The Benefits of Windows

A scoping review and research agenda for the effects of daylight and view content on health and well-being.

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Executive Summary

This report describes the benefits of outdoor views and daylight exposure through windows. Windows provide us information about the outside world, a relieve for claustrophobia, a view to the outside, and daylight exposure. People generally prefer being in a room with a window and believe that windows are good for health. The question is which elements of windows are beneficial and which specific outcomes of health and well-being they may affect. Therefore, a scoping review was performed to provide an overview of the beneficial effects of windows and view on health and well-being.

Most research on the effects of window views on well-being has focused on the amount or type of nature in the view. Exposure to natural views can improve health through three pathways. First of all, it facilitates recovery from daily stressors and attention fatigue (restoration). It can also help people build resources to be better able to face future stressors (instoration). In addition, natural environments often lack certain elements that are detrimental to an individual's health and well-being, such as traffic noise coming in through open windows (mitigation). The effects of the natural environment on well-being depends on the dose (amount, exposure duration, and frequency), the type of natural elements in the view, and the experience (e.g., a very joyful vs a very dull visit experience to a park) people have (had) with these natural elements (internal dose). The effects of nature in the view are potentially confounded by the effects of real (outdoor) exposure to these elements. People who have greener views may also have easier access to these green environments and can therefore potentially profit more from actual exposure to these environments. Besides the naturalness of the view, though, there are also some characteristics of the view composition that appear important. These include the number of layers in the view and the level of openness or overview over the terrain versus the ability to find shelter. Typically all three layers of ground, landscape or city, and sky should be present.

The benefits of daylight through windows on human health and well-being are highly complex and affect visual comfort and performance as well as human health with acute and lagged (circadian) effects. Effects depend highly on geographical location, season, weather type, and time of day. In addition, architectural elements such as window size and window orientation influence the amount of daylight that enters via the window. Light exposure (in modern society almost always a combination of both daylight and electric light) at the right time of day with biologically correct intensity and spectral composition can improve sleep, physiological functioning, mood, cognitive performance, and alertness. These effects may depend highly on previous exposure to light, for instance, when commuting to work. Conversely, night-time exposure to light may counteract any potential benefits from daylight exposure during the day. The lighting environment may also trigger psychological responses, guiding behaviour and mood. The psychological effects of daylight have, however, received little to no attention yet.

Benefits of windows have been studied in a range of different settings. Especially windows in office environments have received much attention. Comparisons have been made between workplaces with and without windows, the type and composition of the view, and different daylight characteristics such as the use of blinds or the presence of sun patches. Studies in these environments have reported benefits on a wide range of health outcomes, including mental and physical health and even job engagement. Besides health outcomes, especially the presence of windows affected satisfaction with the office environment.

In an educational setting, studies have focused on the presence and amount of daylight in classrooms and the type of view. Effects were studied for primary school children, but also for students at university. School performance received the most attention, and benefits of daylight and natural views were reported. Studies also reported benefits on other outcomes such as stress, creativity, and hormonal functioning.

In health care environments, beneficial effects have been reported for both the patients and nurses working in these environments. Especially the provision of daylight was studied in healthcare environments, and view type received less attention. Benefits were found on patient recovery and well-being but also on well-being of healthcare workers.

Windows at home also matter for well-being. Studies looked at the amount of nature in the view, including views of the sea, with beneficial effects reported on mental health, general health, satisfaction with the environment, well-being, and cognitive performance. For daylight, there was a special focus on daylight exposure before waking up. In most studies, having daylight entering the bedroom (no black-out curtains) was found to improve sleep and mood during daytime.

Looking at effects of different window elements across settings, there is consistent evidence for the benefits of windows on physiology, satisfaction with the environment, well-being, and visual comfort. Daylight exposure and natural views both consistently improved well-being, physiology, physical health, and job engagement. Natural views were also consistently related to better mental health, but not daylight exposure. View composition appeared to matter for satisfaction with the environment and well-being. There are thus considerable overlaps in the beneficial effects of daylight and view content on health, but also some differences.

There are still quite a number of studies that only look at the effects of either daylight or view while not taking the other aspect into account. This may lead to confounds, as both view and daylight entrance can influence health. Few studies have purposely looked at daylight and view separately, but these studies do (again) point at both agreements and differences in effects of daylight and view content.

It may not always be possible, or desirable, to separate the effects of daylight and view content as they are sometimes highly interrelated. First of all, the light environment and temporal dynamics in light exposure depend on view content. For example, the proportion of the sky visible in the view may also affects the characteristics of the

daylight entering through that window. This works the other way round as well: light characteristics (such as the weather) influence how the window view is perceived. View content influences glare perception and the frequency of looking out of the window. This, in turn, can influence the dose of daylight exposure.

Besides being highly interrelated, there are some factors to consider when looking at the benefits of daylight exposure and view content through windows. First of all, many studies look at windows as static objects, whereas both the view and daylight entrance are highly dynamic over the course of the day and seasons. In addition, when opening a window, the effects of the window go beyond mere visual exposure and include both feelings of control and influences from other senses (e.g., hearing, smelling, feeling).

What goes on outside of the window may be correlated with outdoor exposure to nature and daylight. Outdoor exposure, in turn, may have beneficial effects on health and well-being that are difficult to separate from indoor exposure through windows. An additional complicating factor in daylight research is that daylight exposure interacts with other indoor parameters, such as perceived temperature.

For some health outcomes, the results were not always consistent. For instance, for daylight, there was no consistent beneficial relation with mental health. These inconsistent findings for daylight may result from the high diversity in the way daylight entrance has been operationalized in the reported studies. For example, daylight exposure could be characterized as the presence or shape of sun patches, the presence of curtains or blinds, window size or orientation, and in some studies, the actual intensity and composition of daylight entering the room. Finding a more homogeneous characterisation of daylight may help progress research on the benefits of windows. Conversely, for research looking at view content, studies suggest that looking at amount of nature in the view alone may not be enough to explain beneficial effects. Instead, a better account of the separate view elements (e.g., trees, other buildings) as well as the composition of the view (e.g., number of view layers, presence of the sky) may be necessary to fully understand the benefits of view content.

The present report again underlines that windows are quintessential for human health and well-being and that both daylight and view content contribute significantly and sometimes differently to these benefits. The studies in this scoping review suggest that the effects of window elements may depend on individual differences (e.g., age), setting (e.g., healthcare vs residential), location (e.g., latitude), or climate (e.g., tropical vs land climate). Understanding differences in the effects of windows between individuals, locations, and settings may help to exploit the benefits of windows even better in the future.

Aim and Scope

This report presents the results from a scoping review aimed at collating evidence for the beneficial effects of views and daylight entering through windows. The scoping review was conducted with financial support from Saint-Gobain SageGlass. The main questions posed by Saint-Gobain SageGlass were:

1. What are the psychological and physiological benefits that can be related to views specifically ?
2. What are the psychological and physiological benefits related to daylight specifically ?
3. Which are the benefits (if any) that are both attributed to daylight *and* views?
4. Are there any benefits that cannot be obtained if we have daylight but no view, or if we have a view but no daylight?
5. Do the benefits of views compensate poor daylight (quantity and quality)? Or, does access to good daylight balance a lack of views? Or do we really both daylight and views to fulfill human's needs ?
6. What are the mechanisms behind the effects observed?
7. Are there some specific factors that may enhance the views-related benefits?
8. What are the key research gaps that need to be filled to progress on this topic?

The search

The present report presents an update on an earlier scoping review: “Salutogenic effects of the environment: Review of health protective effects of nature and daylight” (F. Beute & Y. A. de Kort, 2014), focusing on effects of exposure to nature and daylight in outdoor and indoor environments. Therefore, the search focused mainly on articles published after the release of this article in 2014. The search terms for the environmental characteristics (e.g.: window, daylight, sunlight, exposure, orientation, view, exposure) were combined with health outcome search terms (e.g., health, sleep, stress, affect, well-being, ADHD). As the focus of this scoping review is on the effects of windows on health and well-being, studies in which effects of indoor exposure to daylight and natural views were selected. A citation search was performed after the initial database search to find additional relevant papers. Only peer-reviewed and papers written in English were included.

Since 2014, a number of related reviews have been published. Several review articles have focused on the beneficial effects of daylight through windows (M. B. Aries, Aarts, & van Hoof, 2015) and daylight exposure in general (Knoop et al., 2020). For window views, reviews mostly focus on indoor and outdoor exposure to green spaces and not specifically on natural views (through windows) alone. Some examples are exposure to green spaces at schools (Browning & Rigolon, 2019) or in the residential area (Gascon et al., 2016). In addition, other reviews have focused on specific health and well-being outcomes of general nature exposure, such as sleep (J. C. Shin, Parab, An, & Grigsby-Toussaint, 2020), self-regulation (Moens et al., 2019), or asthma prevalence (Hartley, Ryan, Brokamp, & Gillespie, 2020). No review has specifically focused on the psychological and physiological benefits of daylight and views through windows, which is the main aim of the present scoping review.

The Benefits of Windows

When a child draws a house, it usually has a roof, a door, a window, and a chimney. A window is not only a stereotypical element of a home; it also serves important functions that foster human well-being and functioning. Whereas humans have evolved in close connection to nature and the natural day-night cycle, we now spend more and more time indoors. Office workers have reported spending approximately 90 % of their time indoors (McCreddin, Gill, Broderick, & McNabola, 2013). On average, people spend over 15,5 hours indoors at home (Brasche & Bischof, 2005), where we are only connected to the outdoor world through windows. The significance of windows for human functioning and well-being has been made painfully clear during the COVID-19 pandemic. Research indicates that people have re-appreciated the importance of windows during the pandemic (Batool, Rutherford, McGraw, Ledgeway, & Altomonte, 2021).

The importance of windows for human health and well-being has been recognized for decades. P. J. Keep (1977) proposed that preference for sunshine through windows may depend on the function of the building, with for instance more confined hospital patients preferring direct sunlight more than people working in a factory. Additionally, he posed that a good view consists of three layers: ground, landscape, sky. In addition, Collins (1975) proposed that besides a view to the outside and daylight entrance, windows provide information about the weather and time of day, bring relief from feeling enclosed, and help combat boredom. In some situations, however, windows can also bring unwanted aspects such as glare and overheating.

Even though windows could provide effects beyond views and daylight access, the lion's share of research has centred around these two elements. Therefore, the next two sections will introduce the theoretical backgrounds for these two elements of a window view.

Naturalness of the view: theoretical background

The lion's share of the research into the effects of views on people has focused on the effects of natural views. Therefore the theoretical basis for the beneficial effects of nature on mental and physical health is first introduced. After that, some other aspects of window views that have been investigated are introduced, such as view quality, the number of view layers, and the composition of the view.

Naturalness of the view

Research looking at the beneficial effects of nature on health and well-being has a long tradition, dating back to the 1980's. This research has not only focused on effects of passively viewing nature (through windows), but also on actively engaging with it, through nature visits, nature therapy, or interaction with nature (e.g., gardening). For a long time, the field has been dominated by two theories: Attention Restoration Theory (R. Kaplan & Kaplan, 1989) and Stress Reduction Theory (Ulrich, 1983).

Attention Restoration Theory (R. Kaplan & Kaplan, 1989) builds primarily on cognitive functioning and poses that restorative environments can help regain the capacity to focus attention by a process that is labelled involuntary attention. This refers to attention that does not require executive control, which is triggered in environments that include four components: being away, containing soft fascinating elements, with good coherence, and ample extent. From this point of view, not only natural environments adhere to these four components, but also other built environments could be considered restorative environments, such as a museum (S. Kaplan, Bardwell, & Slakter, 1993). The main proposed benefits within this theoretical framework pertain to improved cognitive functioning. Executive functioning is not only important to perform well on tasks, it is also vital for self-regulation and asserting self-control. These executive functions affect many aspects of everyday life such as being able to resist temptation, maintaining stable social relations, and overall academic success (Tangney, Boone, & Baumeister, 2018). Natural environments have been proposed to improve self-regulation and self-control (Berman, Jonides, & Kaplan, 2008; Schertz & Berman, 2019), and a number of studies have confirmed these improvements in cognitive performance and self-regulation after exposure to nature, see e.g., (Beute & De Kort, 2014; Moens et al., 2019; Stenfors et al., 2019).

Stress Reduction Theory (Ulrich, 1983) focuses more on affective processes and outcomes. It is postulated that through evolutionary processes, unthreatening natural environments trigger what is called approach responses. In other words, humans feel attracted to a natural environment that is safe, also called biophilic responses (Ulrich, 1993). More specifically, whereas human's pre-cognitively respond to threatening nature (such as snakes) with a fight-or-flight

response (biophobia), unthreatening nature is assumed to trigger an opposite response leading to the reduction of stress and improvement of mood (biophilia) (Kellert & Wilson, 1995). Laboratory studies with images or videos have indeed shown beneficial effects of the natural environment (often versus urban environments) on several indicators of physiological stress, such as heart rate, heart rate variability, blood pressure, and skin conductance as well as affect and perceived stress (F. Beute & Y. De Kort, 2014; Laumann, Gärling, & Stormark, 2003; Ulrich et al., 1991).

More recently, attention is turning to the fact that in modern society, natural environments typically are places where people have pleasant leisure experiences. Oppositely, urban environments are places where people live, work, and are preoccupied with the daily stressors that people have (Hartig, 2021; A. E. van den Berg, 2021). Thus, nature presents a setting where people are away from the daily hassles often related to the urban world (i.e., work stress, unpaid bills) and enables people to engage in restorative activities, such as physical exercise or social encounters in the park. Viewing these environments can thereby trigger positive associations and positive emotions.

Another recent framework proposes three umbrella pathways from nature exposure to better health outcomes. This framework extends beyond restorative accounts of nature; by including instoration and mitigation as potential pathways (Markevych et al., 2017), see also Figure 1. Besides recovering from stress and attention fatigue, nature exposure can help build resources to be better able to combat future stressors (instoration). It can, for instance, be done by facilitating physical exercise (Barton, Pretty, & technology, 2010; Mitchell, 2013; Pretty, Peacock, Sellens, & Griffin, 2005), better social cohesion (De Vries, Van Dillen, Groenewegen, & Spreeuwenberg, 2013; Jennings & Bamkole, 2019), or by building resiliency against future stressors. Natural environments typically contain less of certain environmental stressors such as (traffic) noise and air pollutants (Von Lindern, Hartig, & Lercher, 2016) (mitigation). People with a more natural window view are therefore likely to be less disturbed by traffic noise.

When having a more natural view, it is likely that people have better access to natural environments in the proximity. Window views are thus potentially confounded with these intentional visits to natural environments and thus relate to whether people also spend time outdoors in the natural environment (Masoudinejad & Hartig, 2020) as well as potential other factors such as a lack of traffic noise when the view is more natural.

Windows are often referred to as allowing micro-breaks or micro-restoration (R. Kaplan, 2001; Masoudinejad & Hartig, 2020). Natural views can thus help restore depleted attentional resources as well as lower stress, but it is still unclear which elements or characteristics of nature are especially beneficial (Femke Beute et al., 2020). A recent structural review has tried to answer this question for nature exposure in general. The study concluded that there is not a particular natural category or characteristic that is superior to others, but that effects may depend on inter- and intraindividual factors

such as who is interacting with nature, where that person is, and how that person is feeling (Femke Beute et al., 2020).

The effects of nature depends on not only specific characteristics of the natural environment, but also on exposure duration (in terms of frequency and duration) (Bratman et al., 2019). Some studies have tried to determine which dose of nature people need on a weekly basis. Results show that, for instance, 30 minutes weekly exposure would decrease depression prevalence by 7% and high blood pressure by 9 % (Shanahan et al., 2016). In contrast, other studies recommend at least 120 minutes per week for good well-being and mental health (White et al., 2019). However, it has also been proposed that the duration and frequency of nature visits are not the only predictors of the effects of nature on health. Instead, people's experiences with the natural environment influence how exposure duration affects mental health outcomes (Bratman et al., 2019). The authors refer to this as the internal dose, indicating that exposure effects depend on, for instance, whether past and present experiences were positive or negative and how intense they were. A short duration with very positive experiences can have stronger effects than a long duration with only moderately pleasant experiences. Experiences with nature through windows may thus depend on factors such as how near the natural elements are or the characteristics of the window (e.g., type of curtains or blinds, shape, or size). Importantly, opening a window may provide an entirely different experience of the 'view', including, for instance, sounds and smells. Thus, again, this model refers to the importance of people's experiences with the environment. See Figure 1 for an overview of how nature exposure affects mental and physical health.

