



Short-Term Exposure to Nature and Benefits for Students' Cognitive Performance: a Review

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Abstract

There is growing interest recently in the outdoor environment surrounding schools where students spent time during breaks, in-school activities, and after-school programs. Several reviews have examined the impact of long-term exposures to nearby nature on students' academic achievement, but none has focused on the effects of short-term contacts with nature on students' cognitive performance. The aim of this review is to understand the context in which short-term passive exposures to greenness occur, how cognitive performance is measured, and the conditions under which cognitive benefits emerge at various educational levels. We reviewed 14 studies in the extant literature that report investigations involving students at different educational levels, from elementary school to university, in a short exposure to nature lasting from 10 to 90 min during a study day. The review shows that in 12 out of the 14 studies, across educational levels, cognitive benefits emerge in terms of directed attention restoration from mental fatigue due to contact with nature. A no-cost opportunity to sustain students' cognition is a break in a green environment after mentally demanding activities.

Keywords Cognitive performance · Student cognitive functioning · School environment · Natural environment · Green breaks · Attention

Introduction

In educational psychology research, it is well known that academic functioning is influenced by cognitive (e.g., Petrill & Wilkerson, 2000), motivational (e.g., achievement goals; Wirthwein et al., 2013), and socio-emotional (e.g., Kulkarni et al., 2020) individual factors. Contextual variables, for example, family socioeconomic

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status (e.g., Rodríguez-Hernández et al., 2020) and parental expectations (Pinquart & Ebeling, 2020), have also been investigated, as well as school-related factors such as technological resources (e.g., Zheng et al., 2016), school climate (e.g., Wang & Degol, 2016), and teaching strategies (e.g., Caro et al., 2016). In contrast, except for very few studies (Weinstein, 1979), in educational psychology research, the physical environment of the school, where students spend a lot of time, has not received relevant attention like in other areas of psychology. For example, in environmental and urban design research, it has been shown how noise, lighting, thermal comfort, quality of indoor air, and conditions of the buildings all affect students' achievement (Cheryan et al., 2014).

Even more recent is the growing interest in the outdoor environment surrounding schools where students spent time during recess, in-school activities (e.g., physical education), and after-school programs (e.g., Li et al., 2019), as well as interest in green spaces on campuses (e.g., Föllmer et al., 2021). Specifically, the impact of exposure to nearby nature has become the focus of empirical studies aimed at documenting the benefits that such exposure has for academic achievement and behavior. Positive effects of green surroundings have been documented for university students (Föllmer et al., 2021; Liu et al., 2018) and students of primary and secondary school when considering their academic performance in main school subjects (Kuo et al., 2021; Kweon et al., 2017; Leung et al., 2019; Lin & Van Stan II, 2020; Luis et al., 2020; Matsuoka, 2010; Tallis et al., 2018; Wu et al., 2014).

In this regard, it has been suggested that school performance might even “grow on trees” as in more than three hundred of urban, high-poverty public elementary schools of a district in Chicago (USA), students' better math scores were predicted by green cover, specifically tree cover in the schoolyards, after controlling for a number of variables (e.g., disadvantage as a combination of poverty and minority status; Kuo et al., 2018a, b). Similar results were obtained when considering a large number of elementary schools in the Toronto (Canada) school district for standardized scores in reading, writing, and math in third and sixth graders (Sivarajah et al., 2018); a large number of primary schools in the Twin Cities metropolitan area in Minnesota (USA) for students' reading performance (Hodson & Sander, 2016); a large number of schools in Oregon (USA) for students' standardized reading and math scores (Donovan et al., 2020); or, again, elementary schools attended by a diverse population in the metropolitan area of Atlanta (USA) for achievement in four subjects (English language arts, math, science, and social science; Lin & Van Stan II, 2020). These outcomes are impressive and add to our knowledge the relevance of greenness in general, given the estimation that in ten large US cities, children growing up in environments with the most vegetative cover will earn, on average, cumulatively \$28,000 more in a 30-year career compared to children growing up in environments with the least cover (Browning & Rigolon, 2019).

