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Green Walls for a Restorative Classroom Environment: A Controlled Evaluation Study

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Abstract

In the present research, we evaluated the restorative impacts of green walls with living plants in classrooms of two elementary schools using a controlled, prospective design with baseline measurements and follow-ups at 2 and 4 months. At each time of measurement, children's (n = 170, age = 7-10) cognitive performance, well-being, and classroom evaluations were measured with attentional tests and self-report questionnaires. Results show that children in the four classrooms where a green wall was placed, as compared with children in control groups, scored better on a test for selective attention; processing speed was not affected by the green wall. The green wall also positively influenced children's classroom evaluations. There were no measurable effects of the green wall on children's self-reported well-being. The green walls were generally evaluated positively during the two follow-ups. These results provide some of the first empirical support for green walls as a means for restorative classroom design.

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green walls, schoolchildren, plants, classroom, attention

Children spend more time in school than in any other indoor environment outside the home (Mendell & Heath, 2004). It is therefore of vital importance to ensure a high-quality classroom environment. Plants can help to achieve this aim. Plants can make a positive contribution to indoor environmental quality through their air-purifying and climate control functions (Pegas et al., 2012). Moreover, there is increasing recognition of the potential for plants to create an attractive environment that supports social and emotional well-being, recovery from stress, and cognitive performance (Bringslimark, Hartig, & Patil, 2009; van den Berg & van den Berg, 2014). These psychological effects, which are commonly known as the "restorative benefits of nature" (S. Kaplan, 1995) are the focus of the present article.

Most research on the benefits of plants in the school environment has focused on outdoor greenery (for a review, see Chawla, 2015). Among other things, this research has shown better performance on standardized tests of English and mathematics when there are more plants, trees, and other types of vegetation around the school (Wu et al., 2014), and significant increases in self-reported psychological well-being and reductions in physiological stress after schoolyard greening, compared with control schools (Kelz, Evans, & Röderer, 2015). Several studies also indicate that children perceive schoolyards and other types of playgrounds as more restorative if they contain greater amounts of vegetation and grass cover (Bagot, Allen, & Toukhsati, 2015; Corraliza, Collado, & Bethelmy, 2012; van den Berg & van den Berg, 2011). Notably, children may benefit from outdoor greenery even when they are inside the classroom. This is, for example, illustrated by a randomized trial at five high schools, which showed that students who were assigned to classrooms with views to green space, as compared with peers in classrooms without green views, performed significantly better on tests of attention and recovered faster from a stressful experience (Li & Sullivan, 2016).

The possible mechanisms underlying the restorative benefits of being exposed to plants have been described by two main theoretical frameworks, each one dealing with different types of restorative benefits. First, Attention Restoration Theory (ART; S. Kaplan, 1995; R. Kaplan & Kaplan, 1989) posits that plants and natural settings foster restoration from mental fatigue because they invoke involuntary attention, which allows the capacity for directed attention to rest and replenish. ART distinguishes four qualities of environmental experiences that support attention restoration: fascination or the capacity of an environment to automatically and effortlessly draw

attention, being away from daily hassles and obligations, a sense of extent and connectedness with the environment, and a compatibility between the individual's inclinations and the characteristics of the environment. These four components provide a useful framework for studying the conditions that foster an effective school learning environment (Bagot et al., 2015).

The second theory, Stress Recovery Theory (SRT; Ulrich, 1983; Ulrich et al., 1991) focuses on recovery from stress and negative mood rather than on cognitive benefits. This theory proposes that plants and other types of vegetation elicit immediate, positive affective responses, accompanied by physiological changes indicative of relaxation. According to SRT, these restorative, psychophysiological reactions to plants reflect an innate, evolutionary mechanism, whose function was to guide and support our ancestors in the process of finding food, water, and shelter (Joye & van den Berg, 2011). Thus, there is theoretical ground for the expectation that plants can contribute to a restorative indoor school environment that supports both the cognitive and affective functioning of children.

A few studies have empirically examined benefits of plants in classrooms, mostly among adolescent and student populations (Daly, Burchett, & Torpy, 2010; Doxey, Waliczek, & Zajicek, 2009; Fjeld, 2000; Han, 2008; Park, Song, Kim, Yamane, & Son, 2008). These studies have focused primarily on the impact of plants on students' physical health, school performance, and behavior. For example, a study among 120 students (age = 14-16) of a junior high school in Norway found that pupils in classrooms with tropical plants and full-spectrum lights reported fewer physical symptoms of discomfort related to poor air quality compared with a control group in classrooms without plants and lights (Fjeld, 2000). A study among 360 students in Grades 6 and 7 of three junior high schools in Australia showed marked improvements in students' spelling and mathematics scores at two of the three schools where three large plants were placed in the classrooms, as compared with classrooms without plants (Daly et al., 2010). A study among 76 students of a Taiwanese junior high school (age = 13-14) found that the placement of six large plants in the back of a classroom led to a decrease in students' sick leave and misbehaviors, as compared with a control group in a classroom with no plants (Han, 2008). The latter study also included psychological measures of well-being and restoration but found no effects on these measures. Taken together, there is some empirical support for benefits of plants in classrooms, but the available evidence is scarce and somewhat inconclusive, and little consideration has been given to the restorative potential of plants. Moreover, research to date has targeted high school and university students rather than schoolchildren who are the main target group for environmental education and classroom interventions.

School teachers tend to support and encourage the presence of plants in the classroom. A survey among teachers of elementary schools in the United States revealed that 85% of them currently used potted plants or seeds in their classrooms (Dobbs, Relf, & McDaniel, 1998). However, issues related to maintenance are a major concern and threat to a successful implementation of plants in the school environment. Care for classroom plants is often inconsistent, from overwatering to neglect in long holidays, and plants may suffer from exposure to drafts, sudden changes in temperature, too much (or too little) sunlight, and proximity to radiators (CLEAPPS, 2009). Green walls, also known as living walls, vertical planting systems, or vertical gardens, provide an innovative, low-maintenance alternative for potted plants in classrooms (Manso & Castro-Gomes, 2015). The use of self-supportive drip water irrigation systems makes the plants in these systems easier to maintain than potted plants. The vertical placement of the system against a wall ensures that they take up little space. Moreover, green walls, due to their dense plant coverage over a large surface, can foster an immersive experience of nature with strong psychological impact.

