Article:

Morales-Bravo, J. and Navarrete-Hernandez, P. (2022) Enlightening wellbeing in the home: the impact of natural light design on perceived happiness and sadness in residential spaces. Building and Environment, 223. 109317. ISSN 0360-1323

https://doi.org/10.1016/j.buildenv.2022.109317

Building and Environment 223 (2022) 109317

Contents lists available at ScienceDirect

Building and Environment

journal homepage: www.elsevier.com/locate/buildenv

Enlightening wellbeing in the home: The impact of natural light design on perceived happiness and sadness in residential spaces

Javiera Morales-Bravo [a], Pablo Navarrete-Hernandez [b,*]

[a] Department of Architecture, University of Chile, Santiago, Chile
[b] Department of Landscape Architecture, University of Sheffield, Sheffield, UK

A B S T R A C T

As more people move towards work-from-home options during the COVID-19 pandemic, residential indoor environments are increasingly becoming places where we spend a large share of our time living, working and studying. While the relevance of indoor environments for our emotional wellbeing is well established, little is known about the specific aspects of residential indoor spaces that affect negative and positive emotions. This article studies the relationship between natural lighting in the home and the emotional subjective wellbeing (E-SWB) of its inhabitants. In a randomised control trial, we test the hypothesis that natural lighting improvements in housing contribute to residents' E-SWB, determining which aspects of housing daylight design are more relevant for this. A total of 750 participants took part in the experiment and rated, according to their perceived happiness or sadness, a series of 3D computer simulations representing seven types of natural lighting improvements in the home. The results show that the natural lighting conditions of housing significantly impact people's perceptions of happiness and sadness, with settings that have an increased amount of daylight entering the home leading to the greatest impacts.

1. Introduction

The quality of indoor environments has been shown to impact human wellbeing by affecting people's mood as well as their mental health [1–4]. Staying indoors for a prolonged period can lead to increased negative emotions, such as anxiety, stress and sadness [5]. Several studies show, for instance, that during lockdowns related to the COVID-19 pandemic, diagnoses of Post-Traumatic Stress Disorder (PTSD) and depression increased [6,7]. Ettman et al. further demonstrate that the prevalence of depression in the adult population of the United States tripled during the lockdown period [8], while Pierce et al. show that calls to emergency services related to suicidal thoughts in the United Kingdom increased tenfold compared to previous years [9]. With the rapid increase in working from home during the pandemic, the residential space is increasingly becoming a location used simultaneously for living, studying and working [10]. Despite the resulting increased relevance of these residential indoor environments to people's emotional wellbeing, little is known about which specific aspects of indoor spaces trigger negative emotions and suppress positive emotions [11], and about which housing environment configurations might be able to increase the emotional subjective wellbeing (E-SWB) of people in the home.

Light is a fundamental element of our visual perception of interior space in the daytime, and thus is a central candidate for affecting the emotional state at home. Several studies show that artificial lighting characteristics change the perception of interior spaces and the emotions of those who inhabit them. Odabaşioğlu & Olguntürk show that different colours of light affect participants' perception of comfort, with white- and green-lit spaces described as bringing significantly more comfort to indoor spaces than those lit with red light [12]. Lan et al. demonstrate the strong relationship between warmth of light (measured in lux and kelvin) and emotions, finding that indoor spaces with neutral warm light (300 lx, 300 K) and bright cool light (2000 lx, 6000 K) condition positive emotions, such as joviality and enthusiasm, when compared with indoor environments of bright warm light (2000 lx, 3000 K) [13]. Li et al. investigate the effects of illuminance — luminous flux incident on a surface, measured in lux — and its correlation with colour temperature on perceived emotions in indoor spaces, finding that light of 100 lx is perceived as being more pleasant than light of 1000 lx [14]. Along similar lines, Ru et al. find that the exposure to low illuminance, when compared with high illuminance, generates positive effects on participants' moods [15].

Sunlight constitutes a fundamental component of architecture, with LeCorbusier himself recognising that a building's architectural considerations go on to affect the natural lighting characteristics of interior spaces [16]. Given the relevance of indoor lighting to emotional wellbeing, the question naturally arises as to the capacity of architecture, via natural lighting conditions, to generate negative or positive emotions in

* Corresponding author.
E-mail addresses: Javiera.morales.b@ug.uchile.cl (J. Morales-Bravo), p.navarrete@sheffield.ac.uk (P. Navarrete-Hernandez).

https://doi.org/10.1016/j.buildenv.2022.109317
Received 11 February 2022; Received in revised form 14 June 2022; Accepted 15 June 2022
Available online 8 August 2022

the inhabitants of a space. Burgeoning empirical evidence shows this effect to be plausible and warranting further study. Smolders et al., for instance, show that the greater the amount of natural light entering an office, the more vitality people perceive the space to possess [17]. Aljunaidy et al., in a systematic review, discuss several studies of the ways in which stress disorders can be treated or managed through indoor environmental factors [18], including light levels and the number of windows in a room [19–23]. In an experimental study, Van Hoof et al. show that high-intensity lighting interventions can manage restless behaviour and anxiety symptoms of patients with dementia [24]. Heschong indicates that indoor views and exposure to daylight are major environmental factors affecting human cognitive function, health and wellbeing [25]. Moreover, hedonic studies show that people's preferences for levels of indoor sunlight influence their real estate decisions, ultimately reflected in higher property values [26,27]. Fleming et al., for instance, estimate that an extra hour of sunlight per day is associated with an increase of 2.4% in a property's sale price [28]. Taken together, these studies suggest that natural lighting conditions in various types of interior spaces do indeed have an impact on perceived emotions, and therefore it is reasonable to consider that natural lighting in residential spaces may be capable of affecting the E-SWB of its inhabitants. However, to the best of our knowledge, there are no studies that systematically analyse the impact of daylight conditions in the home on people's E-SWB.

This paper analyses the relationship between natural light in housing design and interior living spaces, and inhabitants' E-SWB, measured through happiness (as a proxy for positive emotions) and sadness (as a proxy for negative emotions). To analyse this, a Randomised Controlled Trial (RCT) technique is implemented, using 3D computer simulations of a house in control (no intervention) and treatment (with daylight design improvements) conditions that reflect improvements related to the amount and the reflection and absorption of natural light at home. For this purpose, six improvement conditions of natural indoor lighting are tested: distance from nearby buildings, window orientation, window size, number of windows, surface material of indoor wall-finishes and brightness of indoor wall-finishes. Participants assessed their perception of happiness and sadness under these different conditions through an adapted version of the psychometric Positive and Negative Affect Schedule (PANAS) scale. Ultimately, the analysis shows that natural light in interior living spaces affects people's positive and negative emotions, and configurations that favour the amount of light entering a house are relevant design factors to consider for improving the E-SWB of those using indoor residential spaces.

The following section presents a review of the literature related to subjective wellbeing, perception of happiness and sadness, and light in housing. The methodology of the study is then presented. Following this, the main results are discussed, showing the causal relationship between natural light at home and the perception of happiness and sadness. Finally, a discussion of the results is given, and the conclusion is presented, highlighting implications for housing policy, planning and design.

2. Literature review

2.1. Subjective wellbeing

Subjective wellbeing is defined as a person's cognitive and affective evaluations of his or her life [29]. The cognitive component of wellbeing refers to satisfaction with life and an appreciation of its various aspects [30], such as work, family, leisure, health, income, satisfaction with oneself and in one's relationships with others. The affective component refers to the emotions experienced by people such as happiness, sadness, or fear [31], i.e. emotional subjective wellbeing (E-SWB). Although there is no clear-cut consensus on a definition of emotions [32], they can be understood as the perception of a variation in our basal state due to the result of neuropsychological activity — expression of emotion — [33–37] and conscious processing — experience of emotion — where we are able to interpret through our own awareness changes of emotions [38,39]. For Larsen and Van Schuur et al., these emotional variations can be of two types, positive or negative [40,41] as proposed in Bradburn's affective scale [42]. A positive variation of emotion — such as joy, euphoria, pride, affection, enthusiasm, or happiness — is understood as the reflection of satisfaction in response to a specific stimulus or situation, while a negative emotion — such as stress, anxiety, anger or sadness — is understood as the reflection of dissatisfaction or discomfort in response to a specific stimulus or situation [43].

The measurement of E-SWB is commonly performed through psychometric scales, such as Positive and Negative Affect Schedule (PANAS) or the International Affective Picture System (IAPS). These scales allow for the quantification of emotions in a standardised manner [44] employing self-assessments that facilitate their temporal, intra-subject and inter-subject comparison. PANAS (and its variants) is one of the most widely used emotional scales, since it has demonstrated strong reliability, validity and normativity, possessing high internal consistency (Cronbach's alpha, coefficient of reliability = 0.86–0.90 for positive affect and 0.84–0.87 for negative affect). The correlation of PANAS with Beck's anxiety and depression questionnaires has been determined with coefficients ranging from 0.32 to 0.55. Its use has been validated in the clinical and general population, and amongst adolescents, adults and older adults. In the PANAS-X scale Watson and Clark systematise peoples' experience through general positive and negative affects within five positive emotions (joviality, self-assurance, attentiveness, serenity and surprise), and six negative ones (fear, sadness, guilt, hostility, shame and fatigue) [45]. Each of these general emotions can be further broken down, resulting in a total of 60 items.

This study focuses on two emotions drawn from two general affects: The first one happiness, is defined as the emotional element of the general positive affect of joviality and the second one sadness, is defined as the emotional element of the general negative affect of the same name [46].Happiness is a positive emotion that is essential for indicating values of E-SWB; it can be defined as feeling good, enjoying life [47], and as the summation of emotional wellbeing [48]. Happiness constitutes one of the most relevant aspects of people's lives. For example, Ballas and, Smith and Reid show that diverse groups participating in their studies place it above success, health, intelligence, or possession of material goods [49,50]. In addition, it has been widely used in research studying the relationship between the built environment and E-SWB [51]. Sadness, on the other hand, is defined as an emotional state of unhappiness, varying in intensity from medium to extreme, and usually caused by the loss of something valuable; prolonged sadness is one of the definitions of depression [52]. It is also associated with a feeling of mental pain produced by a related stimulus, such as feeling depressed [53], and triggers expressions of this emotion, such as increased heart rate [54,55], crying [56,57], or heightened blood pressure [58]. Sadness is often studied in conjunction with happiness in E-SWB studies and is used to contrast a positive with a negative emotion [59].

2.2. The built environment and E-SWB

A growing number of studies show the relationship between aspects of the built environment and people's E-SWB. A substantial body of evidence, for instance, establishes the impact produced by the outdoor built environment. Rappe shows that the presence of different types of green areas in long-term care environments improves older adults' perception of E-SWB [60], and Navarrete-Hernandez and Laffan, using photo simulations showing streets with or without greenery, establish a causal relationship between the presence of vegetation in streetscapes and increased happiness and decreased stress [61]. Using ecological momentary assessments (EMAs), Su et al. assess perceptions of happiness for people moving around city areas, finding that higher-density environments with intersecting streets led to a decrease in happiness [62]. Finally, in Navarrete-Hernandez et al.'s image-based randomised control trial studying the impact of transformations to the built environment on perceptions of safety shows that the removal of blind walls significantly decreases perceptions of fear in public spaces [63].

A less abundant body of literature considers the relationship between indoor built spaces and people's emotions. Various studies have shown that the presence of nature indoors – for example, the incorporation of plants into interior spaces – increases the E-SWB of those in offices, classrooms, and hospital waiting rooms [64–66]. In a meta-analysis of research on indoor built environment design, Bower et al. conclude that a limited number of studies have analysed the impact of different architectural design variables on neurophysiological responses correlated to human emotions [67]. For example, Baenei et al. find that curvilinear versus linear spaces score higher in measurements of pleasure and excitement — the physiological and psychological states of being awake or reactive to stimuli [68]. In other studies, high ceilings and the presence of wood and furniture were found to increase positive emotions measured at the neurophysiological level [69–71] In spite of the impacts established by these studies, important design features of the built indoor spaces – such as colours, proportions and natural light – have not been explored in depth [72]. Moreover, the studies that have been conducted have been based on small samples, rendering their extrapolation to a larger population difficult, and a more detailed study of intersectionality of emotions in indoor spaces is generally non-existent [73].

Given that the studies presented above establish the tangible impact of the built environment on E-SWB, it is fair to suppose that, as part of the built environment, residential interior spaces also influence the emotions of their inhabitants. Residential interior spaces are of course composed of various elements — their materials, colours, sizes and shapes, for instance — however we do not thoroughly understand the direct effect of these elements on the emotions of people living in these spaces [74]. Natural light, being a fundamental part of our visual construction of space in the daytime, presents a feasible candidate for an element of the home space that influences people's E-SWB. The next section will assess the viability of this proposal.

2.3. Natural light and human beings

The human being is an eminently visual creature: we devote about one-third of our cortical neurons to processing visual stimuli, more than any other sense [75]. The light stimuli that we process are perceived differently depending on their source, wavelength, exposure range and type of light [76]. Our visual perception of the built environment is constructed through the interaction of light sources with objects in the space, which have properties of reflection, absorption, refraction, scattering and diffraction. Therefore, it is not only the amount of natural light entering an interior space that constitutes our visual perception of the indoor environments, but also the source of this light and its interaction with surfaces and objects in the space.

A wide range of studies demonstrate the impact of lighting conditions on people's emotions at the psychological and neurophysiological levels [77,78], triggering positive and negative experiences and expression of emotions [79–81] in a range of contexts and environments. It is well-established that daylight influences the circadian rhythm in both physiological behaviour – such as hormone secretion (cortisol and melatonin) – and body behaviour – such as lethargy, eating and sleeping – over a 24-h period [82,83]. For instance, research shows that shorter days, during which people are less exposed to sunlight, see an increase in the secretion of cortisol associated with the emotional expression of stress [84], and seasonal affective disorder (SAD), a form of depression. Ross et al. demonstrate the impact of coloured light modulation compared to white light of the same intensity on the autonomic nervous system, observing a decrease in the total mood disturbance index measured through the psychological scale POMS (Profile of Mood States) [85]. According to Küller et al., light in workspaces impacts the mood of workers, where an exceptionally dark or bright space worsens mood, and a balanced or 'just right' amount of light improves it [86]. In office spaces more specifically, both physical and psychological well-being have been related to natural light conditions and the presence of greenery, whether natural (plants, trees) or artificial (ornaments or imitations of nature) [87]. Furthermore, light has been used in various contexts to mitigate mood disorders. Benedetti et al., for instance, show that exposure to natural morning light can reduce hospitalisation time in patients diagnosed with mood disorders such as depression [88], and Oldhan and Ciraulo demonstrate that the use of bright light (via Bright Light Therapy or BLT) has a significant autonomic effect, serving as an antidepressant in treatments for SAD and for non-stationary depressions [89]. Taken together, these studies show the relevance of light as a conditioning factor of people's emotions. Given that both light and the built environment affect E-SWB, it is to be expected that natural light conditions in indoor residential spaces could impact people's emotions [90,91]. This study thus seeks to analyse this relationship, as well as to understand the elements of housing design that could significantly improve E-SWB at home.

2.4. Virtual stimuli and environment perception

Photo simulation techniques are based around the graphic modification of an environment, creating new versions of a space. They have been widely used in environmental psychology and urban planning, helping researchers to understand people's preferences [92,93]. For example, Junker and Buchecker use photo simulations to study the impact of river restoration on people's satisfaction with various landscape options [94], while Cerina, Fomara and Manca used the technique to study the impact of architecture design on satisfaction levels in care home facilities [95]. Aside from measuring satisfaction, other studies have used static images to investigate the impact of environmental features on various perceptions, such as safety [96], liveliness and beauty [97], and happiness and stress [98,99]. Further research has shown that images can trigger physiological responses: studies in psychology have established that threatening and unpleasant images trigger involuntary emotional physiological expression, such as higher skin conductivity and increased heart rate [100,101]. Furthermore, research demonstrates that environmental conditions correlate with the activation of brain areas related to emotion. For instance, by using functional magnetic resonance techniques, Kim et al. show that exposure to rural images activates the basal ganglia, a cerebral area related to positive emotions, while images of cities correlated with high activation of the amygdala, associated with feelings of fear and anger [102]. These examples demonstrate the wide use and suitability of images and photo simulations in the study of emotions in the built environment. Drawing from these precedents, the present study uses 3D model-based computer imaging as a means of controlling daylight conditions.

