Landscape and Urban Planning 214 (2021) 104146

Contents lists available at ScienceDirect

Landscape and Urban Planning

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

Research Paper

Associations between the naturalness of window and interior classroom views, subjective well-being of primary school children and their performance in an attention and concentration test

Petra Lindemann-Matthies [a,*], Dorothee Benkowitz [b], Felix Hellinger [a]

[a] Institute of Biology, Karlsruhe University of Education, Germany
[b] Institute of Biology, Weingarten University of Education, Germany

HIGHLIGHTS

- Natural window views were associated with less perceived stress and more attention.
- Natural views were not associated with performance in a concentration test.
- Children's nature experiences were associated with less perceived stress in school.
- Children's nature experiences were associated with perceived well-being in school.

ARTICLE INFO

Keywords:
Primary school
Stress
Concentration
Comfort
Window view
Interior plants

ABSTRACT

There is increasing evidence for the restorative and stress-reducing benefits of natural window views and indoor vegetation. However, few studies have investigated associations between the naturalness of window and interior classroom views and students' well-being and performance in primary schools. The present cross-sectional study investigated associations between the naturalness of window and interior classroom views and primary students' subjective well-being and actual performance in a standardized attention and concentration test. Well-being was assessed with a written survey, covering students' satisfaction and comfort in school, ability to concentrate and learn in class, satisfaction with achievements, perceived stress, and social belonging. Attention and concentration were measured with the d2-revision test. Social density, wall color, and degree of classroom decoration were controlled for. Students (n = 785; 8–11 years old; all 4th graders) reported less stress and were more focused on a task in classrooms with more natural window views, i.e., in rooms where more natural elements could be seen outside. Natural interior views, and thus the number of plants in a classroom, were not significantly associated with the tested variables. Children's nature connectedness (measured as their time spent in nature and on plant care) was positively associated with feelings of comfort and learning satisfaction in school. Time spent in nature was also associated with less perceived stress and fatigue, and with more attentive behavior during lessons. Performance in the d2-revision test was not associated with the naturalness of classroom views, but was lower for children who perceived stress in school.

1. Introduction

There is increasing evidence for the restorative and stress-reducing benefits of green space in the proximity of residential homes (e.g., Kaplan, 2001; Maas, Verheij, Groenewegen, de Vries, & Spreeuwenberg, 2006; Navarrete-Hernandez & Laffan, 2019; Stigsdotter et al., 2010; Thompson et al., 2012; Wells & Evans, 2003), workplaces (e.g., Dravigne, Waliczek, Lineberger, & Zajicek, 2008; Leather, Pyrgas, Beale, & Lawrence, 1998), and schools (e.g., Chawla, Keena, Pevec, & Stanley, 2014; Kelz, Evans, & Röderer, 2015; Wu et al., 2014). Research also provides support for the restorative and stress-reducing benefits of indoor vegetation, for instance in hospitals (e.g., Beukeboom, Langeveld, & Tanja-Dijkstra, 2012; Dijkstra, Pieterse, & Pruyn, 2008; Park & Mattson, 2008, 2009), and at workplaces (e.g., Bringslimark, Hartig, &

* Corresponding author at: Institute of Biology, Karlsruhe University of Education, Bismarckstrasse 10, D-76060 Karlsruhe, Germany.
E-mail address: petra.lindemann-matthies@ph-karlsruhe.de (P. Lindemann-Matthies).

https://doi.org/10.1016/j.landurbplan.2021.104146
Received 4 June 2020; Received in revised form 4 May 2021; Accepted 6 May 2021
Available online 16 May 2021

Patil, 2007; Chang & Chen, 2005; Fjeld, 2000; Fjeld, Veiersted, Sandvik, Riise, & Levy, 1998; Larsen, Adams, Deal, Kweon, & Tyler, 1998). However, much less is known about associations between the naturalness of window and interior classroom views and students' well-being and performance in school (Daly, Burchett, & Torpy, 2010; Fjeld, 2000; Han, 2009; Li & Sullivan, 2016; Matsuoka, 2010; Van den Bogerd, Dijkstra, Tanja-Dijkstra, et al., 2020), especially at the primary-school level (except Van den Berg, Wesselius, Maas, & Tanja-Dijkstra, 2017; Daly et al., 2010). The present study aims to contribute to filling this knowledge gap.

1.1. Theoretical framework

Psychological benefits of nature can either be due to stress reduction (Ulrich, 1983) or due to recovery of the capacity to focus attention (Berman, Jonides, & Kaplan, 2008; Berto, 2005; Kaplan & Kaplan, 1989). Stress reduction theory (SRT) proposes that positive psychophysiological responses to non-threatening natural environments have evolved over the course of human evolution (Kellert, 1993; Ulrich et al., 1991). Natural in contrast to human-made environments can thus be calming after a stressful experience, with the emotional response being immediate, unconscious, and spontaneous (Ulrich, 1983). A view of nature from a window or the visual presence of plants in a room might thus reduce stress through the automatic generation of physiological and psychological responses (Bratman, Hamilton, & Daily, 2012). Attention restoration theory (ART) offers an alternative explanation for the psychological benefits of nature (Kaplan, 1995). Directing attention to challenging tasks and dealing with disruptive environmental factors can lead to mental fatigue. Environments dominated by elements of nature provide the opportunity for effortless attention and thus an opportunity for mental restoration (Kaplan, 1995; Matsuoka, 2010). In human-made environments, on the contrary, certain stimuli may require full and directed attention (e.g., when crossing a major road), which makes them less restorative (Berman, Jonides, & Kaplan, 2008). However, both the psycho-evolutionary and attention restoration theory support the idea that nature functions well as a restorative and stress-reducing environment, and it can be assumed that children's well-being and performance in school is positively associated with the naturalness of their window and interior classroom views. As outlined in the following, recent studies support this assumption. However, most of these studies have focused on secondary or higher education, and only few have been conducted in primary schools.

1.2. Natural window views in educational settings

A randomized controlled experiment at five high schools in Illinois demonstrated that classroom views to green landscapes significantly increased student's recovery from stressful experiences and caused better performance on tests of attention than views to a built space (Li & Sullivan, 2016). Likewise, university dormitory residents with more natural window views scored better than those with less natural views on standardized tests of directed attention (Tennessen & Cimprich, 1995). Natural views were characterized by trees, grass, bushes, lakes, and no evidence of human influence, while built views were characterized by other buildings, streets, or parking lots. Window views towards natural elements were also found to enhance creativity, course satisfaction and test performance among university, college and high school students. Business students in the UK, who had window views towards a green area, performed better in a visual creativity test than students in a course room with blocked views (Studente, Seppala, & Sadowska, 2016). College students who had a view towards open grassy areas and flowering trees were more satisfied with their course and also scored higher than students who had an obstructed view from their otherwise similarly designed classroom (Benfield, Rainbolt, Bell, & Donovan, 2015). An investigation of 101 public high schools in southeastern Michigan revealed consistent and systematically positive relationships between nature exposure and student performance (Matsuoka, 2010). Specifically, views with greater quantities of trees and shrubs from cafeteria as well as classroom windows were positively associated with standardized test scores, graduation rates and percentages of students planning to attend a four-year college. In addition, large expanses of landscape lacking natural features were negatively related to these same test scores and college plans. However, there is a lack of research on possible associations between the naturalness of window views and primary children's well-being and performance in school.