Natural areas are more than just green space; they often include blue space (such as a sea, a lake, or a river). Blue spaces, and potentially mostly the sea and coast, have multiple benefits for mental health, including lower depression rates and better mood (Beute et al., 2020b; (Gascon et al., 2017)).

When looking at the beneficial effects of nature on health and well-being, there may be a confound with outdoor exposure to nature. When the window view is more natural, one is more likely to be exposed to nature outdoors, for instance, during breaks at the office or during leisure time at home, or simply by getting to and from the building. Epidemiological studies indeed have shown a beneficial relationship between surrounding green space and health (see, e.g., Browning & Rigolon, 2019; Lachowycz & Jones, 2011; M. Van den Berg et al., 2015). Benefits of nature may come about because these environments are highly preferred. Indeed, a recent study indicated that mood improvements from viewing natural scenes were because the type of view was highly preferred (Meidenbauer et al., 2020). Importantly, preference in this study was operationalized as aesthetic quality. There may be aspects of natural environments that make them especially restorative, which can also be found in non-natural views.

Beyond naturalness: view layers, quality, distance, and openness

One of these aspects of natural environments that could enhance the restorative capacity is the fractal composition of objects. Fractals are

patterns that repeat and occur in different sizescales), and they can often be found in natural environments. These fractal patterns can also improve health and well-being (Hagerhall et al., 2015).

Other theoretical contributions have focused more on the composition of the objects in the environment. For example, Markus (1967) postulated that window views could be divided into three different horizontal layers, and all three serve a different function: the sky, the landscape (or city), and the ground. A recent study found that window views with more layers are highly preferred (Matusiak & Klöckner, 2016). Potentially related is the aspect of openness versus closure of the environment. The Prospect / Refuge theory (Appleton, 1996) claims that people prefer environments high in prospect (i.e., being able to see what is going on around them well) from an evolutionary perspective. It is therefore claimed that open spaces (high in prospect) are preferred over highly enclosed spaces. According to Stamps (Stamps, 2010; Stamps III, 2005), visual permeability (i.e., how open the boundaries of a space are) is an important key for the perception of the openness of the space. This perception relies heavily on the type of boundary (i.e., wall, ceiling: horizontal area, transparency) but also on the amount of light in the environment, with lighter environments being judged as more open.

Besides the composition of the view, authors have claimed that the aesthetic quality of the view (also called preference) is important for restorative effects (M. B. Aries, Veitch, & Newsham, 2010; Meidenbauer et al., 2020), including awe-evoking visual content (Collado, Staats, & Sorrel, 2016; Joye & Bolderdijk, 2015).

Other functions of the window view have been mentioned, such as providing information about the weather or time of day or connecting with the outside world. There is, however, too little empirical evidence for these aspects to say something meaningful about these aspects, other than that more research is required.

In sum: Window views

Most research on the effects of window views on well-being has focused on the naturalness of the view. Exposure to natural views can help people recover from daily stressors and attention fatigue (restoration). It can help people build resources to be better able to face future stressors (instoration). In addition, natural environments often lack certain elements that are detrimental to an individual's health and well-being, such as traffic noise (mitigation). The effects of the natural environment on well-being depend on the dose (exposure duration and frequency), the types of natural elements in the view, and the experiences people have with these natural elements (internal dose). Effects of the naturalness of the view are potentially confounded by effects of real (outdoor) exposure to these elements, as people who have greener views may also have easier access to these green environments and can therefore potentially also profit more of real exposure to these environments. Besides naturalness of the view, there are some characteristics of the view composition that appear important. These include the number of layers in the view (typically all three layers of ground, landscape or city, and sky should be present), the openness of the view, and the level of prospect and refuge.

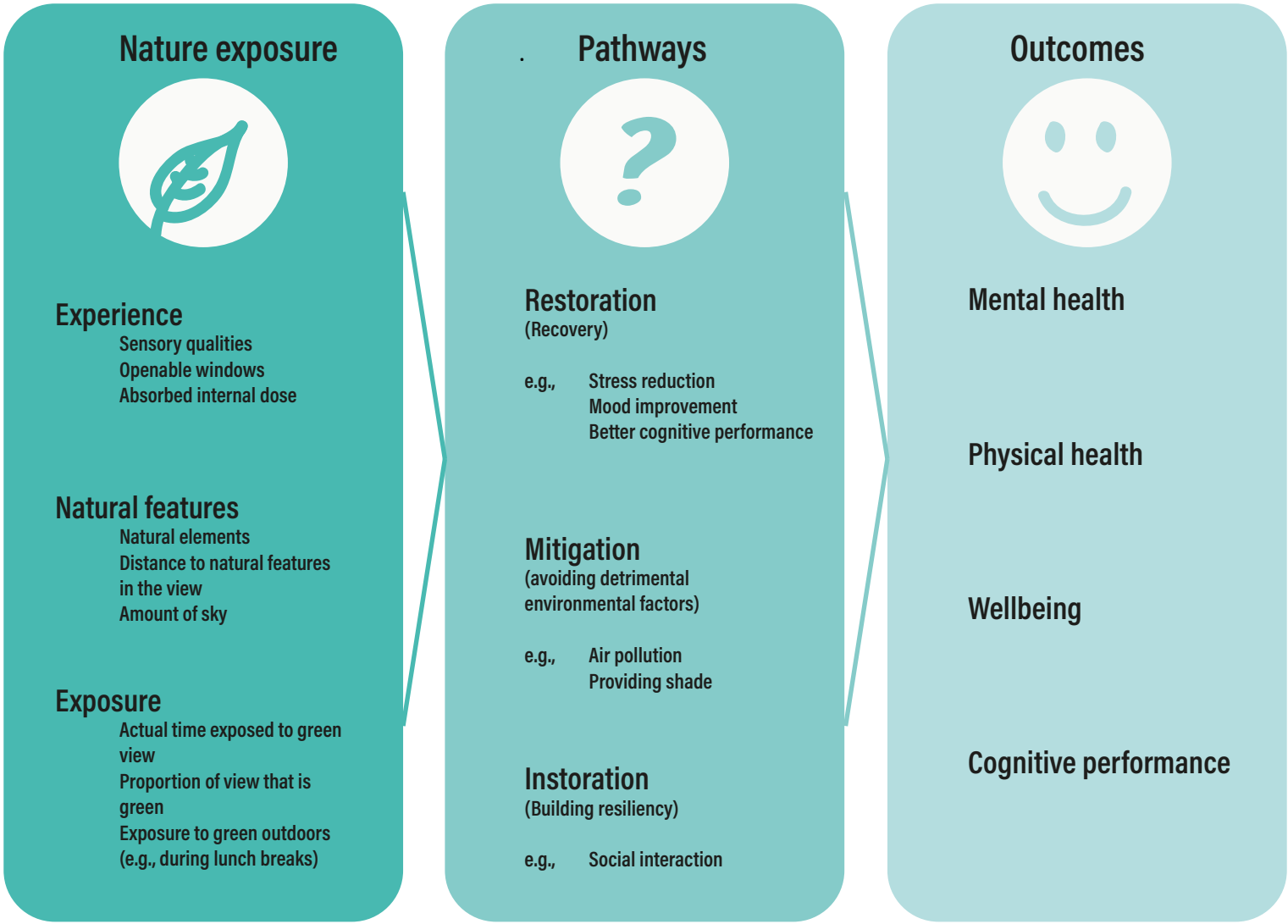


Figure 1. Pathways from nature exposure to mental health, adapted from (Beute et al., 2020, Markevych et al., 2017).

Daylight: Theoretical Background

Daylight entering through windows affects the room and its inhabitants in a myriad of ways. It affects the aesthetics of the room, visual performance, but also well-being and health of the occupant. How much daylight enters the room and reaches the inhabitants at a given moment in time depends on various factors, including the room design, outdoor or contextual aspects, and the window itself. Room design elements that influence daylight entrance for instance are where the person is seated relative to the window, the orientation of the window, the size and placement of the window relative to the room it is placed in, and the furnishment of the room itself. Outdoor or contextual aspects that are relevant include the time of day, the season, the weather outside, the geographical location, adjecents buildings or foliage of nearby trees that screen daylight entrance. Window elements that influence daylight entrance are the glazing type and the choice of solar shading (indoors/outdoors). Perhaps the most eminent effects of daylight on well-being run through the effects of light exposure on the biological clock. Especially the timing of the light exposure and the intensity and spectral composition of the light are relevant for circadian functioning, thereby influencing sleep quality, alertness, and physiological functioning. Daylight is highly variable, with changes in quality and quantity ranging over a short time (seconds) to a long time (seasons). Daylight changes in amount, spectral composition, and directionality. Besides, at most locations on Earth, the photoperiod (length of day) varies every day.

Circadian rhythm

For centuries, the cycle of day and night has been orchestrated by the sun and this has dictated human rest and activity cycles. Humans have evolved to be active during the day and sleep during the night. Daylight is therefore seen as the most important cue for our sleep and wake cycle (Roenneberg, Kantermann, Juda, Vetter, & Allebrandt, 2013). The emergence of electric light has allowed people to be productive before sunrise and after sunset. This, however, also allows for the wrong light exposure at biologically wrong times, thereby potentially hindering good circadian functioning. The intensity and spectral composition of electric light is also different than sunlight. Especially bright light exposure late at night is detrimental for our circadian rhythm (Tähkämö, Partonen, & Pesonen, 2019; Vetter et al., 2021). A disturbed circadian rhythm has been found related to a number of diseases, including Alzheimer (Riemersma-Van Der Lek et al., 2008), seasonal and non-seasonal depression (Walker, Walton, DeVries, & Nelson, 2020), ADHD (Bijlenga, Vollebregt, Kooij, & Arns, 2019), and schizophrenia (Meyer et al., 2020; Walker et al., 2020).

Research looking at the effects of light on circadian functioning is however still an evolving field. Only in the beginning of this century, it was discovered that besides rods and cones there were also retinal

cells in the eye that appeared unrelated to vision (Berson, Dunn, & Takao, 2002; Hattar, Liao, Takao, Berson, & Yau, 2002). Instead, these so-called intrinsically photoreceptive retinal ganglion cells (ipRGCs) were found to send information to the suprachiasmatic nuclei, where the body's biological clock resides (Baver, Pickard, Sollars, & Pickard, 2008). And these cells appeared sensitive to light in a particular part of the spectrum of light, namely what is often referred to as 'blue' light. This led many light researcher to divide the effects of light into the ' visual effects' of light (e.g.,, vision and visual performance; the rods and cones) and the ' non-visual effects' (e.g., circadian and acute alerting effects; the ipRGCs) of light. It has also led to the creation of a number of measurement units of light, corrected for the sensitivity of the human visual system to specific wavelengths, including the application lux, corrected by the V(λ) curve (Vos, 1978), the melanopic lux (Lucas et al., 2014), or the circadian stimulus (Rea, Figueiro, Bierman, & Bullough, 2010).

Daylight changes in intensity and spectral composition throughout the day, between different weather types, and between seasons (Granzier & Valsecchi, 2014). For instance, during twilight, daylight has a different intensity (displaying a peak), composition (i.e., more blue light), and angle (more horizontal) (Roenneberg & Foster, 1997). There is still no consensus on the dose, timing, and composition of daylight necessary for good health (Münch et al., 2020).

Vision research is now increasingly demonstrating that there is not such a strict separation between what is often referred to as the visual (i.e., seeing the world; rods and cones) and the non-visual (i.e., effects of light on circadian functioning; ipRGC's) pathway. Instead, there appears to be a complex relation between the different pathways, where the visual system also receives information from the ipRGc's and vice versa (Allen, Martial, & Lucas, 2019; Milosavljevic et al., 2018).

A recently proposed methodology to classify the light environment, the ELF method, criticises the dominant use of illumination and radiance in research investigating the effects of light on human functioning as these entities do not necessarily directly relate to the functioning of human vision (Nilsson & Smolka, 2021). Instead, the authors have proposed an alternative method to capture the biological relevance of a lighting environment by looking at the environment as a whole instead of only the portion that reaches the eye, thereby incorporating elements such as reflection, elevation angle in relation to the position of the eye, contrast, and spectral composition of the light. This method goes beyond looking at light sources and how much light is radiated, but instead focuses on the elements or objects that comprise the environment and how these reflect, refract, and transmit the light. It also includes light from different horizontal and vertical angles in relation to the eye. Lighting environments differ between different types of physical environments (e.g., indoor versus outdoor, man-made versus natural environments), but also within the same environment based on type of day, weather type, and season.

Importantly, the authors postulate that since the subliminal process of light's influence on biological function appears modulated by the

visual pathway (i.e., input from the rods and cones) this may signal that the environmental characteristics serve a biological purpose guiding approach and avoidance behavior for different habitats (Nilsson & Smolka, 2021). This proposed biological significance of the lighting environment is very much in line with previously asserted evolutionary-based benefits of natural environments by Roger Ulrich (Ulrich, 1983).

Daylight mainly reaches our eye through the sky, constituting a large and extended light source as opposed to for instance electric light that usually comes from a relatively small target. Based on studies in non-humans looking at the distribution of the photosensitive retinal cells in the eye (Dacey et al., 2005), it is assumed that light affects us most when it comes from a large source (such as the sky). The directionality of light and size of the light source may therefore also influence how light affects human well-being and health, but more research in humans is needed to substantiate this (Münch et al., 2020).

The effects of light exposure on circadian functioning has mostly been conducted with electric light in laboratory studies or ambulatory studies monitoring a mix of electric light and daylight (Tähkämö et al., 2019). The dynamic and unpredictable nature of daylight, which highly depends on the weather, time of day, orientation, and season makes it difficult to control and implement in laboratory studies.

Field studies, using everyday exposure to light not always corroborate the findings from the laboratory, where more extreme light levels are used and the light exposure before and after the test manipulation is highly controlled (Aries, Fischl, Lowden, & Beute, *submitted*, Beute, Lowden, & Aries, *submitted*). In fact, everyday light levels also matter for circadian function but might depend more on for instance the light history, i.e.: the prior amount of light you have been exposed (A.-M. Chang, Aeschbach, Duffy, & Czeisler, 2015; Münch, Linhart, Borisuit, Jaeggi, & Scartezzini, 2012; Münch et al., 2016).

In addition to lagged effects on human functioning and well-being via sleep and the circadian system, light can also have acute effects on for instance alertness mood, and physiology (such as heart rate) (see, e.g.,Jung et al., 2010; Souman, Tinga, Te Pas, Van Ee, & Vlaskamp, 2018; Vandewalle, Maquet, & Dijk, 2009; Vandewalle et al., 2010).

Electric light interventions sometimes also simulate daylight, i.e.; implementing bright light exposure to combat affective disorders (Golden et al., 2005) or burn-out symptoms (Meesters & Waslander, 2010) ; dawn/dusk simulation to improve sleep hygiene (Gasio et al., 2003; Terman, Schlager, Fairhurst, & Perlman, 1989); or dynamic light patterns in the office to improve performance (Aries, Beute, & Fischl, 2020).

Effects of daylight on health and well-being through psychological pathways have not received (m)any attention yet, unfortunately (Beute, 2014). As with view types, the effects of daylight exposure

through the windows should always be seen in a context. Throughout the day, people are not only exposed to light through windows, but also to daylight exposure outdoors (e.g., during the commute between home and work or home and school (Dumont & Beaulieu, 2007; van Duijnhoven, Aarts, Aries, Böhmer, & Rosemann, 2017)) and also to electric lighting, both when sitting by the window and during dark periods of the day. This light history also affects and potentially confounds the effects of daylight through windows.

Visual and psychological effects of daylight

Daylight through windows can also influence comfort and visual performance, which is especially relevant for windows in offices. Visual comfort is related to concepts such as glare and contrast whereas visual performance concerns how well and how quickly you can perform tasks (Knoop et al., 2020).