The Present Research

In the present study, we evaluated the restorative impacts of green walls in classrooms using a prospective design with four experimental groups and four control groups in two elementary schools. The study was carried out in the context of a pilot project among 10 schools in a Dutch municipality, which aims at improving the indoor environmental quality of the schools. Specifically, we hypothesized that, at 2 and 4 months after the placement of the green walls, children in the experimental classrooms, as compared with children in control groups without green walls, would display (a) better cognitive performance, (b) improved emotional and social well-being, and (c) more positive evaluations of their classrooms.

Method

Study Location

The study took place at two elementary schools (Schools "A" and "B") in Haarlemmermeer, a medium-sized Dutch municipality close to Amsterdam. The two schools were selected from a group of 10 schools that participated in the pilot project "Green Walls in Classrooms in Haarlemmermeer," a joint initiative of local governments and horticultural organizations to encourage the implementation of green walls in classrooms. Criteria for inclusion in the

Figure 1. Impressions of the Intervention and Control Groups 7 at School A.
Source. Photos by the first author.

study included the willingness of the teaching staff to facilitate the research and the suitability of the location. An important precondition was the presence of parallel groups at the same grade levels in comparable classrooms with sufficient natural light for plant growth, which could serve as matched experimental and control groups.

School A is a public elementary school with more than 300 pupils. The school is housed in a modern, elongated building along a main thoroughfare road. Windows of the classrooms at the sunny front side of the building look out over a parking lot adjacent to the road, and windows of classrooms at the shadier backside look out over a paved schoolyard in front of a grassy field. At School A, two Grade 6 groups and two Grade 7 groups participated in the study. Because groups at the same grade level were housed in classrooms at opposite sides of the building, the placement of the green walls was counterbalanced for building side. In the Grade 6 groups, the green wall was placed in the classroom at the front side of the building overlooking the parking lot, with the control group at the backside of the building overlooking the schoolyard. In the Grade 7 groups, the green wall was placed in the classroom at the backside, with the classroom at the front side serving as a control group (see Figure 1 for impressions of the Grade 7 intervention and control groups' classrooms at School A).

School B is a Catholic elementary school with more than 300 pupils. The school is housed in an older building from the 1970s with several more recent extensions. The school is located right next to a highway, and therefore, air-purifying systems are installed in all the classrooms and windows cannot be opened. At School B, two Grade 5 groups, one Grade 6 group, and one combined Grade 6/7 group participated in the study. All four groups were located in similar classrooms on the first floor of the newer part of the building. The

Figure 2. Close-up of green wall.
Source. Photo by the first author.

two Grade 5 groups were located at the same side of the building with windows overlooking the backside of residential houses. The Grade 6 and the Grade 6/7 groups were located at the other side of the building with windows overlooking a paved schoolyard.

Green Walls

The green walls were of the type "Wall so green" (Figure 2). A "Wall so green" is a closed system, which consists of a metal frame with layers of felt,

which provide fertile soil for the plants. Once every 2 weeks, water must be filled into a tank at the bottom of the frame, after which a circulation system ensures that the plants are provided with water. In each classroom, a single wall unit of 1.25 m wide and 2 m high was placed in the back of the room against the rear wall or in one of the corners against a sidewall. The unit was stocked with eight types of green plants, including Spathiphyllum, Philodendron, and Dracaena.

Participants

A total of 206 children in Grades 5 to 7 participated in the study (105 at School A, and 101 at School B). Due to illness and other circumstances, 36 children were absent during 1 or more times of measurement. The total sample for which data for each of the three measurements were available consisted of 170 children (97 boys, 73 girls, *M* age = 9 years). Of these, 84 were in the experimental classrooms, and 86 were in the control classrooms. During the sessions, some children were called out of the classroom for remedial teaching or other reasons, resulting in incomplete data for some outcome measures.

Table 1 provides a summary of the characteristics of the children in the eight groups. At School A, there were two experimental groups at Grade Levels 6 and 7, with control groups at the same levels. At School B, there were two experimental groups at Grade Levels 5 and 6, and control groups at Grade Levels 5 and 6/7. Thus, at School B, the experimental group of Grade 6 students was matched with a control group that combined both Grades 6 and 7 students. Preliminary examination of the data of this combined control group revealed that responses of Grades 6 and 7 students were very similar, and therefore we decided to include all children in the analyses.

Following the guidelines of the Research Ethics Committee of the University of Groningen, it was affirmed that the study would not induce negative consequences above minimal risk. The study and study protocol were also approved by the school boards.

Questionnaire and Measures

Data were obtained through self-administered questionnaires, which were filled in by the children at baseline, and 2 and 4 months after placement of the green walls. The questionnaires were designed in a child-friendly manner, with colorful illustrations and easy-to-answer options. Most of the questions were selected and adapted from test materials used in previous studies, in particular, research on the greening of schoolyards (Wesselius, Maas, & Hovinga, 2015). At each time of measurement, the children received the

Table 1. Characteristics of the Children in the Experimental Groups (With Green Wall) and Control Groups (Without Green Wall).

	Green wall			No green wall		
Grade level	Complete data	% girls	*M* age	Complete data	% girls	*M* age
School A						
Grade 6 (*n* = 52)	23	52	8.9	19	53	8.9
Grade 7 (*n* = 47)	19	32	10.1	22	46	10.1
School B						
Grade 5 (*n* = 39)	18	41	8.1	17	41	7.9
Grade 6 (*n* = 54)	24	33	8.8	28	50	9.5
Total	84	40	9.0	86	48	9.2

Note. Percentage of girls and mean age are calculated for children who were present at all 3 times of measurement; mean age was assessed during baseline measurement; the Control Group 6 at School B without a green wall was a mixed group that combined Grade 6/7 students.

same questions to measure their attentional capacity, their emotional, cognitive, and social well-being, and their evaluation of the classroom. During the two post-measurements, the children in the experimental groups answered additional questions about the green wall. The questionnaire also included questions about children's physical health which are outside the scope of the present article and will not be discussed.