1.3. Natural interior views in educational settings

In a controlled experiment in Taiwan, high school students' sick leave and punishment records due to misbehavior decreased after six large plants had been placed in the classroom (Han, 2009). Moreover, students displayed stronger feelings of friendliness and comfort in the presence of these plants than an untreated control group. In a junior high school in Norway, students considered classrooms enriched with tropical indoor plants also more comfortable than classrooms without plants (Fjeld, 2000). A recent study investigated the restorative impacts of green walls with living plants in primary-school classes in the Netherlands. Children in the classrooms where a green wall was placed, as compared to children in control groups, evaluated their classrooms more positively, and also scored better on a test for selective attention. However, processing speed was not affected by the green wall's presence nor was children's self-reported emotional and social well-being. Other studies showed also mixed results. Korean high school students, for instance, perceived classrooms enriched with indoor plants as more comfortable than classrooms without and had fewer visits to the infirmary than a control group, but saliva cortisol content as an indicator of stress was not reduced by the presence of plants (Park, Song, Kim, Yamane, & Son, 2008). Similarly, the presence of indoor plants (green wall) had no effect on Dutch secondary students' self-reported levels of stress (Van den Bogerd, Dijkstra, Tanja-Dijkstra, et al., 2020). Undergraduate students assigned to a classroom containing natural elements remembered more of a single lecture, although only in the short term, than students in a room that lacked any natural presence. However, mood was not affected (Holden & Mercer, 2014). The six-week presence of three plants in classrooms of 6th and 7th graders in Brisbane region, Australia, fostered test performance in reading, writing and math, but not in students who were actively involved in a school-gardening program, i.e., already enjoyed a continuing contact with nature (Daly et al., 2010).

1.4. Rationale of the study

The above shown findings let to the assumption that students in classrooms with views of nature are more content and less stressed than those who see only built views and no indoor plants. However, studies on this subject are scarce and mainly carried out with adolescents. Nevertheless, more research in primary schools would be important as nearby nature in places where children live, play, and learn were found to reduce stress and enhance protective factors for resilience (Chawla, 2015; Chawla et al., 2014; Gill, 2014; Soga & Gaston, 2016). However, whether this also applies to natural window views and classroom vegetation has hardly been investigated so far. The present cross-sectional study aimed to contribute to this knowledge gap by investigating the potential benefits of natural window and interior classroom views for primary children's well-being and task performance in class. We also captured children's self-reported connectedness to nature as this was found to be positively correlated with well-being, attention and concentration (Cervinka, Röderer, & Hefler, 2012; Mayer & Frantz, 2004; Mayer, Frantz, Bruehlman-Senecal, & Dolliver, 2008).

Results of the present study complement existing literature on the benefits of natural school environments (overview in Van den Bogerd, Dijkstra, Koole, et al., 2020) by focusing on the primary-school level,

and contribute to the few studies that have addressed associations between classroom vegetation and primary students' well-being, stress recovery and cognitive performance (Van den Berg et al., 2017; Daly et al., 2010). If our results supported the notion that even a view towards natural elements in primary schools can be beneficial for children's feelings of comfort, social connectivity, relaxation and concentration, they would make a valuable contribution to future landscape planning and design. In times, when children are increasingly alienated from nature experiences (Soga & Gaston, 2016), especially in highly-urbanised regions, the greening of nearby-school environments together with school buildings might counteract the 'nature deficit syndrome' as described by Louv (2006). 'Landscaping' for primary children's well-being should not exclude the environment within schools.

Main objectives of the present study were to investigate:

(1) whether primary-school children's subjective well-being in school is positively associated with the naturalness of their window and interior classroom views,
(2) whether children's actual performance in a standardized attention and concentration test (d2-revision test) is positively associated with the naturalness of their window and interior classroom views, and their subjective well-being in school,
(3) whether children's subjective well-being in school and performance in the d2-revision test is positively associated with their connectedness to nature.

Based on the findings of previous studies we put forward the following hypotheses:

H1: Children's perceived well-being, social connectivity and ability to learn in class will be positively associated with the naturalness of their window and interior views. More natural window views will be associated with higher perceived course satisfaction and learning. More natural indoor views will be associated with more positive emotions such as feelings of comfort and friendliness and less negative ones such as feelings of anxiety, fatigue and stress.

H2: Children's performance in the d2-revision test of attention and concentration will be positively associated with the naturalness of their window and interior views. Moreover, test performance will be negatively associated with children's perceived stress in school.

H3: Children's subjective well-being in school and performance in the d2-revision test will be positively associated with their connectedness to nature.

2. Methods

2.1. Recruitment of classes and data collection

Head teachers of 387 primary schools in southwest Germany (state of Baden-Württemberg) were addressed via email and informed about the aims and design of the present study. They were asked to encourage teachers of 4th grade classes to participate in the study. In primary schools in Germany, children usually change classroom in two-year intervals, i.e., from second to third grade. Involving 4th-graders ensured that children had been in their classroom for more than a year. They were thus accustomed to their window and interior views. 3rd-graders would have been in their classroom for only a few weeks (data collection took place in fall), and 2nd-graders cannot read confidently and quickly enough to fill in the questionnaire. Imperative for participation was that classes were taught in the same room as one year before, as otherwise effects of window or interior views might not be expected. Overall, 41 teachers from 29 primary schools agreed to participate. Schools were situated in the regions of six medium-sized cities in southwest Germany.

In order to comply with the principles of ethically responsible handling of research subjects, of collected documents and of data, students and their parents were informed about the research objective and the research methods. They were assured of anonymity (confidentiality, anonymity in publication), and that the d2-revision test and the written questionnaire was not an assessment. Teachers who had agreed to participate with their classes were each sent a template for obtaining parental consent. Only children whose parents had signed the document took part in the study.

Initially, 785 primary-school children (all 4th graders) participated. However, children diagnosed with attention deficit disorder (4.3%) and children who had recently participated in a d2-revision test, as well as those new in class and those with incomplete questionnaires were later-on excluded from the analyses. Teachers had been discretely asked for the relevant information. Our final data set included 634 children (48% girls), aged between eight and eleven years, from 41 classes. Class sizes varied between 14 and 26 students (Table 1).

Data were collected with the help of a standardized test (d2-revision test) and a written survey, always by the same person and always after the morning break. Before the start of the exercises, all classrooms were ventilated for a few minutes to optimize air quality. Low air quality was found to increase error rates in a standardized concentration test (Twardella et al., 2012). Moreover, all windows and doors were shut to avoid distractions, and curtains or blinds drawn back for maximum view of the outside. All children had window views during the exercises. As data were collected in autumn (October and November), electric lighting was turned on.

Data collection always followed the same schedule. After the first major break (about nine thirty) the investigator (author 3) came to the classroom, welcomed the children, briefly explained the reasons for his visit, and handed out both the d2-revision test and the questionnaire. The procedure of the d2-revision test was explained to the children based on the instructions in the test manual (Brickenkamp, Schmidt-Atzert, & Liepmann, 2010). Step by step, the elements and stages of the test were visualized on the classroom board, and the test procedure was explained. In addition to crossing out specific letters (see Section 2.2.2), children were informed that they should stop working on a line every 20 s on the instructor's command and immediately start with the next, that they should work on each line as quickly and accurately as possible, and that they should be quiet and not interfere with each other during the test. Questions to the children and two little exercises were used to verify their understanding. After all children had finished the test, the questionnaire part was explained. Children were told that only their personal opinion counted, that all questions should be answered honestly, and that all answers would be treated confidentially. The instructor explained the handling of a 5-step scale as this was used in the questionnaire. With the help of an example, which was unrelated to the study content, the procedure of ticking an answer option was practiced until the instructor was convinced that children had understood the procedure. Afterwards, the children filled out the questionnaire.

The whole exercise was pilot tested in two classes that did not participate in the main study. Piloting showed that the method was suitable for primary-school children and that no changes had to be made to the questionnaire. The items were not difficult to understand, the questionnaire format was fine, and the whole exercise did not take longer than one lesson hour.

2.2. Constructs and measures

2.2.1. Subjective well-being

Subjective well-being was assessed with the help of a written questionnaire. The questionnaire included 19 statements that covered relevant aspects of school satisfaction among primary-school students, i.e., general well-being in school, attentiveness in the classroom, interest in and motivation towards learning tasks, academic self-concept, perceived health status, and social integration in class (e.g., Hascher & Edlinger, 2009; Konu, Lintonen, & Rimpelä, 2002; Verkuyten & Thijs, 2002). The statements were formulated specifically for the present study, but were

Table 1
Descriptive statistics for the study population and the variables included in the final models. Wall color was also included (white: 34% of classrooms; yellow: 27%; mixed color: 39%) as were the three factors of the factor analysis.