Whether a person experiences glare from (for instance) a window depends on a complex interaction of factors, including for instance the orientation of the window, the position of a person relative to the window, whether the view from the window contains many different illuminances (i.e, is a non-uniform light sources), the colour distribution of the view (which is, for instance affected by some types of glazing), time of day, season, and even the quality and type of the view (for an overview, see (Pierson, Wienold, & Bodart, 2018)). The amount of nature in the view, the quality of the view, and the distance within the view, for instance, can all influence perceived glare (J. Y. Shin, Yun, & Kim; Tuaycharoen & Tregenza, 2005, 2007)

Another recent function of daylight is related to the prevalence of myopia. It has been found that bright light can protect against developing myopia, and there is also some evidence that peripheral defocus by spending times outdoors (i.e., looking more in the distance) also contributes to this protective effect (Lingham, Mackey, Lucas, & Yazar, 2020).

Not a lot of research has focused on pure psychological effects of daylight. There is a strong preference for daylight, though (M Boubekri & Haghighat, 1993; Haans, 2014; Veitch & Gifford, 1996). The appraisal of daylight is often found interrelated with other factors in the environment, such as thermal comfort and acoustics (Huang, Zhu, Ouyang, & Cao, 2012; Yang & Moon, 2019). For instance, two studies looking at effects of daylight through windows investigated effects on thermal comfort. One study found that there was a cross-modal effect between light level and temperature (Chinazzo, Wienold, & Andersen, 2019), with cooler temperatures experienced as being colder under low daylight circumstances and warmer temperature experienced as cooler under high daylight circumstances. A second study used electric light and also found an opposite relation, with the perceived light intensity and colour temperature affected by thermal comfort (Te Kulve, Schlangen, & van Marken Lichtenbelt, 2018). In addition, a higher visual comfort also resulted in a higher reported thermal comfort.

In sum: Daylight through windows

The benefits of daylight through windows on human health and well-being is highly complex and affects both visual comfort and

performance as well as human health with both acute and lagged (circadian) effects. Effects depend highly on geographical location, season, weather type, and time of day. In addition, architectural elements such as window size and orientation influence the amount of daylight enters via the window. Light exposure (in modern society almost always a combination of both daylight and electric light) at the right time of day and with the right composition and intensity can improve sleep, physiological functioning, and also mood, cognitive performance, and alertness. These effects may depend highly on our previous exposure to light, for instance when commuting to work. Conversely, night-time exposure to light may counteract any potential benefits gained from exposure to daylight during the day. Our lighting environment may have evolutionary significance in a similar fashion as natural environments, evoking approach and avoidance behaviour and subsequent affective responses. Psychological effects of daylight have, however, received little to no attention yet. See Figure 2 for an overview of the pathways from daylight to health.

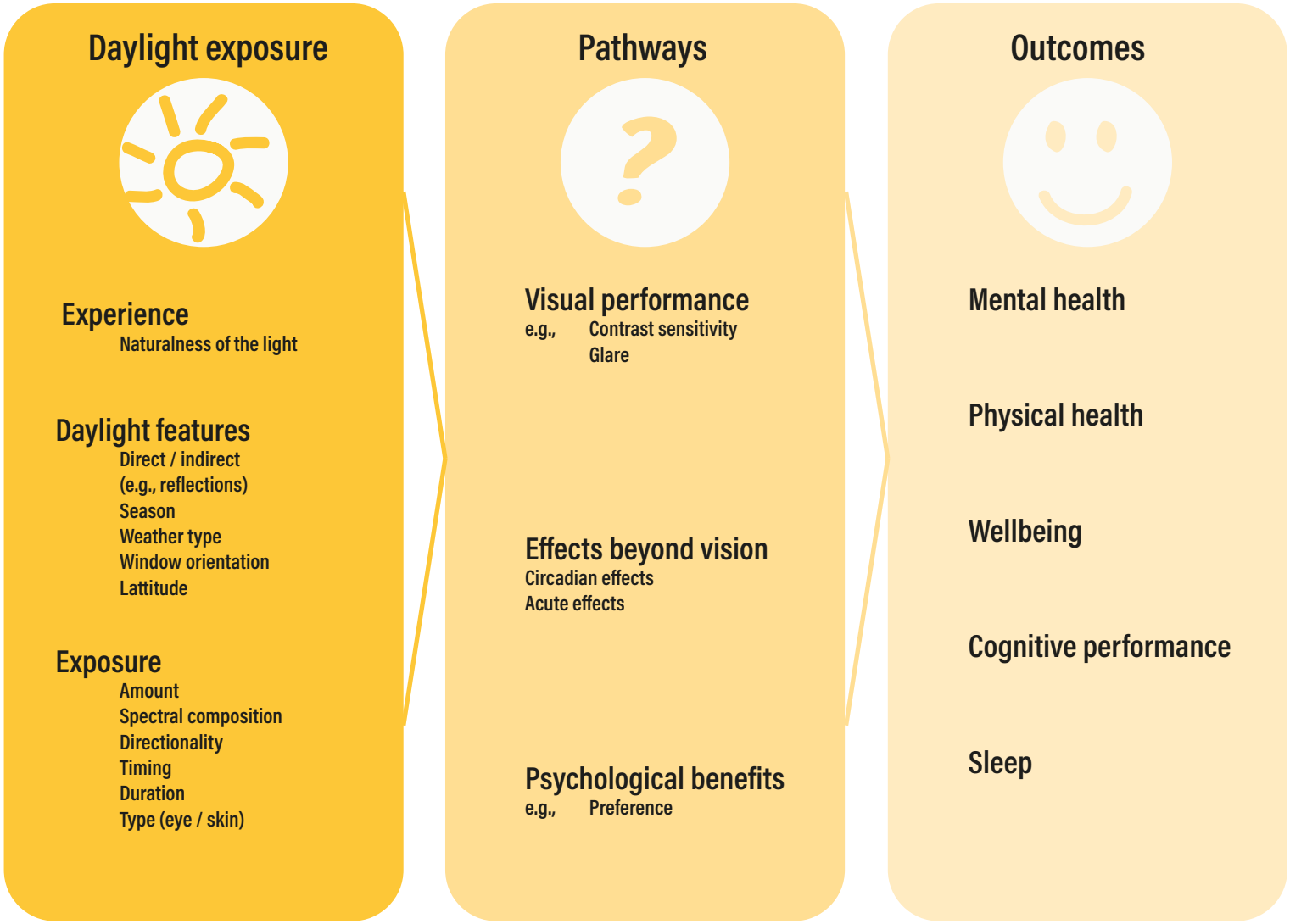


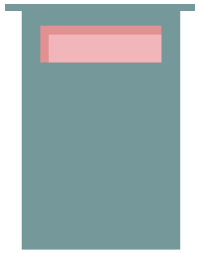
Figure 2. Pathways from nature exposure to mental health..

Empirical evidence for the benefits of windows

Since 2013, a number of studies have been published looking specifically at the effects of windows on health outcomes. Most of these studies focused on view content only, whereas others had daylight as the main predictor. Other studies either explicitly looked at daylight and view content simultaneously, or focused on having access to a window or not. In this section, an overview of studies performed on the effects of windows in four different settings: the office, educational settings, healthcare environments, and residential settings. In addition, studies looking at windows without a particular context (e.g., performed in a psychological laboratory) are included in a fifth section. The sections will mostly report studies performed after 2013, but will also include some that were performed before that time. Each section will discuss effects of naturalness of the view, other aspects of the view (beyond naturalness), daylight exposure, studies combining view and daylight, and studies looking at window access (i.e., comparing having a window versus no window). Each section includes a summary table of the studies discussed in that section.

Summary table explanation

Type of research: In the table, two different research types are distinguished; **experimental** and **cross-sectional** research. In **experimental** studies, one or more components related to windows are manipulated (e.g., windows are covered with blinds versus not) and the effects of this manipulation are tested. Experiments can be performed in a psychology laboratory, or in the real world. Experimental studies generally have better control over the relation between the intervention (e.g., different uses of window blinds) and the health outcome. In **cross-sectional** studies, relationships between two variables (e.g., window elements and health outcomes) are often investigated without manipulating them. This allows for measuring effects in everyday life and in everyday situations. In cross-sectional studies, it is often easier to reach larger numbers of participants. In addition, (national) databases can be used to reach conclusions. Because there is no intervention, it is more difficult to find causal relationships between the variables. In other words, because the window element and health outcome vary at the same time it is not always clear in which direction the effect goes. For instance: does a high quality view improve mood, or do people rate the view better when they are in a better mood?
Sample size: refers to the number of people that participated in the study.
Intervention / measurement: refers to an intervention for experimental studies (i.e., what is manipulated in the window) and the measurement in cross-sectional studies (e.g., amount of green in the view).
Outcome measure: The environmental rating or health outcome where the effect is tested on. For instance: view quality or satisfaction with the lighting as environmental rating, and sleep or mood as health outcome.
Results: The outcomes of the studies summarized in positive (**+**), neutral or no effect (□), or negative effect (**-**).



Windows in the office

Naturalness of the view

Effects of naturalness of the view was most often studied in a cross-sectional design. Two studies reported higher life satisfaction when office workers had more natural views from the office (C.-c. Chang et al., 2020; van Esch, Minjock, Colarelli, & Hirsch, 2019). One of these studies found a positive relation between naturalness of the view and subjective well-being as well (van Esch et al., 2019). However, another study did not find an association between naturalness of the view and subjective well-being (Gilchrist, Brown, & Montarzino, 2015). In addition, those that spend most time in open space (in terms of duration, not frequency) had higher subjective well-being scores. This study further looked at particular natural components of the view and found that trees/woodland, lawn/mown grass, bushes/flowering plants all had positive effects on subjective well-being. No effects were found for the built characteristics (nor for water features, fields and distant countryside, meadow/rough grass) or the sky. Another study, in Denmark, also looked at separate view elements. This study did find an effect of the sky on satisfaction with the view, along with trees, flowers, park-like environments, and having indoor plants, whereas buildings / signs or having no outdoor view was related to lower satisfaction (Lottrup, Stigsdotter, Meilby, & Claudi, 2013). No effect was found for cars/traffic, mowed lawns, wild self-seeded environments. A higher satisfaction with the view was additionaly related with higher job-satisfaction. A study looking at amount of green as a whole (without looking at separate elements) did not find an effect of greenness on view quality (Matusiak & Klöckner, 2016).

In South-Korea, it was found that office workers with a window view to the forest experienced less stress and had a higher job satisfaction than office workers without a view to the forest (Sop Shin, 2007). A study in a high-rise office building found that a natural view from a high floor level yielded better health outcomes in terms of physiology, brain activity, and mood than looking at an urban environment form a high floor (Elsadek, Liu, & Xie, 2020). One longitudinal study (measured across a year) in Finland could not find a long-term relation between nature exposure at work (including the window view) and vitality (often defined as positive energy and of course only represents a part of the mental health benefits available) (Korpela, De Bloom, Sianoja, Pasanen, & Kinnunen, 2017).

Table 1. Windows in the office: Naturalness of the view

Windows in the office: Naturalness of the view						
Article	Country	Type of research	Sample size	Intervention / measurement	Outcome measure	Results
(C.-c. Chang et al., 2020)	Singapore	Cross-sectional	1262	Presence nature in view	Life satisfaction	+ Higher life satisfaction when a window with natural view was present.
(Elsadek et al., 2020)	China	Experiment	30	Office window with urban vs natural view	Physiology, mood	+ Participants with a natural view had more parasympathetic activity and better mood.
(Gilchrist et al., 2015)	UK	Cross-sectional	366	Amount of nature & natural & urban elements in the view, *satisfaction with the view.*	Subjective well-being	+ Trees/woodland, lawn/mown grass, bushes/flowering plants were positively related to well-being. □ Naturalness of the view was not related to well-being. No relation with well-being was found for built elements, water features, fields and distant countryside, meadow/rough grass, sky.
(Korpela et al., 2017)	Finland	Cross-sectional	841	Nature exposure at work (including Views from the window, looking out of the window)	Subjective well-being	□ No long-term relation between nature exposure at work and well-being (vitality). There was also no effect of frequency of looking out of the window.
(Lottrup et al., 2013)	Denmark	Cross-sectional	402	View content, natural & urban elements	View satisfaction	+ Sky, trees, flowers, park, indoor plants in view increased satisfaction with the view. □ Cars/traffic, mowed lawns, wild self-seeded environments had no effect on view satisfaction. - Buildings / signs, having no outdoor view were related with lower view satisfaction.
(Matusiak & Klöckner, 2016)	Norway	Cross-sectional	106	Naturalness, *view distance, layers, quality landscape, composition view, width, weather, quality,*	View quality	□ Amount of green did not predict view quality
(Sop Shin, 2007)	South-Korea	Cross-sectional	931	Forest in the view or not	Job satisfaction, stress	+ Those who had a forest in their view reported a higher job satisfaction and less stress.
(van Esch et al., 2019) Study 2	USA	Cross-sectional	303	Naturalness view, *coherence, eligibility, legibility, mystery, prospect, refuge*	Subjective well-being, job satisfaction	+ Amount of nature was related to better outcomes on all-but-one measures. □ No effect was found of amount of nature on physical well-being

View characteristics beyond naturalness

A number of studies investigated effects of view characteristics on top of or beyond the effects of naturalness of the view. The first study found that view characteristics such as legibility, complexity, coherence, and mystery were related to several factors of job-related health and satisfaction outcomes and that these effects were found on top of beneficial effects of natural content (van Esch et al., 2019). A study conducted in Norway found no relation between greenness of the view and reported view quality, but did report effects of view depth and the number of view layers (Matusiak & Klöckner, 2016). Another study found no relation of greenness of the view as a compound measure with subjective well-being, but did find effects of individual green elements as well as satisfaction with the view with subjective well-being (Gilchrist et al., 2015). A third study found benefits of individual natural elements on satisfaction with the view. A higher view satisfaction, in turn, was found related to higher job satisfaction (Lottrup et al., 2013).

Table 2. Windows in the office: Characteristics of the view (beyond naturalness)

Windows in the office: Characteristics of the view (beyond naturalness)							
Article	Country	Type of research	Sample size	Intervention / measurement	Outcome measure	Results	
(Gilchrist et al., 2015)	UK	Cross-sectional	366	Satisfaction with the view. *Amount of nature & elements in the view.*	Subjective well-being	+	Higher well-being was reported with a higher satisfaction with the view.
(Lottrup et al., 2013)	Denmark	Cross-sectional	402	View satisfaction, *View content, natural & urban elements*	Job satisfaction, view satisfaction	+	Higher view satisfaction related to higher job satisfaction.
(Matusiak & Klöckner, 2016)	Norway	Cross-sectional	106	View distance, layers, quality landscape, composition view, width, weather, quality, *naturalness*	View quality	+	View distance, number of view layers, quality of the landscape/elements, and composition of the view predicted view quality
						□	Width of the view, presence of water, and weather condition did not predict view quality
(van Esch et al., 2019) Study 2	USA	Cross-sectional	303	Coherence, eligibility, legibility, mystery, prospect, refuge, *naturalness view.*	Subjective well-being, job satisfaction	+	The view characteristics (especially coherence and refuge) were related to better outcomes for well-being and satisfaction, beyond naturalness on all outcomes.

Daylight entrance

Daylight entrance was investigated in terms of sun patches and different types of shading. The presence of sun patches in the office, as well as the shape of these sun patches has been investigated in relation to visual quality, environmental satisfaction, mood, and cognitive performance. No effect of sun patches were found on cognitive performance (N. Wang & Boubekri, 2010), seating preference (N. Wang & Boubekri, 2010), visual comfort and interest (Abboushi et al., 2021), environmental satisfaction (Mohamed Boubekri, Hull, & Boyer, 1991), and cognitive performance (N. Wang & Boubekri, 2010). Larger sun patches were related to higher relaxation ratings, whereas window size did not affect mood or environmental satisfaction (Mohamed Boubekri et al., 1991).

One study compared effects of mesh shades and dynamic tinting glass to a condition with no daylight or view (blackout) and found better outcomes for both conditions that provided access to daylight in terms of satisfaction with the light, eye strain, and cognitive performance, but did not find any differences between the two conditions (Jamrozik et al., 2019).