Attention. At each time of measurement, two attentional tests were administered: the Digit Letter Substitution Test (DLST) and the Sky Search task. DLST is a variant of the Digit Symbol Substitution Test (Natu & Agarwal, 1995). This test measures information processing speed as a fundamental cognitive ability to support "normal" cognitive function. The DLST requires participants to convert as many randomly ordered digits (1 to 9) as possible to letters (L, H, Y, N, R, E, D, T and S), according to a key that assigns a letter to each number. Scores are derived by counting the number of digits correctly converted within 90 s. Different versions were used at the 3 times of measurement, using the same letters but with differing corresponding digits to reduce learning effects. Validation in a sample of secondary school students in India has shown that the DLST has good test–retest reliability, $r = .97$, as well as fair convergent validity with other established measures of information processing speed such as Letter copying, $r = .40$ (Pradhan, 2013).

The Sky Search task is a subtest from the Test of Everyday Attention for Children (TEA-Ch), a well-known instrument for measuring the attention of

children (Manly et al., 2001). The Sky Search task measures children's selective attention independent of their reading ability. Selective attention is a component of executive function that is posited to play a significant role in the learning process (Yli-Krekola, Särelä, & Valpola, 2009) and is defined as the ability to attend to relevant stimuli while ignoring irrelevant stimuli. The test consists of an A4 sheet with rows of figures depicting pairs of spacecrafts. Some pairs consist of two different figures (or spacecrafts), other pairs consist of identical figures. Children were instructed to underline as many pairs of identical spacecrafts in 40 s. The test score was calculated as the total number of correctly underlined identical pairs. Different versions of the test with different configurations of the spacecrafts were used at each time of measurement to reduce learning effects. Validation of the TEA-Ch in a sample of Australian children has shown that the Sky Search subtest has good test–retest reliability across age groups, $r = .90$, as well as convergent validity with other established measures of attention such as the Stroop task, $r = .40$, and the Trails Test A, $r = .69$ (Manly et al., 2001).

Well-being. At each time of measurement, children answered several questions about their emotional, cognitive, and social well-being. Momentary mood state was assessed by an author-developed smiley-test with eight emotions (content, happy, confident, angry, tired, anxious, quiet, and sad). Every emotion was displayed on a Likert-type scale ranging from 1 = *not at all applicable* to 5 = *very applicable*. The two ends of the scale (i.e., *not happy–very happy*) were always illustrated with matching smiley faces. The scale showed good reliability, with Cronbach's α of .78 at baseline, .72 at first follow-up, and .75 at second follow-up.

Self-reported ability to concentrate was assessed with five questions from a validated Dutch instrument for assessing children's functioning in the educational and school environment (Local and National Youth Health Monitor, 2010). Sample questions are as follows: "Do you find it difficult to sit still during the lessons?" "Can you keep your attention focused on the lessons?" and "Do you get bored during the lessons?" Responses were given on a 4-point scale with 1 = *never*, 2 = *sometimes*, 3 = *often*, 4 = *very often*. The reliability of the scale was somewhat low but sufficient, with Cronbach's α of .61 at baseline, .66 at first follow-up, and .69 at second follow-up.

The social climate in the classroom was measured with 10 statements from the Dutch Climate Scale, a well-validated instrument for use among schoolchildren that has been found to show good test–retest reliability and convergent validity with related instruments like the Achievement motivation test for children (Donkers & Vermulst, 2011). Sample items are "I think my class is fun," "children in this class help each other," and "there are children

in my class who sometimes hit or kick each other." Children rated each statement on a 4-point scale with 1 = *not true*, 2 = *somewhat true*, 3 = *true*, 4 = *very true*. The scale showed good reliability, with Cronbach's α of .72 at baseline, .78 at first follow-up, and .81 at second follow-up.

Self-image was measured using a list of four positive statements (sample item "I am proud of myself") and four negative statements (sample item "I would rather be somebody else than myself") from the subscales on physical appearance and global self-worth of a Dutch version from the well-validated and established Harter's Self-Perception Profile for Children (Harter, 1985). Children rated each statement on a 4-point scale with 1 = *not true*, 2 = *somewhat true*, 3 = *true*, 4 = *very true*. The scale showed good reliability, with Cronbach's α of .71 at baseline and .74 at the two follow-ups.

For each of the well-being scales, responses to the single items were combined into one average score in such a way that higher scores indicated greater well-being.

Classroom evaluation. At each time of measurement, children answered several questions about their classroom. First, they were asked, by means of an open-ended question, to give a description of the classroom in three key words or phrases. The words were classified into three categories: positive, neutral, and negative. Words that referred to the green wall were coded as neutral if the wall or the plants were simply mentioned without further addition (e.g., "plants"), they were coded as positive if a positive adjective was used (e.g., "nice plants"), and they were coded as negative if a negative adjective was used (e.g., "boring plants"). For each child, the number of words in each category was counted and an overall score was calculated as the number of positive words minus the number of negative words (minimum = −3, maximum = 3).

After the open question, children provided a numerical score for their classroom on a scale from 1 to 10 (1 = *worst score* and 10 = *best score*). They also evaluated the attractiveness of the classroom on an author-developed environmental assessment scale that consisted of six positive words (beautiful, special, natural, relaxing, cheerful, a nice place) and six negative words (boring, barren, uncomfortable, crowded, dirty, and small). Similar scales have previously been used in research on benefits of interior plants (Lohr & Pearson-Mims, 2008). Children rated each item on a 4-point scale with 1 = *not true*, 2 = *somewhat true*, 3 = *true*, 4 = *very true*. The scale showed good reliability with Cronbach's α of .77 at baseline and .82 at the two follow-ups. Responses were combined into one average score, with higher scores indicating a more attractive classroom.