Variable	Mean	Median	SD	Minimum	Maximum
Descriptive statistics					
Age of participants (n = 634)	9.2	9.0	0.52	8.0	11.0
Number of children per class	20.4	20.0	2.84	14.0	26.0
Population of cities where schools were located	233′583.3	138′000.0	213′950.6	55′100.0	635′000.0
Variables used in the models					
Naturalness of window views (scores; 7-step scale from not natural to very natural)	3.7	3.9	1.2	1.3	5.6
Naturalness of interior views (scores; 7-step scale from not natural to very natural)	2.9	2.9	1.4	1.1	5.8
Time spent in nature (scores; 5-step scale from very little to very much)	3.7	4.0	1.0	1.0	5.0
Time spent on plant care (scores; 5-step scale from very little to very much)	3.1	3.0	1.1	1.0	5.0
Space per child (m^2/child)	3.3	3.1	0.8	2.4	6.7

based on questions already used in other studies to measure the subjective well-being of children (e.g., Konu et al., 2002). Based on factor analyses, items of the questionnaire were assorted to the different aspects of well-being as follows (see Table 2): general satisfaction and perceived comfort in school (items 1–5), ability to concentrate and learn, and satisfaction with achievements in class (items 6–8), perceived stress (items 9–14), and social integration (items 15–19). Children had to state their opinion on 5-step Likert scales, ranging from 1: strongly disagree to 5: strongly agree; a type of response option that was found suitable for primary-school children who actually preferred it over other options (van Laerhoven, Zaag-Loonen, & Derkx, 2004).

2.2.2. Attention and concentration test (d2-revision test)

The d2-revision test (attention and concentration test) is used to record concentrated attention over a short period of time (Brickenkamp et al., 2010). It measures the subject's ability to concentrate as well as speed and accuracy in distinguishing similar visual stimuli (detail discrimination). For most subjects, the test presents a conflict as an increase in working speed usually leads to more errors, or when trying to work without errors, speed decreases. The paper-and-pencil test is frequently used in German-speaking countries, and was found to be an internally consistent and valid measure of visual scanning speed and accuracy (Bates & Lemay, 2004; Brickenkamp et al., 2010). Test participants have to identify targets (the letter d with two dashes that may be located either both above, both below, or one above and one below the d) and to ignore distracters (d's with one, three, or four dashes or p's with one or two dashes). The stimuli are arranged in 14 rows containing 57 letters each. Each row may be scanned for 20 s after which the experimenter tells the participant to move to the subsequent row. Overall test duration is 4:40 min. Scores are calculated as follows: performance speed (S): number of processed target objects (d with two dashes); number of commission errors (CE, nontarget characters cancelled); number of omission errors (OE, target characters respondents failed to cancel); total number of errors (E = CE + OE); error-corrected performance speed = number of correct responses (S-E). Rows 1 and 14 are not included in the calculations (as recommended in Brickenkamp et al., 2010; but see discussion in Steinborn, Langner, Flehmig, & Huestegge, 2018). The number of correct responses is regarded as a measure of concentration performance, indicative of selective attention and sustained attention, while the number of commission and omission errors is seen as a measure of control, sustained attention, inhibitory control, and impulsivity (Lozano, Capote, & Fernández, 2015).

Table 2
Self-assessed well-being in class. Primary-school children (n = 634) had to indicate their opinion on 19 statements with the help of 5-step Likert scales, ranging from 1: totally disagree to 5: totally agree. Items were reduced to three factors (F1 – F3). Factor loadings > 0.04 are shown. Factor 1 can be captioned with ‚comfort and learning satisfaction", factor 2 with ‚stress", and factor 3 with , social well-being".

No	Items and mean scores ± 1 SE	F 1	F 2	F 3
1	I like to go to school (3.8 ± 0.05)	0.75		
2	I like to learn something new (4.3 ± 0.04)	0.72		
3	I like to be in my classroom (4.2 ± 0.04)	0.68		
4	I feel comfortable in my classroom (4.4 ± 0.03)	0.57		0.46
5	I can relax in my classroom (3.5 ± 0.05)	0.53		
6	I have the feeling that I can learn well in my classroom (4.3 ± 0.04)	0.53		
7	I can work long and persistently at a task in my classroom (3.9 ± 0.04)	0.40		
8	I am satisfied with my achievements (4.2 ± 0.04)		-0.43	
9	I have difficulties to concentrate during my lessons (2.5 ± 0.04)		0.71	
10	I can easily be distracted from lessons (2.6 ± 0.04)		0.65	
11	I am easily stressed during lessons (2.2 ± 0.05)		0.65	
12	I am sometimes tired during lessons (2.5 ± 0.05)		0.64	
13	I feel exhausted during lessons (2.1 ± 0.04)		0.60	
14	I feel under pressure during lessons (2.1 ± 0.05)		0.51	
15	I like working together with my classmates (4.4 ± 0.04)			0.67
16	I like being in my class and with my classmates (4.5 ± 0.03)			0.67
17	My classmates are helpful (4.1 ± 0.04)			0.60
18	I like my position in class (4.2 ± 0.04)			0.48
19	Quarreling occurs in my class (3.4 ± 0.04)			-0.43

2.2.3. Connectedness to nature

With respect to participants' young age and stamina, connectedness to nature was only briefly captured by asking children about their weekly amount of time spent in nature (e.g., visits to meadows, forests, lakes) and on plant care at home or elsewhere (5-step scales, ranging from 1: very little to 5: very much). Time spent on both activities was found to be positively correlated with a person's connectedness to nature (e.g., Cox, Hudson, Shanahan, Fuller, & Gaston, 2017). Children indicated that they spent much time each week in natural places (M = 3.7) and a medium amount of time on plant care (M = 3.1; see Table 1).

2.2.4. Control variables

As social density can negatively affect academic achievement and classroom behavior (Maxwell, 2003), floor area of classrooms were measured with the help of an ultrasonic distance measure device and social density calculated (space/child; see Table 1). Moreover, wall color and degree of classroom decoration were recorded, as both may influence children's well-being and academic achievement (Barrett, Zhang, Moffat, & Kobbacy, 2013; Fisher, Godwin, & Seltman, 2014). Both variables were recorded on the days of visit during morning break, when children were absent. About 34% of classrooms had a white, 27% a yellow, and 39% a mixed wall color. The degree of classroom decoration was taken from the photographs. This was done separately by three researchers (85% congruency). None of the classrooms was considered empty, while 63% were classified as normal, and 37% as full.

2.3. Assessment of the naturalness of window and interior classroom views

During morning breaks, window and interior classroom views were recorded with a digital camera (Canon PowerShot SX100 IS). One picture was taken from the wall opposite the window front (either a full view or, if this was not possible, a view of the middle part of the window front). Two more pictures were taken of the outer windows from a distance of approx. 1.5 to 2.0 m. Pictures of the classroom interior, including close-ups of plants if they were present, were taken from all four directions. Window views from all classes (n = 41) were included in one and interior views in another power-point presentation. The subsequent evaluation of the naturalness of window and interior views was based on the assessment of a group of 20 students enrolled in a natural science course. Ten of these students were asked to evaluate the naturalness of each window view. They were instructed to strictly focus on natural elements that can be seen outside a window and not on indoor plants on the sills. A further ten students were asked to evaluate the naturalness of each interior view. In this case, students were instructed to strictly focus on indoor plants (their number, size, and appearance) and not on natural elements such as trees in front of the windows. The assessments took place in a university computer room (one computer per student), where the depicted window and interior views could be viewed on large screens. Students were told to assess each scenario's degree of naturalness intuitively. They could scroll up and down in the presentation, compare the scenarios with each other and then form a judgment about the naturalness of a scene. Assessments were done on 7-step scales, ranging from 1: not natural at all to 7: very natural, and scores entered in a record sheet. For each window and each interior view the mean of assessment and its standard deviation (SD) were calculated. The *SD* of window views varied between 0.48 and 1.73, while the *SD* of interior views varied between 0.32 and 1.65. The overall mean and *SD* for window views were 4.27 and 1.04, and for interior views 5.06 and 1.12.