Table 3. Windows in the office: Daylight entrance

Windows in the office: Daylight entrance						
Article	Country	Type of research	Sample size	Intervention / measurement	Outcome measure	Results
(Abboushi et al., 2021)	USA	Experimental	33	Three different sun patch patterns (striped, fractal, clear)	Visual comfort, view quality, visual interest	+ The clear (unobstructed) condition scored better on view quality □ There was no difference in scores on visual comfort or visual interest (of the sun patches).
(Mohamed Boubekri et al., 1991)	USA	Experimental	40	Window size and sun penetration	Mood, environmental satisfaction	+ Relaxation was higher with more sun penetration □ No effect of window size or sun penetration on satisfaction with the environment or excitement. No effect of window size on relaxation.
(Jamrozik et al., 2019)	USA	Experimental	10	Mesh shades vs automatic tinting vs control (no daylight or view)	Satisfaction with environment and view, job satisfaction, productivity, headache and eyestrain, cognitive performance	+ Better performance on the working memory load task and inhibition task for both daylight conditions. No difference between the two shadings. Higher satisfaction with the work environment and less eyestrain for both daylighting conditions. The only difference between mesh and automatic was higher aesthetic experience of the work place in dynamic condition (vs control) □ No difference on the task switching task. - Higher reported glare in the two daylighting conditions
(N. Wang & Boubekri, 2010)	USA	Experiment	100	Office room with sun patches	Seating preference, performance	□ No relation between seating location (relative to sun patches) and performance was found. No clear pattern of preferred seating location relative to the sun patch was found

Views and daylight

A study in the Netherlands revealed that a more pleasant view can reduce physical and mental discomfort, but sitting close to the window and being dissatisfied with the lighting environment (in general) increased discomfort in terms of temperature and glare (M. B. Aries et al., 2010). In addition, having a natural view was related to more physical and mental discomfort. However, natural views decreased physical and psychological discomfort indirectly through better office impressions. Other studies did find more pronounced benefits of natural views and daylight entrance. A survey study investigated exposure to direct sunlight, indirect sunlight, and natural elements in the office (An, Colarelli, O'Brien, & Boyajian, 2016). In this study, it was found that natural elements (including indoor plants, window views, potted plants, nature content on the pc, pictures, and artwork) lowered depression and increased job satisfaction and organizational commitment. Direct sunlight (outdoor exposure to the sun) was related with lower anxiety, higher job satisfaction, and more organizational commitment. Indirect sunlight (having a window) was related with lower depression and higher organizational commitment. Further analysis indicated that indirect sunlight had the largest effects on depression and organizational commitment. Note, though, that this category was measured by the question having a window available (as well as being able to control the blinds, and being satisfied with the amount of sunlight) and therefore still includes both a view and daylight exposure. Having a window view together with the presence of indoor plants and exposure to natural light in the office was related with better general health (Largo-Wight, Chen, Dodd, & Weiler, 2011). Another study investigated the effects of sunlight (measured as perceived floor area of sun patches) and naturalness of the view for office employees (Leather, Pyrgas, Beale, & Lawrence, 1998) and found that more sun patches were related to lower job strain, higher job satisfaction, feeling less worn-out, and tense. Naturalness of the view did not affect these scores, but office workers with high job strain reported a lower intention to quit when they had a more natural view. A last study included a compound measure of indoor nature contact, taking exposure to indoor plants, outdoor views, and sunlight together in a single measure (Bjørnstad, Patil, & Raanaas, 2016). Greater indoor nature contact was related to lower job stress, fewer health complaints, and fewer sick leave days. Outdoor nature contact was measured as well, but no association with any of the outcomes were reported.

Access to daylight and views was manipulated in one study compared having a view and daylight entry through a window versus a blocked window in two identical offices (Mohamed Boubekri et al., 2020). In one office, the blinds were rolled down during the study period, whereas the other office employed electrochromic glazing and the view to the natural outdoor areas was unobstructed throughout the study period. Results show that participants with daylight and a view slept on average 37 minutes longer, and this benefit was most pronounced for people that scored as poor sleepers. Cognitive performance was better in the daylight and view

condition. No differentiation was made between view content and daylight entry.

Table 4. Windows in the office: Views and daylight

Windows in the office: Views and daylight						
Article	Country	Type of research	Sample size	Intervention / measurement	Outcome measure	Results
(An et al., 2016)	USA & India	Cross-sectional	444	Exposure to natural elements (in office) and indirect sunlight (through windows*)	Depression, anxiety, job satisfaction, organizational commitment.	+ Natural elements were related with lower depression and a higher job satisfaction and commitment. Indirect sunlight was related to lower depression, and a higher job satisfaction and commitment. Relations with mental health were stronger for sunlight than for nature views* □ No relation between natural elements or indirect sunlight and anxiety.
(M. B. Aries et al., 2010)	The Netherlands	Cross-sectional	333	View quality, naturalness view, window distance	Discomfort, sleep quality, environmental utility, light quality, office impression, seasonality	+ A higher view quality was related to lower psychological and physical discomfort. Natural elements in the view increased environmental satisfaction. □ Window distance, view type, and view quality did not relate to sleep quality, seasonality, light quality. No relation between view type or quality and environmental utility (glare, thermal discomfort). No relation between window distance and discomfort. - Viewing nature increased physical and psychological discomfort. A closer distance to the window resulted in more glare and thermal discomfort.
(Bjørnstad et al., 2016)	Norway	Cross-sectional	565	Indoor nature contact (indoor plants, outdoor views, sunlight)	Job stress, general health, sick leave	+ Indoor nature contact was related to lower job stress, less health complaints, and less days of sick leave. With relations with job stress and sick leave being mediated by organizational support.
(Mohamed Boubekri et al., 2020)	USA	Experimental	30	Electrochromic glazing versus dark fabric roller at 75 % (1,5% transparent)	Sleep, cognitive performance	+ Workers in the office with electromagnetic glazing slept better than in the office with blinds, this difference was most pronounced for people classified as poor sleepers. Cognitive performance was also higher in the electromagnetic glazing office than in the office with blinds.

Table 5. Windows in the offide: Views and daylight continues

Windows in the office: Views and daylight (continued)						
Article	Country	Type of research	Sample size	Intervention / measurement	Outcome measure	Results
(Largo-Wight et al., 2011)	USA	Cross-sectional	503	Indoor nature contact (including view, natural light, indoor plants)	Stress, general health, mental health	+ Workers with more indoor nature contact reported better general health. □ No relation was found between indoor nature contact and stress and number of days with poor health.
(Leather et al., 1998)	Southern Europe	Cross-sectional	100	Sunlight (perceived floor area of sun patches), illumination, naturalness of the view	Exhaustion, intention to quit, job satisfaction, subjective well-being	+ Sunlight was positively related to job satisfaction and well-being and a lower intention to quit. View interacted with job strain, indicating that natural views may buffer the negative effects of job strain on well-being. □ View was not related to job satisfaction or intention to quit.

* please note that the items measuring exposure to indirect sunlight also included items measuring having a view or not.

Window access

Studies have investigated access to a window both in terms of comparing offices with a window to those without a window, and by comparing access to the window in terms of different distances to the window.

Studies focusing on the presence of a window have done so irrespective of daylight entrance and view content characteristics. Working in windowless environments has been found to increase feelings of being enclosed (Fich et al., 2014; Küller & Wetterberg, 1996; E. H. Lee, Christopoulos, Kwok, Roberts, & Soh, 2017), an increased sense of a lack of control (E. H. Lee et al., 2017), an avoidance response (Vartanian et al., 2015), increased stress levels (Vartanian et al., 2015), and disturbed hormonal patterns (Küller & Wetterberg, 1996). Compensation for windowlessness could occur through skylights, paintings, plants, and light panels (Biner, Butler, Lovegrove, & Burns, 1993). Office workers without windows often compensate for this by including natural decorations such as nature images and plants (Bringslimark, Hartig, & Grindal Patil, 2011; Heerwagen & Orians, 1986), although another study found no evidence for compensation for windowlessness by these factors while there was evidence for the importance of personalization of the space in the choice of decoration (Biner et al., 1993). The presence of office decorations may influence effects of the presence of windows, as one study found that workers with a view in the office had higher scores for job satisfaction than colleagues without a window, but this effect was influenced by the presence of indoor plants (Dravigne, Waliczek, Lineberger, & Zajicek, 2008). Workers with a window view but no plants scored lower on job satisfaction.

Office workers reported higher vitality levels, longer sleep duration, better sleep quality, and better mental health for those working in a room with windows compared to those working in a room without windows (Mohamed Boubekri, Cheung, Reid, Wang, & Zee, 2014). In addition, the light exposure was higher during work hours for those with a window, in the evening and -surprisingly- during their days off.

Having access to a window was related with higher satisfaction with the lighting environment but not with job satisfaction, the authors state this may be because most windows in the survey could not open (Leder, Newsham, Veitch, Mancini, & Charles, 2016). A second study found that employees with better access to a window and with lower discomfort glare (overall, not specifically from the window) had a higher satisfaction with the lighting (Leder et al., 2016). A positive relation between access to the window and environmental satisfaction was also found in a study conducted in Turkey (Yildirim, Akalin-Baskaya, & Celebi, 2007). Most studies have been conducted in a European or Northern-American context, and therefore different outcomes may be found for different cultures and climates. In Egypt, for example, office workers preferred sitting away from the window, and on the South façade (equivalent to the North façade in European regions) (Aboulfotouh, Tolba, & Ezzeldin, 2020), which is contrary to the outcomes in most European or American studies.

Table 6. Windows on the office: Window access

Windows in the office: Window access						
Article	Country	Type of research	Sample size	Intervention / measurement	Outcome measure	Results
(Aboulfotouh et al., 2020)	Egypt	Cross-sectional	391	Proximity to window	Satisfaction with environment	□ Proximity to the window did not affect satisfaction with most of the IEQ parameters measured - Those sitting close to the window were less satisfied with their acoustic privacy than those sitting further away from the window. Overall, more dissatisfaction with IEQ was reported for those sitting close to a window.
(Biner et al., 1993)	USA	Cross-sectional	47 (S1), 173 offices spaces (S2)	Room with and without windows	Window substitutes	□ Other apertures, paintings, living things were rated as substitutes for windows. No difference in substitutes (number, size) were found between the two office types.
(Mohamed Boubekri et al., 2014)	USA	Cross-sectional	49	Room with and without windows	Sleep quality, general health, activity level, sleep	+ Workers in offices with a window received and perceived more daylight exposure. They also reported a better general health, and slept longer. □ No difference was found in activity level on days off and sleep onset, offset, fragmentation, latency, and efficiency. No effect on total activity level was found.
(Bringslimark et al., 2011)	Norway	Cross-sectional	385	Room with and without windows	Window substitutes	+ Workers in windowless offices has 5 times higher odds of bringing a plant and 3 times higher odds of bringing a nature picture.
(Dravigne et al., 2008)	USA	Cross-sectional	~450	Room with and without windows (with and without plants)	Job satisfaction, quality of life	+ Higher job satisfaction and quality of life was reported by those with a window view and plants - Lower scores were reported for those with a window view but no plants.
(Fich et al., 2014)	Sweden	Experimental	49	(Virtual environment) room with and without windows	Cortisol, physiology	+ Cortisol increase was lower in the virtual room with a window □ No effects were found on physiology (autonomic nervous system)

Table 7. Windows in the office: Window access continued

Windows in the office: Window access (continued)						
Article	Country	Type of research	Sample size	Intervention / measurement	Outcome measure	Results
(Küller & Wetterberg, 1996)	Sweden	Cross-sectional	132	Subterranean military bases vs above ground military basis	Cortisol and melatonin, assessment of the work environment, mood, work-related discomfort, job satisfaction, sleep, sick leave	+ Subterranean offices were rated more enclosed and old-fashioned and the lighting was rated as being less bright and less pleasant, with more complaints of glare, and visual discomfort than the above ground offices. A seasonal variation in cortisol was found in the above ground office, but not for the subterranean offices. A larger variation in melatonin production was found for the subterranean workers. □ The offices scored similar in terms of pleasantness, unity, complexity, potency, social status, and originality. No difference in temperature ratings were given. No difference in work-related discomfort (other than visual). No differences in mood or sick leave were found. - Lower job satisfaction was reported in the above ground offices. A longer sleep duration as well as falling asleep more easily was reported by the subterranean workers.
(Leder et al., 2016)	Canada & USA	Cross-sectional	779	Proximity to a window	Satisfaction with the work environment	+ Higher satisfaction with the light was related to greater window access and lower perceived glare. □ No relation between greater access to a window and thermal comfort or acoustic comfort
(Vartanian et al., 2015)	?	Experimental	18	(Images) Room with and without windows, with high and low celing height.	Preference, approach and avoidance (enter or exit), fMRI	+ Participants were more likely to approach (enter) open spaces and rated open rooms as beautiful more often. Neural responses to enclosed rooms were also different.
(Yildirim et al., 2007)	Turkey	Cross-sectional	41	Proximity to a window	Satisfaction with environment space in terms of planning, privacy, lighting	+ Workers sitting close to a window reported better satisfaction with planning, privacy, and lighting.

Windows in an educational setting

Naturalness of the view

Naturalness of the view was investigated using both real, everyday exposure and effects of photos. Exposure was measured both in terms of presence of nature in the view, or the amount of nature in the view.

Presence of nature was investigated in three studies. Two of these studies compared a window with an open view to a window facing an adjacent wall in an educational setting. The first study compared having a break for schoolchildren in three different break rooms: no window, a window overlooking an adjacent brick wall, and a window with an open, natural view (D. Li & Sullivan, 2016). This study found that attentional capacity improved most and stress recovery was largest during the break in a room with a window opening up to an open, natural space than in the other two conditions. No difference was found between the condition with no window and the condition overlooking a brick wall. A second study investigated differences in the evaluation of an undergraduate course between two classrooms, one with an adjacent concrete wall and one overlooking an open field with blossoming trees (Benfield, Rainbolt, Bell, & Donovan, 2015). Students were seated with their backs towards the window.

No differences were found in the evaluation of the classrooms, but the quality of the course, classroom resources, and course materials were evaluated more favourably in the natural view classroom. Having a window with plants increased visual (but not verbal) creativity (Studente, Seppala, & Sadowska, 2016), whereas a view to nature as opposed to having no view at all resulted in higher perceived restorativeness ratings (Felsten, 2009).

Amount of nature in the view was related to lower stress and better concentration, but not to cognitive performance and social well-being for primary school children in Germany (Lindemann-Matthies, Benkowitz, & Hellinger, 2021). A study looking at both window size and naturalness of the view of classroom and cafeteria windows found mixed results. Naturalness of the window view in the cafeteria but not of the classroom was related to performance, whereas the size of the window only appeared to matter in the classroom (Matsuoka, 2010).

Table 8. Windows in an educational setting: Naturalness of the view

Windows in an educational setting: Naturalness of the view						
Article	Country	Type of research	Sample size	Intervention / measurement	Outcome measure	Results
(Benfield et al., 2015)	USA?	Experiment	567	Naturalness of the view (nature vs urban)	Course evaluation, student attendance and grades	+ Students in the classroom with natural views gave higher ratings to the quality of the course, the classroom resources, and the course materials. Students in the classrooms with natural views had a higher grade at the end of the course. □ No effects of classroom view were found on ratings of subject matter, enthusiasm of the instructor, quality of the building, classroom features, or the other students. No effects of window view was found on attendance or mid-term grade.
(Felsten, 2009)	USA		236	Photos with natural views vs no (natural) views from relaxation areas (e.g., café, lounge) on campus	Perceived restoration (being away, fascination, compatibility, extent)	+ All perceived restoration variables were rated higher by the students for the natural views.
(D. Li & Sullivan, 2016)	USA	Experiment	94	Classroom with no window, built view, and nature view	Cognitive performance, stress, physiology	+ The high school students had better attention (in a measure combining perceived attentional capacity with performance on an attention task) in the classroom with a view to nature than in rooms with no window or a built view (no difference between these latter 2 conditions). Change in stress levels (combining perceived stress and physiology) showed a similar pattern. □ No effect of window condition was found on stress levels (only on change in stress levels)
(Lindemann-Matthies et al., 2021)	Germany	Cross-sectional	634	Naturalness of the view and indoor nature views (i.e., plants)	Subjective well-being, cognitive performance	+ More natural views were related to lower feelings of stress and lack of concentration for primary school children. □ Naturalness of the view was not related to cognitive performance, nor to comfort and learning satisfaction or social well-being of primary school children.