Evaluation of the Green Wall

During the two follow-ups, children in the experimental groups answered several additional questions about the green wall. They indicated their liking of the green wall on a scale with response options 1 = *I like it very much*, 2 = *I like it a little*, 3 = *I do not like it*, 4 = *I do not care*. Children provided a score for the green wall on a scale from 1 to 10 (1 = *worst score* and 10 = *best score*). Children were asked to give a description of the green wall in three key words or phrases. The words were classified into three categories: positive, neutral, and negative. For each child, the percentage of words in each category was calculated. Children were presented with a list of 10 statements that described possible changes after the placement of the green wall. The statements were consistent with the effect measures that were administered at each time of measurement. Sample statements are "the plants have made the classroom more attractive," "the air quality has improved after the placement of the plants," and "the plants make the classroom more crowded." Each item was rated on a 4-point scale with 1 = *not true*, 2 = *somewhat true*, 3 = *true*, 4 = *very true*. During the second follow-up, children were asked whether they wanted the green wall to stay in their classroom, with response options 1 = *very much*, 2 = *a little*, 3 = *no*, 4 = *do not care*.

Procedure

Two research assistants visited each school 3 times to collect the data. The first visit (baseline measurement) took place in the first week of October 2014—a few days before the green walls were placed. The second visit (first follow-up) took place 2 months after the placement of the green walls in the first week of December 2014. The third visit (second follow-up) took place 4 months after the placement of the green walls in the first week of February 2015. Schools were always visited on the same day of the week (School A on Wednesdays and School B on Tuesdays), and on every study day, classes were visited in the same order, so that the time of data collection for each class was about the same for each measurement. In each class, the tests and questionnaires were administered group-wise according to a standardized protocol. To reduce influences of momentary events and disturbances, each test session started with a short breathing exercise. In the classrooms with a green wall, children were asked to look at the plants during the exercise. In the classrooms without a green wall, children were asked to close their eyes. The relaxation exercise was followed by the attentional tests, with the DLST being administered first at each session, followed by the Sky Search task.

Each test started with a practice trial on a limited number of items. After completing the two attentional tests, children were allowed to independently fill in the questionnaires. They were instructed to be quiet and to not talk to each other. They were encouraged to ask questions if anything was unclear to them, in which case the assistant would go to their table to help out. The total duration of each session was about 20 min; sessions in the groups with a green wall took a little longer because of the extra questions about the green wall.

Analysis

Statistical analyses were performed using SPSS version 20. Prior to analyzing the effects of the green wall, we screened the data for baseline differences and differences between schools and grade levels using one-way ANOVAs. Effects of the green walls were tested using repeated measures ANCOVAs, with time (T2, T3) as a within-subjects factor, condition (green wall, control) as between-subjects factor, and baseline scores, school, and grade level as covariates. Evaluations of the green wall at the two follow-up measurements were analyzed using descriptive statistics and frequency distributions. For outcome variables that comprised both positively and negatively worded items (e.g., mood, classroom attractiveness, social climate, self-image), exploratory analyses were carried out on scores for positive and negative subscales separately. The results of these analyses did not differ appreciably from those conducted with the overall scores; therefore, we report only the results for the overall measures. Detailed information on all outcome variables, including mean values, frequencies, and statistical tests results is available in Tables A1 to A3 in the online appendix.

Results

Preliminary Analyses

At baseline, the experimental groups gave a higher average score to their classroom, $M = 8.29$, $SD = 1.42$, than the control groups, $M = 7.81$, $SD = 1.39$, $F(1, 164) = 4.90$, $p = .03$, $\eta_p^2 = 0.03$. There were no significant baseline differences between groups with and without a green wall on any of the other outcome measures, $ps > .19$ (see Table A1 in the online appendix for an overview of means and standard deviations). Baseline scores were significant predictors of the follow-up scores, all $ps < .01$. There were significant differences between schools and grade levels, independent of the green wall. Across times of measurements, children of School A scored better on the DLST than

children of School B, and they evaluated their classroom more positively, *p*s < .01. Scores on the attentional tests increased with grade level, whereas evaluations of the classroom decreased with grade level, *p*s < .05.

Comparison of Groups With and Without a Green Wall

Attention. Scores on the DLST improved from the first to the second follow-up, as indicated by a significant main effect of time, $F(1, 165) = 11.68$, $p = .001$, $\eta_p^2 = 0.07$. This improvement could reflect a learning or maturation effect. However, inconsistent with Hypothesis 1, the green wall did not significantly influence the DLST scores, neither as a main effect, nor in interaction with time, *F*s < 1.

Scores on the Sky Search also improved from the first to the second follow-up, $F(1, 164) = 10.21$, $p = .002$, $\eta_p^2 = 0.06$. In addition, the main effect of condition was significant, $F(1, 164) = 4.55$, $p = .035$, $\eta_p^2 = 0.03$. As illustrated in Figure 3, children in the classrooms with a green wall identified more identical spacecrafts at the two follow-ups than children in the control groups, after controlling for baseline scores, grade level, and school, mean adjusted difference = 0.82, 95% confidence interval (CI) = [0.06, 1.57]. Although the difference between groups with and without a green wall was somewhat larger at the second follow-up than at the first follow-up, the interaction between condition and time did not reach significance, $F(1, 164) = 2.29$, $p = .132$, $\eta_p^2 = 0.01$. Thus, Hypothesis 1, concerning a positive impact of the green wall on children's cognitive performance, was supported for the Sky Search task but not for the DLST.

Well-being. Children reported high and stable levels of well-being at each time of measurement, with an overall mean mood score of 4.18, *SD* = 0.45; an overall mean concentration score of 3.04 *SD* = 0.52; an overall mean self-image score of 3.37, *SD* = 0.40; and an overall mean social climate score of 3.01, *SD* = 0.42. During the two follow-up measurements, no significant differences emerged between the groups with and without a green wall on any of the four well-being measures, neither as a main effect of condition, nor in interaction with time, *p*s > .11. Thus, Hypothesis 2, concerning a positive impact of the green wall on children's emotional and social well-being, was not supported.