Naturalness of window and interior views varied strongly between classrooms (scores between 1.1 and 5.8 on the 7-step scales; see Table 1; Fig. 1). Nevertheless, about 51% of all window views and 73% of interior views received mean scores below midpoint of the 7-step scale. Only about 1% of classrooms received mean scores higher than 5, which indicates a rather natural appearance of window and interior views. Classrooms did not harbor many plants ($M = 3.1$, $SD = 3.3$). About 37% of the rooms included no plant at all, and 60% had less than four plants. Naturalness of interior classroom views and number of plants present were correlated (*Pearson's* $r = 0.882$, $p < 0.001$), while naturalness of window and of interior classroom views were not ($p = 0.616$).

2.4. Statistical analysis

Before the analyses, the number of items (19 questions related to different aspects of well-being in class) was reduced by factor analysis. An orthogonal type of factor rotation (varimax) was used according to the recommendations in Frane & Hill (1976), and three factors were extracted (see Table 2). The three factors accounted for 43.5% of the variance in the variables. Based on the loadings of the items on the factors, the factors were interpreted. Factor 1 comprised items related to children's comfort and learning satisfaction in school, factor 2 items

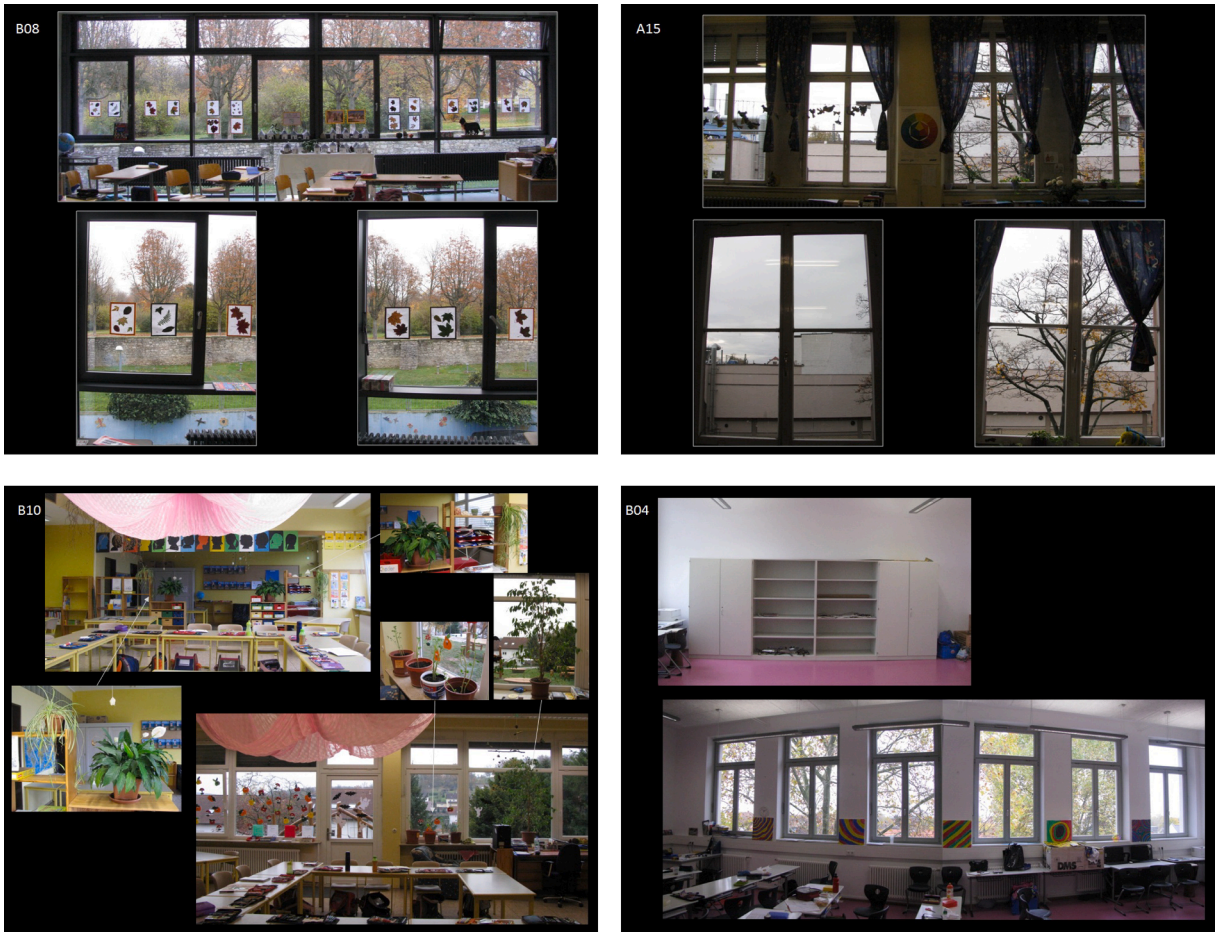

Fig. 1. Classrooms with the most (upper left) and least (upper right) natural window view, and classrooms with the most (lower left) and least (lower right) natural interior view.

related to children's stress in class, and factor 3 items related to social well-being in class.

Linear mixed models were used to test whether children's subjective well-being in school and actual performance in the d2-revision test were associated with the naturalness of their window and interior classroom views as well as their connectedness to nature. As this type of analysis does not allow strong correlations between explanatory variables ($r >$ 0.35), Pearson correlations between nominal and metric explanatory variables were tested first (Crawley, 2005). Fullness, i.e., the amount of classroom decoration, was negatively correlated with the naturalness of window views (r = -0.37, $p < 0.001$) and positively correlated with the naturalness of interior classroom views ($r = 0.40$, $p < 0.001$). Fullness was thus excluded from the models. Due to the nested design, i.e., classes within schools and children within classes, school and class were treated as random factors, while the other variables were treated as fixed factors. Wall color was included as a factor (three categories), while naturalness of window and interior classroom views, social density, amount of time spent in nature, and amount of time spent on plant care were treated as covariates.

To identify associations with children's subjective well-being in school (summarized in three factors), the following variables were included in the models: wall color (factor), naturalness of window views (mean scores on 7-step scales), naturalness of interior classroom views (mean scores on 7-step scales), social density (space per child), amount of time spent in nature (mean scores on 5-step scales), and amount of time spent on plant care (mean scores on 5-step scales). To identify associations with children's actual performance in the d2-revision test, the same variables were included in the models plus factor 1 (comfort and learning satisfaction; scores), factor 2 (stress; scores), and factor 3 (social well-being; scores).

To provide insight into the confounding magnitude of the covariables, single analyses with one covariate at a time and school and class as random factors were also carried out. However, as results were qualitatively the same as in the full linear mixed models, they will not be presented. Inspection of residuals from all analyses showed that they were normally distributed. All analyses were carried out with IBM SPSS Statistics 24 for Windows.

3. Results

3.1. Associations between the naturalness of window and interior classroom views and subjective well-being (objective 1)

Feelings of stress and lack of concentration during lessons (summarized in factor 2) were negatively associated with the naturalness of window views (Table 3). In other words, children felt more relaxed and attentive during lessons, the more natural elements could be seen from their classroom windows.

Against our first hypothesis, natural interior views and children's self-reported stress were not significantly related ($p = 0.099$; see Table 3). Moreover, feelings of comfort and learning satisfaction (summarized in factor 1) and social integration in class (summarized in factor 3) were not significantly associated with the naturalness of the window or interior classroom views (all $p > 0.109$).

Feelings of comfort and learning satisfaction were positively associated with the available space per child in a classroom (see Table 3), and thus negatively associated with social density.