Table 9. Windows in an educational setting: Naturalness of the view (continued)

Windows in an educational setting: Naturalness of the view (continued)						
Article	Country	Type of research	Sample size	Intervention / measurement	Outcome measure	Results
(Matsuoka, 2010)	USA	Cross-sectional	101 high schools	Naturalness view and window size in classroom and cafeteria	Student performance	+ Cafeteria naturalness of the view (not window size) was positively related to student performance (awards, graduation rate, planning to attend 4-year college). Larger classroom windows were related to a higher willingness to attend 4-year college plans and less criminal activity. □ Classroom naturalness of the view was not related to student performance. No relation of classroom window size with number of awards or graduation rates) No relation with criminal behavior was found for cafeteria measures.
(Studente et al., 2016)	UK	Experimental	108	Naturalness view * presence windows * presence plants * getting a green paper	Creativity (verbal and visual)	+ Visual creativity was higher in the view (& plants) condition than in the condition with no view or plants, and equal to the condition were participants received the green paper. □ No difference was found on the verbal creativity test between having a view and plants and the other two conditions.

Daylight entrance

An often sited report indicates that daylight in classrooms can enhance school performance (Heschong, Wright, & Okura, 2002)[1]. Two further large scale cross-sectional studies in the UK indicated that student performance was better when the light quality was better. Light quality in this study was defined as a combination of daylight entrance and adequate light control.

Another study found mixed effects of the presence of daylight on performance, with better cognitive performance in classrooms with traditional windows but lower cognitive performance in classrooms with skylights, potentially due to an increase in temperature (potentially due to a lack of control over daylight) (Küller & Lindsten, 1992). Having control over daylight also appears important in terms of visual comfort (Winterbottom & Wilkins, 2009).

[1] This is not a peer-reviewed article and is therefore not included in the summary table

One study indicated that, besides cognitive performance, having daylight available in the classroom was important for hormonal functioning. Children in classrooms with windows namely showed better seasonal patterns in hormone production related to the circadian rhythm.

Table 10. Windows in an educational setting: Daylight entrance

Windows in an educational setting: Daylight entrance						
Article	Country	Type of research	Sample size	Intervention / measurement	Outcome measure	Results
(Barrett, Zhang, Moffat, & Kobbacy, 2013)	UK	Cross-sectional	751	Light quality (combining daylight and light control)	Student performance	+ Light positively influenced learning progression.
(Barrett, Davies, Zhang, & Barrett, 2015)	UK	Cross-sectional	3766	Light quality (combining daylight and light control)	Student performance	+ Light positively influenced learning progression.
(Küller & Lindsten, 1992)	Sweden	Cross-sectional	+/- 90	Classroom with window vs skylight vs daylight tubes vs no daylight	Behavior, cortisol, body growth, sick leave	+ In the classroom without daylight, seasonal patterns in cortisol secretion were delayed for the schoolchildren. Concentration remained high longer in the dark months for the two classrooms with windows. Sociability followed the cortisol curve and was highest in the classroom with windows and the one with daylight tubes. □ No differences (or inconclusive differences) were found for growth and sick leave. - The classroom with a skylight had a high increase in temperature, which may have caused a drop in concentration.
(Winterbottom & Wilkins, 2009)	UK	Cross-sectional	90 (secondary school) classrooms	Light measurements	Discomfort glare	+ Daylighting had lower flicker - Excessive illumination at the desk occurred most often in daylit classrooms. Blinds were often ineffective in controlling daylight. Number of luminaires was not related to window size (i.e., controlling for daylight by switching off electric lights was sometimes not possible).

Views and daylight

When views and daylight are investigated simultaneously, daylight - again- positively influenced cognitive performance (Baloch et al., 2021; Tanner, 2009). On study included several measurements of daylight (and only one of view content) and found that some, but not all daylight measurements affected performance, such as shading control, type of glazing, and window/floor ratio (but e.g., not for orientation, openable windows, sun patches). The results for naturalness of the view where mixed, with one study reporting no effect of having a natural view (Baloch et al., 2021), whereas another found a slightly superior relation for naturalness of the view on cognitive performance than daylight (Tanner, 2009).

Table 11. Windows in an educational setting: Views and daylight

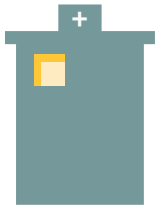
Windows in an educational setting: Views and daylight						
Article	Country	Type of research	Sample size	Intervention / measurement	Outcome measure	Results
(Baloch et al., 2021)	Europe	Cross-sectional	2670	Daylighting, view type	School performance	+ Percentage window area towards the South, window/floor ratio, type of shading, daylight index, type of glazing were positively related with school performance. □ No difference on school performance between urban and natural views. No effect percentage of window area for North, East, West. No association was found with direct sunlight entrance and openable windows.
(Tanner, 2009)	USA	Cross-sectional	10650	School daylighting and views	Study performance	+ Daylighting was related to reading vocabulary and science, whereas having a view (incl nature, but also e.g., indoor views) was positively related to reading vocabulary, language arts, and math □ No relation was found between daylighting and reading comprehension, language arts, math, and social studies. No relation was found between views and reading comprehension, social studies, and science.

Window access

Even though benefits of daylight and a view on cognitive performance have been reported, one study comparing a short stay in a room with a window to a short stay in a room without a window and did not find an effect on cognitive performance.

Table 12. Windows in an educational setting: Window access

Windows in an educational setting: Window access						
Article	Country	Type of research	Sample size	Intervention / measurement	Outcome measure	Results
(Stone & Irvine, 1994)	USA?	experiment	180	Room with and without window, with direct (parallel to the window) or indirect (perpendicular to the window) interaction	Cognitive performance (filing, creative, computational)	□ No difference was found between the two rooms on performance or perception of any of the tasks.



Windows in healthcare environments

Studies in healthcare environments have focused both on patient outcomes and effects on medical staff.

Naturalness of the view

Looking at window content, recovery after surgery was better for patients in a room having an open view to nature than for those overlooking a brick wall (Ulrich, 1984).

View characteristics beyond naturalness

Not only naturalness of the view may matter for patient recovery. One study reported beneficial effects of satisfaction with the view on perceived pain. This effect was, however, not translated into lower pain medication use.

Daylight entrance

From a daylight perspective, patient rooms with more sunlight have been found to shorten the length of stay for psychiatric patients than in rooms with less sunlight (Beauchemin & Hays, 1996), and those receiving morning sunlight also had shorter lengths of stay than those receiving afternoon sunlight (Benedetti, Colombo, Barbini, Campori, & Smeraldi, 2001). Sunnier rooms have further been found to lower the use of pain medication and perceived stress at discharge (Walch et al., 2005), whereas another study even reported higher mortality in darker rooms in the cardiac intensive care as opposed to brighter rooms (Beauchemin & Hays, 1998). Yet another study found benefits of higher illuminance in patient rooms on length of stay (Choi, Beltran, & Kim, 2012), but this effect depended on season and surgery type.

In a care institution for dementia patients, depression got lower after patients were brought to a room with more daylight each morning (Konis, Mack, & Schneider, 2018). This, however, did not result in less symptoms.

Views and daylight

Length of stay was shorter in brighter rooms and rooms with a view for people that had underwent a bypass surgery (Joarder & Price, 2013). One study looked at pain experience and pain medication use after a caesarean section in rooms differing in naturalness of the view and daylight entrance (C.-H. Wang, Kuo, & Anthony, 2019) and found no evidence of benefits of daylight or type of window view. Satisfaction with the view, though, was related to lower pain perception.

Table 13. Windows in a healthcare setting: Naturalness of the view

Windows in a healthcare setting: Naturalness of the view						
Article	Country	Type of research	Sample size	Intervention / measurement	Outcome measure	Results
(Ulrich, 1984)	USA	Cross-sectional	46	Natural view	Recovery after surgery: length of stay, use of pain killers, use of tranquilizers, minor complications	+ Patients overlooking a natural view had a shorter length of stay, received less negative notes from the nurse, used less pain medication. □ No difference was found in the use of anti-anxiety drugs

Table 14. Windows in a healthcare setting: View characteristics beyond naturalness

Windows in a healthcare setting: Views characteristics beyond naturalness						
Article	Country	Type of research	Sample size	Intervention / measurement	Outcome measure	Results
(Wang et al., 2019)	Taiwan	Cross-sectional	296	Daylight exposure, window view, window satisfaction	Experienced pain, use of painkillers	+ A higher satisfaction with the window view was associated with lower perceived pain

Table 15. Windows in a healthcare setting: Daylight entrance

Windows in a healthcare setting: Daylight entrance						
Article	Country	Type of research	Sample size	Intervention / measurement	Outcome measure	Results
(Beauchemin & Hays, 1996)	Canada	Cross-sectional	174	Illuminance level	Length of stay	+ Depressive patients had a shorter length of stay in bright rooms.
(Beauchemin & Hays, 1998)	Canada	Cross-sectional	628	Illuminance level	Length of stay and mortality	+ Length of stay was shorter in the sunny rooms, with more pronounced detrimental effects for women in sunless rooms. Mortality was lower in sunny rooms.
(Benedetti et al., 2001)	Italy?	Cross-sectional	602	Orientation room (morning vs afternoon sunlight)	Length of stay	+ Length of stay was shorter for bipolar patients staying in the East rooms (receiving morning sunlight) □ No effect was found for unipolar patients.
(Choi et al., 2012)	Korea	Cross-sectional	1167	Orientation patient room and orientation bed head to window	Length of stay	+ Length of stay was shorter in south-east rooms with higher illuminance (not for all comparisons thought). □ No effect was found for orientation of the bed head. In addition, differences in length of stay were not found for all types of surgery or in all seasons
(Konis et al., 2018)	USA	Experimental	78	Illuminance level (bringing patients to rooms with more daylight in the morning)	Depression, dementia symptoms	+ The patients in the daylight intervention group had lower depression scores than the control group after 12 weeks □ No difference between the two groups were found on neuropsychiatric symptoms (though they did decrease during the intervention).
(Walch et al., 2005)	USA	Experimental	89	Illuminance level	Use of painkillers, perceived pain, depression, perceived stress, anxiety	+ Patients in the bright rooms required less pain medication and reported lower stress on discharge. □ No difference was found in perceived pain, anxiety, and depression.

Table 16. Windows in a healthcare setting: Views and daylight

Windows in a healthcare setting: Views and daylight							
Article	Country	Type of research	Sample size	Intervention / measurement	Outcome measure	Results	
(Joarder & Price, 2013)	Bangladesh	Cross-sectional	263	Illuminance level measured above bed head and provision of view	Length of stay	+	Both higher (day)light levels and a provision of view resulted in a shorter length of stay.
(C.-H. Wang et al., 2019)	Taiwan	Cross-sectional	296	Daylight exposure, window view, window satisfaction	Experienced pain, use of painkillers	□	No relation was found of window view and daylight exposure with perceived pain.

Window access

Other studies have taken a look at the influence of windows as a whole. Windows in an intensive care unit can decrease the incidence of delusions (P. Keep, James, & Inman, 1980; Wilson, 1972)[2], improve memory on the length of stay (P. Keep et al., 1980), and reduce the need for feeding tubes (Wunsch, Gershengorn, Mayer, & Claassen, 2011). Patients at regular wards (from different wards, not the emergency ward and not people older than 80 years old) near a window also recovered faster than patients furthest away from the window (Park, Chai, Lee, Moon, & Noh, 2018). As a sidenote, those residing near the door, may also have been exposed to more noise from the hallway. In addition, the satisfaction with the view was also measured.

Windows do not only appear to matter for patients, but also for the staff. A study indicated that the presence of windows in an acute-care department had positive effects on nurses' blood pressure. They also had a higher body temperature, a better communication, expressed more laughter, less sleepiness and better mood (Zadeh, Shepley, Williams, & Chung, 2014). In addition, in a study using virtual images, breakrooms with window views to nature were preferred by nurses over break rooms without a view, with highest score for a breakroom with a balcony (Nejati, Rodiek, & Shepley, 2016).

[2]Please note that both these studies did not employ / report significance testing

Table 17. Windows in a healthcare setting: Window access

Windows in a healthcare setting: Window access						
Article	Country	Type of research	Sample size	Intervention / measurement	Outcome measure	Results
(P. Keep et al., 1980)	UK	Cross-sectional	150	Room with and without windows	Memory of length of stay	+ Patients in the windowed ICU unit had less deliriums, hallucinations, and a more accurate memory of their length of stay (no test of significance).
(Nejati et al., 2016)	USA	Cross-sectional	958	(images) rooms with and without windows (with natural view)	Perceived restoration	+ Break rooms with no window were perceived least restorative, followed by a breakroom with: a plant, a natural image, a window with natural view, a window with natural view and balcony
(Park et al., 2018)	Korea?	Cross-sectional	67842	Proximity to the window	Length of stay	+ Shorter length of stay for those closer to the window
(Wilson, 1972)	USA	Cross-sectional	100	Room with and without windows	Delirium, depression, fever	+ Less delirium and less depression was reported in the ICU unit with windows (no test of significance) □ No difference in fever was found
(Wunsch et al., 2011)	USA	Cross-sectional	988	Room with and without windows	Global functioning, length of stay in ICU and hospital, need for respiratory or feeding aid, mortality	+ In summer, patients in the window room required less feeding aid (tube) □ No difference in global functioning, length of stay (ICU and hospital), need for respiratory aid, feeding aid, or mortality was found.
(Zadeh et al., 2014)	USA	Cross-sectional	12	Room with and without windows	Physiology, frequency of communication and positive social interaction, caffeine intake, illumination levels, subsidiary behaviors (coping with sleepiness), sleepiness	+ Blood pressure was lower and oxygen saturation and temperature were higher when working on the ward with windows. More communication and laughter was observed in the ward with windows. Less subsidiary behaviors to battle sleepiness and deteriorated mood were performed in the window ward. □ No effect was found on heart rate, caffeine intake, or reported sleepiness.

Please note that both these studies did not employ / report significance testing

Windows at home

Naturalness of the view

Natural views from home has been found related with a number of benefits; effective functioning (R. Kaplan, 2001), feeling at peace (R. Kaplan, 2001), satisfaction with the environment (R. Kaplan, 2001), satisfaction with life (C.-c. Chang et al., 2020), cortisol levels (for views high in amount and diversity of vegetation) (Honold, Lakes, Beyer, & van der Meer, 2016). One study looked at separate elements of the view and found benefits related to some, but not all natural elements (R. Kaplan, 2001). This study also found a relation between getting information about the weather through the window and effective functioning and satisfaction with the environment (R. Kaplan, 2001). One study found no relation of naturalness of the window view at home (or at work) and vitality (Korpela et al., 2017).

Some studies specifically pointed at the importance of natural views during the covid-19 pandemic. On study reported higher self-esteem, satisfaction with life, happiness, and lower levels of loneliness and depression / anxiety when having more green views at home (the same results were reported for local green space use) (Soga, Evans, Tsuchiya, & Fukano, 2021). A survey conducted during the COVID-19 lockdown found that for students living in apartments and students that felt less connected to nature a greener view resulted in lower reported anxiety levels, whereas presence of a garden and indoor plants were related to lower depressive symptoms (Dzhambov et al., 2020). An older study with students also found that those with more natural views from their dormitory had better cognitive performance (Tennessen & Cimprich, 1995).In addition, cognitive performance was better for younger children with more natural views, though this relation was only found for girls and not for boys (Taylor, Kuo, & Sullivan, 2002).

Nature views not only need to be green. Research looking at effects of blue space found that being able to see the sea from home decreased the risk of depression (Dempsey, Devine, Gillespie, Lyons, & Nolan, 2018), reported better general health (but no better well-being) (Garrett et al., 2019), and lower psychological distress (not found for visible green space) (Nutsford, Pearson, Kingham, Reitsma, & place, 2016).