3. Methodology

3.1. Study design

This study analyses the impact of natural light in residential interior spaces and its relationship with people's perception of happiness and sadness. For this, we use an image-based Randomised Controlled Trial (RCT) methodology, using computer-generated photo simulations of a standard social housing unit in Santiago de Chile under control condition (with no intervention) and with treatments (with interventions) – specifically, different conditions of natural lighting design visible throughout the same house.

A total of 750 participants were presented with 25 randomly assigned images of interior housing living spaces, in either control or treatment conditions, which they rated according to how happy or sad they felt in that space. To assess the emotions, an adaptation of the Watson and Clark PANAS-X questionnaire [103] was used, in which participants were asked to rate either their perceived happiness or sadness on a series of presented images. The participants gave ratings on a scale from 1 to 10, with 1 indicating “not at all sad/happy” and 10 indicating “extremely sad/happy”. Whether a participant was asked to rate the happiness or the sadness of a given image was determined at random. As with any RCT, this experiment has strong internal validity, however the results should not be directly extrapolated to other population groups, as we used a convenience sampling technique, or to other geographical contexts, as all images were modelled for the natural light conditions of Santiago de Chile.

Natural Light Design (NLD) interventions were broadly classified into two categories, namely those that affect (1) the amount of light entering a room, and (2) the interaction of light inside a room. These two categories were modelled across seven NLD factors that influence the natural lighting of indoor spaces: climate conditions, distance from neighbouring buildings, orientation of light entry, size of windows, number of light entry points, interior wall material, and tone of interior walls. Each of these seven factors was modelled across four room types: bedroom, kitchen, bathroom and living-dining room (Fig. 1). With this experimental design, we are able to differentiate the results of natural lighting conditions on E-SWB for each room type.

We propose the following hypotheses:

Ha1. Under equal natural lighting conditions, relevant socioeconomic conditions influence E-SWB at home.

Ha2(a). Summer weather conditions positively relate to people’s E-SWB at home.

Ha2(b). Sunny weather conditions positively relate to people’s E-SWB at home.

Ha2(c). NLD improvements positively relate to E-SWB at home.

Ha3. NLD improvements positively relate to people’s E-SWB at home across all socioeconomic conditions.

Ha4(a). NLD improvements that increase the amount of light entering a room are positively related to people’s E-SWB at home

Ha4(b). NLD improvements that improve the reflection of light in a room are positively related to people’s E-SWB at home

Ha5(a). The impact of NLD improvements increasing the amount of light is positively related to the housing room types in which people spend more time awake at home.

Ha5(b). The impact of NLD improvements increasing the reflection of light is positively related to housing room types in which people spend more time awake at home.

Ha6(a). NLD factors that increase the amount of light entering a room are positively related to people’s E-SWB at home,

Ha6(b). NLD factors that increase the reflection conditions of light in a room are positively related to people’s E-SWB at home.

Ha7. (a): The extent of NLD improvements is positively related to larger gains in people’s E-SWB at home.

To simulate precise natural lighting conditions, the four rooms were modelled in 3D using Sketchup + Vray software, maintaining natural light conditions according to geolocation, time of year and time of day. The control natural lighting conditions were set in Chile, Santiago Metropolitan Region, in winter (June 20th) at 12:00. As Chile is situated in the southern hemisphere it is important to clarify that north facades face towards the sun. The relative dimensions of the floor plan were kept constant (2:3 ratio) across all room types, to ensure comparability of natural lighting conditions. The dimensions used were: 2 m × 3 m for the

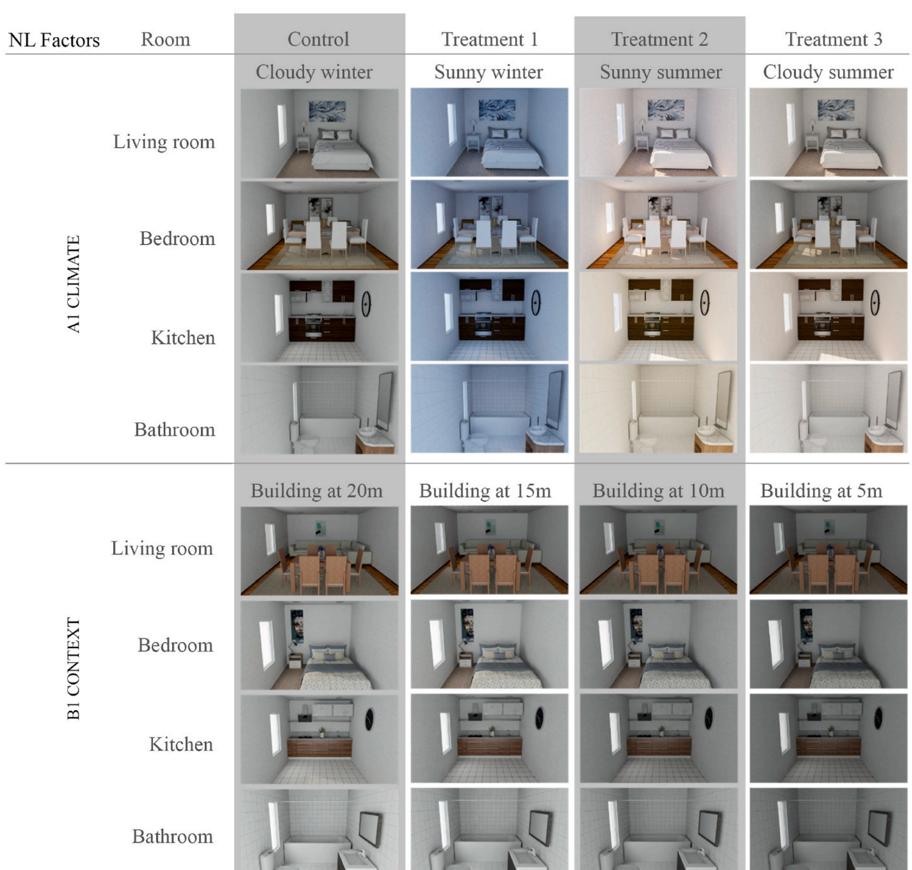


Fig. 1. Photo simulations.

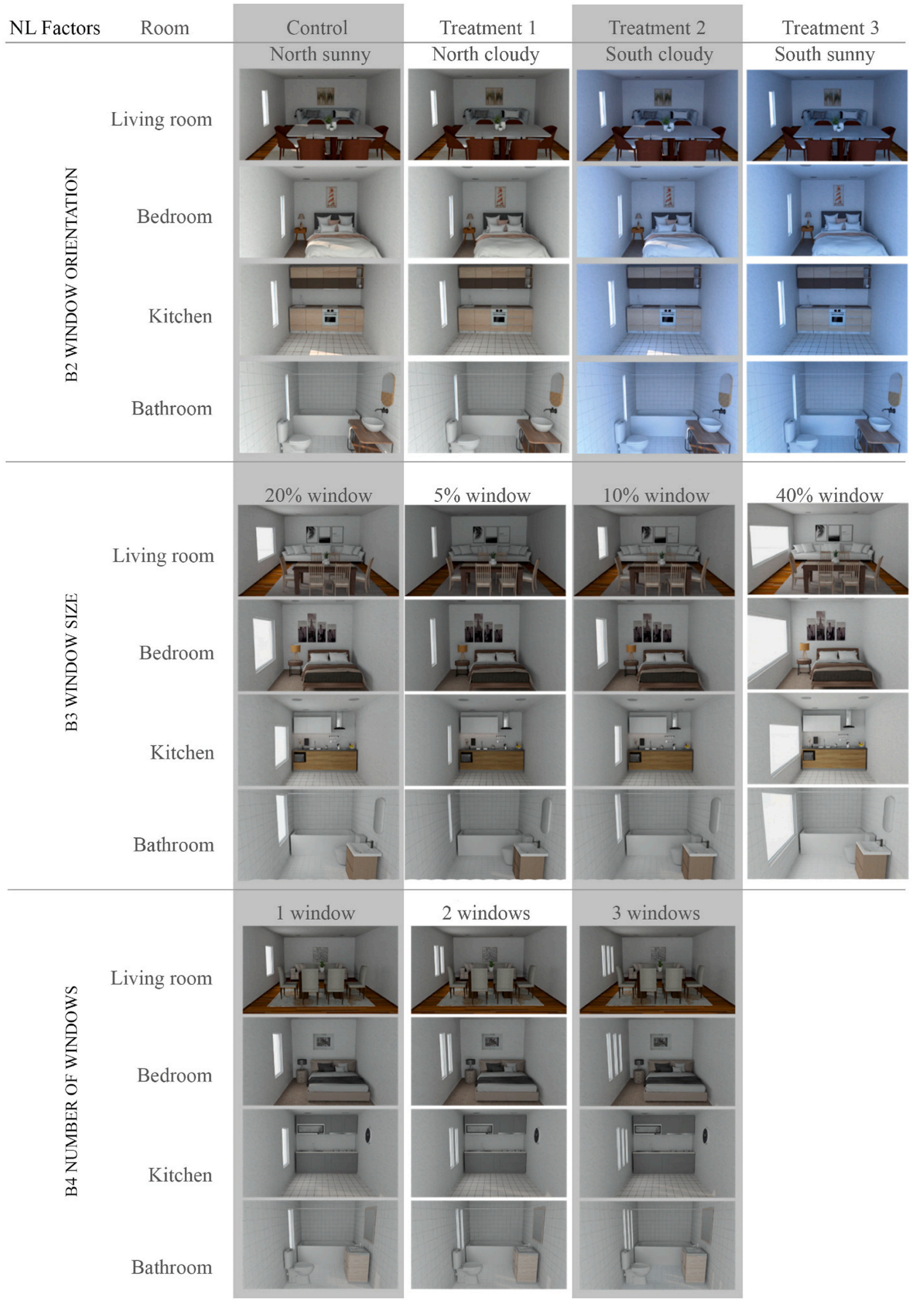


Fig. 1. (*continued*).

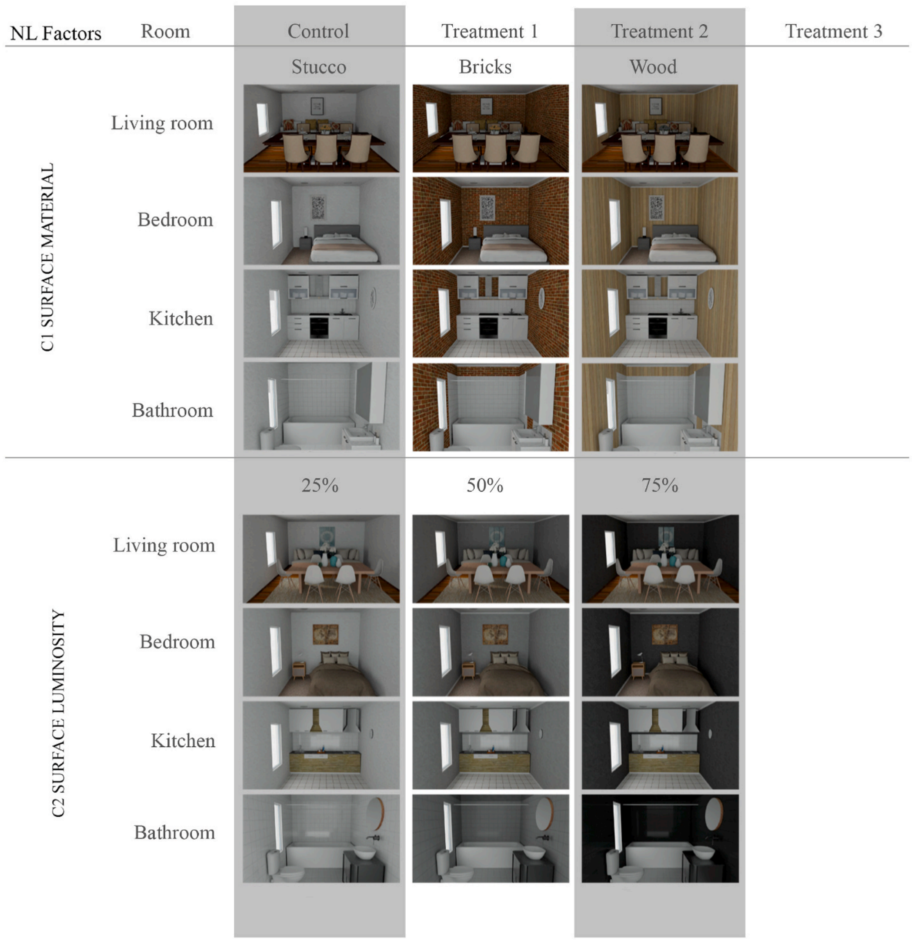
bathroom; 2.65 m × 4 m for the bedroom and kitchen; and 3.35 m × 5 m for the living-dining room. Slight changes were made to the furniture design in all images to prevent participants from identifying the NLD factor as a treatment.

3.2. Sampling strategies

The online platform Urban Experiment (www.urban-experiment.com) was used to collect the data. Due to COVID-19 lockdowns and mobility restrictions, the experiment was distributed using social networks, with participants having the option of responding using their mobile phone, tablet or computer.

The experiment was divided into three sections, the first of which consisted of an explanation of the experimental procedure and signing an informed consent form. The participants then answered a series of sociodemographic questions. Finally, each participant was asked to imagine that they were in the room shown in the presented image and rate how happy or sad they would feel in it.

A double randomisation process was performed to balance participants' covariates between control and treatment image responses. The order of the presented NLD categories was randomised to avoid spillover or fatigue effects when evaluating several photo simulations, which could potentially affect the participants' ratings from one image to the next. Alongside this, whether the subject would view a control image or one of the treatment images was randomly assigned, thus balancing covariates between the control and treatment groups. To empirically test this, we conducted our balance tests at the treatment level to examine whether systematic differences existed across the control/treatment groups for the observed characteristics of gender, age, place of residence, participant's own type of housing, image order, day of the test and time of the test. Across the 211 tests conducted, only ten came out significant at the 5% level, suggesting the randomisation was successful



A: Seasonal and weather factors B: Amount of light factors C: Reflection and absorption of light factors

Fig. 1. (*continued*).

(balance test tables available on request). As with any RCT, this experiment has strong internal validity, though results should not be extrapolated to other population groups as we used a convenience sampling technique.

3.3. Experiment data

To carry out our analysis, we used three sources of data: 1) participants' sociodemographic characteristics; 2) measurements related to the experimental conditions; and 3) participants' perceptions of happiness and sadness. The sociodemographic information contains participants' gender identity, age, place of residence, income and current type of housing (descriptive details in Table 1, Appendix). The second source of data collected contained the conditions of each image in the experiment, including its treatment conditions, order of appearance and date and time on which the experiment took place. Finally, we collected participants' stated perceptions of happiness and sadness from 1 to 10 for each image as the dependent variable in the study.

3.4. Empirical strategy

To analyse the relationship between natural lighting at home and E-SWB, random intercept models with image-level fixed effects were used. Random intercepts were included to account for the assumption that each participant might have a unique predisposition to feel sad or happy independent of the image shown. We included image fixed effects to control for each image's average sadness and happiness rating. The models take the following form:

$$\text{Perception ij} = \beta 1\text{Treatment i} + \beta 2\text{Image i} + \text{Uj} + \text{Eij} \quad (1)$$

Where Perception *ij* is the stated perception of happiness and sadness of participant *j* for image *i*. Treatment is a categorical variable corresponding to the baseline (control) image or one of the three treatments (as presented in Fig. 1) if the *i*-th image contains a NLD improvement. *β1*, the Average Treatment Effect, is the central coefficient of interest that captures the impact of natural lighting improvements in the home on participants' reported perception of happiness or sadness. *Image i* is an image fixed effect for the *i*-th image. *Uj* is the random intercept associated with individual number *j*. *Eij* is the error term.