Classroom evaluation. At baseline, the children in both the experimental and control groups predominantly used positive terms to describe their classroom, like "nice," "fun," and "beautiful," with an overall mean score of 1.21 positive-minus-negative words, *SD* = 1.52. During follow-up, there was a

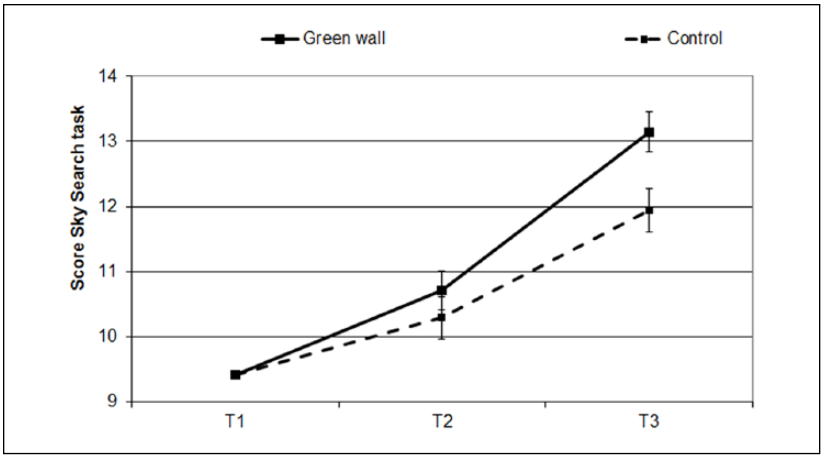

Figure 3. Scores on the Sky Search task in the experimental and control groups at the 3 times of measurement (T1 = baseline, T2 = first follow-up at two months after placement of green wall, T3 = second follow-up at three months after placement of green wall).
Note. Follow-up scores at T2 and T3 are adjusted for baseline scores, school, and grade level; error bars represent the standard error of the mean. For illustrative purposes, the overall mean baseline score at T1 is included in the graph.

significant interaction between time and condition, $F(1, 161) = 4.42$, $p = .037$, $\eta_p^2 = 0.03$. This interaction is illustrated in Figure 4. At the first follow-up, classroom descriptions in both the experimental and control groups were similar to baseline level, $F < 1$. At the second follow-up, children in the classrooms with a green wall described their classroom more positively than at baseline, whereas children in the control groups described their classroom less positively than at baseline, resulting in a significant difference between the experimental and control groups, mean adjusted difference = 0.64, 95% CI = [0.18, 1.10], $p = .007$. In particular, at the second follow-up, children in the groups with a green wall more frequently used words like "nice," "colorful," "beautiful," and "peaceful" to describe their classroom, and they less frequently used neutral words like "teacher," "computer," and "digiboard."

The classrooms were generally rated as "good" at each time of measurement, with an overall mean score of 8.01 on a 1 to 10 scale, $SD = 1.07$. Children in groups with a green wall gave a higher score to their classroom at baseline than children in the control groups, and this difference persisted during the two follow-ups. The green wall did not significantly affect the classroom scores at follow-up independent of the baseline differences, neither as a main effect, nor in interaction with time, Fs < 1.

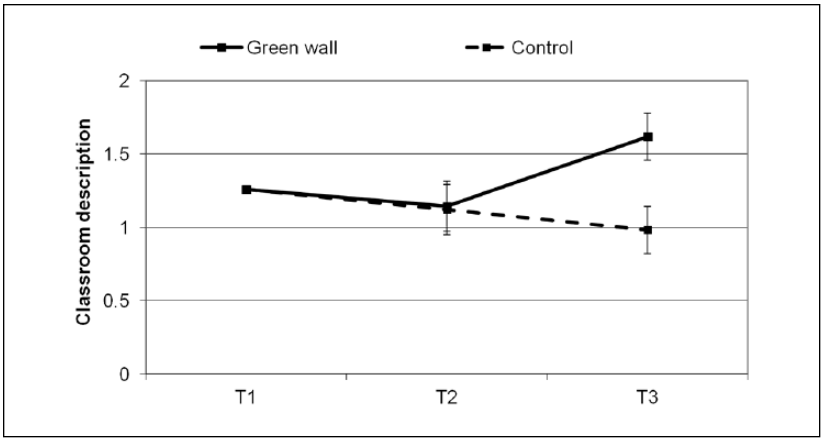

Figure 4. Description of the classrooms of the experimental and control groups at the 3 times of measurement (T1 = baseline, T2 = first follow-up at two months after placement of green wall, T3 = second follow-up at three months after placement of green wall)
Note. Scores represent the number of positive words minus the number of negative words used to describe the classroom (range = −3 to +3). Follow-up scores at T2 and T3 are adjusted for baseline scores, school, and grade level; error bars represent the standard error of the mean. For illustrative purposes, the overall mean baseline score at T1 is included in the graph.

At baseline, children in the experimental and control groups rated their classroom about equally attractive on a scale with 12 adjectives, with a mean overall baseline score of 3.0, $SD = 0.42$. Ratings of attractiveness of the classrooms generally decreased from the first to the second follow-up, $F(1, 153) = 10.82$, $p = .001$, $\eta_p^2 = 0.07$. In addition to this main effect of time, there also was a significant main effect of condition, $F(1, 153) = 4.00$, $p = .047$, $\eta_p^2 = 0.03$. During the two follow-up measurements, children in the groups with a green wall generally rated their classroom as more attractive than children in the control groups, mean adjusted difference = 0.11, 95% CI = [0.001, 0.227]. These effects are illustrated in Figure 5. In conclusion, Hypothesis 3, concerning a positive impact of the green wall on classroom evaluations, was supported for children's own descriptions and children's attractiveness ratings, but not for the classroom scores.