Table 18. Windows in a residential setting: Naturalness of the view

Windows in a residential setting: Naturalness of the view						
Article	Country	Type of research	Sample size	Intervention / measurement	Outcome measure	Results
(C.-c. Chang et al., 2020)	Singapore	Cross-sectional	1262	Presence nature in the view	Life satisfaction	+ Higher life satisfaction when a window with natural view was present.
(Dempsey et al., 2018)	Ireland	Cross-sectional	8504	Sea view	Depression	+ Lower risk of depression when sea view increases
(Dzhambov et al., 2020)	Bulgaria	Cross-sectional	323	Amount of nature	Depression and anxiety	+ More green in the view was associated with less depression and anxiety
(Garrett et al., 2019)	China	Cross-sectional	1000	Sea view	General health, well-being	+ Those with a sea view reported better general health □ No association of having a sea view was found with well-being.
(Honold et al., 2016)	Germany	Cross-sectional	32	Amount of nature and vegetation diversity in the view	Cortisol	+ People with high vegetation quantity together with high vegetation diversity had the lowest cortisol levels □ No direct effect of vegetation quantity or diversity was found on cortisol levels.
(R. Kaplan, 2001)	USA	Cross-sectional	188	Natural and built elements of the view, seeing the weather	Satisfaction with the neighbourhood and nature, well-being (effective functioning, distraction, at peace)	+ Reported effective functioning was related to landscaped/garden. Feeling at peace was related to the presence of trees in the view. Feeling distracted was negatively related to trees and a farm/field. Satisfaction with nature was related to landscaped/garden, trees, and large mowed area, and satisfaction with the neighbourhood was related with landscaped/garden and a park. A quiet street was also related to better reported effective functioning. Being able to see the weather was positively related to effective functioning, and with satisfaction with nature and the neighbourhood. □ Not all landscaped elements were related to better well-being / higher satisfaction (those not mentioned above). No relations with well-being or satisfaction were found for stream/river or wildlife. No relations were also found for sidewalk, vacant lots, houses, non-residential building, fences/walls, parking/people. - A busy street in the view was associated with a lower satisfaction with nature and the neighbourhood.

Table 19. Windows in a residential setting: Naturalness of the view (continued)

Windows in a residential setting: Naturalness of the views (continued)						
Article	Country	Type of research	Sample size	Intervention / measurement	Outcome measure	Results
(Korpela et al., 2017)	Finland	Cross-sectional	841	Nature views at home	Subjective well-being	□ No relation was found between having a more natural view at home and vitality.
(Nutsford et al., 2016)	New Zealand	Cross-sectional	442	Sea view	Psychological distress	+ Higher levels of visible blue space was related to lower psychological distress □ No association between levels of visible green space and psychological distress was found.
(Soga et al., 2021)	Japan	Cross-sectional	3000	Presence of nature	Self-esteem, satisfaction with life, happiness, loneliness, depression and anxiety	+ Having a green view was related to higher self-esteem, satisfaction with life, and happiness, as well as to lower levels of loneliness and depression / anxiety (as was local greenspace use).
(Taylor et al., 2002)	USA	Cross-sectional	169	Amount of nature in the view	Cognitive performance,	+ Girls performed better on cognitive performance (self-control) tasks when the view was more natural. □ No association was found between amount of green in the view and cognitive performance for boys.
(Tennessen & Cimprich, 1995)	USA	Cross-sectional	72	Naturalness of the view	Cognitive performance, perceived cognitive effectiveness, mood	+ Those with all natural views scored better on 2 of the 4 cognitive performance tests, and also reported better cognitive effectiveness □ No differences were found on the other 2 cognitive performance tests or on mood.

Daylight entrance

Daylight entrance at home can influence health and well-being even when we are sleeping. A higher pre-awakening daylight exposure (e.g., by having no or light curtains) was found related to better mood and sleep quality (depending on the season) (Dong & Zhang, 2020, 2021), less sleep disturbances (Shimura et al., 2020), shorter sleep latency (Takeuchi, Hino, Iwanaga, Matsuoka, & Harada, 2001), and a higher sleep quality (Youngstedt, Leung, Kripke, & Langer, 2004). Though in one study there was an adverse relation between light and sleep, with higher levels of pre-awakening light exposure related to more sleep disturbances for the elderly (Obayashi, Saeki, & Kurumatani, 2018).

Daylight exposure at home during daytime also appears to matter. People with electrochromic glazing (as opposed to those with blinds) reported better sleep and mood (Nagare et al., 2021), whereas people with depression and people who recently fell at home were more likely to report insufficient light at home (Brown & Jacobs, 2011).

Table 20. Windows in a residential setting: Daylight entrance

Windows in a residential setting: Daylight entrance						
Article	Country	Type of research	Sample size	Intervention / measurement	Outcome measure	Results
(Brown & Jacobs, 2011)	Lituania, Switzerland, Italy, Germany, Portugal, Hungary, Slovakia, France	Cross-sectional	6017	Having insufficient daylight at home	Falls, depression	+ Respondents with depression were more likely to report having insufficient daylight at home. Participants who reported a fall during the past year were also more likely to report having insufficient lighting.
(Dong & Zhang, 2020)	China	Cross-sectional	90	Illuminance level before waking up	Mood, alertness, sleep	+ In summer, there was a significant correlation of light with happiness, feeling jittery, and morning alertness. In winter, a significant correlation with feeling frenzied and sleep quality was found. □ No relation daylight and alertness and happiness was found in winter. In summer, no relation of light exposure with sleep quality or feeling frenzied was found. No other relations with mood were found.
(Dong & Zhang, 2021)	China	Cross-sectional	16	Illuminance level before waking up	Mood, alertness, sleep	+ In Summer, morning daylight exposure was positively related with alertness, mood and deep sleep duration. □ No relations between pre-awakening daylight exposure and mood, alertness, or sleep were found in winter. No relation was found with morning fatigue.
(Nagare et al., 2021)	USA	Experimental	20	Electrochromic glazing vs blinds	Sleep, melatonin, mood, depression, anxiety	+ Higher sleep regularity, better mood, and vitality at awakening were reported with Electrochromic glazing. A delay in DLMO when using blinds was found. □ No effect on sleep duration, sleep onset latency, sleep efficiency, depression, anxiety, and stress was reported
(Obayashi et al., 2018)	Japan	Cross-sectional	1108	Illuminance level before waking up	Sleep	- More sleep disturbances and lower sleep efficiency were reported with higher pre-awakening daylight exposure.
(Shimura et al., 2020)	Japan	Cross-sectional	6342	Illuminance level before waking up	Sleep	+ Less sleep disturbances were reported by those having sunlight in the morning in the bedroom.

Table 21. Windows in a residential setting: Daylight entrance (continued)

Windows in a residential setting: Daylight entrance (continued)						
Article	Country	Type of research	Sample size	Intervention / measurement	Outcome measure	Results
(Takeuchi et al., 2001)	Japan	Cross-sectional	381	Illuminance level before waking up	Sleep	+ Students with a curtain in the bedroom had a longer sleep latency than students without a curtain. □ Wake up time and the peak of activity was not affected by having a curtain.
(Youngstedt et al., 2004)	USA	Cross-sectional	459	Window covering and ambulatory light measurement	Depression, sleep	+ Those with only light shades reported better sleep quality and less awakenings (as compared to those with no coverings or black out curtains). □ No association was found between window covering and depression.

Windows miscellaneous

Effects of windows have been studied in the laboratory or in survey studies without a particular context. This can be using (virtual) images of spaces to test for instance effects of different window sizes and configurations on satisfaction with the view, or actual exposure but without a particular setting.

Naturalness of the view

Studies using virtual images found that satisfaction with the view was higher for natural than for urban images (Kent & Schiavon, 2020), views with more street trees received higher perceived restorativeness ratings (Masoudinejad & Hartig, 2020), and a view to a virtual green roof resulted in a higher perceived restorativeness and better cognitive performance (K. E. Lee, Williams, Sargent, Williams, & Johnson, 2015).

Cognitive performance was also tested using real exposure, together with recovery after an athletic task. The recovery of nine athletes after brief exercise was compared in a room facing a window with a natural view with recovering without access to a window and found larger improvements in cognitive performance and cardiovascular recovery (Engell, Lorås, & Sigmundsson, 2020). The authors attributed this improvement to the natural view, but as the window remained covered by blinds in the comparison condition, it is unclear whether improvements were due to the natural view or the mere presence of the window (with both a view and daylight entrance).

When the view is more natural, people reported lower discomfort glare (Tuaycharoen & Tregenza, 2007).

Table 22. Windows miscellaneous: Naturalness of the view

Windows miscellaneous: Naturalness of the view							
Article	Country	Type of research	Sample size	Intervention / measurement	Outcome measure	Results	
(Engell et al., 2020)	Norway	Experimental	9	Presence nature	Cognitive performance, physiology	+	Cognitive performance improved after resting with the blinds up (and nature visible). Heart rate recovery was faster when blinds were up (with a natural view).
						□	No difference was found in resting heart rate.
(Kent & Schiavon, 2020)	USA	Experimental	50	(virtual window) Naturalness of the view *and viewing distance*	Connection to the outside, visual satisfaction, visual privacy	+	Satisfaction with the view and privacy was higher for natural than for urban scenes.
(K. E. Lee et al., 2015)	Australia ?	Experimental	150	(Virtual view) Presence nature	Cognitive performance, perceived restorativeness	+	A view towards a green roof was rated as more restorative than the view to the concrete roof, and resulted in better cognitive performance.
(Masoudinejad & Hartig, 2020)	Iran	Experimental	212	(Images) amount of sky, sky type, naturalness view, view distance	Perceived restoration, preference	+	Amount of street trees (and the presence of a window box) increased perceived restoration ratings.
(Tuaycharoen & Tregenza, 2007)	UK	Experimental	72, 96	Naturalness of the view, view layers	Discomfort glare	+	Natural scenes were related to lower ratings of discomforting glare

View characteristics beyond naturalness

View characteristics beyond naturalness have been manipulated in a number of studies using virtual images. A first study using images of virtual spaces tested their effects on students living in Northern Norway . These images differed in scenario (socializing versus work), room size, window size and weather type. When evaluating the room, window size and size of the space both affected relatively many attributes of the room (pleasantness, interest, excitement, spaciousness, satisfaction with the amount of view), with an additional effect on complexity for window size only. Weather type did not affect any of the attributes of the room, but it must be noted that brightness of the images were kept constant. Therefore, views with an overcast sky resulted in the same light distribution in the room as a clear sky. Larger windows were highly preferred. In addition, the larger windows received a higher satisfaction with the amount of view in the smaller spaces (Moscoso, Chamilothori, Wienold, Andersen, & Matusiak, 2020). The effects of window size on space perception may also differ between geographical location. A recent study found difference in evaluations of windows in daylit spaces between Northern, Middle, and South Europe (Moscoso, Chamilothori, Wienold, Andersen, & Matusiak, 2021).

Another study with virtual images, again with students, compared a window view in terms of percentage of the wall occupied by the window (Yeom, Kim, Hong, Park, & Lee, 2020). This study found that 20% window ratio scored lowest on psychological satisfaction, whereas the 60% window ratio scored highest (and not the highest ratio of 80%). The 80% ratio also scored relatively high, but with a much larger standard deviation than the 60% ratio, indicating that there was more variability in the scores of the students for this window size. Some students were very positive, whereas other were not. As the window view is from a relatively high floor, this might have been due to vertigo as the windows in the 80% ratio condition nearly stretched to the floor.

The amount of sky that was visible was manipulated in a VR study (Masoudinejad & Hartig, 2020). This study reported that amount of visible sky (besides number of street trees and view layers) was positively related to perceived restorativeness. This study could not find an effect of weather type.

The importance of the number of view layers was corroborated in two additional studies. Views with a larger distance were preferred (Kent & Schiavon, 2020), with nature being preferred to be closer by and urban features from further away. In line, real window views with three layers (as opposed to only one) resulted in lower discomfort glare reports (Tuaycharoen & Tregenza, 2007).

Table 23. Windows miscellaneous: View characteristics beyond naturalness

Windows miscellaneous: View characteristics beyond naturalness						
Article	Country	Type of research	Sample size	Intervention / measurement	Outcome measure	Results
(Kent & Schiavon, 2020)	USA	Experimental	50	(virtual window) viewing distance *and naturalness of the view*	Connection to the outside, visual satisfaction, visual privacy	+ Higher satisfaction ratings were given for larger viewing distances. Viewing distance effects were especially pronounced for urban scenes.
(Masoudinejad & Hartig, 2020)	Iran	Experimental	212	(Images) amount of sky, sky type, naturalness view, view distance	Perceived restoration, preference	+ Amount of sky, view distance, and street trees (and the presence of a window box) increased perceived restoration ratings. Preference was higher for views with more sky. □ No effect of weather type was found on preference or perceived restorative potential.
(Moscoso et al., 2020)	Norway	Experimental	150	(Virtual environment) Window size, sky type	Perception of the space (pleasantness, calmness, interest, excitement, complexity, spaciousness, amount of view, brightness)	+ Bigger windows were related to higher scores on all perceptions except calmness. Window size was also positive related to perceived brightness. □ No effect of window size on calmness was found. Sky type did not influence any of the perceptions.
(Moscoso et al., 2021)	Norway, Greece, Switzerland	Experimental	406	(Virtual environment) Window size, sky type	Perception of the space (pleasantness, calmness, interest, excitement, complexity, spaciousness, amount of view, brightness)	+ Bigger windows were related to higher scores on all perceptions except calmness. Differences in the perception of pleasantness and calmness were found between Greece and Norway, and between Greece and Switzerland. Effects and differences depended on size of the window and size of the space pointing at geographical or cultural differences in room perception. □ No effect of window size on calmness was found. No effect was found for sky type.

Table 24. Windows miscellaneous: View characteristics beyond naturalness (continued).

Windows miscellaneous: View characteristics beyond naturalness (continued)							
Article	Country	Type of research	Sample size	Intervention / measurement	Outcome measure	Results	
(Stamps, 2010)	USA	Experimental (2 studies)	46, 18	Permeability	Perception of the space	+	A room was perceived as less enclosed during day and with higher levels of permeability (more / larger windows). Lighter rooms were also perceived as more open.
(Tuaycharoen & Tregenza, 2007)	UK	Experimental	72, 96	Naturalness of the view, view layers	Discomfort glare	+	Views with three layers were related to lower discomfort glare than views with one layer
(Yeom et al., 2020)	South Korea	Experimental	37	(Virtual environment) window size (20, 40, 60, 80 %)	Perception of the space (privacy, inner space, openness), mood	+ □	Larger windows were related to a better perception of the space, and better mood outcomes (depression, vigor, confution, tension, fatigue) No correlation was found between window size and anger.

Daylight entrance

A laboratory experiment tested cognitive performance and mood in two different rooms, one with a window to the outdoors (daylit space) and one with a window towards an indoor space (artificially lit space)(Gou, Lau, & Qian, 2015). No difference was found in cognitive performance, and there where even indications of worse mood in the daylit space. This was attributed to an increase in temperature in the daylit space.

Table 25. Windows miscellaneous: Daylight entrance.

Windows miscellaneous: Daylight entrance						
Article	Country	Type of research	Sample size	Intervention / measurement	Outcome measure	Results
(Gou et al., 2015)	China	Experimental	52	Window to outdoor space[3] vs window to indoor space	Cognitive performance, mood	□ No difference was found in cognitive performance between the two rooms. - Mood scores were analysed per item instead of sum scores. In the daylit environment, positive mood appeared to decrease more and negative mood increased more (on some of the items). In the daylit room, cognitive performance appeared to decrease with an increase in illuminance and temperature.

[3] window view was natural

Window access

Other studies have been completed in a laboratory environment, without a specific setting. Two studies focused on effects of having a window or not. Participants with a window reported less eye problems (Ko et al., 2020), but no difference in stress levels where found. Illuminance levels differed much more in the condition with the window, whereas the indoor temperature remained the same. Still, participants reported feeling cooler in the window condition (on a relatively warm day). More positive and less negative emotions and some improvements in cognitive performance were found.

Another study found no difference in performance, mood, or satisfaction with the environment (Stone & Irvine, 1993), but did report that those in the windowless room felt more in control. The only benefit of windows reported in this study related to participants feeling cooler in the room with the window.