3.2. Associations between the naturalness of window and interior classroom views and test performance (objective 2)

Against our prediction, children's performance in the d2-revision test was not significantly associated with the naturalness of their window or interior classroom views (all $p > 0.168$). However, test performance in terms of speed and concentration was negatively associated with children's perceived level of stress in class (as summarized in factor 2; Table 4).

3.3. Associations between perceived connectedness to nature and subjective well-being as well as test performance (objective 3)

The weekly amount of time spent in natural places and on plant care was positively associated with children's feelings of comfort and learning satisfaction (summarized in factor 1), which is in line with our third hypothesis. Time spent in nature was also positively associated with to children's social integration in class (summarized in factor 3), and negatively associated with children's feelings of stress and lack of concentration during lessons (summarized in factor 2; see Table 3). However, time spent in natural places and on plant care was not significantly associated with any of the variables in the d2-revision test (all $p > 0.111$; see Table 4).

4. Discussion

Our results support the assumption that views of natural elements are beneficial for stress reduction (Kaplan, 1995; Ulrich, 1983). More natural window views were associated with less perceived stress among the participating primary school children. Positive associations between a view towards natural elements, such as green space, trees and bushes, and mental stress reduction were also found in office workers (e.g., Chang & Chen, 2005; Dravigne et al., 2008; Hartig, Evans, Jamner, Davis, & Gärling, 2003; Leather et al., 1998; Lohr, Pearson-Mims, & Goodwin, 1996) and high school students (Li & Sullivan, 2016). In contrast to results of other studies (Han, 2009; Park et al., 2008), and against our first hypothesis, children's perceived comfort in class was not associated with the naturalness of their interior classroom views, and thus amount of indoor plants. One explanation could be that we worked with natural classroom conditions, which, according to the teachers, had not changed at least for a year, rather than with experimental ones. When plants had been introduced in classrooms in

Table 3
Associations with children's self-assessed well-being in class. Results of linear mixed models with school and class as random factors, and naturalness of window and interior views, space per child in a classroom, wall color, time spent in nature, and time spent on plant care as fixed factors. In bold: p < 0.050.

Source of variation	Factor 1(comfort & learning satisfaction) Regression coefficient ± 1SE	F	p	Factor 2(stress) Regression coefficient ± 1SE	F	p	Factor 3(social well-being) Regression coefficient ± 1SE	F	p
Naturalness of window view	−0.080 ± 0.049	2.71	0.109	−0.090 ± 0.035	6.46	**0.011**	0.039 ± 0.048	0.65	0.425
Naturalness of interior view	0.004 ± 0.040	0.01	0.930	0.047 ± 0.029	2.72	0.099	0.009 ± 0.041	0.04	0.834
Space per child	0.185 ± 0.076	5.89	**0.020**	−0.026 ± 0.058	0.20	0.654	−0.029 ± 0.075	0.15	0.699
Wall color		0.14	0.869		0.99	0.374		0.58	0.562
Wall color 1 (white)	*−0.041 ± 0.129*			*−0.131 ± 0.093*			*0.094 ± 0.125*		
Wall color 2 (yellow)	*−0.072 ± 0.138*			*−0.068 ± 0.099*			*0.128 ± 0.127*		
Time spent in nature	0.104 ± 0.040	6.77	**0.009**	−0.126 ± 0.041	9.30	**0.002**	−0.108 ± 0.042	6.77	**0.009**
Time spent on plant care	0.153 ± 0.036	18.32	**<0.001**	0.023 ± 0.037	0.39	0.534	−0.014 ± 0.037	0.14	0.705

Table 4
Associations with children's performance in the d2-revision test. Results of linear mixed models with school and class as random factors, and naturalness of window and interior views, space per child in a classroom, wall color, factor 1 (comfort & learning satisfaction), factor 2 (stress), factor 3 (social well-being), time spent in nature, and time spent on plant care as fixed factors. In bold: $p < 0.050$.

Source of variation	Speed			Accuracy(errors*100/speed)			Concentration(speed - error)		
	Regression coefficient ± 1SE	F	p	Regression coefficient ± 1SE	F	p	Regression coefficient ± 1SE	F	p
Naturalness of window view	0.563 ± 0.801	0.49	0.486	−0.293 ± 0.326	0.81	0.288	0.722 ± 0.761	0.90	0.348
Number of classroom plants	0.946 ± 0.671	1.99	0.168	0.371 ± 0.267	1.94	0.175	0.393 ± 0.634	0.39	0.540
Space per child	−0.360 ± 1.240	0.08	0.773	−0.491 ± 0.504	0.95	0.336	0.255 ± 1.953	0.05	0.830
Wall color		0.46	0.634		0.22	0.804		0.22	0.806
Wall color 1 (white)	*0.070 ± 2.039*			*−0.200 ± 0.855*			*0.681 ± 0.125*		
Wall color 2 (yellow)	*−1.802 ± 2.080*			*−0.583 ± 0.882*			*−0.744 ± 1.994*		
Factor 1 (comfort & learning)	−0.118 ± 0.652	0.03	0.857	−0.241 ± 0.281	0.74	0.390	0.376 ± 0.650	0.33	0.563
Factor 2 (stress)	−2.139 ± 0.629	11.55	**0.001**	−0.172 ± 0.271	0.41	0.524	−1.683 ± 0.628	7.18	**0.008**
Factor 3 (social well-being)	1.068 ± 0.635	2.83	0.093	0.122 ± 0.272	0.20	0.655	0.794 ± 0.633	1.58	0.210
Time spent in nature	−0.962 ± 0.670	2.06	0.152	0.300 ± 0.288	1.08	0.298	−1.066 ± 0.669	2.55	0.111
Time spent on plant care	−0.382 ± 0.592	0.42	0.518	0.062 ± 0.255	0.06	0.806	−0.585 ± 0.591	0.98	0.322

intervention studies, as in Han (2009), Park et al. (2008), effects on feelings of comfort and aesthetic quality were initially substantial but then diminished as students got used to their new classroom situations.

In line with van den Berg et al. (2016), we were unable to demonstrate associations between the naturalness of interior views and children's self-reported social integration in class. One reason could be that the children already felt rather integrated in class (all $M > 4.1$ on the 5-step scales). Another reason could be a genuine lack of relationship between the tested variables. Other parameters, not included in our study, might have been better predictors for children's perceived social well-being. Research on school satisfaction suggests that teachers, as well as strategies teachers use to teach, are strong predictors for students' feelings of happiness and social integration in class, and for their academic achievements (Hattie, 2009; Verkuyten and Thijs, 2002). In our study, the class explained most of the variation in children's perceived comfort and learning satisfaction as well as social integration in class. Part of this variation could probably be assigned to the different teacher personalities.

Performance in the d2-revision test was negatively associated with children's perceived stress and lack of concentration during lessons (summarized in factor 2), as was to be expected. Children who have difficulties to concentrate should do worse in the d2-revision test than children without such difficulties. More unexpected was the finding that performance in the d2-revision test was not significantly associated with the naturalness of window and interior classroom views. As the d2-revision test measures concentration in tasks that demand attention (concentrated attention; Brickenkamp et al., 2010), our results are comparable to those of other studies that have measured attentional capacity (e.g., Li & Sullivan, 2016; Raanaas, Evensen, Rich, Sjøstrøm, & Patil, 2011). Contrary to our findings, the presence of indoor plants increased attention capacity of students in a controlled laboratory experiment (Raanaas et al., 2011), and window views to greenspaces produced better attentional functioning in high school students than rooms without such views (Li & Sullivan, 2016). Our non-significant results are most likely not due to unfavorable classroom conditions or the test instrument itself. All classrooms were ventilated before the test to optimize air quality, windows and doors were shut to avoid distractions, and curtains or blinds drawn back for maximum view outside. The d2-revision test is highly reliable and suitable for primary-school children. Moreover, test results in our study were rather normally distributed. So what could be reasons for the, in view of attention restoration theory (Kaplan, 1995), rather unexpected results of the d2-revision test? As discussed in Bringslimark et al. (2007), benefits of natural views might be greater for those who have relatively high levels of stress, and thus high restoration needs, than for those who are quite relaxed. Children in our study had rather low scores on perceived stress (all $M <$ 3.0 on the 5-step scale). That we conducted the d2-revision tests immediately after morning break, i.e., a good time for restoration, might also have contributed to the weak associations between the tested variables.