The use of natural spaces surrounding schools is important to support academic functioning (Lin & Van Stan II, 2020), but this issue seems poorly acknowledged. Yet, there is evidence of the benefits of regular education that systematically takes place outside the classroom in natural environments. For instance, over one school year of outside education for at least 2 h a week, students in grades three to six improved their reading performance (Otte et al., 2019). Interestingly, Kuo et al.

(2018b) also documented positive effects in students after lessons in nature, in terms of their engagement during indoor instructional periods. Teacher ratings of classroom engagement, the number of times teachers stopped instruction to redirect students' attention back to the task at hand, and independent photo-based ratings revealed an advantage for lessons in nature compared to carefully matched classroom lessons.

Of note is that also the nature that is viewed from the classroom windows can make a difference. Matsuoka (2010), for example, indicated that high school students' standardized test scores and graduation rates were positively associated with greater density of trees and shrubs of window landscapes of school cafeterias and classrooms, while negative associations emerged between landscapes without natural elements and the same indices of academic performance. Benfield et al. (2015) documented that college students had higher scores for a writing course at the end of the semester when they were in a classroom with a view of a natural setting compared to a classroom with a concrete retaining wall.

Van den Berg et al., 2017 found that elementary students in classrooms with a green wall of living plants had high scores in selective attention. Furthermore, natural features of school landscapes are also associated with students' improved adjustment (Sajady et al., 2020). However, for the sake of a more complete introduction, it should be pointed out that academic functioning and success are not only related to the presence of natural elements in the physical environment of the schools or surrounding areas. Other aspects of environmental quality, for instance, air pollution, can also make a difference in academic success or failure. Research has documented that students attending schools in areas with high levels of air pollutants had the lowest attendance rate—which may reflect health problems—and failed to meet state educational testing scores (Mohai et al., 2011).

As we will introduce in the next section, given that the focus of the present investigation is on greenness, the underlying explanation for the positive cognitive effects is that nature recovers mental resources as it increases attentional capacity (Kaplan, 1995), which is crucial in executing cognitive tasks (Demaray & Jenkins, 2011; Diamond et al., 2007). We also know that nature not only positively impacts cognition but also affects as it reduces psychophysiological stress (Ulrich et al., 1991) and increases affective benefits in terms of reduced anxiety, rumination, and negative emotions (Bratman et al., 2015). Positive affect is positively associated with cognitive functioning and academic performance (e.g., Scrimin & Mason, 2015).

Interestingly, many empirical studies documenting the nature-academic performance relationship are published in journals outside the area of psychological research, even though they are psychologically founded to explain why exposure to nature is beneficial, as we will argue in the next section. When the relation nature-academic functioning is examined within the psychological research, it mainly regards environmental psychology. Yet, educational psychology research must be interested in the possible influences that the physical environment may have on students' performance, behavior, and wellbeing at all educational levels.

Reviews and meta-analyses have confirmed that long-term exposure to greenness is beneficial to academic achievement (e.g., Browning & Rigolon, 2019; Kuo et al., 2019; Lin & Van Stan II, 2020), although there is also evidence of some mixed

results (Beere & Kingham, 2017; Browning et al., 2018) that may even be due to the variety of the measures of green spaces surrounding schools, which are provided by sensors at different resolutions (Browning & Locke, 2020). However, if the positive effects of long-term exposure to nature are well documented, we know much less about short-term contacts with greenness. These include brief exposures to nature that may, for example, occur daily at no cost when students take a break. The aim of this review is to contribute to the literature by enriching our knowledge of the effects of the physical environment—specifically short-term exposures to a green environment—on students’ cognitive or academic performance at different educational levels.

Restorative Effects of Nature

Why is exposure to nature assumed to be beneficial? Two theoretical approaches have been proposed to explain its positive effects: attention restoration theory (ART; Kaplan, 1995) and stress reduction theory (SRT; Ulrich et al., 1991).