Table 26. Windows miscellaneous: Window access

Windows miscellaneous: Window access						
Article	Country	Type of research	Sample size	Intervention / measurement	Outcome measure	Results
(Ko et al., 2020)	USA	Experimental	86	Room with and without a window[4]	Thermal perception, mood, cognitive performance, stress, eyestrain	+ Students felt cooler and reported less negative and more positive affect in the room with a window. Cognitive performance was also better on some tasks (working memory, concentration), and less eye problems were reported. □ No difference was found in thermal acceptability between the two rooms. Cognitive performance was not affected in some tasks (creativity, short-term memory, planning). No difference in stress was found.
(Stone & Irvine, 1993)	USA	Experimental	40	Room with and without a window[4]	Performance on a managerial or computational task, mood, satisfaction, room evaluation	+ Students felt cooler in the room with a window □ No difference was found in performance, mood, satisfaction, or the evaluation of the rooms. - Students in the windowless room felt more in control than those with a window.

[4] Window view was (at least partly) natural.

In sum: Emperical evidence for the benefits of windows

Benefits of windows on health and well-being are well-established. Especially office environments have received a lot of attention. Studies in these environments have reported benefits on a wide range of health outcomes, including mental and physical health but also occupational health. Windows in the office may, for instance, even influence commitment to work or the intention to resign. In health care environments, beneficial effects have been reported for both the patients and nurses working in these environments. Less studies have focused on residential settings and educational setting, although beneficial effects have been reported here as well. Below (Table 3) is a summary of the health benefits reported in this section, with differentiation between the elements of windows that have been studies, as well as categories of outcomes.

The elements of window included are:

- Naturalness of the view: presence of nature, amount of nature, natural vs urban elements.
- View quality: view quality and satisfaction with the view.
- View composition: perception of the space, composition (e.g., prospect/refuge, elegibility), view distance, view layers.
- Sky type or the weather: amount of sky, presence of sky, overcast vs sunny.
- Proximity to the window.
- Indoor nature exposure (combining view, natural light, and often indoor plants).
- Window presence.
- Daylight exposure: orientation, illumination level, position towards the window, use of shades.

The outcome variables are:

- Satisfaction with the environment: view quality, light quality, preference, aesthetics, satisfaction with the room or neighbourhood.
- Well-being, including: subjective well-being, mood, stress, satisfaction with life, quality of life, perceived restoration.
- Physiology and hormones: physiology, EEG, neuroendocrinology.
- Performance: subjective ability for executive functioning, cognitive performance, alertness, creativity, school performance.
- Sleep.
- Mental health: mental health, depression, anxiety, delirium, self-esteem, loneliness.
- Physical health: physical health, length of stay in healthcare, use of painkillers, experienced pain, fever, falls.
- Job engagement: job satisfaction, intention to quit, productivity, organizational commitment.
- Visual comfort: visual comfort, glare, environmental utility, eye strain, eye problems.

Figure 3 presents a Venn-diagram of the elements of windows, where elements placed in overlapping squares are interrelated.

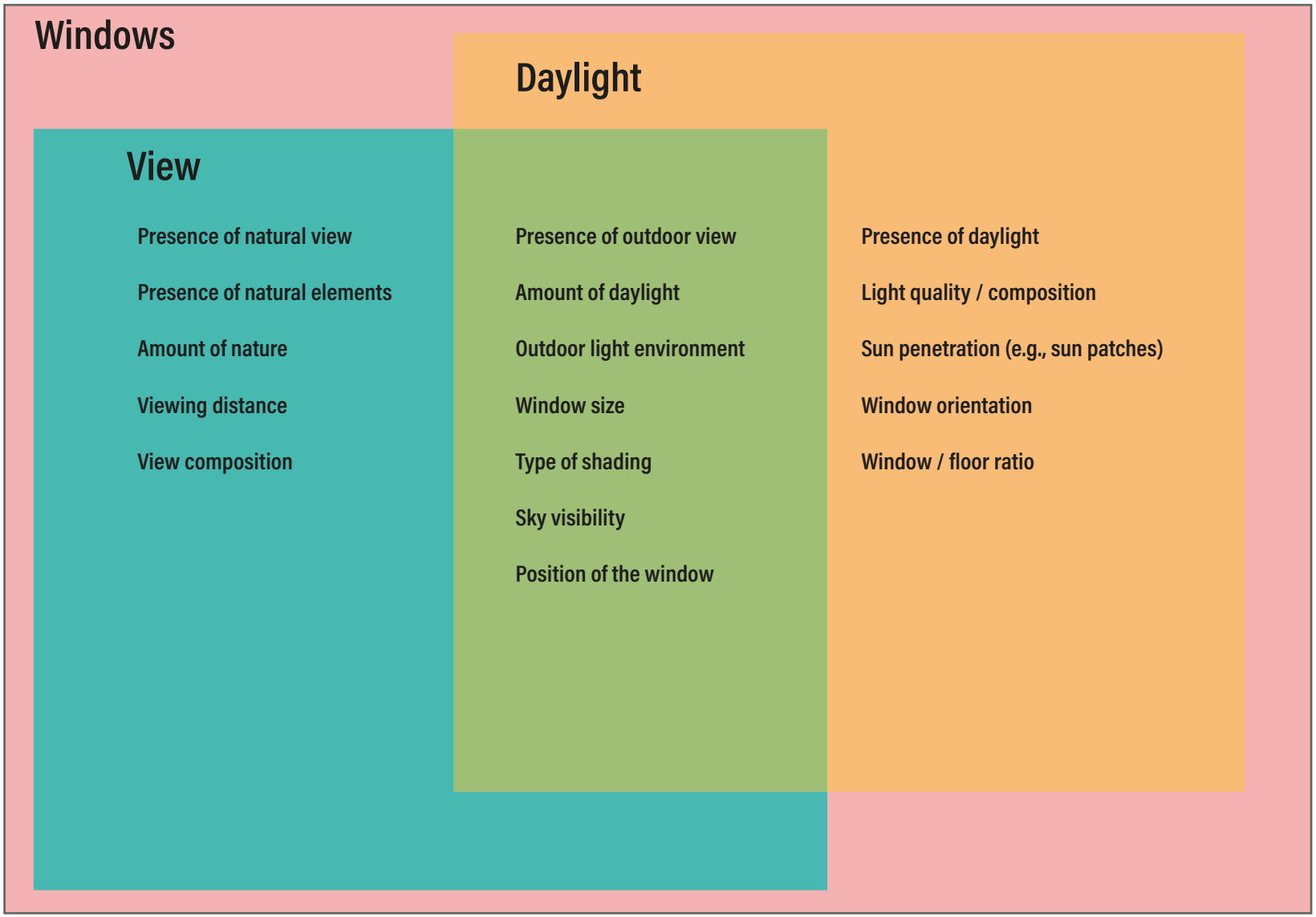


Figure 3. Summary window elements (Venn-Diagram: window elements placed where the squares overlap are related to both or all window benefits).

Table 27. Overview of the reported health effects for view content, having access to a window, and daylight.

		Satisfaction environment	Well-being[1]	Physiology hormones	Performance	Sleep	Mental health	Physical health	Job engagement	Visual comfort
Natural views[a]	+	********** ***	********** ********	****	********** *****		*******	****	******	*
	□	********** *****	********** *	**	********** **	*	**		**	*
	-		*					*		
View quality	+		***					*	**	*
	□	*				*		*		
	-									
View composition	+	**********	******		******			*	**	*
	□	***	*		*****			*		
	-									
Sky type / weather	+	****	*		*					
	□	****	***							
	-									
Indoor nature exposure (including light)	+		*				*	***		
	□		*					*		
	-									
Proximity window	+	**								*
	□	****				*				*
	-	*								*
Window presence	+	********	*****	******	**	*	*****	**	*	**
	□	****	***	**	***	**	*****	*****		
	-					*		*	*	
Daylight	+	****	**********	**	******	*******	*******	********	****	**
	□	***	********		******	********	*******	***		*
	-				**	**				**

[1] When separate natural elements were reported (e.g., trees vs grass vs park), effects were reported as *at least* one positive, neutral, or negative effect to not distort the overview. The same holds for studies reporting multiple emotional states separately.

The benefits of windows

In this scoping review, the benefits of windows were investigated in terms of window views and daylight access. Benefits of windows have been reported in different settings (e.g., at home or in the hospital) and on many different health domains, including for instance job satisfaction, life satisfaction, sleep, mood, and subjective well-being. Sometimes, studies have looked at effects of view only, whereas others focused only on daylight exposure. A limited amount of studies have looked at daylight and view at the same time.

Effects of window elements: view content, daylight, and window access

Effects of windows on health and well-being have been investigated by looking at a number of different aspects of a window, including the view content, daylight entrance, and having access to the window. A selection of studies looked at window content and daylight exposure simultaneously. The following section will summarize the outcomes for each of these window elements.

View content

Naturalness of the view received most attention and showed the most consistent benefits on mental and physical health and job engagement. Beneficial effects were also reported for well-being, physiology, and cognitive performance, though these outcomes rendered relatively many neutral effects. In addition, there were two negative relationships reported between a more natural view and well-being. Sleep received too little attention in relation to naturalness of the view and satisfaction with the environment resulted in both positive and (even more) neutral relationships with naturalness of the view.

Some studies looked at amount of green as a composite measure, whereas others investigated effects of separate view elements (both natural and urban) (e.g., Gilchrist et al., 2015; R. Kaplan, 2001; Lottrup et al., 2013), and pointed at different effects for different landscape elements in the view (e.g., forests, lawns, parks) (Gilchrist et al., 2015; R. Kaplan, 2001; Lottrup et al., 2013). A third group of studies looked at a specific type of green space, such as effects of viewing the forest (e.g., Sop Shin, 2007). Potentially, there is a need to differentiate more between different natural elements, or different view elements in general, and their effects on view quality and health as different types and characteristics of natural environments may yield different outcomes (see also, Femke Beute et al., 2020; F Beute et al., 2020; Bratman et al., 2019).

Ratings of the environment (and in particular view quality), indeed, did appear highly and positively affected by the composition of the view including a wide range of factors such as window size, number of view layers, viewing distance, and prospect/refuge characteristics. Preference ratings of environments are often discussed as either the prerequisite for, or the first step in the process of, the beneficial paths leading from environment to restorative effects (Ulrich, 1983). This link appeared less consistent for naturalness of the view, but may run partly through composition of the view. View composition positively impacted well-being, whereas it rendered mixed results for

cognitive performance and received too little attention on the other outcomes to see a relationship. Quality of the view was also positively related to well-being.

Naturalness of the view and composition or quality of the view where combined as measurements of window content in a number of studies. These studies showed effects of composition or view quality beyond benefits of nature (Lottrup et al., 2013; van Esch et al., 2019), whereas others found effects of window composition or view quality / satisfaction but not of naturalness of the view (M. B. Aries et al., 2010; Gilchrist et al., 2015; Matusiak & Klöckner, 2016). It remains unclear whether benefits of natural views are due to higher view quality or specific compositions (e.g., being more open), but these outcomes do signal that composition of the view beyond naturalness matters and deserves attention in future studies.

Another important gap in the research is the lack of knowledge on the effects of nighttime views on health and wellbeing. The current research exclusively focuses on effects of daytime views, but these views may change dramatically during night. Nighttime views may depend on the type of outdoor (street) lighting (which, in turn also influences evening and night time exposure to light) and the type and usage of window coverings.

Weather type of the view or the amount of sky visible in the view may be elements of the view that also require additional attention. The few studies that looked at this element rendered mixed results for satisfaction with the environment, well-being, and performance. Being able to get information about the weather is often mentioned as one of the merits of having a window (Markus, 1967). However, most studies in this review looked at the effects of the weather type on appraisal of the view and well-being. One study probed the ability to see the weather and did find a beneficial effect on satisfaction with the environment, but not on well-being (R. Kaplan, 2001). In addition, some studies looked at the presence or amount of sky visible in the view. More research is necessary to establish which element of the weather or sky visibility could benefit well-being. There is a relatively large overlap between the weather type or the amount of sky visible and the type and amount of daylight entrance in the room, which is something that should be taken into consideration given that daylight entrance can influence health and well-being.

Daylight entrance

Daylight exposure showed consistent and beneficial effects of daylight on well-being, physical health, and job engagement. Physiology and hormones appeared to benefit from daylight entrance, though this was only measured in two studies. There was no consistent evidence for benefits of daylight access on satisfaction with the environment, mental well-being, performance, and sleep. Negative effects were reported for performance, sleep, and visual comfort. These negative effects of daylight entrance may be related to the complex interactions that daylight has with other room variables, as for instance both negative effects of daylight entrance on performance were proposed to be related to an increase in temperature in the room (Gou et al., 2015; Küller & Lindsten, 1992). On the other hand, the inconsistency in finding may be explained by the large heterogeneity of the measurement of daylight in these

studies. Daylight could for instance be operationalized as having curtains or blinds versus not, the pattern of sunlight patches, sunny versus dim rooms, or the orientation of the room. Only few studies looked at the actual amount and spectral composition of daylight entering the room. In addition, almost none of the studies reported the type of window glazing present, or whether daylight could be controlled and how. Some studies have pointed at differences between different glazing types (Baloch et al., 2021; Mohamed Boubekri et al., 2020), and the importance of having control over daylight entrance, for instance in an educational setting (Barrett et al., 2015; Barrett et al., 2013; Winterbottom & Wilkins, 2009).

The lack of consistent benefits of daylight on sleep, performance, and mental health was unexpected as these three domains of health outcomes are often mentioned in relation to beneficial effects of daylight. It could be that the lack of consistent outcomes was due to the type of measurement of daylight in the reported studies. Potentially, effects may depend on the setting or sample. For instance, in a healthcare setting there were rather consistent benefits of daylight exposure on mental health. These benefits were, however, not found for all patient groups. As another example, pre-awakening daylight exposure at home was beneficial for all groups, except for the elderly. In addition, light exposure is often highly related to other environmental factors, such as temperature or visual comfort. Especially temperature was proposed to be a mediator of the effect of daylight on performance. Alternatively, indoor electric light exposure can influence health in many ways, which is a factor that is not always taken into account in studies looking at effects of daylight.

In order to fully understand the benefits of daylight through windows, we therefore need to know more about the lighting environment as a whole, the interaction of daylight with other environmental parameters (e.g., temperature), the interaction with task type and setting, and potential individual differences in responses to daylight exposure. On top of that, we need a better understanding of which of the different elements of daylight affects humans, and in which way.

Access to a window

Access to a window included both comparisons of rooms with and without windows and studies looking at proximity to the window. Studies comparing a windowless room with a room with a window found mixed results on most outcomes. Four outcomes did appear to be affected positively by the presence of a window, namely satisfaction with the environment, well-being, physiology / hormones and visual comfort. Some studies also found that office workers compensated for working in a windowless room by adding more nature attributes (Bringslimark et al., 2011; Heerwagen & Orians, 1986). However, not all studies found evidence for compensatory decoration (Biner et al., 1993).

More insight may be found by studies looking at artificial substitutes for windows. Research looking at artificial skylights indicate that in windowless spaces, these are found highly attractive (M Canazei et al., 2016) and can improve connectedness to nature, improve mood, and relieve from feelings of claustrophobia (Markus Canazei, Pohl, Bliem, Martini, & Weiss, 2017). Another study investigated effects of

an artificial window and indoor plants in a windowless (underground) room, and found superior effects of the indoor plants on perceptions of the space (Kim, Cha, Koo, & Tang, 2018). A lack of windows may thus (partly) be compensated by adding components of the window exposure (e.g., exposure to nature).

Proximity to the window was studied in a limited amount of studies and did not point to a particular benefit at present. These results seem to indicate that the presence of a window is important to keep the human circadian and seasonal rhythms in synchrony with the outside world, as well as to reduce eye problems. It appears that the presence of a window alone is not enough to improve mental and physical health. In order to achieve these benefits, there need to be optimal conditions in terms of view content and daylight entrance - beyond the sheer presence of a window.