The positive relationship between children's amount of time spent in natural places and their feelings of comfort and social integration in class supplements results of other studies, in which frequent nature experiences fostered pleasant moods, life satisfaction, and social well-being (Cervinka et al., 2012; Nisbet & Zelenski, 2011; Zelenski & Nisbet, 2014). We found a negative association between the time children assessed to spend in natural places and their perceived stress and lack of concentration during lessons. As with natural window and interior classroom views, children's nature exposure might thus be beneficial to decrease stress in school, and to contribute to attention and relaxation. Nature connectedness of adults was found to be positively related to attention and concentration (Mayer & Frantz, 2004; Mayer et al., 2008), and health-related quality of life (Stigsdotter et al., 2010).

There are certain limitations to our study. Since participation was voluntary, our sample was not necessarily representative. To our knowledge, none of the schools was from a particularly deprived area. However, children from deprived areas have higher odds of emotional disorder (Rudolph, Stuart, Glass, & Merikangas, 2014), stressful life experiences (Thompson et al., 2012), and a lack of self-discipline (Taylor, Kuo, & Sullivan, 2002), and might have reacted differently to a green indoor and outdoor school environment than our non-representative sample. Moreover, the present study involved only schools in one part of Germany, which limits the generalization of the results. Another limitation is that we took interest in the visual experiences of plants without controlling for variables such as the number and exposure of plants, their size, appearance, and scent. We did also not control for the presence of green space in the close vicinities of the schools, a green school yard, or plants in the main hall ways. Moreover, individual parameters of building conditions can affect well-being of occupants through complex interactions (Heschong Mahone Group, 2003; Chang & Chen, 2005; Bluyssen, Janssen, van den Brink, & de Kluizenaar, 2011), which we did not account for. For example, it was not entirely possible to control for air quality in the classrooms. To let in oxygen, ventilation was provided before the d2-revision test. However, indoor air quality is directly affected by outdoor air quality, which in turn may depend on a school's environment, e.g., proximity to major roads (Leung, 2015; Tong, Chen, Malkawi, Adamkiewicz, & Spengler, 2016). A further limitation was that we did not control for the degree of daylighting in the classrooms. Full-spectrum daylighting in classrooms might, in combination with green space, affect student attentional functioning (Li & Sullivan, 2016). We can thus not be certain whether the results would have been the same if the study had been conducted in summer instead of autumn. Nevertheless, despite its limitations, the present study is the first to show that natural window views may

contribute to primary children's attentiveness and concentration in class.

5. Conclusions

Naturalness of window views and children's well-being in school was positively correlated. As already suggested by Chang & Chen (2005), plants and landscapes around buildings should more often be viewed from the perspective of an inside-out view, and the question more often asked what people can actually see when looking out of their windows. More natural school surroundings may not only help to reduce stress in students, but may also increase their love of nature and decrease feelings of human dominance over nature (Chawla et al., 2014; Harvey, 1990). If, on the other hand, the school landscape is characterized by impervious surfaces instead of natural elements, this may be associated with anxiety, depression, and behavioral problems (Sajady, Gower, McCullough, & Jordan, 2020). Although the present results failed to show a relationship between the naturalness of a classroom interior and children's behavior, this does not mean that more nature in school buildings is unnecessary. As our results show, nature experiences do contribute to children's perceived comfort and learning satisfaction, attentiveness and concentration as well as social connectivity in school. Nature both outside and inside school can thus promote children's well-being. However, while greening measures in nearby school environments can be expensive and must be planned long in advance, or might even be impossible to provide in some urban environments, equipping classrooms with potted plants, flowers or a green wall might be more easy to implement and be less costly. In a time when children, at least in highly industrialized western countries, are increasingly alienated from nature (e.g., Louv, 2006), our results provide strong arguments for bringing nature closer to schools and in the classroom.

Author statement

PLM, DB and FH conceived the ideas and designed the study, FH carried out the study, and PLM and FH analyzed the data and wrote the manuscript

Acknowledgements

We would like to thank all teachers and students for their time, Diethart Matthies for valuable comments on an earlier version of the manuscript, and Chris Auber for checking the English.

References

Barrett, P., Zhang, Y., Moffat, J., & Kobbacy, K. (2013). A holistic, multi-level analysis identifying the impact of classroom design on pupils' learning. *Building and Environment, 59*, 678–689. https://doi.org/10.1016/j.buildenv.2012.09.016.

Bates, M. E., & Lemay, E. P. (2004). The d2 test of attention: Construct validity and extensions in scoring techniques. *Journal of the International Neuropsychological Society, 10*, 392–400. https://doi.org/10.1017/S135561770410307X.

Benfield, J. A., Rainbolt, G. N., Bell, P. A., & Donovan, G. H. (2015). Classrooms with nature views: Evidence of differing student perceptions and behaviors. *Environment and Behavior, 47*(2), 140–157. https://doi.org/10.1177/0013916513499583.

Berman, M. G., Jonides, J., & Kaplan, S. (2008). The cognitive benefits of interacting with nature. *Psychological Science, 19*(12), 1207–1212. https://doi.org/10.1111/j.1467-9280.2008.02225.x.

Berto, R. (2005). Exposure to restorative environments helps restore attentional capacity. *Journal of Environmental Psychology, 25*(3), 249–259. https://doi.org/10.1016/j.jenvp.2005.07.001.

Beukeboom, C. J., Langeveld, D., & Tanja-Dijkstra, K. (2012). Stress-reducing effects of real and artificial nature in a hospital waiting room. *The Journal of Alternative and Complementary Medicine, 18*(4), 329–333. https://doi.org/10.1089/acm.2011.0488.

Bluyssen, P. M., Janssen, S., van den Brink, L. H., & de Kluizenaar, Y. (2011). Assessment of wellbeing in an indoor office environment. *Building and Environment, 46*(12), 2632–2640. https://doi.org/10.1016/j.buildenv.2011.06.026.

Bratman, G. N., Hamilton, J. P., & Daily, G. C. (2012). The impacts of nature experience on human cognitive function and mental health. *Annals of the New York Academy of Sciences, 1249*, 118–136. https://doi.org/10.1111/j.1749-6632.2011.06400.x.

Brickenkamp, R., Schmidt-Atzert, L., & Liepmann, D. (2010). Test d2-revision: Aufmerksamkeits- und Konzentrationstest. [Test d2-revision: Attention and concentration test]. Göttingen, Germany: Hogrefe.

Bringslimark, T., Hartig, T., & Patil, G. G. (2007). Psychological benefits of indoor plants in workplaces: Putting experimental results into context. *HortScience, 42*(3), 581–587. https://doi.org/10.21273/HORTSCI.42.3.581.

Cervinka, R., Röderer, K., & Hefler, E. (2012). Are nature lovers happy? On various indicators of well-being and connectedness with nature. *Journal of Health Psychology, 17*(3), 379–388. https://doi.org/10.1177/1359105311416873.

Chang, C.-Y., & Chen, P.-K. (2005). Human response to window views and indoor plants in the workplace. *HortScience, 40*(5), 1354–1359. https://doi.org/10.21273/HORTSCI.40.5.1354.

Chawla, L., Keena, K., Pevec, I., & Stanley, E. (2014). Green schoolyards as havens from stress and resources for resilience in childhood and adolescence. *Health & Place, 28*, 1–13. https://doi.org/10.1016/j.healthplace.2014.03.001.

Chawla, L. (2015). Benefits of nature contact for children. *Journal of Planning Literature, 30*(4), 433–452. https://doi.org/10.1177/0885412215595441.