Attention Restoration Theory (ART) The salutary effects of nature on cognitive functioning are explained by the ART. According to ART, visual exposure to nature has intense restorative impact on directed attention (Kaplan, 1995; Kaplan & Berman, 2010). Kaplan relied on a distinction between two types of attention on the basis of the effort involved: involuntary attention and voluntary or directed (sustained) attention. Involuntary attention regards automatic attention that does not require mental resources; for example, when something interesting or unusual happens, we pay involuntary attention to it as an act of “looking to discover what is going on” (Kaplan & Berman, 2010, p. 46). According to Kaplan and Berman (2010), involuntary interesting stimuli are, for example, strange things or wild animals that attract our attention. In contrast, voluntary or directed attention is not automatically invoked as it is activated when we put effort to pay attention to what is not particularly interesting per se, and to remain focused on it. Although it is difficult to define an action as entirely automatic or not and attentional tasks are not necessarily entirely voluntary or entirely directed, it can be said that involuntary attention is more automatic and bottom-up stimulus-driven, while directed attention is more controlled and goal directed. The latter is also susceptible to fatigue and takes distractions under control through the use of inhibition (Kaplan, 1995; Kaplan & Berman, 2010). We all know that after intense mental work, we feel exhausted. Mental fatigue is a familiar experience related to cognitive overload and concomitant depletion of mental resources, which are often accompanied by irritability.

ART theory grounds on the assumption that directed attention more likely recovers if it is allowed to rest. One way to allow voluntary or directed attention to rest is to use involuntary attention, so that the former is not necessary. Restorative environments are those that generate “soft fascination” as they gently attract our involuntary attention without overwhelming the entire attentional system. Natural environments, like gardens, parks, and forests are rich of stimuli (e.g.,

bird songs, butterflies) that softly capture our involuntary attention minimizing voluntary attention. After exposure to greenness, the cognitive capacity to focus attention is restored (Kaplan, 1995; Kaplan & Berman, 2010). Most studies that document the benefits of contact with nature are based on ART (e.g., Johnson et al., 2019). Unlike natural environments, urban environments have only poor restorative power as they offer bottom-up stimuli that require directed attention to overcome them, for example, avoiding traffic and ignoring advertising. The simultaneous combination of capturing involuntary attention and limiting the need for directing attention is the essence of a restorative environment like a natural one (Kaplan & Berman, 2010, p. 49). A systematic review has reported the diversity of evidence of ART when considering samples, study designs, and outcomes but also positive effects of natural environment on attention functioning (Ohly et al., 2016).

Stress Reduction Theory (SRT) The salutary effects of nature on emotional functioning are also explained by the stress reduction theory (Ulrich, 1981; Ulrich et al., 1991). Stress is an individual physiological, psychological, and behavioral response to an environmental stimulus that challenges or threatens our wellbeing. The physiological component manifests in various systems of our body, for example, the cardiovascular and neuroendocrine systems that are activated to cope with the environmental demands, but this activation (arousal) spends resources and fatigue occurs when it is prolonged. The psychological component can be linked with emotions like sadness, anxiety, or anger as a result of the cognitive appraisal of a situation. The behavioral component refers to various manifestations, such as performance avoidance and decrease in cognitive functioning (Ulrich et al., 1991).

According to SRT, exposure to nature sustains stress recovery as physiological parameters indicate, for example, reduction in blood pressure and stress hormone. Unlike urban environments, natural environments have restorative power because of the role they played during our species evolution (Ulrich, 1981). From this perspective, contact with nature activates the parasympathetic nervous system that reduces physiological arousal for our innate connection to the natural world which offered protection for safety. In Ulrich's (1981) theory, restoration from stress does not include only recovery from extremely high psychophysiological arousal, but also refuel of energy that has been used in responding to stress. Recovery from psychophysiological stress leads to enhancing wellbeing. Several studies support SRT indicating lower physiological stress responses in individuals of different ages (e.g., Tyrväinen et al., 2014). It has also been documented that redesigning a schoolyard to make it greener increased students' psychological wellbeing, who perceived the outdoor environment as more restorative after the redesign, and reduced their physiological stress (Kelz et al., 2015).