3.5. Robustness check

The robustness of the results is examined by running Eq. (1) with and without control variables (Eq. (2)). Control variables include the sociodemographic characteristics of the respondent (gender, age, place of residence, income and current type of housing) as well as three study conditions: order of appearance, time of response, and day of response. All figures below display estimates with the full model incorporating all controls. The model takes the following form:

$$\text{Perception ij} = \beta 1\text{Treatmenti} + \beta 2\text{Imagei} + \beta 3\text{Xij} + \text{Uj} + \text{Eij} \quad (2)$$

This model takes the same form as Eq. (1), except for *Xij*, which contains the demographic and study conditions variables for participant *j* and the measure of study conditions for image *i*.

Eq. (2) was performed in a number of different ways, each of which is described in detailed in the subtext of Figs. 2–8 in the following section. Only results that show a significant difference below 5% in mixed-regression models with and without controls are discussed.

4. Results

In this section, we present the results of our analysis of the impact of natural lighting conditions in the home on perceived happiness and sadness.

4.1. Do sociodemographic factors matter for E-SWB perceptions?

Here, we analyse whether socioeconomic characteristics affect people's perception of happiness and sadness in the home. For this, we consider the impact of different socioeconomic and housing factors –region, gender, age group, income level and type of housing – on the two emotions in the control situation. This is done by running Eq. (2) restricting the responses to control images only (see Fig. 1). As shown in Fig. 2, the results suggest that besides participants' sociodemographic characteristics, people perceive equal levels of happiness and sadness in response to the same natural lighting conditions in the home except for people of medium income level (estimate = −0.607, SE = 0.310, p = 0.050). For more details see Table A.2.

4.2. Are natural light improvements effective for enhancing E-SWB?

Fig. 3 shows the impact of daylight conditions on participants' perceptions of happiness and sadness in indoor home spaces. In this specification, we run Eq. (2) comparing seasonal, weather and NLD

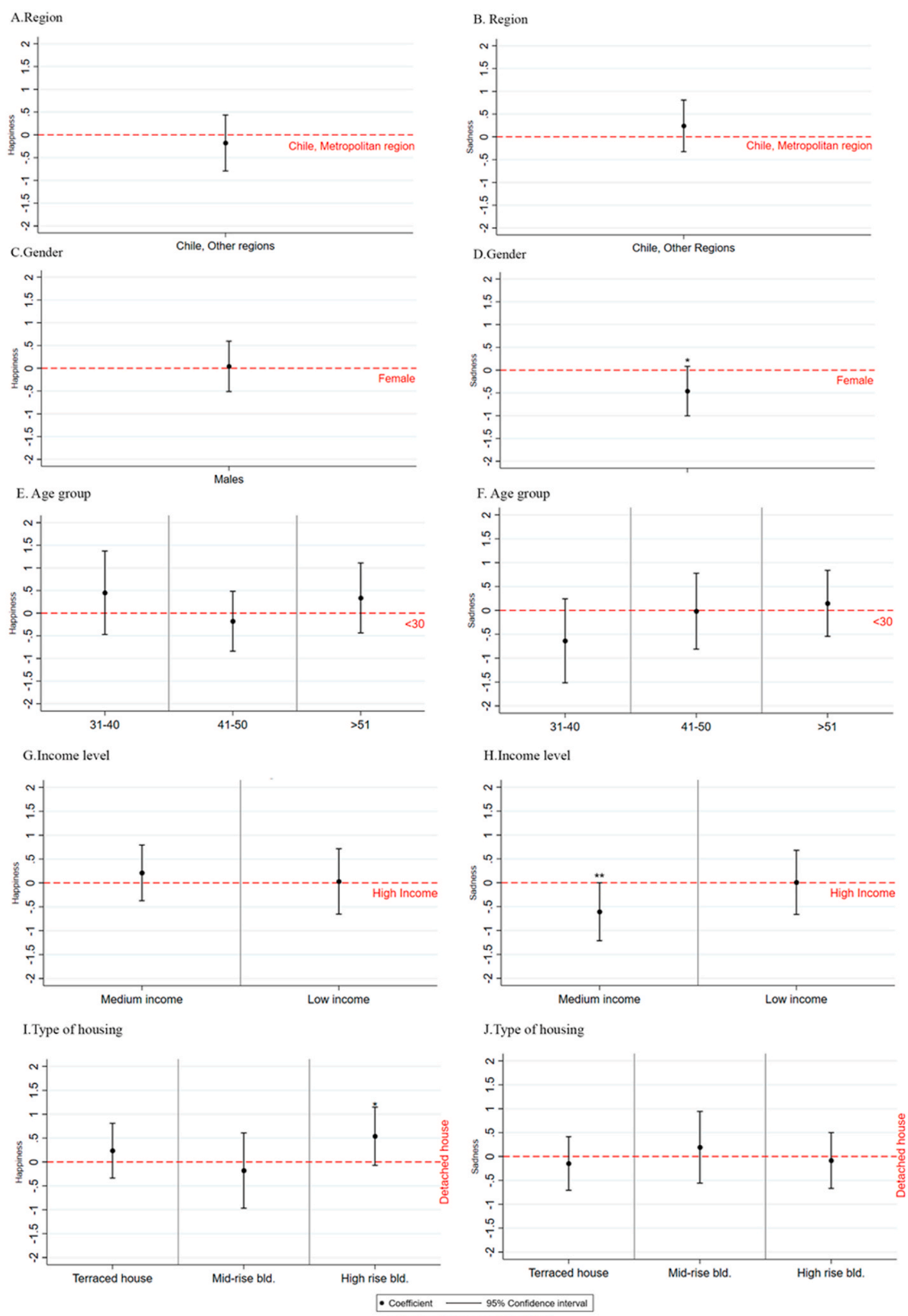


Fig. 2. Perceptions of happiness and sadness by sociodemographic features with equivalent natural lighting conditions.
Note: Using the sample of all ratings of control images (see Fig. 1), Fig. 2 reports OLS regression results of deviation of happiness or sadness perception from a baseline category for different sociodemographic independent variables. In panels A and B, the independent variable is a dummy indicating whether the participant lives in region different from the Santiago 'Metropolitan Region'. In C and D, the independent variable is a dummy indicating whether the participant is a 'man'. In E and F the independent variable is a categorical one indicating the participant's age (4 categories total), where the baseline category is the age range '18–30' years old. In G and H, the independent variable is a categorical one indicating the participant's income (3 categories total), where the baseline category is 'high income'. In I and J the independent variable is a categorical one indicating participant's housing type (4 categories total), where the baseline category is 'detached house'. The dashed red line in each panel indicates the baseline sociodemographic category level. Mixed regression estimates with and without controls can be found in the Appendices in Table A.2.

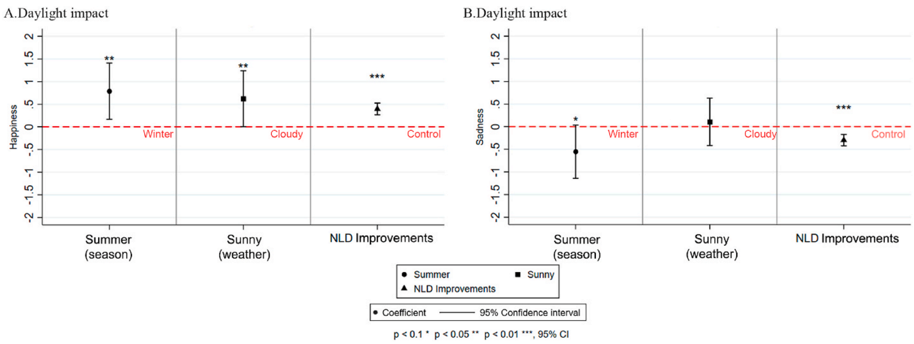


Fig. 3. Daylight impact on perceived happiness and sadness
Note: Using different subsamples for season, weather, and NLD, Fig. 4 reports OLS regression results of deviation of happiness or sadness perception from a baseline category for three natural light factors. For the *Season* factor, the 'Summer' category groups together 'cloudy summer' and 'sunny summer' image responses (see natural light factor A1 in Fig. 1), while the 'Winter' category groups together 'cloudy winter' and 'sunny winter' images. Results are computed by running Eq. (2) on the sample of participants' ratings of *Season* images where the independent variable is a dummy with 'Winter' as the baseline category. To construct the *Weather* factor, the 'Cloudy' category groups together 'cloudy winter' and 'cloudy summer' image responses, while 'Sunny' groups together ratings of 'sunny winter' and 'sunny summer' images. Results are computed by running Eq. (2) on the sample of participants' ratings of *Weather* images where the independent variable is a dummy with 'Cloudy' as the baseline category. The 'NLD improvements' results are computed running Eq. (2) on the sample of participants' ratings of NLD factors (B1 to B4, C1 and C2 in Fig. 1) where the treatment dummy variable is equal to 0 for control images and 1 for all images of the treatment groups 1, 2 and 3 (as in Fig. 1). The dashed red line in each panel indicates the natural light factor baseline category. Mixed regression estimates with and without controls can be found in the Appendices in Table A.3.

improvements against the baseline condition for perceived happiness and sadness. We find that season, weather daylight conditions and NLD improvements have a significant impact on perceived happiness (estimate[*season*] = 0.783, SE = 0.315, p = 0.013; estimate[*weather*] = 0.627, SE = 0.313, p = 0.046; estimate [NLD] = 0.398, SE = 0.066, p < 0.001). However, perceived sadness is only significantly reduced by NLD improvements (estimate = −0.298, SE = 0.064, p < 0.001), with season having a weakly significant impact. For further detail, see Table A.3.

4.3. Do natural lighting interventions have a differentiated sociodemographic impact?

Fig. 4 shows how the previous results vary across differing participant characteristics. For this, we run a separate regression interacting NLD improvements with each sociodemographic condition. NLD improvements have a significant positive impact on perceived happiness for people living in the Santiago Metropolitan Region (estimate = 0.462, SE = 0.070, p < 0.001), but not for those residing in other Chilean regions, with no significant difference among these two categories. For perceived sadness, we find a significant positive impact for residents of both the Metropolitan and other Chilean regions (estimate [Metropolitan region] = -0.339, SE = 0.077, p < 0.001) (estimate [Other regions] = -0.294, SE = 0.112, p = 0.009) with no significant difference between these groups.

Regarding gender, we find a significant increase in perceived happiness for both females and males (estimate [Female] = 0.391, SE = 0.081, p < 0.001) (estimate [Male] = 0.414, SE = 0.117, p < 0.001), while no significant difference exists between genders. Perceived sadness significantly decreases with NLD improvements only for women (estimate = -0.370, SE = 0.082, p < 0.001), showing a significant impact difference between genders (estimate [Gender*NLD] = 0.285, SE = 0.128, p = 0.025).

We also find a significant increase in perceived happiness (estimate [<30] = 0.576, SE = 0.0796, p < 0.001) and decrease in perceived sadness (estimate [<30] = -0.474, SE = 0.0889, p < 0.001) with NLD improvements only for the age group under 30 years. Regarding happiness, a significant difference in the impact of NLD improvements exists between the under-30-year-olds and age groups of 31–40 and over 51 years old (estimate [31–40*NLD] = -0.441, SE = 0.209, p = 0.035; estimate [>51*NLD] = -0.597, SE = 0.204, p = 0.003), while for sadness the under-30 group has a significant impact difference with the 41–50 and 51+ age groups (estimate [41–50*NLD] = 0.557, SE = 0.187, p = 0.003; estimate [51–60*NLD] = 0.365, SE = 0.148, p = 0.013).

For all income levels, NLD improvements significantly increase perceived happiness (estimate [High income] = 0.488, SE = 0.128, p < 0.001) (estimate [Medium income] = 0.343, SE = 0.0907, p < 0.001) (estimate [Low income] = 0.446, SE = 0.142, p = 0.002) with not-significant impact differences among these groups. Perceived sadness is only significantly decreased for the high- and medium-income groups (estimate [High income] = -0.275, SE = 0.135, p = 0.041) (estimate [Medium income] = -0.416, SE = 0.0893, p < 0.001) with no significant impact difference between these groups.

Regarding housing type, we find that NLD improvements significantly increase perceived happiness for those in all types of housing (estimate [Detached] = 0.335, SE = 0.103, p < 0.001; estimate [Terraced] = 0.437, SE = 0.105, p < 0.001; estimate [Mid-rise bld.] = 0.438, SE = 0.241, p = 0.069; estimate [High rise bld.] = 0.572, SE = 0.164, p < 0.001), with no significant difference between these housing typologies. Perceived sadness is only significantly decreased for participants living in detached and terraced housing types (estimate [Detached] = -0.409, SE = 0.0971, p < 0.001) (estimate [Terraced] = -0.291, SE = 0.117, p = 0.013), while no significant impact different exist among categories. For more detail see Tables A.4.1 and A.4.2.

4.4. What types of home lighting improvements are most effective?

Fig. 5 shows the impact of NLD improvements divided into two categories: the amount of natural light entering a room and the reflection and absorption of light in indoor housing spaces. To produce these results, we group NLD improvement images by a binary variable where "amount of light" comprises the responses to images containing four of the NLD factors – distance from neighbouring buildings, orientation of light entry, size of windows, and number of light entry points – while "reflection and absorption of light" contains responses from the two remaining NLD factors – interior wall material, and tone of interior walls. For this analysis, we then run Eq. (2) comparing NLD improvements of these two types against the baseline condition for each category. Fig. 5 indicates that natural light improvements for both amount and reflection/absorption of daylight in indoor spaces significantly increased perceived happiness (estimate [amount] = 0.555, SE = 0.089, p < 0.001; estimate [reflection and absorption] = 0. 263, SE = 0.081, p < 0.001) and reduce participants' perceived sadness in the home (estimate [amount] = -0.396, SE = 0.096, p < 0.001; estimate [reflection and absorption] = -0.169, SE = 0.082, p = −0.041). However, the effect is more pronounced for the amount of daylight than for reflection and absorption. For more details see Table A.5.