Cox, D. T., Hudson, H. L., Shanahan, D. F., Fuller, R. A., & Gaston, K. J. (2017). The rarity of direct experiences of nature in an urban population. *Landscape and Urban Planning, 160*, 79–84. https://doi.org/10.1016/j.landurbplan.2016.12.006.

Crawley, M. J. (2005). *Statistics. An introduction using R*. Chichester, UK: Wiley.

Daly, J., Burchett, M., & Torpy, F. (2010). Plants in the classroom can improve student performance. National Interior Plantscape Association. http://interiorplantscape.asn.au/wp-content/uploads/2016/04/Plants-in-the-classroom-can-Improve-Student-Performance-Report-2010.pdf.

Dijkstra, K., Pieterse, M. E., & Pruyn, A. (2008). Stress-reducing effects of indoor plants in the built healthcare environment: The mediating role of perceived attractiveness. *Preventive Medicine, 47*(3), 279–283. https://doi.org/10.1016/j.ypmed.2008.01.013.

Dravigne, A., Waliczek, T. M., Lineberger, R. D., & Zajicek, J. M. (2008). The effect of live plants and window views of green spaces on employee perceptions of job satisfaction. *HortScience, 43*(1), 183–187. https://doi.org/10.21273/HORTSCI.43.1.183.

Fisher, A. V., Godwin, K. E., & Seltman, H. (2014). Visual environment, attention allocation, and learning in young children. When too much of a good thing may be bad. *Psychological Science, 25*(7), 1362–1370. https://doi.org/10.1177/0956797614533801.

Fjeld, T., Veiersted, B.o., Sandvik, L., Riise, G., & Levy, F. (1998). The effect of indoor foliage plants on health and discomfort symptoms among office workers. *Indoor and Built Environment, 7*(4), 204–209. https://doi.org/10.1177/1420326X9800700404.

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

Frane, J. W., & Hill, M. (1976). Factor analysis as a tool for data analysis. *Communications in Statistics, Part A: Theory and Methods, 5*(6), 487–506. https://doi.org/10.1080/03610926076088273 70.

Gill, T. (2014). The benefits of children's engagement with nature: A systematic literature review. *Children Youth and Environments, 24*, 10–34. https://doi.org/10.7721/chilyoutenvi.24.2.0010.

Han, K.-T. (2009). Influence of limitedly visible leafy indoor plants on the psychology, behavior, and health of students at a junior high school in Taiwan. *Environment and Behavior, 41*(5), 658–692. https://doi.org/10.1177/0013916508314476.

Hartig, T., Evans, G. W., Jamner, L. D., Davis, D. S., & Gärling, T. (2003). Tracking restoration in natural and urban field settings. *Journal of Environmental Psychology, 23*(2), 109–123. https://doi.org/10.1016/S0272-4944(02)00109-3.

Harvey, M. R. (1990). The relationship between children's experiences with vegetation on school grounds and their environmental attitudes. *The Journal of Environmental Education, 21*(2), 9–15. https://doi.org/10.1080/00958964.1990.9941926.

Hascher, T., & Edlinger, H. (2009). Positive Emotionen und Wohlbefinden in der Schule - ein Überblick über Forschungszugänge und Erkenntnisse [Positive emotions and well-being in school – an overview of methods and results]. *Psychologie in Erziehung und Unterricht, 56*(2), 105–122.

Hattie, J. (2009). *Visible learning: A synthesis of over 800 meta-analyses relating to achievement*. New York, NY: Routledge.

Heschong Mahone Group (2003). Windows and classrooms: A study of student performance and the indoor environment. Sacramento, CA: California Energy Commission. http://aceee.org/files/proceedings/2004/data/papers/SS04_Panel7_Paper01.pdf.

Holden, L. J., & Mercer, T. (2014). Nature in the learning environment: Exploring the relationship between nature, memory, and mood. *Ecopsychology, 6*(4), 234–240. https://doi.org/10.1089/eco.2014.0034.

Kaplan, R., & Kaplan, S. (1989). *The experience of nature. A psychological perspective*. New York, NY: Cambridge University Press.

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

Kaplan, R. (2001). The nature of the view from home: Psychological benefits. *Environment and Behavior, 33*(4), 507–542. https://doi.org/10.1177/00139160121973115.

Kellert, S. R. (1993). The biological basis for human values of nature. In S. R. Kellert & E. O. Wilson (Eds.), The biophilia hypothesis (pp. 42-69). Washington, DC: Island Press.

Kelz, C., Evans, G. W., & Röderer, K. (2015). The restorative effects of redesigning the schoolyard: A multi-methodological, quasi-experimental study in rural Austrian middle schools. *Environment and Behavior, 47*(2), 119–139. https://doi.org/10.1177/0013916513510528.

Konu, A. I., Lintonen, T. P., & Rimpelä, M. K. (2002). Factors associated with schoolchildren's general subjective well-being. *Health Education Research, 17*, 155–165. https://doi.org/10.1093/her/17.2.155.

Larsen, L., Adams, J., Deal, B., Kweon, B. S., & Tyler, E. (1998). Plants in the workplace: The effects of plant density on productivity, attitudes, and perceptions. *Environment and Behavior, 30*(3), 261–281. https://doi.org/10.1177/001391659803000301.

Leather, P., Pyrgas, M., Beale, D.i., & Lawrence, C. (1998). Windows in the workplace sunlight, view, and occupational stress. *Environment and Behavior, 30*(6), 739–762. https://doi.org/10.1177/001391659803000601.

Leung, D. Y. (2015). Outdoor-indoor air pollution in urban environment: Challenges and opportunity. *Frontiers in Environmental Science, 2*, 1–7. https://doi.org/10.3389/fenvs.2014.00069.

Li, D., & Sullivan, W. C. (2016). Impact of views to school landscapes on recovery from stress and mental fatigue. *Landscape and Urban Planning, 148*, 149–158. https://doi.org/10.1016/j.landurbplan.2015.12.015.

Lohr, V. I., Pearson-Mims, C. H., & Goodwin, G. K. (1996). Interior plants may improve worker productivity and reduce stress in a windowless environment. *Journal of Environmental Horticulture, 14*, 97–100. https://doi.org/10.24266/0738-2898-14.2.97.

Louv, R. (2006). *Last child in the woods. Saving our children from nature-deficit disorder.* Chapel Hill, NC: Algonquin Books of Chapel Hill.

Lozano, J. H., Capote, E., & Fernández, M. P. (2015). Convergent validity of the measures of attention and impulsivity in the trees: Simple visual discrimination test (DiViSA-UAM). *Anales de Psicología/Annals of Psychology, 31*, 74–83. https://doi.org/10.6018/analesps.31.1.161371.

Maas, J., Verheij, R. A., Groenewegen, P. P., de Vries, S., & Spreeuwenberg, P. (2006). Green space, urbanity, and health: How strong is the relation? *Journal of Epidemiology & Community Health, 60*, 587–592. https://doi.org/10.1136/jech.2005.043125.

Matsuoka, R. H. (2010). Student performance and high school landscapes: Examining the links. *Landscape and Urban Planning, 97*(4), 273–282. https://doi.org/10.1016/j.landurbplan.2010.06.011.

Maxwell, L. E. (2003). Home and school density effects on elementary school children: The role of spatial density. *Environment and Behavior, 35*(4), 566–578. https://doi.org/10.1177/0013916503035004007.

Mayer, F. S., & Frantz, C. M. (2004). The connectedness to nature scale: A measure of individuals' feeling in community with nature. *Journal of Environmental Psychology, 24*(4), 503–515. https://doi.org/10.1016/j.jenvp.2004.10.001.

Mayer, F. S., Frantz, C. M., Bruehlman-Senecal, E., & Dolliver, K. (2008). Why is nature beneficial? The role of connectedness to nature. *Environment and Behavior, 41*(5), 607–643. https://doi.org/10.1177/0013916508319745.