A Synthesis of ART and SRT Both theories consider natural environments as more restorative than urban environments but differ for what drives individuals toward a restorative environment. For ART, this is mental fatigue, while physiological stress

for SRT (Berto, 2014). However these two theories are not incompatible. From the one hand, lack of directed attention, due to inadequate resources, can be related to stress. On the other hand, attention restoration can be based on stress reduction with consequential positive changes in physiological responses and emotional states (Han, 2017; Li & Sullivan, 2016).

Linking Attention Restoration, Cognitive Functioning, and Academic Performance

Directed attention is a fundamental cognitive resource shared by executive functioning and self-regulation tasks (Kaplan & Berman, 2010) that are essential to academic performance (Diamond, 2013; St Clair-Thompson & Gathercole, 2006). Both executive functioning and self-regulation, in fact, require volitional effort or attention which, as a resource, is limited in amount and subject to depletion (Kaplan & Berman, 2010). Executive functions are fundamental mechanisms underlying complex cognitive tasks that involve planning, impulse control, flexible application of strategies, and goal-directed behavior. According to the Miyake et al. (2000) well-known model, the three main executive functions are updating, shifting, and inhibition. Updating is the continuous refreshing of task-relevant information and its maintaining in working memory. Shifting means switching between task goals or sets of tasks, that is, adjustment to change. Inhibition includes self-control (behavioral inhibition) and interference control (selective attention and cognitive inhibition) to suppress dominant responses in favor of more task appropriate responses.

From a developmental perspective, it is worth noting that both sustained attention and executive functions are subject to progression from childhood to adulthood. Specifically, attention has been widely studied in primary school-aged children (5–12 years) and research has indicated rapid development from 5–6 to 8–9 years, followed by a plateau from 8–9 to 11–12 years with only minor improvements (e.g., Betts et al., 2006). More recently, attention development has been investigated not only during adolescence, showing larger improvements with the age until 16 (Thomson et al., 2020), but also over the life span. After adolescence, sustained attention ability continues to improve, although slowly, and peaks in the mid-1940s, and then gradually declines in older adults (e.g., Fortenbaugh et al., 2015). The larger improvement during adolescence is related to neurobiological changes (e.g., myelination, synaptic pruning) associated with protracted maturation of the frontal lobes that continues into early adulthood (Thillay et al., 2015).

Executive functions have also been widely studied in young children, especially preschoolers, but there is established evidence that working memory updating, shifting, and inhibition develop through childhood into adolescence and early adulthood, although with some variations in their trajectories. Specifically, according to most evidence, the developmental trajectory of updating in working memory is linear from preschool through adolescence (Best & Miller, 2010; Diamond, 2013). The trajectory of inhibition shows rapid early improvements that are then followed by slower advances through adolescence and further development into adulthood, while the trajectory of shifting is characterized by a protracted development through adolescence (Best & Miller, 2010).

Executive functions are related to self-regulation, that is, the process that maintains optimal levels of cognitive, motivational, and emotional arousal leading to positive adjustment and adaptation, as reflected in engagement, achievement, and positive social relationships and self-concept (Blair & Diamond, 2008). In essence, self-regulation skills imply regulation of attention and behavior to meet the demands of a situation (Liew, 2011). It is quite intuitive that executive functioning and self-regulation play an important role in cognitive performance in educational contexts (e.g., Butterfuss & Kendeou, 2018; Mason & Zaccoletti, 2021). During a science reading comprehension task, for example, a text on a physical phenomenon about which students have a misconception, partial processing results should be stored in working memory and retrieved, refreshed, or replaced whenever is necessary; reading strategies should be adopted and applied flexibly; the interference from dominant but inappropriate responses related to the misconception should be inhibited in order to produce a response based on the correct, scientific conception of the phenomenon (Mason et al., 2018, 2020). All the execution of the reading comprehension task relies on self-regulatory skills over emotion, behavior, and attentional focus (Diamond, 2013). The positive relation between self-regulation in learning and academic achievement has been documented (Dent & Koenka, 2016; Duckworth et al., 2019).