4.5. Is there a difference in the impact on different rooms in the home?

Fig. 6 shows the impact of the NLD improvements for four room

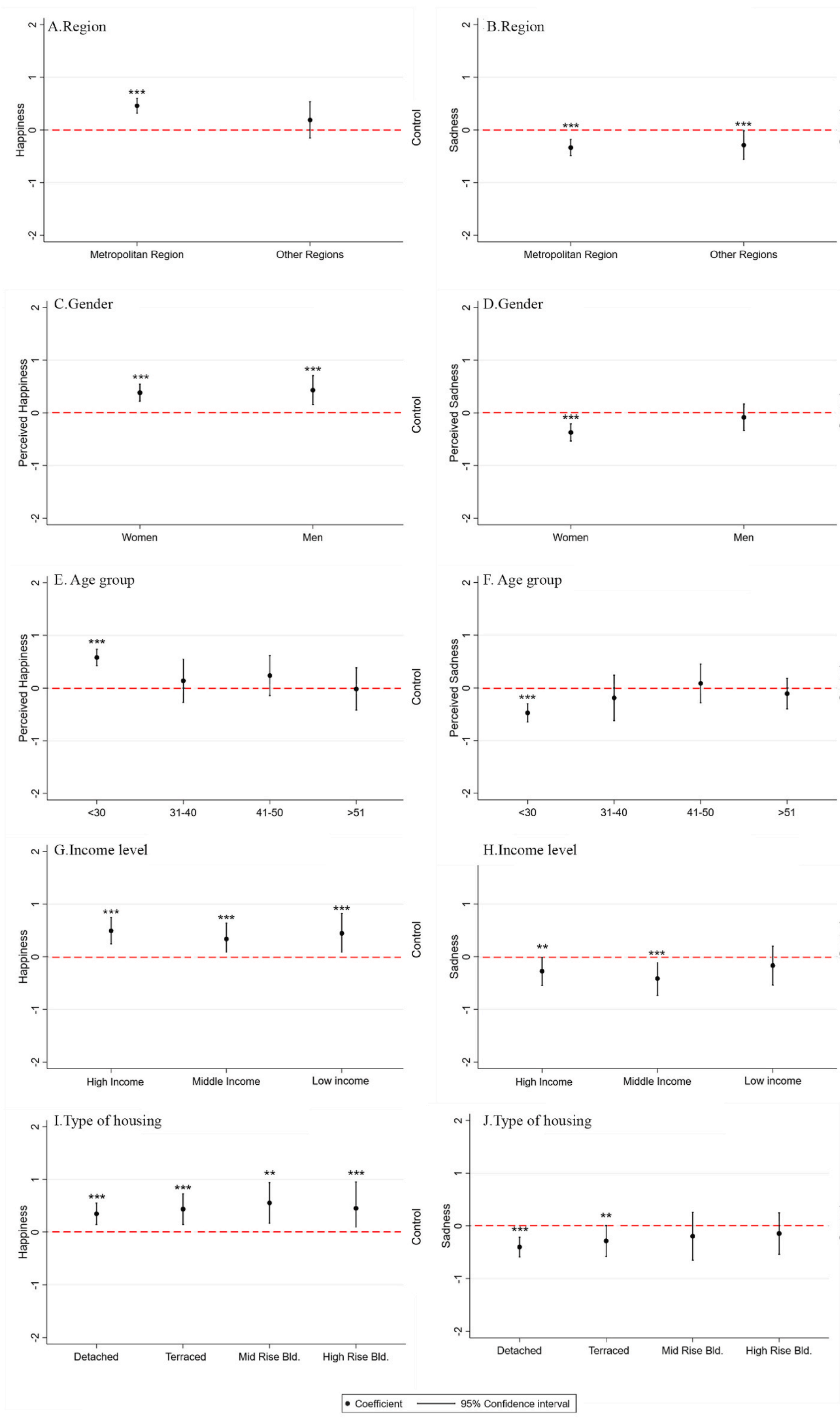


Fig. 4. Impact of natural light design by sociodemographic features.

Note: Using the sample of all participant image ratings, Fig. 4 reports OLS regression results of deviation of happiness or sadness perception on the interaction of a treatment dummy with the corresponding sociodemographic category. For all panels, the treatment dummy variable is equal to 0 for control images and 1 for all images in the treatment groups 1, 2 and 3 (as in Fig. 1). In panels A and B results are computed by running Eq. (2) on the treatment dummy interacted with a participant's region dummy variable, having the 'Santiago Metropolitan Region' as the baseline. In C and D, results are computed by running Eq. (2) on the treatment dummy interacted with a participant's gender dummy variable with 'female' as the baseline category. In E and F, results are computed by running Eq. (2) on the treatment dummy interacted with four participant age categories with '18–30' as the baseline category. In G and H, results are computed by running Eq. (2) on the treatment dummy interacted with three respondent income categories, with 'high income' being the baseline category. In I and J, results are computed by running Eq. (2) on the treatment dummy interacted with the four housing typologies, with the baseline category being a 'detached house'. The dashed red line in each panel indicates the baseline sociodemographic category level. Mixed regression estimates with and without controls can be found in the Appendices in Table A.4.

types: bathroom, kitchen, bedroom and living-dining room. In this specification, we run Eq. (2) comparing for NLD improvements in the amount of light and reflection/absorption against the control condition for each room type. The results indicate that the amount of light has a significant impact on perceived happiness in the kitchen, bedroom and living-dining room (estimate [kitchen] = 0.616, SE = 0.191, $p < 0.001$; estimate [bedroom] = -0.730, SE = 0.197, $p < 0.001$; estimate [living room] = -0.801, SE = 0.200, $p < 0.001$) and on perceived sadness only in the living-dining room (estimate = −0.646, SE = 0.203, p = 0.002). For reflection and absorption of light, we find significant results only for perceived happiness in the bathroom and living-dining room (estimate [bathroom] = -0.414, SE = 0.180, p = 0.022; estimate [living room] = -0.474, SE = 0.182, p = 0.009) but not for perceived sadness. While results in all rooms are significant for at least one of the two tested emotions, the greatest E-SWB impact was seen in the living-dining room. For more details, see Table A6.

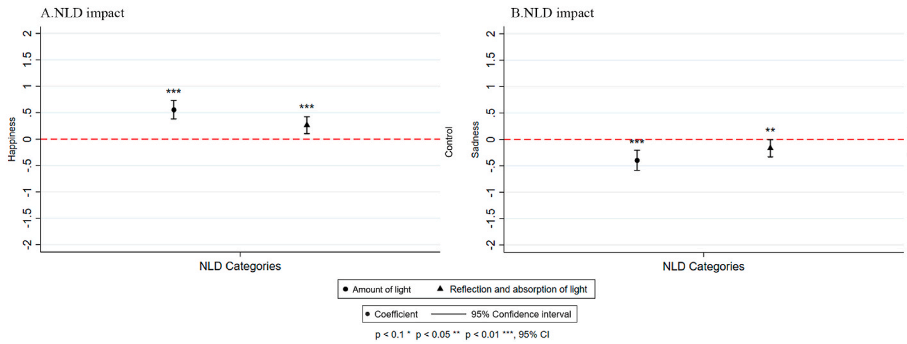


Fig. 5. Impact of natural light design improvements (amount and reflection/absorption).
Note: Fig. 5 reports OLS regression results of deviation of happiness or sadness perception on a treatment dummy indicator for two NLD factors. In all panels, the treatment dummy variable is equal to 0 for all control images and 1 for all images in the treatment groups 1, 2 and 3 (as in Fig. 1). The 'Amount of light' results are computed by running Eq. (2) on the sample of all participants' ratings of images B1 to B4 (as in Fig. 1). The 'Reflection and absorption of light' results are computed by running Eq. (2) on the sample of all participants' ratings of images C1 and C2 (as in Fig. 1). The dashed red line in each panel indicates the control category level. Mixed regression estimates with and without controls can be found in the Appendices in Table A.5.

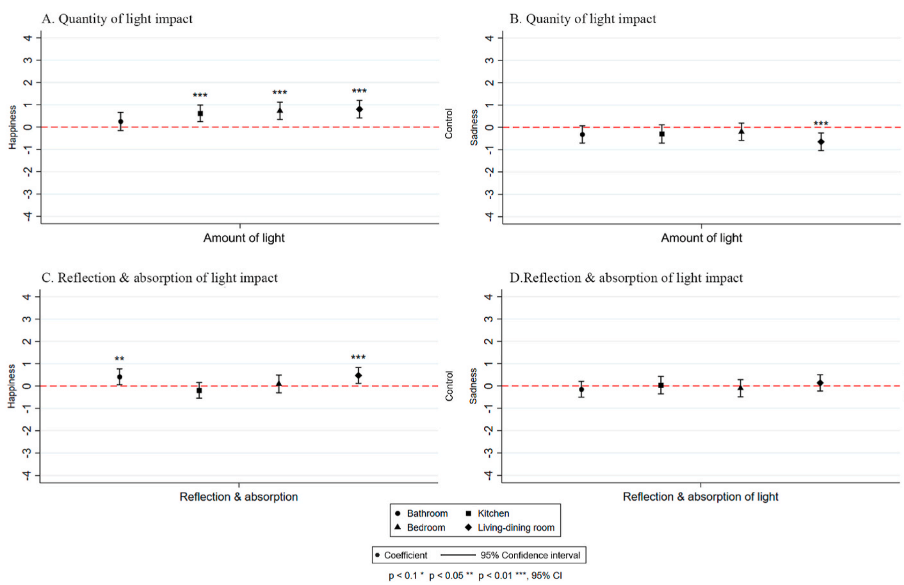


Fig. 6. Impact of natural lighting conditions by room type.
Note: Using different subsamples for the amount of light and the reflection and absorption of light, Fig. 6 reports OLS regression results of deviation of happiness or sadness perception on a treatment dummy indicator. In all panels, the treatment dummy variable is equal to 0 for all control images and 1 for all images in the treatment groups 1, 2 and 3 (as in Fig. 1). Panels A and B are computed by running Eq. (2) on the sample of all participant image ratings in the 'amount of light' category (B1 to B4 in Fig. 1). Panels C and D are computed by running Eq. (2) on the sample of all participant image ratings in the 'reflection and absorption of light' category (C1 to C2 in Fig. 1). In all panels, we run regressions in room type subsamples. Bathroom is represented by a circle; kitchen is represented by a square; bedroom is represented by a triangle; and living-dining room is represented by a diamond. The dashed red line in each panel indicates the control category level in each room type. Mixed regression estimates with and without controls can be found in the Appendices in Table A6.

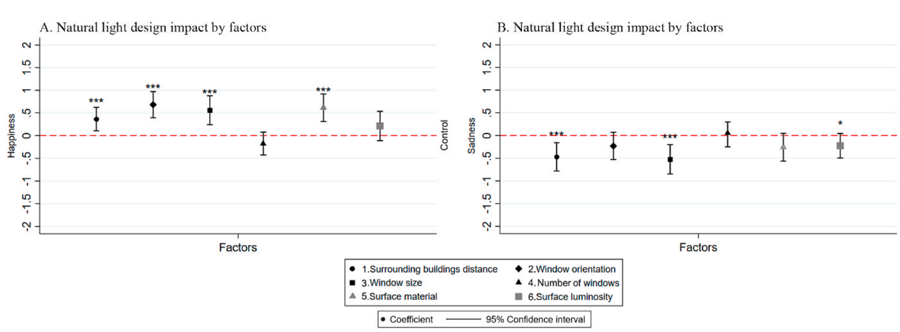


Fig. 7. Impact of six natural light design factors.
Note: Fig. 7 reports OLS regression results of deviation of happiness or sadness perception on a treatment dummy indicator for different NLD subsamples. In all panels, the treatment dummy variable is equal to 0 for all control images and 1 for all images in the treatment groups 1, 2 and 3 (as in Fig. 1). Panels A and B present the results from running Eq. (2) on six different NLD subsamples: (1) 'Surrounding buildings distance' reports OLS regressions results for image ratings of the B1 natural light factor in Fig. 1; (2) 'Window orientation' reports results for the subsample of B2 image ratings; (3) 'Window size' reports results for the subsample of B3 image ratings; (4) 'Number of windows' reports results for the subsample of B4 image ratings; (5) 'Surface material' reports results for the subsample of C1 image ratings; and (6) 'Surface luminosity' report results for the subsample of C2 image ratings. The dashed red line in each panel indicates the control category level. Mixed regression estimates with and without controls can be found in the Appendices in Table A.7.

4.6. *Results for all six NLD factors*

Here, the NLD improvements are once again considered by their original six NLD factors – distance from neighbouring buildings, orientation of light entry, size of windows, number of light entry points, interior wall material, and tone of interior walls – to assess which interventions are more effective to improve measurements of happiness and sadness. For this, we run Eq. (2) comparing NLD improvements against the baseline condition for each of the seven NLD factors. As shown in Fig. 7, there is a significant impact for both perceived happiness and sadness with a greater distance from nearby buildings, (*Surrounding building distance*) (estimate [happiness] = 0.365, SE = 0.131, p = 0.006; estimate [sadness] = -0.470, SE = 0.159, p = 0.003) and with larger window sizes (*Window size*) (estimate [happiness] = 0.559, SE =

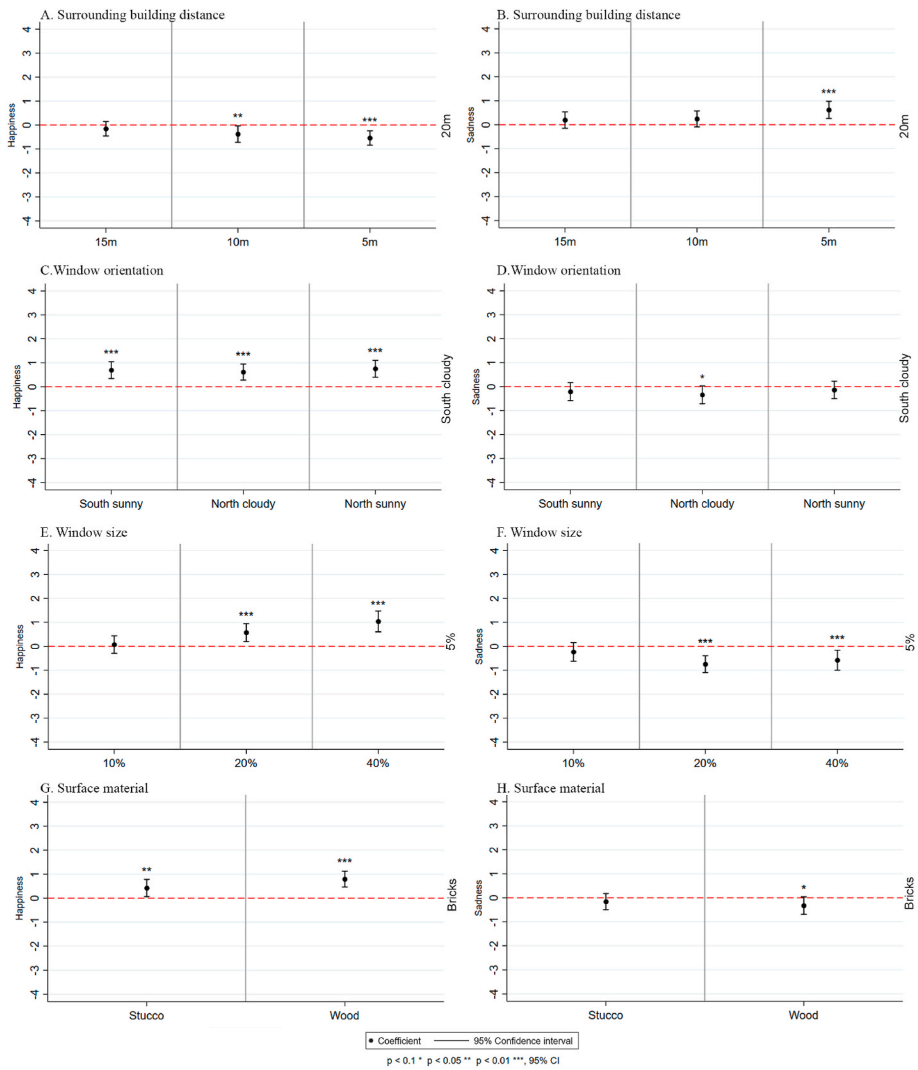


Fig. 8. Impact of different natural light improvement options
Note: Using four different NLD factors subsamples, Fig. 8 reports OLS regression results of deviation of happiness or sadness perception on a treatment categorical variable. In all panels, the treatment categorical variable is equal to 0 for control images, 1 for treatment 1, 2 for treatment 2, and 3 for treatment 3, as shown in Fig. 1. In A and B, the independent variable is a categorical one indicating the distance of surrounding buildings (4 categories total as per B1 in Fig. 1), where the baseline category is '20 m'. In C and D, the independent variable is a categorical one indicating the window orientation (4 categories total as per B2 in Fig. 1), with 'south cloudy' as the baseline category. In E and F, the independent variable is a categorical one indicating the window size as a percentage of the wall (4 categories total as per B3 in Fig. 1), with '5%' as the control category. In G and H, the independent variable is a categorical one indicating the wall surface material (3 categories total as per C1 in Fig. 1), with 'bricks'as the control category. The dashed red line in each panel indicates the baseline category level for each NLD factor. Mixed regression estimates with and without controls can be found in the Appendices in Table A.8.

