[156]
Stuffy air (instead of fresh air)	↓	[60, 61]	↓	[84, 137, 179]	-	-	-	-
Satisfaction with air quality	↑	[47, 56, 58, 65, 161, 164]	↑	[57, 130, 179]	-	-	↑	[132]
Indoor air problems	-	-	↓	[84]	-	-	-	-
Satisfaction with ventilation	↑	[128, 129]	-	-		-	-	-
Noise, acoustics, and privacy								
Acoustic privacy	↑	[57, 65, 123, 134]	↑	[73]	-	-	-	-
Satisfaction with acoustic quality	↑	[47, 85, 164]	↑	[157]	↓	[68]	-	-
Sound level below 45dB	↑	[47, 164]	-	-	-	-	-	-
Satisfaction with privacy	↑	[90]	-	-	-	-	-	-
Disturbance/ annoyance by noise	↓	[55, 65, 85, 87, 89, 126, 134, 136, 157, 161]	↓	[47, 55, 73, 75, 85, 87, 89, 157, 164, 172, 176]	↑	[68, 89, 90, 174]	-	-
Thermal comfort and temperature								
Temperatures below/above 20-24°C	↓	[61, 180, 181]	↓	[176, 180, 181, 183]	↑	[182]	-	-
Relative humidity below/ above 40-55%	↓	[65, 164]	-	-	↑	[52]	↓	[52]
Satisfaction with thermal comfort	↑	[57, 72, 119, 166, 189]	↑	[166, 189]	-	-	↑	[132]
Satisfaction with temperature	↑	[161]	-	-	-	-	-	-
Satisfaction with relative humidity	↑	[161]	-	-	-	-	-	-
Office layout and design								
Private office	↑	[55, 58, 73, 89, 90, 164]	↑	[55, 73, 89, 90, 96, 164]	↓	[89, 90, 96, 116]	-	-
Open-plan office	↓	[85, 90, 127, 133]	↓	[73, 96, 120]	↑	[96, 127]	↓	[42]
Presence of concentration/ break-out rooms	↑	[58, 89, 126, 130, 164]	↑	[134]	↓	[90, 96, 117]	-	-
Satisfaction with office layout	↑	[56]	-	-	-	-	↑	[123]
Activity-based working	↑	[64, 65, 90, 119, 125, 128]–[130]	↓	[55, 90]	↓	[67]	-	-
Biophilia and views								
Presence of plants at desk	↑	[48, 59, 92, 121]	↑	[59, 78, 92, 121, 191, 194]	↓	[59, 78, 92, 167, 193, 194]	-	-
Presence of plants at breakout/ refresh area	0	[59]	0	[59]	-	-	-	-
Satisfaction with (natural) views outside	↑	[65, 114, 125, 131, 156, 160]	↑	[158]	↓	[190, 193]	↑	[70, 95, 132, 156, 158]
Look and feel								
White and blue room colours	↑	[49, 100, 163]	-	-	↓	[77, 100, 163, 195]	-	-
Satisfaction with looks/ aesthetics	↑	[56, 57, 65, 130]	-	-	-	-	-	-
High colour saturation, low brightness	↑	[194]	-	-	↓	[86]	-	-
Natural materials and colours	-	-	-	-	-	-	-	-

Table C
Physical office characteristics – Mental health indicators (2/2)

Physical office	Mental health											
	Mood		Well-being		Fatigue		Depression		Engagement		Burnout	
Light and daylight												
Increased daylight exposure	↑	[142]	–	–	↓	[82,142]	–	–	–	–	–	–
Reduced visual comfort	–	–	–	–	↑	[145,158]	–	–	–	–	–	–
Increased CCT values	↑	[69,110,138,140,142, 150]	–	–	↓	[69,147]	↓	[140]	–	–	–	–
Increased illuminance	↑	[83,141,152]	–	–	↓	[71,83,151]	–	–	–	–	–	–
Personal control over light	↑	[80,81,132,155]	↑	[81,155]	–	–	–	–	↑	[132]	–	–
Increased CS scores	↑	[142,148,154]	↑	[53,135, 142]	–	–	↑	[154]	–	–	–	–

(continued on next page)

Table C (*continued*)

Physical office	Mental health											
	Mood		Well-being		Fatigue		Depression		Engagement		Burnout	
Insufficient light exposure	↓	[82]	–	–	–	–	–	–	–	–	–	–
Indoor air quality and ventilation												
Suboptimal CO_2 concentration	–	–	–	–	↑	[184,186]	–	–	–	–	–	–
Suboptimal ventilation rate	–	–	–	–	↑	[156,186]	–	–	–	–	–	–
Stuffy air (instead of fresh air)	–	–	–	–	↑	[84,137,179,188]	–	–	–	–	–	–
Increased TVOC concentration	–	–	–	–	↑	[137,184,191]	–	–	–	–	–	–
Satisfaction with air quality	↑	[132]	↑	[63]	–	–	↓	[161]	–	–	–	–
Indoor air problems	–	–	–	–	↑	[84]	–	–	–	–	–	–
Noise, acoustics, and privacy												
Acoustic privacy	–	–	↑	[134]	–	–	–	–	–	–	–	–
Satisfaction with acoustic quality	–	–	–	–	–	–	↓	[177]	0	[120]	–	–
Satisfaction with privacy	–	–	↑	[90]	–	–	–	–	–	–	–	–
Disturbance/annoyance by noise	↓	[51,72]	–	–	↑	[73,151,157,176]	↑	[161,177]	–	–	–	–
Thermal comfort and temperature												
Temperatures below/above 20–24 °C	↓	[132]	↓	[164]	↑	[176,181,183]	–	–	–	–	–	–
Relative humidity below/above 40–55%	↓	[132]	–	–	↑	[186,188]	–	–	–	–	–	–
Satisfaction with thermal comfort	↑	[132]	–	–	–	–	–	–	–	–	–	–
Satisfaction with temperature	–	–	↑	[95]	–	–	–	–	–	–	–	–
Satisfaction with relative humidity	–	–	–	–	–	–	↓	[161]	–	–	–	–
Office layout and design												
Private office	–	–	–	–	–	–	–	–	–	–	–	–
Open-plan office	–	–	↓	[42]	–	–	–	–	↓	[120]	–	–
Activity-based working	–	–	↑↑	[90,135]	–	–	–	–	–	–	–	–
Presence of concentration/break-out rooms	–	–		[118]	–	–	–	–	↑	[123]	↓	[117]
Biophilia and views												
Presence of plants	–	–	↑	[192]	–	–	↓	[191]	–	–	–	–
Presence of plants at breakout/refresh area	–	–	–	–	–	–	–	–	–	–	–	–
Satisfaction with (natural) views outside	↑	[51,95,132,156,160]	↑	[95,132,156]	↓	[156]	–	–	–	–	–	–
Look and feel												
White and blue room colours	–	[77,100,163,195]	–	–	–	–	–	–	–	–	–	–
Satisfaction with looks/aesthetics	↑	[135]	–	–	–	–	–	–	–	–	–	–
Colourful work environment	↑	[152]	–	–	–	–	–	–	–	–	–	–