Attentional resource as the basis of executive functioning and self-regulation is therefore fundamental for academic performance as reported in specific domains, like reading (Liu et al., 2018) and math (Anobile et al., 2013), and overall achievement (Zhang et al., 2020). However, attention is also limited and subject to depletion when prolonged for particular demands, so it is necessary to find easy and costless ways to restore it. As mentioned in the previous sections, exposure to nature has been found to restore attentional resources.

In the current literature, the beneficial effects of long-term exposure to nature nearby school are well documented in systematic reviews (e.g., de Keijzer et al., 2016; van den Bogerd et al., 2020). What is missing is a synthesis of empirical findings about short-term contacts with nature. Yet, knowing whether costless short-term exposures to greenness are beneficial for students' cognitive and academic functioning would have theoretical and practical significance. Theoretical significance is related to accumulated evidence that the fundamental cognitive function of directed attention can be restored in green spaces in a short time frame. Practical significance concerns the feasibility of giving students the opportunity of brief experiences with nature. Short-term exposures, in fact, include the breaks in a school or study day. Breaks are necessary, so if they take place outdoor in green areas, they can be restorative and make students feel less fatigued and stressed at no cost.

Objective of the Review

The aim of this comprehensive review is to examine empirical studies that focused on short-term exposure to nature and its benefits on cognitive performance in students at all educational levels, from elementary school to university. In the selected studies, we identified the educational level (and age) of participants, the context of short-term exposure to greenness, how cognitive and/or academic performance was

measured, and if the benefits of short-term exposure to nature emerged. Thus, in our review, we were guided by the following three research questions:

1. In what context does short-term exposure to nature take place in students attending primary and secondary school, and university?
2. How are the cognitive benefits of short-term exposure measured?
3. Do cognitive benefits of short-term exposure to nature emerge across all educational levels? If so, under which conditions?

Two clarifications are needed here to better understand this contribution: (1) short-term exposure to nature means a single contact with a green environment that lasts from a few tens of minutes to about an hour and a half; (2) exposure to nature also means a passive exposure, that is, the natural environment “is not actively integrated or consciously used in an activity” (Norwood et al., 2019, p. 79). Therefore, passive exposures do not include experiences with nature as the medium to learn, for example, natural science topics or activities like gardening (e.g., Fägerstam & Blom, 2012).

To the best of our knowledge, this is the first review that focuses on short-term exposures experienced by students and related effects on their cognitive performance. The literature offers several reviews that span across a range of research areas interested in the positive impact of contacts with natural environments. The extant systematic reviews regard the restorative effects of long-term exposure on (a) academic performance (Browning & Rigolon, 2019), (b) cognition across the life span (de Keijzer et al., 2016), (c) health outcomes in general (Twohig-Bennett & Jones, 2018), (d) wellbeing and health in children (Chawla, 2015), (e) attention benefits in any populations (Ohly et al., 2016), and (f) either behavioral, cognitive, or emotional effects on young people under the age of 18 (Norwood et al., 2019). Moreover, there are a systematic review of the impact on long-term immersive nature experiences in various environments (Mygind et al., 2019), a systematic review on regular classes in outdoor educational settings where students may actively interact with them (Becker et al., 2017), and a systematic review on the effects of nature in or around the study environment on secondary and tertiary education students (van den Bogerd et al., 2020). We also identified a systematic review on short-term exposure to natural environments, but it is focused on its effects on depressive mood in university students and adults (Roberts et al., 2019). Therefore, there is no overlap between the previous reviews and the present one.

Search Methodology

According to the guidelines outlined in the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA; Moher et al., 2009), four steps should be followed to select empirical articles: identification; screening based on reading titles and abstracts; eligibility based on reading full texts; and inclusion. To identify the appropriate literature, we conducted the search in relevant research databases in mid-November 2020. The databases were Web of Science, Scopus, PsycINFO,

ERIC, and Education Source (EBSCO). Search strategies included the combination of variations between two groups of keywords/terms referred: (a) NATURE (“experience with nature,” OR “contact with nature,” OR “natural environment,” OR “green space,” OR “greenspace,” OR “greenness,” OR “tree cover”) AND (b) STUDENT COGNITIVE PERFORMANCE (“cognitive performance,” OR “academic performance,” OR “academic achievement,” OR “academic success,” OR “school performance,” OR “school achievement,” OR “school success”). Terms were combined using the logical operators available as search tools.