0.163, $p < 0.001$; estimate [sadness] = -0.523, SE = 0.165, p = 0.002). Improvements related to window orientation (estimate = 0.682, SE = 0.147, $p < 0.001$) and wall material (estimate = 0.613, SE = 0.154 and $p < 0.001$) produce a significant increase in perceived happiness, but no significant decrease in participants' perceived sadness. Surface luminosity has a weakly significant impact on perceived sadness and no significant impact on perceived happiness. The number of windows in a room and the tone of the walls do not significantly impact on participants' perceived happiness or sadness. All results are presented in Table A.7.

4.7. *Defining the most effective levels of natural light improvement*

Next, we analyse how different levels of natural light improvements impact E-SWB for each NLD factor that has been shown to significantly increase perceived happiness and decrease perceived sadness (surrounding building distance, window orientation, window size and surface material). For this, we run Eq. (2) for each significant NLD factor comparing the baseline against different levels of NLD improvements.

Fig. 8 displays the results for each of these four categories. Regarding surrounding building distance, two significant results are found: building at 10 m (estimate = −0.373, SE = 0.175, p = 0.033) and building at 5 m (estimate = −0.536, SE = 0.153, $p < 0.001$) both show a significant reduction in happiness while building at 5 m increase sadness (estimate [5 m] = 0.617, SE = 0.183, $p < 0.001$). In the window orientation category, all orientations have a significant impact on perceived happiness when compared with cloudy south-facing [sunny south-facing] = 0.695, SE = 0.179, $p < 0.001$; estimate [cloudy north-facing] = 0.612, SE = 0.171, $p < 0.001$; estimate [sunny north-facing] = 0.754, SE = 0.179, $p < 0.001$). Perceived sadness remains unchanged regardless of the orientation. In the window size category, incremental significant improvements of perceived happiness and sadness correlate with an increase in the percentage of the wall covered by the window. Results show significant increases of E-SWB from levels of 20% window coverage (estimate [happiness] = 0.569, SE = 0.191, p = 0.003; estimate[sadness] = -0.745, SE = 0.180, $p < 0.001$) to 40% coverage of the wall (estimate[happiness] = 1.035, SE = 0.222, $p < 0.001$; estimate [sadness] = -0.578, SE = 0.213, p = 0.007). Finally, in terms of surface material, wall-finishes of stucco (estimate = 0.420, SE = 0.183, p = 0.021) and wood (estimate = 0.791, SE = 0.170, $p < 0.001$) significantly increase perceived happiness, while none of the tester surface material has a significant impact on sadness, showing that the brick finish is the least favourable of these options for indoor housing spaces in our results. All results are presented in Table A.8 in the appendices.

5. Discussion

This study has sought to examine how natural light affects people's emotions in the home. To this end, we have focused on studying a positive emotion, happiness, and a negative emotion, sadness, by using an experiment based on 3D photo simulations of interior housing spaces under different natural lighting conditions. The results suggest that the daylight conditions of a dwelling have a relevant impact on the emotions of people in their homes. Given our post-pandemic context in which the global population spends a larger share of their time at home, this indicates that NLD factors are a fundamental consideration for improving E-SWB [104]. The study has demonstrated that, regardless of people's sociodemographic conditions, the same levels of happiness and sadness are perceived under the same lighting conditions in the home. While improvements to natural lighting in the home have a positive impact on E-SWB overall, the impacts are felt particularly strongly amongst women and younger populations.

More specifically, the results show that the *amount* of daylight entering a house strongly impacts people's perceived happiness and sadness. These results align with previous studies suggesting that the amount of light entering an interior space can modify or elicit different emotions [105]. In comparison, while improvements in light reflection and absorption within these spaces are also relevant, their impact is less pronounced. When analysing design-independent variables (such as weather) that influence the amount of indoor daylight, we find that people feel happier at home in summer than in winter, even on cloudy summer days. When considering the different rooms in the home, NLD improvements to the living-dining room, kitchen, bathroom and bedroom all presented E-SWB benefits, but these were most pronounced in the living-dining room. This constitutes a new finding regarding the centrality of natural light conditions in this space for enhancing positive and reducing negative emotions in the home.

Regarding specific NLD recommendations, we found that people are happier in a room with a window that faces the equator (i.e. sun-facing), whether on a cloudy or sunny day. Window size is another critical factor; windows covering more than 20% of the wall of a room improved both happiness and sadness indicators, while windows covering more than 40% of the wall produced the largest E-SWB gains of all NLD improvements tested. Similarly, perceived happiness and sadness improve when nearby buildings are more than 10 m away from the dwelling. Regarding the reflection and absorption of daylight in the house, we found that stucco and wood wall-finish surfaces were beneficial to perceived happiness, while brick surfaces were not. When taken together, these findings show the importance of considering NLD factors for enhancing E-SWB in the home. The particularly large gain from maximising window size puts into question the wisdom of the pursuit of energy- and cost-reduction strategies by minimising window sizes, given the potentially negative impact on inhabitants' emotional wellbeing. It is necessary that we find energy-efficient solutions that are able to maximise light gain while minimising energy consumption.

Despite being a causal analysis, this study is not without limitations, and therefore remains room for improvement in future studies. Given that this study was disseminated using social networks across Chile and by QR code within the Santiago Metropolitan Region, the results correspond only to the Chilean population that has ready access to internet networks. For related reasons, the study incorporates a disproportionate number of young adults. Natural light conditions were modelled using the case of Santiago de Chile, and given the variance in natural light conditions, results may differ at other latitudes. For these reasons, and as mentioned before, while the study has strong internal validity, the results cannot be extrapolated to other population groups or other geographical situations. However, future studies can replicate this experiment across a more diverse section of the population and in new geographic contexts to contrast results, incorporating different ethnicities, cultures, gender identities, and age groups. Although there is no immediately evident reason to expect different results, the estimates could of course vary. Potential also exists for future studies to explore how these results change at different latitudes with the changing angle of the sun.

Another limiting factor is the use of photo-simulation technology itself. While this technique of visual representation has been widely used in environmental psychology and allows for the collection of relatively large samples using limited resources, it relies on a person's capacity to imagine themselves in a tridimensional space within a non-immersive environment and from a single viewpoint. However, people's indoor daylight experience may change according to different visual perspectives – for example, while looking around a room, or by moving closer to windows. To overcome this limitation, future studies could use virtual reality technology to allow participants to move around a room and could generate 3D models from different locations within a single room. Furthermore, photo simulation relies only on visual stimuli, and unlike virtual reality technologies is devoid of auditory stimuli, which according to Annerstedt et al. leads to an increase in the strength of perceived emotions [106]. Factors such as a location's smell or temperature equally form part of the built environment, and so they can influence participants' perceptions when interacting with a space visually. 3D modelling techniques were chosen due to their ability to generate the exact same spaces, modifying the natural light conditions precisely by means of computational modelling. The E-SWB effect estimates obtained through this photo-simulation experiment, we argue, can be considered as a conservative estimate, given that studies have shown that immersive videos commonly lead to emotional responses of the same kind, but at stronger intensity, when compared to photo simulations [107]. Since this study has obtained significant results using a mild visual stimulus, it is expected that this impact may very well increase by using more immersive technologies.

6. Conclusion

This study explores subjective emotional wellbeing in housing under different natural light conditions. In doing so, it contributes with causal evidence to the existing literature on the relationship between natural light, subjective emotional wellbeing, and indoor residential spaces. At the same time, it identifies natural lighting design variables relevant for maximising the E-SWB of people at home. Moreover, it presents a flexible methodological tool that can allow built environment researchers and practitioners to identify the most effective natural lighting housing design and design regulations that aim to improve inhabitants' emotional subjective wellbeing. This is particularly important in a post-pandemic word, as the global population spends a larger share of its time living, working and studying at home.

As the urbanisation of the planet progresses and housing density and building heights increase, we will likely see an overall decrease in the access of both direct and indirect natural light to indoor residential spaces. This study suggests that this trend may lead to potentially harmful effects on E-SWB. This finding on emotional wellbeing complements previous studies that warn of the detrimental impacts of narrow spaces between adjacent buildings and increased urban density on the cognitive dimension of subjective wellbeing at the home – that is to say, inhabitants' life satisfaction [108–110]. At the same time, housing policies and designs that aim to decrease the size of windows to increase thermal comfort should factor in the potentially damaging impact on inhabitants' E-SWB and psychological health. Furthermore, the results show that it is important for residential buildings to incorporate windows oriented towards the equator as much as possible, so as to maximise emotional wellbeing. Ultimately, the study suggests that preserving, and hopefully improving, natural light conditions in housing should be a fundamental concern of built environment planning, with the aim of improving people's emotional subjective wellbeing in a world where we spend more time at home than ever before.

CRediT authorship contribution statement

Javiera Morales-Bravo: Writing – review & editing, Writing – original draft, Visualization, Investigation, Formal analysis, Data curation, Conceptualization. **Pablo Navarrete-Hernandez:** Writing – review & editing, Validation, Supervision, Methodology, Investigation,

Funding acquisition, Formal analysis, Conceptualization, Software.

Declaration of competing interest

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

Data availability

The authors do not have permission to share data.

Appendix

Table A.1
Descriptive statistics

Composition of socio demographic and socio economic of the sample (N = 12.593)			
Characteristic		n*	%
	(1)	(2)	(3)
Place of residence	Chile Metropolitan area	9.504	75.47
	Chile (other regions)	2.914	23.14
	Other countries	175	1.39
Gender	Female	8.574	68.09
	Male	3.764	29.89
	Other	255	2.02
Age	<30	7.436	59.05
	31–40	1.434	11.39
	41–50	1.675	13.30
	51–60	1.694	13.45
	>60	354	2.81
Income level	Low income	2.793	22.18
	Medium income	6.577	52.23
	High income	3.048	24.20
	Prefer not to say	175	1.39
Type of housing	Isolated house	4.839	38.43
	Paired house	4.058	32.22
	Mid-rise building (<7 floors)	1.624	12.90
	High rise building (>7 floors)	1.529	12.14
	Other	543	4.31

Table A.2
Perceptions of happiness and sadness for sociodemographic features at equal home natural lighting conditions.

2.Sociodemographic features in control situation									
A.Procedence					B.Gender				
VARIABLES	Happiness		Sadness		VARIABLES	Happiness		Sadness	
	(1)	(2)	(3)	(4)		(1)	(2)	(3)	(4)
Chile, other regions	−0.271	−0.177	0.183	0.242	Male	−0.0199	0.0419	−0.424*	−0.460*
	(0.276)	(0.313)	(0.275)	(0.289)		(0.262)	(0.282)	(0.250)	(0.277)
Constant (Chile, Metropolitan region)	5.124***	5.869***	4.519***	5.443***	Constant (Female)	5.051***	5.869***	4.703***	5.443***
	(0.127)	(0.589)	(0.136)	(0.622)		(0.134)	(0.589)	(0.143)	(0.622)
Controls	No	Yes	No	Yes	Controls	No	Yes	No	Yes
Observations	1699	1699	1768	1768	Observations	1699	1699	1768	1768
Number of groups	253	253	262	262	Number of groups	253	253	262	262
C.Age group					***D.Income***				
VARIABLES	Happiness		Sadness		VARIABLES	Happiness		Sadness	
	(1)	(2)	(3)	(4)		(1)	(2)	(3)	(4)
31–40	−0.0889	0.450	−0.240	−0.637	Medium income	0.111	0.210	−0.421	−0.607**

(*continued on next page*)

Table A.2 (*continued*)

2.Sociodemographic features in control situation

A.Procedence					B.Gender				
VARIABLES	Happiness		Sadness		VARIABLES	Happiness		Sadness	
	(0.350)	(0.471)	(0.406)	(0.449)		(0.267)	(0.297)	(0.276)	(0.310)
41–50	−0.667*	−0.178	0.0973	−0.0163	Low income	−0.351	0.0309	−0.0425	0.00794
	(0.347)	(0.338)	(0.357)	(0.406)		(0.315)	(0.349)	(0.321)	(0.343)
>51	−0.174	0.336	0.208	0.147					
	(0.334)	(0.394)	(0.330)	(0.353)					
Constant (<30)	5.186***	5.869***	4.540***	5.443***	Constant (High Income)	5.079***	5.869***	4.793***	5.443***
	(0.143)	(0.589)	(0.144)	(0.622)		(0.215)	(0.589)	(0.217)	(0.622)
Controls	No	Yes	No	Yes	Controls	No	Yes	No	Yes
Observations	1699	1699	1768	1768	Observations	1699	1699	1768	1768
Number of groups	253	253	262	262	Number of groups	253	253	262	262

E.Type of housing				
VARIABLES	Happiness		Sadness	
	(1)	(2)	(3)	(4)
Paired house	0.371	0.237	−0.0771	−0.146
	(0.284)	(0.293)	(0.276)	(0.286)
Mid rise building	0.107	−0.179	0.263	0.193
	(0.332)	(0.402)	(0.388)	(0.383)
High rise building	0.719**	0.539*	0.307	−0.0834
	(0.312)	(0.311)	(0.293)	(0.298)
Constant (Isolated house)	4.867***	5.869***	4.450***	5.443***
	(0.186)	(0.589)	(0.198)	(0.622)
Controls	No	Yes	No	Yes
Observations	1699	1699	1768	1768
Number of groups	253	253	262	262

Robust standard errors in parentheses: ***p < 0.01, **p < 0.05, *p < 0.1.
Observations: total numbers of spaces images rated.
Number of groups: number of single individuals that undertook the survey.

Table A.3
Daylight impact on perceived happiness and sadness.

3.Daylight impact

A.	Seasonal lighting conditions				B.	Weather lighting conditions			
VARIABLES	Happiness		Sadness		VARIABLES	Happiness		Sadness	
	(1)	(2)	(3)	(4)		(5)	(6)	(7)	(8)
Summer	0.758***	0.783**	−0.436	−0.538*	Sunny	0.549*	0.627**	0.0565	0.108
	(0.283)	(0.315)	(0.289)	(0.295)		(0.300)	(0.313)	(0.281)	(0.268)
Constant (Winter)	3.662***	5.341***	4.724***	6.622***	Constant (Cloudy)	4.037***	5.772***	4.482***	6.466***
	(1.029)	(1.245)	(1.162)	(1.666)		(1.064)	(1.226)	(1.126)	(1.656)
Controls	No	Yes	No	Yes	Controls	No	Yes	No	Yes
Observations	199	199	227	227	Observations	199	199	227	227
Number of groups	146	146	158	158	Number of groups	146	146	158	158

C.	***Natural lighting design conditions***			
VARIABLES	Happiness		Sadness	
	(9)	(10)	(11)	(12)
NLD improvements	0.398***	0.398***	−0.300***	−0.298***
	(0.0661)	(0.0663)	(0.0645)	(0.0646)
Constant (Control)	4.045***	4.845***	5.045***	5.873***
	(0.159)	(0.546)	(0.178)	(0.486)
Controls	No	Yes	No	Yes
Observations	5321	5321	5483	5483
Number of groups	254	254	268	268

Table A.4.1
Impact of natural light design for sociodemographic features.