Evaluation of the Green Wall

Children generally reacted positively to the green wall (see Table A3 in the online appendix for an overview). During both follow-ups, more than half of

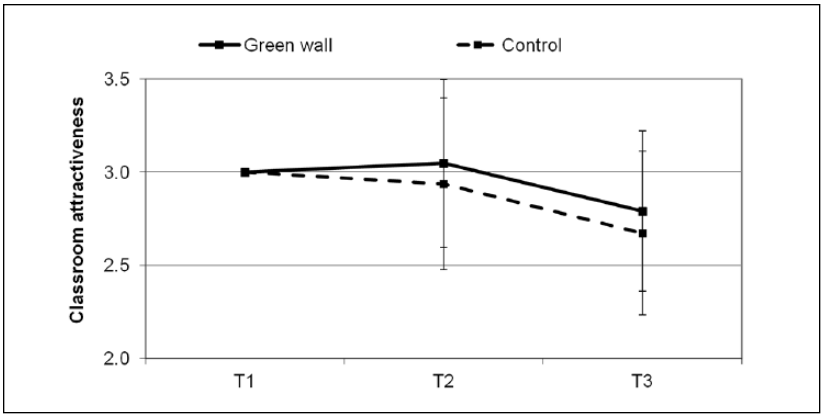

Figure 5. Evaluations of the attractiveness of the classrooms of the experimental and control groups at the 3 times of measurement (range = 1-4). (T1 = baseline, T2 = first follow-up at two months after placement of green wall, T3 = second follow-up at three months after placement of green wall).
Note. Follow-up scores at T2 and T3 are adjusted for baseline scores, school, and grade level, error bars represent the standard error of the mean. For illustrative purposes, the overall mean baseline score at T1 is included in the graph.

the children indicated that they like the green wall very much (T2: 52%, T3: 54%), and about one fifth liked it a little (T2: 20%, T3: 21%). Only a few children said that they do not like the green wall (T2: 2%, T3: 3%), and about a quarter were indifferent (T2: 26%, T3: 22%). Children also generally rated the green wall as "good," with a mean score of 8.33, 95% CI = [8.01, 8.65] at the first follow-up, and a mean score of 8.38, 95% CI = [8.06, 8.70] at the second follow-up. Across the two follow-ups, 93% of the children rated the green wall a 6 or higher, 73% gave an 8 or higher.

When asked to spontaneously describe the green wall in three words, the children predominantly used positive terms, with a mean score of 2.35 positive-minus-negative words, 95% CI = [2.13, 2.58] at the first follow-up, and a mean score of 2.47, 95% CI = [2.24, 2.71] at the second follow-up. Across the two follow-ups, 86% of the words used to describe the plant wall were positive, 6% of the words were negative, and 8% were neutral. The most frequently mentioned positive words were "beautiful," "nice," "natural," and "relaxed." The most frequently mentioned negative words were "boring," "crowded," "ugly," and "small." The most frequently mentioned neutral words were "plants," "usual," "normal," and "cabinet." Some children also provided short, positive comments instead of single words, like "I can work better," "gives atmosphere," "smells like nature," "like to look at it," "I love plants," and "must stay!"

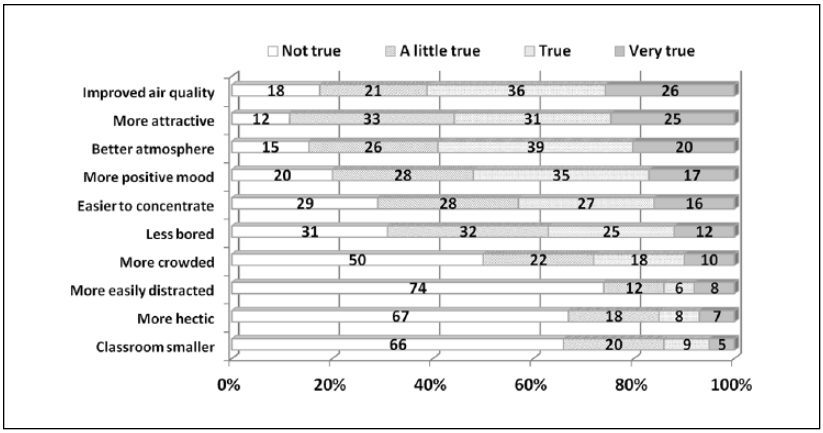

Figure 6. Frequencies of responses to statements about possible changes.
Note. Percentages represent the averages of children in the four classrooms with green walls pooled across the two follow-up measurements (at 2 and 4 months).

At the first follow-up, children tended to agree more strongly with both positive and negative changes that may be brought about by the green wall than at the second follow-up (see Table A3 in the online appendix). This suggests that children's awareness of the impacts of the green wall (both positive and negative) decreased over time. Apart from this difference, the rank-order of the 10 listed changes was very similar across the two follow-ups. Figure 6 gives an overview of the pooled average responses to the list of possible changes. Children agreed most strongly with the statement "the air quality has improved"; 62% of the children found this statement true or very true. A majority of children also found it true or very true that the green wall makes the classroom more attractive and stimulates a better atmosphere in the classroom and a more positive mood. Children were less convinced that the green wall improves their concentration and makes them feel less bored, the majority of the children found these statements only a little true or untrue. Of the negative changes, the statement that the green wall makes the classroom seem more crowded received most support, 28% of the children found this true or very true. There was little support for the other three negative changes ("more easily distracted," "more hectic," and "classroom looks smaller"); only 15% or less of the children found these statements true or very true.

During the second follow-up, children were asked whether they wanted the green wall to stay in their classroom. Sixty-one percent indicated that they want this very much; 19% indicated they want it a little; 4% said no; and 16% said that they do not care.