The first search yielded 285 hits: 86 from Web of Science, 87 from Scopus, 34 from PsycINFO, 43 from ERIC, and 35 from Education Source. To be included in this review, articles had to meet the following eight criteria:

- (1) To be written in English and published in peer-reviewed journals
- (2) To report one or more empirical studies
- (3) To include a short-term exposure to nature
- (4) To include a short-term passive exposure to nature
- (5) To include a comparison between a short-term exposure to a natural environment and a short-term exposure to a non-natural environment
- (6) To involve as participants students at different educational levels, from elementary school to university
- (7) To measure cognitive and/or academic functioning by performance tasks

The flow chart of study search, retrieval, and selection process is reported in Fig. 1.

In sum, the current review is based on 13 articles; as one of them includes two studies that met the inclusion criteria, the reviewed studies are in total 14. The first two authors independently reviewed titles, abstracts, and full texts when necessary to make decisions about article eligibility. Their agreement was very high, 99%. The very few disagreements were settled through discussions between them.

The first and second authors also coded each of the articles included according to the following essential characteristics of each text: (a) the grade level, age, number, and country of students involved; (b) the study design; (c) the context of short-term exposure to nature; (d) the comparison conditions; (e) the measures of cognitive and/or academic performance, and other examined aspects; (f) the presence of cognitive benefits from short-term exposure; and (g) the effect sizes of the results. Agreement for article coding between the first and second author was very high, 97%. Disagreements were reconciled through discussion.

Calculation of Effect Sizes

We computed effect sizes (ES) for all studies with adequate statistical information using the common standardized mean difference statistic Hedges’ g (Brante & Strømsø, 2018). When the “green” condition has a higher outcome score than a comparison condition, g values are positive. For studies that reported the same pre- and post-test scores, we computed ES by subtracting the pre-ES from the post-ES,