A.Procedence

	Happiness				Sadness			
VARIABLES	Metropolitan		Other regions		Metropolitan		Other regions	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
NLD Improvements	0.463***	0.462***	0.192	0.188	−0.340***	−0.339***	−0.296***	−0.294***
	(0.0706)	(0.070)	(0.159)	(0.158)	(0.0777)	(0.0778)	(0.113)	(0.112)
Constant (Control)	4.621***	4.185***	4.689***	5.628***	4.930***	5.073	4.917***	6.223
	(0.126)	(0.306)	(0.258)	(0.000)	(0.137)	(0.364)	(0.228)	(0.828)
Controls	No	Yes	No	Yes	No	Yes	No	Yes
Observations	4108	4108	1213	1213	4047	4047	1287	1287
Number of groups	197	197	57	57	198	198	63	63

B.Gender

	Happiness				Sadness			
VARIABLES	Female		Male		Female		Male	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
NLD Improvements	0.392***	0.391***	0.416***	0.414***	−0.371***	−0.370***	−0.102	−0.099
	(0.0811)	(0.0811)	(0.117)	(0.117)	(0.0830)	(0.082)	(0.0973)	(0.097)
Constant (Control)	4.606***	4.128***	4.654***	5.001***	5.103***	5.228	4.445***	3.741***
	(0.136)	(0.000)	(0.217)	(0.000)	(0.143)	(0.327)	(0.199)	(0.535)
Controls	No	Yes	No	Yes	No	Yes	No	Yes
Observations	3701	3701	1491	1491	3665	3665	1729	1729
Number of groups	175	175	73	73	179	179	84	84

C.Age group

	Happiness							
VARIABLES	<30		31–40		41–50		>51	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
NLD Improvements	0.576***	0.576***	0.159	0.155	0.250	0.249	−0.0139	−0.025
	(0.0796)	(0.000)	(0.198)	(0.430)	(0.173)	(0.148)	(0.156)	(0.186)
Constant (Control)	4.637***	4.111***	4.835***	4.073***	4.187***	3.758***	4.867***	5.868***
	(0.140)	(0.000)	(0.332)	(0.000)	(0.339)	(0.000)	(0.351)	(0.000)
Controls	No	Yes	No	Yes	No	Yes	No	Yes
Observations	3243	3243	668	668	727	727	556	556
Number of groups	156	156	32	32	34	34	26	26

	Sadness							
VARIABLES	<30		31–40		41–50		51–60	
	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
NLD Improvements	−0.478***	−0.474***	−0.181	−0.183	0.0742	0.0739	−0.120	−0.120
	(0.0889)	(0.0888)	(0.201)	(0.201)	(0.166)	(0.166)	(0.119)	(0.119)
Constant (Control)	5.079***	5.013***	4.428***	5.843***	4.657***	4.064***	4.841***	4.270***
	(0.147)	(0.376)	(0.397)	(0.787)	(0.320)	(0.690)	(0.283)	(0.642)
Controls	No	Yes	No	Yes	No	Yes	No	Yes
Observations	3136	3136	556	556	718	718	1073	1073
Number of groups	155	155	27	27	35	35	51	51

D.Income

	Happiness					
VARIABLES	High income		Medium income		Low income	
	(1)	(2)	(3)	(4)	(5)	(6)
NLD Improvements	0.488***	0.488***	0.343***	0.343***	0.444***	0.446***
	(0.128)	(0.128)	(0.0907)	(0.0907)	(0.142)	(0.142)
Constant (Control)	4.406***	3.700***	4.857***	5.090***	4.354***	4.360***
	(0.224)	(0.426)	(0.156)	(0.298)	(0.238)	(0.464)
Controls	No	Yes	No	Yes	No	Yes
Observations	1289	1289	2876	2876	1156	1156
Number of groups	62	62	136	136	56	56

	Sadness					
VARIABLES	High income		Medium income		Low income	
	(7)	(8)	(9)	(10)	(11)	(12)
NLD Improvements	−0.278**	−0.275**	−0.417***	−0.416***	−0.183	−0.193
	(0.135)	(0.135)	(0.0893)	(0.0893)	(0.131)	(0.131)
Constant (Control)	5.089***	4.512***	4.825***	5.005***	4.995***	5.426***

(*continued on next page*)

Table A.4.1 (*continued*)

D.Income

	Happiness					
VARIABLES	High income		Medium income		Low income	
	(0.214)	(0.383)	(0.171)	(0.322)	(0.244)	(0.460)
Controls	No	Yes	No	Yes	No	Yes
Observations	1322	1322	2777	2777	1235	1235
Number of groups	63	63	139	139	59	59

E.Type of housing

	Happiness							
VARIABLES	Detached		Terraced		Mid-rise bld.		High rise bld.	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
NLD Improvements	0.335***	0.335***	0.440***	0.437***	0.440*	0.438**	0.574***	0.572***
	(0.104)	(0.103)	(0.105)	(0.105)	(0.240)	(0.241)	(0.166)	(0.164)
Constant (Control)	4.544***	4.125***	4.892***	5.260***	4.372***	4.321***	4.684***	4.452***
	(0.186)	(0.424)	(0.205)	(0.716)	(0.314)	(0.498)	(0.303)	(0.378)
Controls	No	Yes	No	Yes	No	Yes	No	Yes
Observations	2185	2185	1581	1581	597	597	663	663
Number of groups	104	104	75	75	29	29	32	32

	Sadness							
VARIABLES	Detached		Terraced		Mid-rise bld.		High rise bld.	
	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
NLD Improvements	−0.409***	−0.409***	−0.291**	−0.291**	−0.185	−0.182	−0.162	−0.162
	(0.0971)	(0.0971)	(0.118)	(0.117)	(0.208)	(0.209)	(0.175)	(0.175)
Constant (Control)	4.848***	4.995***	4.745***	6.180***	5.150***	5.379***	4.852***	4.216***
	(0.201)	(0.441)	(0.193)	(0.525)	(0.250)	(0.386)	(0.346)	(0.560)
Controls	No	Yes	No	Yes	No	Yes	No	Yes
Observations	1975	1975	1889	1889	655	655	797	797
Number of groups	97	97	93	93	32	32	38	38

Robust standard errors in parentheses: ***p < 0.01, **p < 0.05, *p < 0.1.
Observations: total numbers of spaces images rated.
Number of groups: number of single individuals that undertook the survey.

Table A.4.2
Impact of natural light design for sociodemographic features (interactions)

4.B Sociodemographic features under Natural light design improvements interactions

A.Procedence					B.Gender				
VARIABLES	Happiness		Sadness		VARIABLES	Happiness		Sadness	
	(1)	(2)	(3)	(4)		(1)	(2)	(3)	(4)
NLD Improvements	0.463***	0.460***	−0.340***	−0.335***	NLD Improvements	0.392***	0.382***	−0.371***	−0.371***
	(0.0706)	(0.0711)	(0.0777)	(0.0777)		(0.0810)	(0.0816)	(0.0829)	(0.0823)
Chile, other regions	0.0679	0.0209	−0.0141	0.106	Male	0.0479	−0.0557	−0.659***	−0.761***
	(0.285)	(0.335)	(0.265)	(0.279)		(0.255)	(0.275)	(0.244)	(0.273)
NLD Improvements x Chile, Other regions	−0.271	−0.270	0.0449	0.0470	NLD Improvements x Male	0.0244	0.0478	0.270**	0.285**
	(0.173)	(0.175)	(0.136)	(0.137)		(0.142)	(0.141)	(0.128)	(0.128)
Constant (Chile, Metropolitan region)	4.621***	4.804***	4.931***	5.898***	Constant (Female)	4.606***	4.854***	5.103***	5.918***
	(0.126)	(0.549)	(0.137)	(0.487)		(0.136)	(0.551)	(0.143)	(0.486)
Controls	No	Yes	No	Yes	Controls	No	Yes	No	Yes
Observations	5321	5321	5483	5483	Observations	5321	5321	5483	5483
Number of groups	254	254	268	268	Number of groups	254	254	268	268

C.Age group					***D.Income***				
VARIABLES	Happiness		Sadness		VARIABLES	Happiness		Sadness	
	(1)	(2)	(3)	(4)		(1)	(2)	(3)	(4)
NLD Improvements	0.576***	0.579***	−0.478***	−0.472***	NLD Improvements	0.488***	0.493***	−0.278**	−0.276**
	(0.0795)	(0.0799)	(0.0887)	(0.0883)		(0.127)	(0.127)	(0.134)	(0.136)
31–40	0.198	0.732*	−0.656	−0.920**	Medium income	0.451*	0.415	−0.265	−0.442

(*continued on next page*)

Table A.4.2 (*continued*)

4.B Sociodemographic features under Natural light design improvements interactions

A.Procedence					B.Gender				
VARIABLES	Happiness		Sadness		VARIABLES	Happiness		Sadness	
	(0.356)	(0.437)	(0.418)	(0.459)		(0.272)	(0.337)	(0.272)	(0.290)
41–50	−0.452	0.0447	−0.423	−0.489	Low income	−0.0511	0.184	−0.0932	−0.0532
	(0.363)	(0.375)	(0.349)	(0.392)		(0.325)	(0.366)	(0.322)	(0.334)
51–60	0.239	0.760*	−0.241	−0.224	NLD Improvements x Medium income	−0.146	−0.156	−0.139	−0.138
	(0.348)	(0.416)	(0.317)	(0.324)		(0.156)	(0.156)	(0.161)	(0.163)
					NLD Improvements x Low income	−0.0435	−0.0492	0.0926	0.107
						(0.190)	(0.192)	(0.187)	(0.188)
NLD Improvements x 31-40	−0.417**	−0.441**	0.299	0.283					
	(0.210)	(0.209)	(0.217)	(0.220)					
NLD Improvements x 41-50	−0.323*	−0.342*	0.554***	0.557***					
	(0.189)	(0.193)	(0.186)	(0.187)					
NLD Improvements x 51-60	−0.589***	−0.597***	0.360**	0.365**					
	(0.201)	(0.204)	(0.148)	(0.148)					
	4.638***	4.686***	5.079***	6.004***					
Constant (<30)	4.638***	4.686***	5.079***	6.004***	Constant (High Income)	4.406***	4.784***	5.089***	5.857***
	(0.139)	(0.516)	(0.147)	(0.489)		(0.223)	(0.551)	(0.213)	(0.488)
Controls	No	Yes	No	Yes	Controls	No	Yes	No	Yes
Observations	5321	5321	5483	5483	Observations	5321	5321	5483	5483
Number of groups	254	254	268	268	Number of groups	254	254	268	268

E.Type of housing

VARIABLES	Happiness		Sadness	
	(1)	(2)	(3)	(4)
NLD Improvements	0.335***	0.346***	−0.409***	−0.402***
	(0.103)	(0.104)	(0.0969)	(0.0963)
Paired house	0.349	0.245	−0.101	−0.267
	(0.276)	(0.300)	(0.278)	(0.270)
Mid rise building	0.139	0.162	0.307	−0.127
	(0.352)	(0.363)	(0.316)	(0.298)
High rise building	−0.174	−0.344	0.00164	−0.0436
	(0.360)	(0.443)	(0.397)	(0.381)
NLD Improvements x Pired house	0.105	0.0892	0.117	0.116
	(0.147)	(0.148)	(0.152)	(0.150)
NLD Improvements x Mid rise building	0.238	0.206	0.216	0.206
	(0.194)	(0.196)	(0.228)	(0.231)
NLD Improvements x High rise building	0.108	0.104	0.254	0.255
	(0.258)	(0.255)	(0.198)	(0.200)
Constant (Isolated house)	4.543***	4.880***	4.846***	5.943***
	(0.186)	(0.550)	(0.201)	(0.486)
Controls	No	Yes	No	Yes
Observations	5321	5321	5483	5483
Number of groups	254	254	268	268

Robust standard errors in parentheses: ***p < 0.01, **p < 0.05, *p < 0.1.
Observations: total numbers of spaces images rated.
Number of groups: number of single individuals that undertook the survey.

Table A.5
Impact natural light design improvements (amount vs reflection and absorption of light)

5.Natural light design improvements

	Amount of light				***Reflection and absorption of light***			
VARIABLES	Happiness		Sadness		Happiness		Sadness	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
NLD Improvements	0.553***	0.555***	−0.401***	−0.396***	0.263***	0.263***	−0.176**	−0.169**
	(0.0890)	(0.0894)	(0.0970)	(0.0969)	(0.0817)	(0.0817)	(0.0825)	(0.0827)
Constant	3.835***	4.654***	5.087***	5.672***	4.215***	5.037***	4.982***	6.152***
	(0.212)	(0.547)	(0.228)	(0.534)	(0.214)	(0.603)	(0.250)	(0.558)

(*continued on next page*)

Table A.5 (*continued*)

5.Natural light design improvements								
	Amount of light				***Reflection and absorption of light***			
VARIABLES	Happiness		Sadness		Happiness		Sadness	
Controls	No	Yes	No	Yes	No	Yes	No	Yes
Observations	2638	2638	2728	2728	2683	2683	2755	2755
Number of groups	254	254	266	266	254	254	266	266

Robust standard errors in parentheses: ***$p < 0.01$, **$p < 0.05$, *$p < 0.1$.
Observations: total numbers of spaces images rated.
Number of groups: number of single individuals that undertook the survey.

Table 6.A
Impact of natural lighting conditions by room type

6.Natural light design improvements by room								
A.	Amount of light							
VARIABLES	Happiness							
	Bathroom		Kitchen		Bedroom		Living room	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
NLD Improvements	0.370*	0.253	0.493**	0.616***	0.791***	0.730***	0.797***	0.801***
	(0.213)	(0.209)	(0.194)	(0.191)	(0.196)	(0.197)	(0.200)	(0.200)
Constant	4.681***	5.358***	3.276***	3.807***	3.342***	4.686***	2.699***	3.445***
	(0.554)	(0.726)	(0.376)	(0.555)	(0.359)	(0.594)	(0.369)	(0.560)
Controls	No	Yes	No	Yes	No	Yes	No	Yes
Observations	656	656	654	654	653	653	675	675

B.	***Amount of light***							
VARIABLES	Sadness							
	Bathroom		Kitchen		Bedroom		Living room	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
NLD Improvements	−0.456**	−0.316	−0.377*	−0.294	−0.143	−0.199	−0.689***	−0.646***
	(0.205)	(0.198)	(0.221)	(0.209)	(0.205)	(0.197)	(0.215)	(0.203)
Constant	4.630***	5.553***	5.068***	5.849***	5.776***	6.284***	5.327***	5.909***
	(0.382)	(0.649)	(0.470)	(0.678)	(0.520)	(0.680)	(0.451)	(0.697)
Controls	No	Yes	No	Yes	No	Yes	No	Yes
Observations	695	695	676	676	671	671	686	686

C.	***Reflection & absorption of light***							
VARIABLES	Happiness							
	Bathroom		Kitchen		Bedroom		Living room	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
NLD Improvements	0.547***	0.414**	−0.129	−0.195	0.0776	0.0923	0.356*	0.474***
	(0.184)	(0.180)	(0.192)	(0.181)	(0.214)	(0.202)	(0.182)	(0.182)
Constant	4.931***	5.590***	3.822***	5.287***	5.030***	6.056***	4.622***	5.031***
	(0.446)	(0.669)	(0.412)	(0.610)	(0.508)	(0.700)	(0.418)	(0.666)
Controls	No	Yes	No	Yes	No	Yes	No	Yes
Observations	666	666	662	662	678	678	677	677

D.	***Reflection & absorption of light***							
VARIABLES	Sadness							
	Bathroom		Kitchen		Bedroom		Living room	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
NLD Improvements	−0.192	−0.150	−0.192	−0.150	−0.170	−0.102	0.145	0.138
	(0.191)	(0.180)	(0.191)	(0.180)	(0.205)	(0.197)	(0.201)	(0.186)
Constant	4.736***	6.560***	4.736***	6.560***	5.680***	6.630***	4.820***	5.466***
	(0.516)	(0.704)	(0.516)	(0.704)	(0.465)	(0.670)	(0.528)	(0.697)
Controls	No	Yes	No	Yes	No	Yes	No	Yes
Observations	698	698	698	698	691	691	692	692

Robust standard errors in parentheses: ***p < 0.01, **p < 0.05, *p < 0.1.
Observations: total numbers of spaces images rated.
Number of groups: number of single individuals that undertook the survey.

Table A.7
Impact of six natural light design factors.