Discussion

In this study, we evaluated the restorative effects of green walls with living plants in four classrooms of two elementary schools, using a controlled prospective design with one baseline measurement and two follow-up measurements at 2 and 4 months. Controlling for baseline scores, children in classrooms with a green wall scored better on the Sky Search task—a test for selective attention—than children in control groups without a green wall. Children in the groups with a green wall also rated their classroom as more attractive than children in the control groups, and during the second follow-up, they used more positive words to describe their classroom. When asked directly at follow-up, a majority of the children said that they like the green wall in their classroom very much and want it to stay. Children also agreed that the plants had brought about many positive changes in the classroom. These findings strengthen the evidence base for benefits of interior plants (Bringslimark et al., 2009; van den Berg & van den Berg, 2014) and extend current knowledge by examining green walls as an innovative indoor plant concept. However, it is important to note that effect sizes were small, and we also uncovered no evidence for beneficial impacts of the green wall on children's emotional and social well-being.

The positive effects of the green wall on children's selective attention are in line with previous studies showing that a natural environment can support and enhance cognitive functioning in both children and adults (for a review, see Bratman, Hamilton, & Daily, 2012). Scores on the DLST—a more basic information processing task—were not significantly affected by the green wall, even though this task was administered before the Sky Search task, and thus, more likely to be directly influenced by children's contemplation of the green wall at the start of each session. Thus, as predicted by ART (S. Kaplan & Berman, 2010), it is directed attention, or executive functioning, specifically, that is improved by the green wall. Executive functions are critically important in learning processes; for that reason, these findings suggest that a green wall may positively contribute to student performance, as has previously been reported in an Australian study on plants in classrooms (Daly et al., 2010).

The finding that the green wall positively influenced children's evaluations and descriptions of their classroom is consistent with previous research on plants in schools (Fjeld, 2000; Han, 2008). Impacts of the green wall on classroom descriptions were, however, only observed at the second follow-up. This may be related to the fact that the first follow-up measurement took place in the beginning of December, close to Saint Nicholas Day [Sinterklaas], an important holiday for children in the Netherlands. In this period,

classrooms are festively decorated, which perhaps made the green wall less noticeable. The stronger impacts of the green wall on classroom descriptions at the second follow-up may also be related to the fact that, after 4 months, the plants in the wall were more lush and fully grown, and thereby perhaps more impactful.

Contrary to the expectations, we were unable to demonstrate any effects of the green wall on the well-being measures, including mood, self-reported concentration, social climate, and self-image. These non-significant findings may indicate a genuine lack of effectiveness of the intervention, which may have been too limited in extent or scope to sustain a prolonged restoration that fosters overall well-being. However, methodological issues may also have played a role. In particular, the finding that children generally reported high levels of well-being suggests the presence of response bias. For reasons of self-protection or to fulfill the experimenter's expectations, children may have overestimated their well-being, or selectively focused on things that are going well at each time of measurement. Another possibility is that our measurements, collected during two brief visits to the schools, failed to capture the full well-being impacts of the green wall. This latter explanation is corroborated by the finding that the majority of children in the experimental groups indicated that the green wall had improved their mood and the atmosphere in the classroom.

Limitations and Suggestions for Future Research

This study is not without limitations. Although the follow-up period extended up to 4 months, prolonged change cannot be implied. Because this was a non-randomized trial, it is not possible to draw strong causal conclusions on effects of the green wall. Alternative explanations for the findings cannot be excluded, including potential non-equivalence of groups at baseline (i.e., on variables not assessed). In addition, these results should be approached cautiously because of the use of self-reported data, which may be prone to response bias and thereby pose a threat to construct validity (Van de Mortel, 2008). The use of author-developed scales for the assessment of mood and the classroom environment presents a further threat to construct validity, and also limits comparability with other studies. Another limitation concerns the homogeneous selection of schools, which were both housed in modern buildings with a good indoor climate and a non-deprived population. This compromises external validity by limiting generalizability to other types of schools. The control group in the study was a passive control group that did not receive any kind of intervention. Therefore, the study does not speak to whether green walls are better than other classroom interventions. Last, the green wall

only formed a decorative intervention that was not included in the educational program and did not invite children to interact with the plants. This may have limited children in their ability to connect with or form an emotional bond with the plants (Kellert, 2002).

To examine prolonged change regarding the restorative effects of green wall, future studies with longer follow-up periods should be conducted. Random assignment of classrooms to conditions is also recommended, as well as the use of objective measures of children's functioning such as parental or teacher ratings, sick leave records, or physiological stress measures (e.g., Li & Sullivan, 2016). Stronger effect sizes may be obtained with schools with more deprived populations or poorer indoor climate. To gain more insight into the relative effects of a green wall, control conditions with other interventions like, for example, artwork, might be included. It would also be interesting to control green walls against traditional potted plants. By including the green wall in educational programs, or by using designs that invite interaction with the plants, the potential benefits of a green wall may be more fully realized.

Conclusion

A green wall provides a low-maintenance and space-efficient indoor solution for bringing nature into the classroom. This is the first research to show that a green wall can support children's cognitive functioning and make the classroom a more attractive place. These are important findings given that children spend a large proportion of their childhood in school. We hope that these results will be utilized to help prioritize the inclusion of green walls in schools.

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References

Bagot, K. L., Allen, F. C. L., & Toukhsati, S. (2015). Perceived restorativeness of children's school playground environments: Nature, playground features and play period experiences. *Journal of Environmental Psychology*, *41*, 1-9. doi:10.1016/j.jenvp.2014.11.005

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*(1), 118-136. doi:10.1111/j.1749-6632.2011.06400.x

Bringslimark, T., Hartig, T., & Patil, G. G. (2009). The psychological benefits of indoor plants: A critical review of the experimental literature. *Journal of Environmental Psychology*, *29*, 422-433. doi:10.1016/j.jenvp.2009.05.001

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

CLEAPPS. (2009). *G42 Plants for classrooms*. Uxbridge: CLEAPPS. Retrieved from www.cleapss.org.uk/attachments/article/0/G42.pdf?Primary

Corraliza, J. A., Collado, S., & Bethelmy, L. (2012). Children's perceived restoration: Adaptation of the PRCS for Children to a Spanish sample. *Psyecology*, *3*, 195-204. doi:10.1174/217119712800337729

Daly, J., Burchett, M., & Torpy, F. (2010). *Plants in the classroom can improve student performance*. Sydney: University of Technology. Retrieved from www.wolvertonenvironmental.com/Plants-Classroom.pdf

Dobbs, K., Relf, D., & McDaniel, A. (1998). Survey on the needs of elementary education teachers to enhance the use of horticulture or gardening in the classroom. *HortTechnology*, *8*, 370-373.