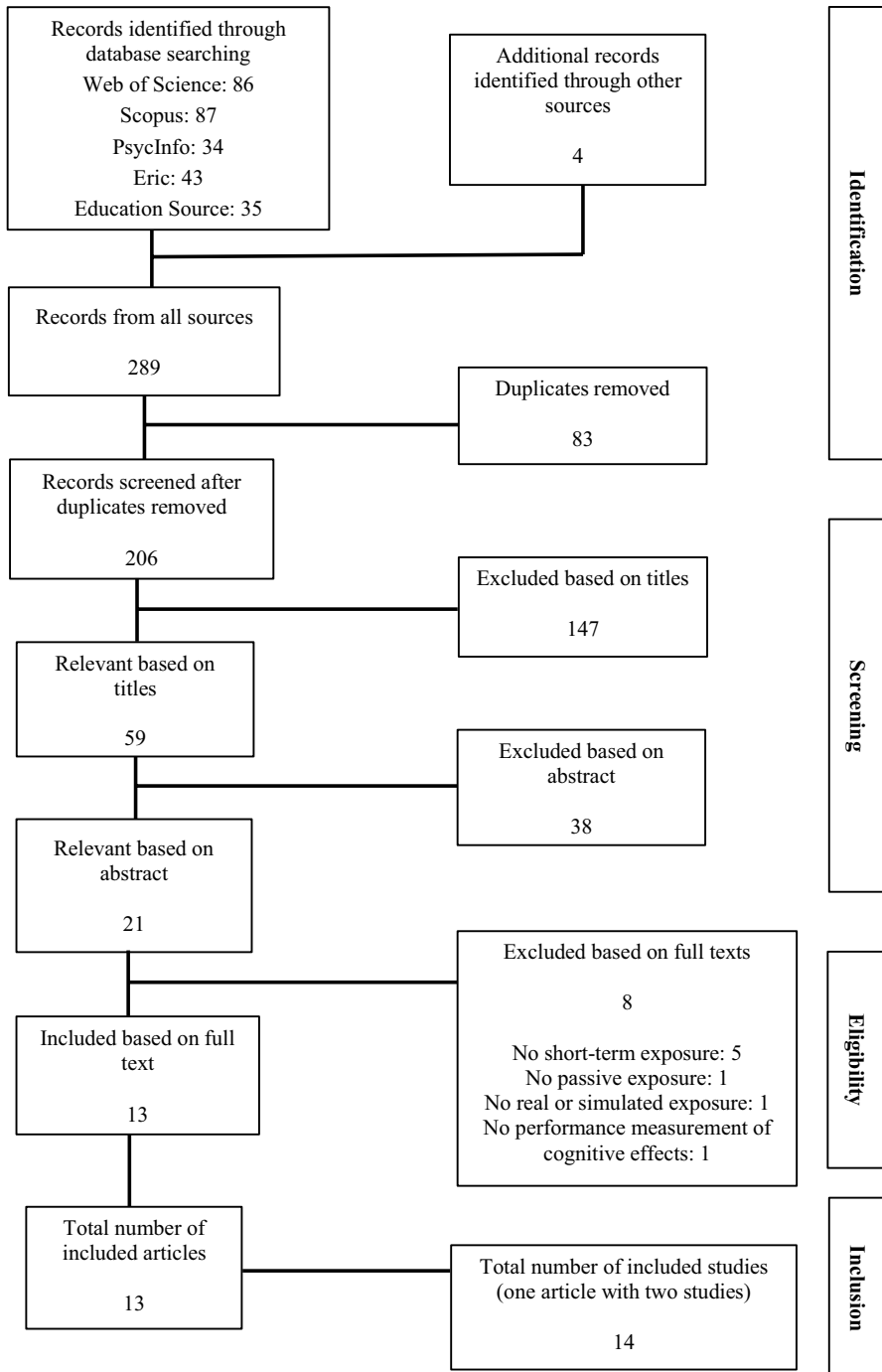


Fig. 1 Flow chart of study search, retrieval, and selection process

as suggested by Durlak (2009). When a study included more than two conditions, we computed a separate ES for each condition. Of note is that there is no direct relationship between a p value and the degree of the effect, as the p value is a function of both the sample size and ES.

Results

Overall, it should be noted that except for one article published in 1991 and another in 2008, all the other articles have been published from 2015 onward, meaning that there has been an increasing interest in the relationship between nature and cognitive performance in the last years. Of note is also that the geographical position of the 14 selected studies is spread across six countries: five studies were carried out in the USA, three in Italy, two in Denmark, and one in Canada, Austria, Taiwan, and China.

The design of five out of 14 studies was between-subjects such as Study 1 in Hartig et al. (1991), Study 2 in Amicone et al. (2018), and the studies by Chen et al. (2020), Li and Sullivan (2016), and Han (2017). The other nine studies had a within-subjects design and students were exposed to different environments at some temporal distance from each other (within a week). Not surprisingly, studies focused on breaks during school days were quasi-experimental as classes were assigned to the various conditions, while the other studies were experimental with participants randomly assigned to conditions. In all studies, at least two environmental conditions were compared: one outdoor and green, the other indoor or outdoor and urban.

In all but two studies (Chen et al., 2020; Mygind et al., 2018), short-term exposures to natural environments were in the form of a break or recess after engaging activities that were specifically performed to induce mental fatigue, or during a school day after having previously accumulated attention fatigue. The length of these breaks ranged from 10 to 90 min in total. In order to induce a comparable mental fatigue across conditions, experimental investigations generally comprised one or more attention-taxing cognitive tasks that were completed by participants, who in some cases carried out the same tasks again after the break. The usual methodological paradigm was therefore the following: school/college activities and/or attention-fatiguing tasks, recess time, and cognitive tasks again.