7.Natural light design factors												
A.	All categories											
	Happiness											
VARIABLES	Building distance		Window orientation		Window size		Surface material		Quantity of windows		Surface luminosity	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
NLD Factors	0.352***	0.365***	0.690***	0.682***	0.546***	0.559***	0.607***	0.613***	−0.169	−0.175	0.210	0.212
	(0.130)	(0.131)	(0.145)	(0.147)	(0.159)	(0.163)	(0.154)	(0.154)	(0.128)	(0.128)	(0.164)	(0.165)
Constant	3.537***	4.476***	3.357***	4.140***	4.448***	4.941***	4.271***	4.936***	4.304***	5.253***	4.348***	5.403***
	(0.314)	(0.660)	(0.339)	(0.652)	(0.342)	(0.669)	(0.368)	(0.680)	(0.384)	(0.709)	(0.367)	(0.778)
Controls	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes
Observations	886	886	874	874	878	878	906	906	886	886	891	891
Number of groups	252	252	252	252	252	252	253	253	251	251	251	251

B.	***All categories***											
	Sadness											
VARIABLES	Building distance		Window orientation		Window size		Surface material		Quantity of windows		Surface luminosity	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
NLD Factors	−0.462***	−0.470***	−0.288*	−0.230	−0.527***	−0.523***	−0.279*	−0.249	0.0119	0.0347	−0.249*	−0.225*
	(0.161)	(0.159)	(0.153)	(0.153)	(0.164)	(0.165)	(0.158)	(0.156)	(0.141)	(0.139)	(0.137)	(0.137)
Constant	4.983***	6.009***	5.455***	6.430***	5.039***	5.350***	4.443***	5.480***	5.662***	6.162***	5.155***	7.010***
	(0.445)	(0.707)	(0.326)	(0.664)	(0.424)	(0.736)	(0.488)	(0.757)	(0.352)	(0.693)	(0.417)	(0.713)
Controls	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes
Observations	915	915	910	910	903	903	926	926	909	909	920	920
Number of groups	263	263	261	261	262	262	261	261	260	260	264	264

Robust standard errors in parentheses: ***p < 0.01, **p < 0.05, *p < 0.1.
Observations: total numbers of spaces images rated.
Number of groups: number of single individuals that undertook the survey.

Table A.8
Impact of different natural light improvements options

8.Natural light design factors by dosage									
A.	Building distance				B.	Window orientation			
VARIABLES	Happiness		Sadness		VARIABLES	Happiness		Sadness	
	(1)	(2)	(3)	(4)		(1)	(2)	(3)	(4)
15 m	−0.163	−0.152	0.192	0.200	South sunny	0.720***	0.695***	−0.244	−0.211
	(0.154)	(0.155)	(0.174)	(0.175)		(0.179)	(0.179)	(0.194)	(0.193)
10 m	−0.402**	−0.373**	0.257	0.245	North cloudy	0.623***	0.612***	−0.440**	−0.342*
	(0.175)	(0.175)	(0.170)	(0.169)		(0.170)	(0.171)	(0.189)	(0.190)
5 m	−0.537***	−0.536***	0.615***	0.617***	North sunny	0.738***	0.754***	−0.175	−0.138
	(0.152)	(0.153)	(0.185)	(0.183)		(0.176)	(0.179)	(0.186)	(0.184)
Constant (20 m)	4.080***	4.985***	4.362***	5.419***	Constant (South cloudy)	3.356***	4.147***	5.454***	6.429***
	(0.316)	(0.652)	(0.424)	(0.684)		(0.338)	(0.651)	(0.324)	(0.666)
Controls	No	Yes	No	Yes	Controls	No	Yes	No	Yes
Observations	886	886	915	915	Observations	874	874	910	910
Number of groups	252	252	263	263	Number of groups	252	252	261	261

C.	***Window size***				***D.***	***Surface material***			
VARIABLES	Happiness		Sadness		VARIABLES	Happiness		Sadness	
	−1	−2	−3	−4		−1	−2	−3	−4
10% window	0.0633	0.0694	−0.235	−0.233	Stucco	0.420**	0.420**	−0.178	−0.163
	(0.185)	(0.186)	(0.195)	(0.199)		(0.182)	(0.183)	(0.175)	(0.173)

(*continued on next page*)

Table A.8 (*continued*)

8.Natural light design factors by dosage

A.	Building distance				B.	Window orientation			
VARIABLES	Happiness		Sadness		VARIABLES	Happiness		Sadness	
20% window	0.549***	0.569***	−0.762***	−0.745***	Wood	0.778***	0.791***	−0.372**	−0.329*
	(0.188)	(0.191)	(0.182)	(0.180)		(0.169)	(0.170)	(0.186)	(0.186)
40% window	1.017***	1.035***	−0.577***	−0.578***					
	(0.217)	(0.222)	(0.214)	(0.213)					
Constant (5% window)	4.445***	4.882***	5.009***	5.358***	Constant (Bricks)	4.265***	4.961***	4.440***	5.490***
	(0.340)	(0.671)	(0.425)	(0.734)		(0.370)	(0.683)	(0.487)	(0.761)
Controls	No	Yes	No	Yes	Controls	No	Yes	No	Yes
Observations	878	878	903	903	Observations	906	906	926	926
Number of groups	252	252	262	262	Number of groups	253	253	261	261

Robust standard errors in parentheses: ***p < 0.01, **p < 0.05, *p < 0.1.
Observations: total numbers of spaces images rated.
Number of groups: number of single individuals that undertook the survey.

References

[1] R. Castro, D.C. Angus, M.R. Rosengart, The effect of light on critical illness, Crit. Care 15 (2) (2011), https://doi.org/10.1186/cc10000, 218.

[2] H. Lau, V. Khosrawipour, P. Kocbach, A. Mikolajczyk, J. Schubert, J. Bania, T. Khosrawipour, The positive impact of lock-down in Wuhan on containing the COVID-19 outbreak in China, J. Trav. Med. (2020), https://doi.org/10.1093/jtm/taaa037.

[3] J. Qiu, B. Shen, M. Zhao, Z. Wang, B. Xie, Y. Xu, A nationwide survey of psychological distress among Chinese people in the COVID-19 epidemic: implications and policy recommendations, Gen. Psychiatr. 33 (2) (2020), https://doi.org/10.1136/gpsych-2020-100213.

[4] X. Zhou, C.L. Snoswell, L.E. Harding, M. Bambling, S. Edirippulige, X. Bai, A. C. Smith, The role of telehealth in reducing the mental health burden from COVID-19, Telemed. E-health. (2020), https://doi.org/10.1089/tmj.2020.0068 tmj.2020.0068.

[5] E. Rasskazova, D. Leontiev, A. Lebedeva, Pandemic as a challenge to subjective well-being: anxiety and coping, Консультативная Психология и Психотерапия 28 (2) (2020) 90–108, https://doi.org/10.17759/cpp.2020280205.

[6] S. Wang, K. Feng, Y. Zhang, J. Liu, W. Wang, Y. Li, Antecedents of public mental health during the COVID-19 pandemic: mediation of pandemic-related knowledge and self-efficacy and moderation of risk level, Front. Psychiatr. 11 (2020), https://doi.org/10.3389/fpsyt.2020.567119.

[7] A. Olszewska-Guizzo, A. Fogel, N. Escoffier, R. Ho, Effects of COVID-19-related stay-at-home order on neuropsychophysiological response to urban spaces: beneficial role of exposure to nature? J. Environ. Psychol. 75 (101590) (2021) https://doi.org/10.1016/j.jenvp.2021.101590.

[8] C.K. Ettman, S.M. Abdalla, G.H. Cohen, L. Sampson, P.M. Vivier, S. Galea, Prevalence of depression symptoms in US adults before and during the COVID-19 pandemic, JAMA Netw. Open 3 (9) (2020) e2019686, https://doi.org/10.1001/jamanetworkopen.2020.19686.

[9] B.R. Pierce, C. Pierce, Pandemic notes from a Maine direct primary care practice, J. Ambul. Care Manag. 43 (4) (2020) 290–293, https://doi.org/10.1097/jac.0000000000000347.

[10] K. Mouratidis, A. Papagiannakis, COVID-19, internet, and mobility: the rise of telework, telehealth, e-learning, and e-shopping, Sustain. Cities Soc. 74 (103182) (2021), https://doi.org/10.1016/j.scs.2021.103182.

[11] K. Smolders, Y. de Kort, S. van den Berg, Daytime light exposure and feelings of vitality: results of a field study during regular weekdays, J. Environ. Psychol. 36 (2013) 270–279, https://doi.org/10.1016/j.jenvp.2013.09.004.

[12] S. Odabaşioğlu, N. Olguntürk, Effects of coloured lighting on the perception of interior spaces, Percept. Mot. Skills 120 (1) (2015) 183–201, https://doi.org/10.2466/24.pms.120v10x4.

[13] L. Lan, S. Hadji, L. Xia, Z. Lian, The effects of light illuminance and correlated color temperature on mood and creativity, Build. Simulat. 14 (3) (2020) 463–475, https://doi.org/10.1007/s12273-020-0652-z.

[14] Y. Li, T. Ru, Q. Chen, L. Qian, X. Luo, G. Zhou, Effects of illuminance and correlated color temperature of indoor light on emotion perception, Sci. Rep. 11 (1) (2021), https://doi.org/10.1038/s41598-021-93523-y.

[15] T. Ru, Y.A. de Kort, K.C. Smolders, Q. Chen, G. Zhou, Non-image forming effects of illuminance and correlated color temperature of office light on alertness, mood, and performance across cognitive domains, Build. Environ. 149 (2019) 253–263, https://doi.org/10.1016/j.buildenv.2018.12.002.

[16] D. Siret, Le corbusier plans. 1940-Studies in sunlight (no place). English version, HAL SHS Sci. Hum. Soc. (2006). https://halshs.archives-ouvertes.fr/halshs-01249648.

[17] K. Smolders, Y. de Kort, S. van den Berg, Daytime light exposure and feelings of vitality: results of a field study during regular weekdays, J. Environ. Psychol. 36 (2013) 270–279. https://doi.org/10.1016/j.jenvp.2013.09.004.

[18] M.M. Aljunaidy, M.N. Adi, Architecture and mental disorders: a systematic study of peer-reviewed literature, HERD: Health Environ. Res. Des. J. 14 (3) (2020) 320–330, https://doi.org/10.1177/1937586720973767.

[19] K. Connellan, M. Gaardboe, D. Riggs, C. Due, A. Reinschmidt, L. Mustillo, Stressed spaces: mental health and architecture, HERD: Health Environ. Res. Des. J. 6 (4) (2013) 127–168, https://doi.org/10.1177/193758671300600408.

[20] A.M. Pot, Improving nursing home care for dementia: is the environment the answer? Aging Ment. Health 17 (7) (2013) 785–787, https://doi.org/10.1080/13607863.2013.828679.

[21] A. Wagenfeld, An environment for health. *OT practice*, Nature (2013), https://doi.org/10.7138/otp.2013.1815f2.

[22] K. Khanade, F. Sasangohar, S.C. Sutherland, K.E. Alexander, Deriving information requirements for a smart nursing system for intensive care units, Crit. Care Nurs. Q. 41 (1) (2018) 29–37, https://doi.org/10.1097/cnq.0000000000000183.

[23] M.A. Gharib, J.A. Golembiewski, A.A. Moustafa, Mental health and urban design – zoning in on PTSD, Curr. Psychol. 39 (1) (2017) 167–173, https://doi.org/10.1007/s12144-017-9746-x.

[24] J. Van Hoof, M. Aarts, C. Rense, A. Schoutens, Ambient bright light in dementia: effects on behaviour and circadian rhythmicity, Build. Environ. 44 (1) (2009) 146–155, https://doi.org/10.1016/j.buildenv.2008.02.005.

[25] L. Heschong, Visual Delight in Architecture: Daylight, Vision, and View, Routledge, 2021.

[26] Y. Ying, M. Koeva, M. Kuffer, K.O. Asiama, X. Li, J. Zevenbergen, Making the third dimension (3D) explicit in hedonic price modelling: a case study of Xi'an, China, Land 10 (1) (2020), https://doi.org/10.3390/land10010024, 24.

[27] S. Yamani, R. Hajji, G.A. Nys, M. Ettarid, R. Billen, 3D variables requirements for property valuation modeling based on the integration of BIM and CIM, Sustainability 13 (5) (2021), https://doi.org/10.3390/su13052814, 2814.

[28] D. Fleming, A. Grimes, L. Lebreton, D. Maré, P. Nunns, Valuing sunshine, Reg. Sci. Urban Econ. 68 (2018) 268–276, https://doi.org/10.1016/j.regsciurbeco.2017.11.008.

[29] E. Diener, S. Oishi, R.E. Lucas, Personality, culture, and subjective well-being: emotional and cognitive evaluations of life, Annu. Rev. Psychol. 54 (1) (2003) 403–425, https://doi.org/10.1146/annurev.psych.54.101601.145056.

[30] N. Schwarz, F. Strack, D. Kommer, D. Wagner, Soccer, rooms, and the quality of your life: mood effects on judgments of satisfaction with life in general and with specific domains, Eur. J. Soc. Psychol. 17 (1) (1987) 69–79, https://doi.org/10.1002/ejsp.2420170107.

[31] K. Scherer, What are emotions? And how can they be measured? Soc. Sci. Inf. (2005) https://doi.org/10.1177/0539018405058216.

[32] M. Cabanac, What is emotion? Behav. Process. 60 (2) (2002) 69–83, https://doi.org/10.1016/s0376-6357(02)00078-5.

[33] K. Scherer, On the nature and function of emotion: a component process approach, in: K.R. Scherer, P.E. Ekman (Eds.), Approaches to Emotion (Pp. 293–317). Hillsdale, NJ: Erlbaum, 1984.

[34] J.E. LeDoux, M.T. Rogan, Emotion: systems, cells, synaptic plasticity, Cell 85 (4) (1996) 469–475, https://doi.org/10.1016/s0092-8674(00)81247-7.

[35] R.D. Lane, K. McRae, Neural substrates of conscious emotional experience: a cognitive-neuroscientific perspective, in: B.M. Amsterdam, J. Benjamins (Eds.), Consciousness, Emotional Self-Regulation and the Brain, 2004, pp. 87–122.

[36] R.D. Lane, The construction of emotional experience: state-related emotional awareness and its application to psychotherapy research and practice, Couns. Psychother. Res. 20 (2020) 479–487, https://doi.org/10.1002/capr.12331.

[37] R.B. Zajonc, Feeling and thinking: preferences need no inferences, Am. Psychol. 35 (2) (1980) 151–175, https://doi.org/10.1037/0003-066x.35.2.151.

[38] P. Ekman, R. Levenson, W. Friesen, Autonomic nervous system activity distinguishes among emotions, Science 221 (4616) (1983) 1208–1210, https://doi.org/10.1126/science.6612338.

[39] A. Pecchinenda, The affective significance of skin conductance activity during a difficult problem-solving task, Cognit. Emot. 10 (5) (1996) 481–504, https://doi.org/10.1080/026999396380123.