Donkers, A., & Vermulst, A. (2011). *Klimaatschaal* [Climate scale]. Retrieved from www.klimaatschaal.nl/docs/Paginateksten/Vragenlijst%20klimaatschaal.pdf

Doxey, J. S., Waliczek, T. M., & Zajicek, J. M. (2009). The impact of interior plants in university classrooms on student course performance and on student perceptions of the course and instructor. *HortScience*, *44*, 384-391.

Fjeld, T. (2000). The effect of interior planting on health and discomfort among workers and school children. *HortTechnology*, *10*, 46-52.

Han, K.-T. (2008). Influence of limitedly visible leafy indoor plants on the psychology, behavior, and health of students at a junior high school in Taiwan. *Environment & Behavior*, *51*, 658-692. doi:10.1177/0013916508314476

Harter, S. (1985). *The Self-Perception Profile for Children: Revision of the Perceived Competence Scale for Children* (Manual). Denver, CO: University of Denver.

Joye, Y., & Van den Berg, A. E. (2011). Is love for green in our genes? A critical analysis of evolutionary assumptions in restorative environments research. *Urban Forestry & Urban Greening*, *10*, 261-268. doi:10.1016/j.ufug.2011.07.004

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*, 169-182. doi:10.1016/0272-4944(95)90001-2

Kaplan, S., & Berman, M. G. (2010). Directed attention as a common resource for executive functioning and self-regulation. *Perspectives on Psychological Science*, *5*, 43-57. doi:10.1177/1745691609356784

Kellert, S. R. (2002). Experiencing nature: Affective, cognitive and evaluative development in children. In P. H. Kahn & S. R. Kellert (Eds.), *Children and nature: Psychological, sociocultural, and evolutionary investigations* (pp. 117-151). Cambridge, MA: MIT 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 & Behavior*, *47*, 119-139. doi:10.1177/0013916513510528

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. doi:10.1016/j.landurbplan.2015.12.015

Local and National Youth Health Monitor. (2010). *Functioning in the educational/school environment-412-questionnaire child*. Available from https://www.monitorgezondheid.nl https://www.monitorgezondheid.nl/jeugdindicatoren.aspx

Lohr, V. I., & Pearson-Mims, C. H. (2008). People's response to discomfort in the presence of interior plants or art. *Acta Horticulturae*, *790*, 173-178. doi:10.17660/ActaHortic.2008.790.24

Manly, T., Anderson, V., Nimmo-Smith, I., Turner, A., Watson, P., & Robertson, I. H. (2001). The differential assessment of children's attention: The Test of Everyday Attention for Children (TEA-Ch), normative sample and ADHD performance. *The Journal of Child Psychology and Psychiatry*, *42*, 1065-1081. doi:10.1017/S0021963001007909

Manso, M., & Castro-Gomes, J. (2015). Green wall systems: A review of their characteristics. *Renewable & Sustainable Energy Reviews*, *41*, 863-871. doi:10.1016/j.rser.2014.07.203

Mendell, M. J., & Heath, G. A. (2005). Do indoor pollutants and thermal conditions in schools influence student performance? A critical review of the literature. *Indoor Air*, *15*(1), 27-52. doi: 0.1111/j.1600-0668.2004.00320.x

Natu, M., & Agarwal, A. (1995). Digit Letter Substitution Test (DLST) as an alternative to Digit Symbol Substitution Test (DSST). *Human Psychopharmacology: Clinical & Experimental*, *10*, 339-343. doi:10.1002/hup.470100414

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*, 447-454. doi:10.2503/jjshs1.77.447

Pegas, P., Alves, C., Nunes, T., Bate-Epey, E., Evtyugina, M., & Pio, C. (2012). Could houseplants improve indoor air quality in schools? *Journal of Toxicology and Environmental Health, Part A*, *75*, 1371-1380. doi:10.1080/15287394.2012.721169

Pradhan, B. (2013). *Effects of cyclic meditation in psychomotor performance on children* (Doctoral thesis, S-VYASA University, Bangaluru). Retrieved from http://hdl.handle.net/10603/9351

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 Press.

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*, 201-230. doi:10.1016/S0272-4944(05)80184-7

Van de Mortel, T. F. (2008). Faking it: Social desirability response bias in self-report research. *The Australian Journal of Advanced Nursing*, *25*(4), 40-48.

Van den Berg, A. E., & Van den Berg, C. (2011). A comparison of children with ADHD in a natural and built setting. *Child: Care, Health and Development*, *37*, 430-439. doi:10.1111/j.1365-2214.2010.01172.x

Van den Berg, A. E., & Van den Berg, M. M. H. E. (2014). Health benefits of plants and green space: Establishing the evidence base. *Acta Horticulturae*. *1093*, 19-30. doi:10.17660/ActaHortic.2015.1093.1

Wesselius, J., Maas, J., & Hovinga, D. (2015). *De 'leerkracht' van schoolpleinen: Hoe leerlingen uit groep 4, 5 en 6 het schoolplein ervaren, gebruiken en waarderen* [The educational power of schoolyards: How children in groups 4, 5 and 6 experience, evaluate and use the schoolyard]. Leiden, The Netherlands: Hogeschool Leiden. Retrieved from https://www.hsleiden.nl/natuur-en-ontwikkeling-kind/publicaties-en-presentaties

Wu, C.-D., McNeely, E., Cedeno-Laurent, J., 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*(10), e108548. doi:10.1371/journal.pone.0108548

Yli-Krekola, A., Särelä, J., & Valpola, H. (2009). Selective attention improves learning. In C. Alippi, M. Polycarpou, C. Panayiotou, & G. Ellinas (Eds.), *Artificial Neural Networks—ICANN 2009* (pp. 285-294). Berlin: Springer.

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