Simultaneous effects of daylight and views

Most studies looking at effects of windows look separately at effects of either daylight or a view. Six studies looked at effects of both daylight and a view at the same time (M. B. Aries et al., 2010; Baloch et al., 2021; Joarder & Price, 2013; Leather et al., 1998; Tanner, 2009; C.-H. Wang et al., 2019). Two studies in the office found superior effects of daylight exposure over effects of view content (An et al., 2016; Leather et al., 1998). One of these studies (An et al., 2016) measured exposure to indirect sunlight in a survey and measured this with the question whether people had access to a window, and therefore still included view content in the measurement though. Leather and colleagues (1998) found effects of sun patches on job-related health whereas the naturalness of the view did not affect these outcomes. A more natural view did mediate the effect of job strain on the intention to quit. A third study did not find positive effects of distance to the window or view type on psychological and physical discomfort, but only of view quality. In an educational setting, a first study found benefits of both daylight and views on performance, with slightly more pronounced effects of view type (Tanner, 2009), whereas another study found effects of daylight exposure but not of view type (Baloch et al., 2021). Two studies investigated views and daylight exposure simultaneously in a healthcare environment and found opposing outcomes, with one study reporting benefits of both views and daylight (Joarder & Price, 2013) while a second study found no effects of both (C.-H. Wang et al., 2019). Thus, these studies that investigated effects of window views and daylight exposure at the same time are rather inconsistent and therefore do not enable making a distinction between effects of view and daylight.

Indoor and outdoor exposure

One additional factor that may complicate effects of indoor exposure to natural views or daylight exposure is a potential confound with outdoor exposure. This particularly pertains to the effects of natural views.

A number of studies in this scoping review investigated effects of the time spent outdoors in addition to the effects of naturalness of the window views. These studies rendered rather mixed results. One study investigated any potential relation with time spent outdoor

during breaks (Gilchrist et al., 2015), as this could potentially confound with the view from the window because a more natural view may signal better accessibility to outdoor nature. Nature visits measured in terms of duration, not the frequency, was found related to subjective well-being (Gilchrist et al., 2015). However, the natural elements in the view appeared to be stronger predictors for subjective well-being that the time that the office workers spent outdoors during breaks. Workers may not spend a lot of time outdoors during working hours, which may differ largely between different companies (Lottrup, Stigsdotter, Meilby, & Corazon, 2012). In a longitudinal, effects of view content were measured in terms of frequency of looking out of the window, and this study reported no effect on vitality (Korpela et al., 2017). They only found a relationship between physical activity during leisure time and vitality. In another study, going outdoors into nature during breaks was related to lower stress and better general health in yet another study, whereas a more natural view was only related to better general health (Largo-Wight et al., 2011).

When being outdoors, one is almost always exposed to daylight at the same time. Outdoor daylight exposure, or even direct sunlight exposure, may have additional benefits on health and well-being. A recent study, for instance, pointed at clear benefits of outdoor daylight exposure on mood and sleep (Burns et al., 2021). Time spent outdoors, thus, may be a potential confound in studies looking at effects of windows on well-being, as what you see usually is what you get: if you have a more natural view, you will probably be able to go outdoors in this environment as well.

One very window-specific form of outdoor exposure to natural elements and daylight is whether or not the window can be openable. When opening a window, exposure expands from mainly visual commodities to other senses, including the smell, hearing, and feeling. Up till now, only some studies have looked at whether the windows present were openable, but always in context of having control, not as a means to create a potentially stronger or even different effect of the outdoor environment on the occupant. The window as a medium connecting inside and outside deserves more investigation.

The connection with the outside world also works both ways, windows also provide a view *in*. In most cases this is limited to the first five meters of the room behind the window during daytime, but potentially larger areas of the room are revealed during nighttime, which is highly affected by the choice of window coverings (and the usage of these). Little to no research has yet focused on the view *in*, for instance in relation to communicating meaning and personality to the outside world as well as potential effects of privacy issues, which can be highly related to mental health.

Beneficial effects of window elements - Highlights

Natural environments had positive effects on mental and physical health, physiology, well-being, and job engagement. For well-being there were relatively many studies reporting no effect. Mixed results were found for satisfaction with the environment.

View composition (e.g., including window size, view layers, viewing distance, prospect/refuge) had a positive influence on ratings of the environment (mostly view quality) and well-being. Too few studies tested the effects of view composition on actual health outcomes.

View quality received too little attention to make firm conclusions. A positive relation was found between view quality and well-being, physical health, job engagement, and visual comfort. These effects need to be corroborated and replicated in future research.

The sky / weather type was included in a number of studies, either focusing on the amount of visible sky or the sky type (sunny versus overcast). Again, too little studies have included this variable to draw firm conclusions. Studies looked at effects on satisfaction with the environment, well-being, and performance.

Proximity to the window did not receive a lot of attention and rendered mixed results on satisfaction with the environment and visual comfort.

Indoor nature exposure is a composite measure combining having a (natural) view, with being exposed to daylight, and indoor plants. Not many studies looked at this composite measure, but single beneficial effects were reported on well-being and mental health. Slightly more evidence was found for beneficial effects on physical health. More research is necessary to corroborate these findings.

Presence of a window had a clear positive relation with physiology. Satisfaction with the environment, well-being, and visual comfort appeared better with a window present. For sleep, physical health, and job engagement both positive and negative effects were reported.

Daylight exposure was positively related to well-being, physical health, and job engagement. Two studies were performed looking at physiology, and both reported beneficial effects of daylight. Mixed results were reported for satisfaction with the environment, mental health, performance, sleep, and visual comfort.

Views versus daylight?

The question thus remains whether we can distinguish between effects of view and daylight exposure through windows. First of all, the present scoping review has once again identified that there is a large overlap in the beneficial effects of exposure to daylight and a view through windows on health and well-being. when looking at the outcomes of these different aspects of the window there are some striking overlaps in outcomes very similar to those reported earlier (F. Beute & Y. A. de Kort, 2014) with both daylight and a view positively affecting mood, stress, recovery, pain perception, physiology, well-being, cognitive performance, physical health, and job engagement. There are, however, also differences in outcomes. Mental health did not appear consistently affected by daylight entry whereas this was the case for naturalness of the view. Access to a window, measured irrespective of daylight entry and view type, was found beneficial for satisfaction with the environment, well-being, physiology, and visual comfort. No evidence was found for benefits on sleep, mental health, or physical health. It thus appears that view content and daylight entrance affect health and well-being, at least partly, through different pathways.

On the other hand, view content and daylight exposure are connected in many ways. First of all, view and daylight are represented in many of the same elements and at the same time. For example, the presence of the sky as part of the view content improves restorative potential (Masoudinejad & Hartig, 2020), are one of the three layers that make window content more preferred (Matusiak & Klöckner, 2016), influences the amount and spectral composition of light entering the room (Münch et al., 2020), which may -in turn- trigger certain biological responses (Nilsson & Smolka, 2021). A second example is the openness of the view. A more open view is preferred (Stamps, 2010; Stamps III, 2005) and may therefore give better health outcomes. Many studies looking at window content have differences in openness of the view included. For instance, having no window gives a more enclosed feeling. In addition, some studies comparing different views compare an open natural view to a closed view to an adjacent building (e.g., Benfield et al., 2015; D. Li & Sullivan, 2016; Ulrich, 1984; Walch et al., 2005). In turn, this openness affects the amount of daylight entry. The perception of openness, in turn, depends on the permeability of the environment and the lightness of this environment (Stamps, 2010; Stamps III, 2005), which makes the dependency between view content and daylight exposure complete. As a third example, the aesthetic rating of natural environments depends on the brightness of the image, which appears to influence subsequent beneficial effects of this view. Extending research indicating that people prefer bright (as opposed to dark) natural images (Beute & de Kort, 2013), more recent research indicated that bright virtual forest scenes lowered stress (C. Li, Sun, Sun, Yuan, & Li, 2020). A final example pertains to the use of window size as a pathways from windows to health benefits. Window size is used as a parameter in studies looking at effects of window views as well as in studies looking at effects of daylight entrance. Beneficial effects have been reported of window size for view content (Matsuoka, 2010; Moscoso et al., 2020,

2021; Yeom et al., 2020), but not for daylight entrance (M Boubekri & Haghighat, 1993). However, one of the positive effects of window size reported when looking at view content was that larger windows increased brightness perception (Moscoso et al., 2020). Effects of view and daylight are, however, not separated in these studies and difficult -if not impossible- to disconnect in everyday situations.

A view and daylight entrance are thus in many ways related with each other. Daylight alters the way we perceive the physical world (Beute & de Kort, 2013) and we can only perceive the world around us through the light that enters our eyes. At the same time, the objects comprising the different layers of the view influences the spectral composition and intensity of the light that we receive on our retina (Nilsson & Smolka, 2021), as well as the dynamics of light entrance over time with potentially more pronounced effects for window content than window orientation (Rodriguez, Garcia-Hansen, Allan, & Isoardi, 2021). This way, view content not only becomes relevant in terms of restorative potential (R. Kaplan & Kaplan, 1989; Ulrich, 1983), but also contributes to the biological relevance of the lighting environment.

This connection between daylight and view goes in the opposite direction as well. A pretty view makes people more tolerant for glare by daylight (Tuaycharoen & Tregenza, 2007), and people with more natural views may look out of the window more frequently (R. Kaplan, 2001; Korpela et al., 2017) and thereby receiving more daylight on the retina. The number of layers in the view can influence quality of the view, whereas the content of the view layers influences the lighting environment, with for instance the sky containing a relatively large proportion of blue light. In turn, having more sky in the view has been found related to higher ratings on the factors being away and fascination and resulted in higher reported restoration likelihood (Masoudinejad & Hartig, 2020). In addition, both viewing in the distance and exposure of the eye to daylight can help prevent myopia (Lingham et al., 2020).

Last, what you place in the window can affect both the view out of the window and glare perceptions. For example, it has been found that placing plants on the sill can increase improve restorative outcomes (Masoudinejad & Hartig, 2020), but can also increase contrast (Pierson et al., 2018). The use of curtains or blinds has a major influence on both daylight and view exposure.

Benefits of windows: Conclusion highlights

Windows are important for human health and well-being. The **presence of a window** improved satisfaction with the environment and synchronized circadian rhythms with seasonal patterns. Some indications were found for benefits on well-being, but not for mental or physical health. For beneficial impacts on mental and physical health, the presence of a window alone does not appear enough. Instead **the right conditions of the outdoor content is needed in terms of daylight entrance and view content**.

Daylight and a natural view content both have beneficial effects on well-being, physical health, and job engagement. **Daylight** did not have a consistent beneficial influence on mental health whereas **natural view content** did have a clear beneficial relation with mental health. **Composition of the view** (beyond naturalness) and the presence of a window improved satisfaction with the environment, but no consistent effects on satisfaction where found for naturalness of the view and daylight entrance.

For **daylight**, there is a need for more homogeneity in the measurement of daylight, and a better description of the daylight characteristics (e.g., amount, composition, control, glazing type). For **view content**, effects need to be studied beyond amount of nature by including view elements and composition.

Aspects to take into consideration for the benefits of windows:

1) View content and daylight exposure are highly interrelated as:

a) The light environment and temporal dynamics in light exposure depend on view content.

b) Light characteristics (such as the weather) influence how the window view is perceived.

c) View content influences glare perception and frequency of looking out of the window. This, in turn, can influences the dose of daylight exposure.

d) View composition in terms of viewing distance and number of layers is related to the amount of sky in the view and thereby potentially also to daylight exposure (in terms of both amount and spectral composition).

2) Benefits may differ depending on individual differences (e.g., age), setting (e.g., healthcare vs residential), location (e.g., latitude), or climate (e.g., tropical vs land climate).

3) Window exposure to daylight and view content is correlated with or affected by outdoor nature / daylight exposure and indoor electric light exposure.

4) Daylight exposure interacts with other indoor parameters, such as perceived temperature.

5) For view content, not only naturalness of the view matters but also the characteristics of the view in terms of view elements and view composition.

Research agenda

The existing evidence base points at a clear benefit of windows for health and well-being. The present knowledge could be advanced by a more detailed knowledge of the separate effects of daylight and view content, but also on the instances where they overlap and potentially work together in improving well-being.

For view content, there is a need to look beyond the categorization of natural versus urban elements in the view, by including other compositional elements such as openness, view distance, content elements, and view layers. The evidence for the relevance of these compositional elements needs to go beyond the present focus on effects of view quality, by looking at actual health outcomes. What can be seen from a window can be confounded with what a person is exposed to when outside in proximity to the work, residential, school, or healthcare environment. In addition, whether or not the window can be opened (and whether or not the window actually is opened by the occupant and how often) can influence the exposure and experience of the outdoor environment as well. This refers not only to exposure to outdoor view elements, but also to daylight exposure (turning into sunlight when the window is opened).

For daylight exposure, especially the ways in which daylight was measured differed largely between the studies reporting in this scoping review, including for instance the presence and type of curtains, the presence and shape of sun patches, orientation of the window, and actual amount of daylight exposure. In order to better understand the effects of daylight, there needs to be a more homogeneous set of measures for daylight exposure (see also e.g.,Münch et al., 2020). Far from all studies, for instance, reported actual daylight exposure in terms of amount and composition. It would be a good starting point to look at the actual light exposure. And as only few people stay inside a single room the entire day and daylight is often supplemented with electric light, there is also a need to understand how the daylight exposure relates to both indoor and outdoor light exposure. The experiential benefits of especially daylight exposure are highly underrepresented, there is a need to know more about how people experience daylight exposure, for instance by using more qualitative research methods.

View content and daylight exposure can't be seen as two separate entities, there are a number of areas where they influence each other. The benefits of windows may be better understood and exploited when knowing more about how view content and daylight exposure are related to each other. Potential points of interest are how view content influences the light environment (Nilsson & Smolka, 2021; Rodriguez et al., 2021), frequency of looking out of the window, and the influence of the presence of the sky on health and well-being.

The experiential aspects of windows has received relatively little attention. What do windows mean to people in different settings? One of the benefits of windows, for instance, that is often referred to is the ability to see the weather. This is perhaps information that can't easily be retrieved from surveys, but requires a dialogue with users and occupants. Again, thus, this would imply a need for qualitative research.

A number of studies in this scoping review pointed at differential effects of daylight or nature based on individual differences such as age or gender. The benefits of windows may thus differ on these individual differences, but potentially on the setting in which the window is investigated as well. Mental health, for instance seemed to benefit consistently from daylight exposure in healthcare settings, but not across all settings. Instead, daylight control appeared especially important in performance settings (office and education). Second, differences between seasons, geographical locations, and climates have not received a lot of attention, whereas all these elements can influence both view content and daylight exposure. Think, for instance of the difference at looking outside of a window during the dark winter months with or without snow, or sitting close to a window on a shimmering hot summer day. Understanding differences in effects of windows between individuals, locations, and settings may help to exploit the benefits of windows even better in the future.

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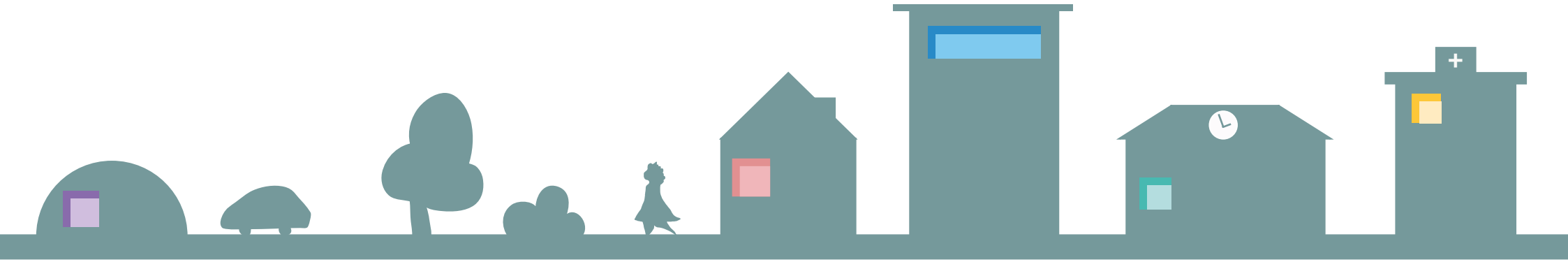

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