[40] R.J. Larsen, E. Diener, R.A. Emmons, An evaluation of subjective well-being measures, Soc. Indicat. Res. 17 (1) (1985) 1–17, https://doi.org/10.1007/bf00354108.
[41] W.H. Van Schuur, M. Kruijtbosch, Measuring subjective well-being: unfolding the Bradburn affect balance scale, Soc. Indicat. Res. 36 (1) (1995) 49–74, https://doi.org/10.1007/bf01079396.
[42] N.M. Bradburn, The structure of psychological well-being, Struct. Psychol. Well Being (1969) (Published).
[43] L. Smith-Lovin, M. Lewis, J.M. Haviland, Handbook of emotions, Contemp. Sociol. 24 (3) (1995), https://doi.org/10.2307/2076468, 298.
[44] J. Karim, R. Weisz, S.U. Rehman, International positive and negative affect schedule short-form (I-PANAS-SF): testing for factorial invariance across cultures, Proc. Soc. Behav. Sci. 15 (2011) 2016–2022, https://doi.org/10.1016/j.sbspro.2011.04.046.
[45] D. Watson, L.A. Clark, The PANAS-X: manual for the positive and negative affect schedule - expanded form, Univ. Iowa (1994), https://doi.org/10.17077/48vt-m4t2.
[46] D. Watson, L.A. Clark. The PANAS-X: Manual for the Positive and Negative Affect Schedule - Expanded Form, University of Iowa, 1994. https://doi.org/10.17077/48vt-m4t2.
[47] R. Layard, Happiness is back, Prospect 108 (2005).
[48] D. Kahneman, A. Deaton, High income improves evaluation of life but not emotional well-being, Proc. Natl. Acad. Sci. USA 107 (38) (2010) 16489–16493, https://doi.org/10.1073/pnas.1011492107.
[49] D. Ballas, What makes a 'happy city'? Cities 32 (2013) S39–S50, https://doi.org/10.1016/j.cities.2013.04.009.
[50] T.S. Smith, L. Reid, Which 'being' in wellbeing? Ontology, wellness and the geographies of happiness, Prog. Hum. Geogr. 42 (6) (2017) 807–829, https://doi.org/10.1177/0309132517717100.
[51] L. Su, S. Zhou, M.P. Kwan, Y. Chai, X. Zhang, The impact of immediate urban environments on people's momentary happiness, Urban Stud. 59 (1) (2021) 140–160, https://doi.org/10.1177/0042098020986499.
[52] American psychologycal association, Sadness, En APA Dict. Psychol. (2020). https://dictionary.apa.org.
[53] C.E. Izard, Assessing emotion, Contemp. Psychol.: Journal. Rev. 36 (7) (1991), https://doi.org/10.1037/029913, 578.
[54] N.B. Allen, D.J.D.L. Horne, J. Trinder, Sociotropy, autonomy, and dysphoric emotional responses to specific classes of stress: a psychophysiological evaluation, J. Abnorm. Psychol. 105 (1) (1996) 25–33, https://doi.org/10.1037/0021-843x.105.1.25.
[55] P. Ekman, R. Levenson, W. Friesen, Autonomic nervous system activity distinguishes among emotions, Science 221 (4616) (1983) 1208–1210. https://doi.org/10.1126/science.6612338.
[56] J.J. Gross, B.L. Fredrickson, R.W. Levenson, The psychophysiology of crying, Psychophysiology 31 (5) (1994) 460–468, https://doi.org/10.1111/j.1469-8986.1994.tb01049.x.
[57] A. Vingerhoets, E. Krahmer, M. Swerts, M. Balsters, Emotional tears facilitate the recognition of sadness and the perceived need for social support, Evol. Psychol 11 (1) (2013), https://doi.org/10.1177/147470491301100114[40,87], 147470491301100.
[58] M. Shirai, T. Soshi, N. Suzuki, Neurophysiological evidence for differentiation of sadness subtypes, Int. J. Psychophysiol. 131 (2018) S149, https://doi.org/10.1016/j.ijpsycho.2018.07.397.
[59] J.T. Larsen, A.P. McGraw, Further evidence for mixed emotions, J. Pers. Soc. Psychol. 100 (6) (2011) 1095–1110, https://doi.org/10.1037/a0021846.
[60] E. Rappe, The influence of a green environment and horticultural activities on the subjective well-being of the elderly living in long-term care, Univ. Helsinki Depart. Appl. Biol. (2005) 36–40 (Published).
[61] P. Navarrete-Hernandez, K. Laffan, A greener urban environment: designing green infrastructure interventions to promote citizens' subjective wellbeing, Landsc. Urban Plann. 191 (103618) (2019), https://doi.org/10.1016/j.landurbplan.2019.103618.
[62] L. Su, S. Zhou, M.P. Kwan, Y. Chai, X. Zhang, The impact of immediate urban environments on people's momentary happiness, Urban Studies 59 (1) (2021) 140–160. https://doi.org/10.1177/0042098020986499.
[63] P. Navarrete-Hernandez, A. Vetro, P. Concha, Building safer public spaces: exploring gender difference in the perception of safety in public space through urban design interventions, Landsc. Urban Plann. 214 (2021), 104180.
[64] C.J. Beukeboom, D. Langeveld, K. Tanja-Dijkstra, Stress-reducing effects of real and artificial nature in a hospital waiting room, J. Alternative Compl. Med. 18 (4) (2012) 329–333, https://doi.org/10.1089/acm.2011.0488.
[65] E.K. Hansen, S.M.L. Nielsen, D. Georgieva, K.M. Schledermann, The impact of dynamic lighting in classrooms. A review on methods. In:, in: A. Brooks, E. Brooks, N. Vidakis (Eds.), Interactivity, Game Creation, Design, Learning, and Innovation. ArtsIT 2017, DLI 2017. Lecture Notes of the Institute for Computer Sciences, Social Informatics and Telecommunications Engineering vol. 229, Springer, Cham, 2018 https://doi.org/10.1007/978-3-319-76908-0_46.
[66] L. Larsen, J. Adams, B. Deal, B.S. Kweon, E. Tyler, Plants in the workplace: the effects of plant density on productivity, attitudes, and perceptions, Environ. Behav. 30 (3) (1998) 261–281, https://doi.org/10.1177/001391659803000301.
[67] I. Bower, R. Tucker, P.G. Enticott, Impact of built environment design on emotion measured via neurophysiological correlates and subjective indicators: a systematic review, J. Environ. Psychol. 66 (101344) (2019), https://doi.org/10.1016/j.jenvp.2019.101344.
[68] M. Banaei, J. Hatami, A. Yazdanfar, K. Gramann, Walking through architectural spaces: the impact of interior forms on human brain dynamics, Front. Hum. Neurosci. 11 (2017), https://doi.org/10.3389/fnhum.2017.00477.
[69] W.H. Ko, S. Schiavon, H. Zhang, L.T. Graham, G. Brager, I. Mauss, Y.W. Lin, The impact of a view from a window on thermal comfort, emotion, and cognitive performance, Build. Environ. 175 (2020), https://doi.org/10.1016/j.buildenv.2020.106779, 106779.
[70] Y. Tsunetsugu, Y. Miyazaki, H. Sato, Visual effects of interior design in actual-size living rooms on physiological responses, Build. Environ. 40 (10) (2005) 1341–1346, https://doi.org/10.1016/j.buildenv.2004.11.026.
[71] G. Vecchiato, A. Jelic, G. Tieri, A.G. Maglione, F. de Matteis, F. Babiloni, Neurophysiological correlates of embodiment and motivational factors during the perception of virtual architectural environments, Cognit. Process. 16 (S1) (2015) 425–429, https://doi.org/10.1007/s10339-015-0725-6.
[72] I. Bower, R. Tucker, P.G. Enticott, Impact of built environment design on emotion measured via neurophysiological correlates and subjective indicators: a systematic review, J. Environ. Psychol. 66 (2019) 101344. https://doi.org/10.1016/j.jenvp.2019.101344.
[73] E. Elbaiuomy, I. Hegazy, S. Sheta, The impact of architectural spaces' geometric forms and construction materials on the users' brainwaves and consciousness status, Int. J. Low Carbon Technol. 14 (3) (2017) 326–334, https://doi.org/10.1093/ijlct/ctx018.
[74] Canepa, E., Scelsi, V., Fassio, A., Avanzino, L., Lagravinese, G., & Chiorri, C. Atmospheres: feeling architecture by emotions. Ambiances, 5. https://doi.org/10.4000/ambiances.2907.
[75] M.F. Bear, B.W. Connors, M.A. Paradiso, Neuroscience: exploring the brain, in: Lippincott Williams & Wilkins Publishers, third ed., 2007.
[76] R. Tomassoni, G. Galetta, E. Treglia, Psychology of light: how light influences the health and psyche, Psychology 6 (10) (2015) 1216–1222, https://doi.org/10.4236/psych.2015.610119.
[77] N. Abbas, D. Kumar, N. Mclachlan, The psychological and physiological effects of light and colour on space users, 2005 IEEE Eng. Med. Biol. 27th Ann. Conf. (2005) 1228–1231, https://doi.org/10.1109/IEMBS.2005.1616646.
[78] R. Küller, N. Abbas, N. Maclachlan, Physiological and psychological effects of illumination and colour in the interior environment, J. Light Vis. Environ. 10 (2) (1986) 1–5, https://doi.org/10.2150/jlve.10.2_1.
[79] C. Gheorghita, M. Grigorovschi, D. Ciolacu-Miron, Light and emotion: achieving emotions in landscape architecture by using light, Academicpres Publ. House 71 (1) (2014) 43–49.
[80] D.H. Kim, K. Mansfield, Creating positive atmosphere and emotion in an office-like environment: a methodology for the lit environment, Build. Environ. 194 (107686) (2021), https://doi.org/10.1016/j.buildenv.2021.107686.
[81] J.E. Roberts, Update on the positive effects of light in humans, Photochem. Photobiol. (2005), https://doi.org/10.1562/2004-12-02-ir-391.
[82] C.A. Czeisler, E.N. Brown, Commentary: models of the effect of light on the human circadian system: current state of the art, J. Biol. Rhythm. 14 (6) (1999) 539–544, https://doi.org/10.1177/074873099129000876.
[83] L. Heschong. *Visual Delight in Architecture: Daylight, Vision, and View*, Routledge, 2021.
[84] L.M. Pyter, J.D. Adelson, R.J. Nelson, Short days increase hypothalamic-pituitary-adrenal Axis responsiveness, Endocrinology 148 (7) (2007) 3402–3409, https://doi.org/10.1210/en.2006-1432.
[85] M.J. Ross, P. Guthrie, J.C. Dumont, The impact of modulated color light on the autonomic nervous system, Adv. Mind Body Med. Fall 27 (4) (2013) 7–16.
[86] R. Küller, S. Ballal, T. Laike, B. Mikellides, G. Tonello, The impact of light and colour on psychological mood: a cross-cultural study of indoor work environments, Ergonomics 49 (14) (2006) 1496–1507, https://doi.org/10.1080/00140130600858142.
[87] S. Colenberg, T. Jylhä, M. Arkesteijn, The relationship between interior office space and employee health and well-being – a literature review, Build. Res. Inf. 49 (3) (2020) 352–366, https://doi.org/10.1080/09613218.2019.1710098.
[88] F. Benedetti, C. Colombo, B. Barbini, E. Campori, E. Smeraldi, Morning sunlight reduces length of hospitalization in bipolar depression, J. Affect. Disord. 62 (3) (2001) 221–223, https://doi.org/10.1016/s0165-0327(00)00149-x.
[89] M.A. Oldham, D.A. Ciraulo, Bright light therapy for depression: a review of its effects on chronobiology and the autonomic nervous system, Chronobiol. Int. 31 (3) (2014) 305–319, https://doi.org/10.3109/07420528.2013.833935.
[90] B. Abboushi, I. Elzeyadi, R. Taylor, M. Sereno, Fractals in architecture: the visual interest, preference, and mood response to projected fractal light patterns in interior spaces, J. Environ. Psychol. 61 (2019) 57–70, https://doi.org/10.1016/j.jenvp.2018.12.005.
[91] J. Scott, J. Theodorson, Psychological, physiological, and phenomenological effects of colored light, SHS Web Conf. 64 (1001) (2019), https://doi.org/10.1051/shsconf/20196401001[53].
[92] L.J. Jorgensen, G.D. Ellis, E. Ruddell, Fear perceptions in public parks, Environ. Behav. 45 (7) (2012) 803–820, https://doi.org/10.1177/0013916512446334.
[93] S.D. Rodiek, J.T. Fried, Access to the outdoors: using photographic comparison to assess preferences of assisted living residents, Landsc. Urban Plann. 73 (2–3) (2005) 184–199, https://doi.org/10.1016/j.landurbplan.2004.11.006.
[94] B. Junker, M. Buchecker, Aesthetic preferences versus ecological objectives in river restorations, Landsc. Urban Plann. 85 (3–4) (2008) 141–154, https://doi.org/10.1016/j.landurbplan.2007.11.002.
[95] V. Cerina, F. Fornara, S. Manca, Architectural style and green spaces predict older adults' evaluations of residential facilities, Eur. J. Ageing 14 (3) (2016) 207–217, https://doi.org/10.1007/s10433-016-0406-z.

[96] B. Jiang, C.N.S. Mak, L. Larsen, H. Zhong, Minimizing the gender difference in perceived safety: comparing the effects of urban back alley interventions, J. Environ. Psychol. 51 (2017) 117–131, https://doi.org/10.1016/j.jenvp.2017.03.012.
[97] A. Larkin, X. Gu, L. Chen, P. Hystad, Predicting perceptions of the built environment using GIS, satellite and street view image approaches, Landsc. Urban Plann. 216 (104257) (2021), https://doi.org/10.1016/j.landurbplan.2021.104257.
[98] P. Navarrete-Hernandez, K. Laffan, A greener urban environment: designing green infrastructure interventions to promote citizens' subjective wellbeing, Landsc. Urban Plann. 191 (2019) 103618. https://doi.org/10.1016/j.landurbplan.2019.103618.
[99] D. Pfeiffer, S. Cloutier, Planning for happy neighborhoods, J. Am. Plann. Assoc. 82 (3) (2016) 267–279, https://doi.org/10.1080/01944363.2016.1166347.
[100] K.H. Choi, J. Kim, O.S. Kwon, M.J. Kim, Y.H. Ryu, J.E. Park, Is heart rate variability (HRV) an adequate tool for evaluating human emotions? – a focus on the use of the International Affective Picture System (IAPS), Psychiatr. Res. 251 (2017) 192–196, https://doi.org/10.1016/j.psychres.2017.02.025.
[101] A. Öhman, Of snakes and faces: an evolutionary perspective on the psychology of fear, Scand. J. Psychol. 50 (6) (2009) 543–552, https://doi.org/10.1111/j.1467-9450.2009.00784.x.
[102] T.H. Kim, G.W. Jeong, H.S. Baek, G.W. Kim, T. Sundaram, H.K. Kang, S.W. Lee, H. J. Kim, J.K. Song, Human brain activation in response to visual stimulation with rural and urban scenery pictures: a functional magnetic resonance imaging study, Sci. Total Environ. 408 (12) (2010) 2600–2607, https://doi.org/10.1016/j.scitotenv.2010.02.025.
[103] D. Watson, L.A. Clark. The PANAS-X: Manual for the Positive and Negative Affect Schedule - Expanded Form, University of Iowa, 1994. https://doi.org/10.17077/48vt-m4t2.
[104] D. Ker, P. Montagnier, V. Spiezia, Measuring telework in the COVID-19 pandemic, OECD Digit. Econ. Paper (2021), https://doi.org/10.1787/0a76109f-en.
[105] K. Axarli, A. Mereci, Objective and subjective criteria regarding the effect of sunlight and daylight in classrooms, Conf. Passive Low Energy Architect. (2008). https://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.552.1299&rep=rep1&type=pdf.
[106] M. Annerstedt, P. Jönsson, M. Wallergård, G. Johansson, B. Karlson, P. Grahn, S. M. Hansen, P. Währborg, Inducing physiological stress recovery with sounds of nature in a virtual reality forest — results from a pilot study, Physiol. Behav. 118 (2013) 240–250, https://doi.org/10.1016/j.physbeh.2013.05.023.
[107] T. Rossetti, R. Hurtubia, An assessment of the ecological validity of immersive videos in stated preference surveys, J. Choice Model. 34 (100198) (2020), https://doi.org/10.1016/j.jocm.2019.100198.
[108] E. Ng, Studies on daylight design and regulation of high-density residential housing in Hong Kong, Light. Res. Technol. 35 (2) (2003) 178–179, https://doi.org/10.1191/1477153503li087oa.
[109] R. Gifford, The consequences of living in high-rise buildings, Architect. Sci. Rev. 50 (1) (2007) 2–17, https://doi.org/10.3763/asre.2007.5002.
[110] K. Mouratidis, Compact city, urban sprawl, and subjective well-being, Cities 92 (2019) 261–272, https://doi.org/10.1016/j.cities.2019.04.013.