Table D
Theories that explain employee-workplace relationships

Theory	Explanation	Mental health	References
Person-Environment theories			
Person-Environment Fit Theory	Extent to which individuals' needs or goals are fulfilled through physical environmental attributes.	–	[95,124]
Flourish model	High-quality physical work environment stimulates individuals' flourishing; promotes an optimal state of human functioning, with high mental well-being and health.	Well-being	[59]
Human-Environment Interaction Model	Interaction between individuals and environment. Stress arises as a response to changing environmental factors.	Stress	[193]
Affective Events Theory	Work environment can influence individuals' affective experience, which influences their behaviours and attitudes.	–	[120]
Place attachment Theory	Explains the affective dimension (i.e. emotional bond) of the relationship between individual and environment.	–	[122]
Psycho-Environmental Potential Model	Interaction between physical work environment and individual explained by six environmental needs: security and shelter, social contact regulation, symbolic identification, pleasure, growth and task instrumentality, which are important for individuals' well-being.	Well-being	[95]
Positive Affect Theory	Physical work environment can increase positive affect, which leads to desirable task performance, well-being, and improved ability to cope with stress.	Productivity, well-being, stress	[81,155]
Stress-related theories			
Job demands-resources model	Jobs consist of job demands (i.e. job aspects that require physical or mental effort of the individual) and job resources (i.e. job aspects that can be functional to achieve goals, reduce job demands, stimulate personal growth), that affect individuals' work engagement, exhaustion and job performance.	Engagement, exhaustion, productivity	[67,134]
Job Demand-Control-Support model/Job Strain model	Work environment consists of job demands (i.e. work load), job control (individuals' ability to control work activities) and job support (i.e. social support/isolation). High job demands, low job control and social support increase stress.	Stress	[167,174,193]
Effort Recovery Model	Individuals who cannot recover from job strain, experience excessive load reactions that result in emotional, cognitive and behavioural symptoms (e.g. fatigue and lower engagement).	Fatigue, engagement	[67,117]
Interaction/arousal-related theories			
Changing State Hypothesis	Office sounds (e.g. telephone calls) that vary continuously cause disruptions. Constant office sounds might be less disturbing.	–	[68,87]
Social Facilitation Hypothesis	Presence of others promotes individuals' performance of routine tasks by acquiring arousal, while it impairs learning of new tasks.	Productivity	[127]

(*continued on next page*)

Table D (*continued*)

Theory	Explanation	Mental health	References
Drive theory of social facilitation	Presence of others increases arousal, which increases tendency to perform dominant responses. Performance increases when tasks are easy or learned but decreases when tasks are more demanding.	Productivity	[96]
Arousal Theory/Yerkes-Dodson principle	Relationship between arousal and performance is curvilinear. If individuals' arousal levels increase, their performance increases as well, up to a certain point. After the optimal arousal level, any arousal will decrease productivity.	Productivity	[49,74]
Social Interference Theory	Four office design features (i.e. density, openness, proximity and workstation boundaries) determine individuals' (un)wanted social interactions that could affect their goal attainment, work performance and satisfaction.	Productivity	[118]
Biophilic/natural theories			
Biophilia Hypothesis	Comprehensive framework to understand individuals' need or desire to connect with nature. Nature at work could lower stress levels, depressive symptoms, fatigue, and improve mood.	Stress, depressive symptoms, fatigue, mood	[59,171,194]
Stress Recovery Theory	Recovery from stress consists of positive emotional changes that reduce feelings of anger or fear. Natural environments could foster stress recovery.	Stress, mood	[59,193]
Attention Restoration Theory	Individuals' ability to focus on a task (i.e. directed attention) is finite, and attention fatigue might occur. Natural environments restore individuals' capacity for directed attention.	Fatigue	[59,108,121,167]
Psycho-evolutionary Theory	The exposure to natural environments increases positive affect (i.e. emotional states) and reduce stress responses.	Stress, mood	[108,167]
Other theories			
Broaden-and-build Theory	Through the cumulative experience of momentary positive emotions, individuals might feel increased health outcomes.	Mood	[97]
Self-determination Theory	Individuals' motivation can be autonomous (i.e. voluntary engagement in activity) or controlled (i.e. involuntary engagement in activity) and can be increased when needs for competence, autonomy, and relatedness are satisfied.	Engagement	[95]

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