Navarrete-Hernandez, P., & Laffan, K. (2019). A greener urban environment: Designing green infrastructure interventions to promote citizens' subjective wellbeing. *Landscape and Urban Planning, 191*, 103618. https://doi.org/10.1016/j.landurbplan.2019.103618.

Nisbet, E. K., & Zelenski, J. M. (2011). Underestimating nearby nature affective forecasting errors obscure the happy path to sustainability. *Psychological Science, 22*(9), 1101–1106. https://doi.org/10.1177/0956797611418527.

Park, S.-H., & Mattson, R. H. (2008). Effects of flowering and foliage plants in hospital rooms on patients recovering from abdominal surgery. *HortTechnology, 18*(4), 563–568. https://doi.org/10.21273/HORTTECH.18.4.563.

Park, S.-H., & Mattson, R. H. (2009). Therapeutic influences of plants in hospital rooms on surgical recovery. *HortScience, 44*(1), 102–105. https://doi.org/10.21273/HORTSCI.44.1.102.

Park, S.-Y., Song, J.-S., Kim, H.-D., Yamane, K., & Son, K.-C. (2008). Effects of interior plantscapes on indoor environments and stress level of high school students. *Journal of the Japanese Society for Horticultural Science, 77*(4), 447–454. https://doi.org/10.2503/jjshs1.77.447.

Raanaas, R. K., Evensen, K. H., Rich, D., Sjøstrøm, G., & Patil, G. (2011). Benefits of indoor plants on attention capacity in an office setting. *Journal of Environmental Psychology, 31*(1), 99–105. https://doi.org/10.1016/j.jenvp.2010.11.005.

Rudolph, K. E., Stuart, E. A., Glass, T. A., & Merikangas, K. R. (2014). Neighborhood disadvantage in context: The influence of urbanicity on the association between neighborhood disadvantage and adolescent emotional disorders. *Social Psychiatry and Psychiatric Epidemiology, 49*(3), 467–475. https://doi.org/10.1007/s00127-013-0725-8.

Sajady, M., Gower, A. L., McCullough, M., & Jordan, C. (2020). More than a view: School landscape features are associated with improved student adjustment. *Journal of Developmental & Behavioral Pediatrics, 41*(6), 436–442. https://doi.org/10.1097/DBP.0000000000000809.

Soga, M., & Gaston, K. J. (2016). Extinction of experience: The loss of human–nature interactions. *Frontiers in Ecology and the Environment, 14*(2), 94–101. https://doi.org/10.1002/fee.1225.

Steinborn, M. B., Langner, R., Flehmig, H. C., & Huestegge, L. (2018). Methodology of performance scoring in the d2 sustained-attention test: Cumulative-reliability functions and practical guidelines. *Psychological Assessment, 30*, 339–357. https://doi.org/10.1037/pas0000482.

Stigsdotter, U. K., Ekholm, O., Schipperijn, J., Toftager, M., Kamper-Jørgensen, F., & Randrup, T. B. (2010). Health promoting outdoor environments - Associations between green space, and health, health-related quality of life and stress based on a Danish national representative survey. *Scandinavian Journal of Public Health, 38*(4), 411–417. https://doi.org/10.1177/1403494810367468.

Studente, S., Seppala, N., & Sadowska, N. (2016). Facilitating creative thinking in the classroom: Investigating the effects of plants and the colour green on visual and verbal creativity. *Thinking Skills and Creativity, 19*, 1–8. https://doi.org/10.1016/j.tsc.2015.09.001.

Taylor, Andrea. Faber., Kuo, Frances. E., & Sullivan, William. C. (2002). Views of nature and self-discipline: Evidence from inner city children. *Journal of Environmental Psychology, 22*(1-2), 49–63. https://doi.org/10.1006/jevp.2001.0241.

Tennessen, C. M., & Cimprich, B. (1995). Views to nature: Effects on attention. *Journal of Environmental Psychology, 15*(1), 77–85. https://doi.org/10.1016/0272-4944(95)90016-0.

Thompson, C. W., Roe, J., Aspinall, P., Mitchell, R., Clow, A., & Miller, D. (2012). More green space is linked to less stress in deprived communities: Evidence from salivary cortisol patterns. *Landscape and Urban Planning, 105*(3), 221–229. https://doi.org/10.1016/j.landurbplan.2011.12.015.

Tong, Z., Chen, Y., Malkawi, A., Adamkiewicz, G., & Spengler, J. D. (2016). Quantifying the impact of traffic-related air pollution on the indoor air quality of a naturally ventilated building. *Environment International, 89*, 138–146. https://doi.org/10.1016/j.envint.2016.01.016.

Twardella, D., Matzen, W., Lahrz, T., Burghardt, R., Spegel, H., Hendrowarsito, L., Frenzel, A. C., & Fromme, H. (2012). Effect of classroom air quality on students' concentration: Results of a cluster-randomized cross-over experimental study. *Indoor Air, 22*, 378–387. https://doi.org/10.1111/j.1600-0668.2012.00774.x.

Ulrich, R. S. (1983). Aesthetic and affective response to natural environment. In I. Altman, & J. F. Wohlwill (Eds.), *Human behavior and environment: Advances in theory and research* (Vol. 6, pp. 85–125). New York, NY: Plenum.

Ulrich, R. S., Simons, R. F., Losito, B. D., Fiorito, E., Miles, M. A., & Zelson, M. (1991). Stress recovery during exposure to natural and urban environments. *Journal of Environmental Psychology, 11*(3), 201–230. https://doi.org/10.1016/S0272-4944(05)80184-7.

Van den Berg, A. E., Wesselius, J. E., Maas, J., & Tanja-Dijkstra, K. (2017). Green walls for a restorative classroom environment: A controlled evaluation study. *Environment and Behavior, 49*(7), 791–813. https://doi.org/10.1177/0013916516667976.

Van den Bogerd, N., Dijkstra, S. C., Tanja-Dijkstra, K., de Boer, M. R., Seidell, J. C., Koole, S. L., & Maas, J. (2020). Greening the classroom: Three field experiments on the effects of indoor nature on students' attention, well-being, and perceived environmental quality. *Building and Environment, 171*, 106675. https://doi.org/10.1016/j.buildenv.2020.106675.

Van den Bogerd, N., Dijkstra, S. C., Koole, S. L., Seidell, J. C., de Vries, R., & Maas, J. (2020). Nature in the indoor and outdoor study environment and secondary and tertiary education students' well-being, academic outcomes, and possible mediating pathways: A systematic review with recommendations for science and practice. *Health & Place, 66*, 102403. https://doi.org/10.1016/j.healthplace:2020.102403.

Van Laerhoven, H., Zaag-Loonen, H. V. D., & Derkx, B. H. F. (2004). A comparison of Likert scale and visual analogue scales as response options in children's questionnaires. *Acta Paediatrica, 93*, 830–835. https://doi.org/10.1111/j.1651-2227.2004.tb03026.x.

Verkuyten, M., & Thijs, J. (2002). School satisfaction of elementary school children: The role of performance, peer relations, ethnicity and gender. *Social Indicators Research, 59*, 203–228. https://doi.org/10.1023/A:1016279602893.

Wells, N. M., & Evans, G. W. (2003). Nearby nature: A buffer of life stress among rural children. *Environment and Behavior, 35*(3), 311–330. https://doi.org/10.1177/0013916503035003001.

Wu, C. D., McNeely, E., Cedeno-Laurent, J. G., Pan, W. C., Adamkiewicz, G., Dominici, F., ... & Spengler, J. D. (2014). Linking student performance in Massachusetts elementary schools with the "greenness" of school surroundings using remote sensing. PloS one, 9, e108548. https://doi.org/10.1371/journal.pone.0108548.

Zelenski, J. M., & Nisbet, E. K. (2014). Happiness and feeling connected: The distinct role of nature relatedness. *Environment and Behavior, 46*(1), 3–23. https://doi.org/10.1177/0013916512451901.