The results are presented according to the educational level of the participants in three synoptic tables (Tables 1, 2, and 3) that report the aforementioned elements of each study for primary (5 studies), secondary (3 studies), and higher education (6 studies) students, respectively. We took into consideration the three different educational levels based on developmental perspectives on attention and executive functions. As previously introduced, both attention and executive function abilities continue to progress from childhood through adolescence or early adulthood (Fortenbaugh et al., 2015). It is therefore theoretically legitimate to analyze the effects of short-term exposure to nature in relation to students' educational levels as they reflect different steps in their development of fundamental cognitive abilities. If the positive effects of short-term exposure to nature would emerge at all educational levels, such results would be even stronger and more solid.

Table 1 Summary of the selected studies with elementary school students

Authors	Country	Study design	Participants grade level and age	Context of short-term exposure to nature	Comparison conditions	Measures of cognitive performance	Other measures	Cognitive benefits and effect sizes (Hedges' <i>g</i>)
Berto et al. (2015)	Italy	Within-subjects quasi-experimental design	<i>N</i> = 48 4th and 5th graders Age = 9–11 years	90' walk in an alpine wood during a longer break (to make it comparable to the other conditions) of a school day	Sitting in the classroom for training in Mindful Silence (MS) Playing in the school courtyard with some small trees (PT) Walking in an Alpine wood	Continuous performance test (CPT)	Perceived restorativeness scale-children (PRS-ch) Connectedness to nature scale-children (CNS-ch) Environmental preference (within PRS-ch) Systolic and diastolic blood pressure Heart rate (HR)	Yes - Greater scores (accuracy) in the CPT after walking in nature than sitting for mindful silence (0.44) and playing in the school courtyard (1.16) - Greater scores (response time) in the CPT after walking in nature than sitting for mindful silence (1.75) - Greater scores and playing in the school courtyard (2.53)

Table 1 (continued)

Authors	Country	Study design	Participants grade level and age	Context of short-term exposure to nature	Comparison conditions	Measures of cognitive performance	Other measures	Cognitive benefits and effect sizes (Hedges' g)
Schutte et al. (2017)	USA	Within-subjects experimental design	$N=33$ Age = 4–5 years $N=34$ Age = 7–8 years	After jigsaw puzzles of age-related varying difficulties to induce cognitive, a 20' walk in a park	Walking in urban streets Walking in a park	CPT Spatial working memory (SWM) task Backward digital span test (DST, for 7–8 years only) Go-no-Go task (inhibition)	No other measures	Yes - Greater scores (response time) in the CPT after walking in nature (0.26) - Greater d' scores in the CPT after walking in nature (school-aged children, 0.98) - More stable scores (constant distance errors) in SWM task after walking in nature (pre-schoolers, 0.57) - No greater scores (accuracy) in the DST after walking in nature (school-aged children, 0.08) - No greater d' scores for inhibition after walking in nature (^d)

Table 1 (continued)

Authors	Country	Study design	Participants grade level and age	Context of short-term exposure to nature	Comparison conditions	Measures of cognitive performance	Other measures	Cognitive benefits and effect sizes (Hedges' <i>g</i>)
Amicone et al. (2018)	Italy	Within-subjects quasi-experimental design (Study 1)	Study 1 <i>N</i> = 82 4th and 5th graders <i>M</i> _{age} = 10.1 years	30' playing during the morning recess time of a school day (competitive team-game play)	Playing in the built environment of school courtyard Playing in the school garden	Bells test Forward and backward DST Go-no-Go task (inhibition)	PRS ^b	Yes - Greater scores (accuracy) in the Bells test (0.17 ^a) and DST (0.21 ^a) after playing in nature - No greater scores (accuracy) for inhibition after playing in nature (0.13 ^a)
		Between-subjects quasi-experimental design (Study 2)	Study 2 <i>N</i> = 36 5th graders <i>M</i> _{age} = 10.8 years	30' playing during the recess time after school lunch (free play)	Playing in the built environment of school courtyard Playing in the school garden	Bells test	PRS ^b	Yes - Greater scores (accuracy) in the Bells tests after playing in nature (0.98)

Table 1 (continued)

Authors	Country	Study design	Participants grade level and age	Context of short-term exposure to nature	Comparison conditions	Measures of cognitive performance	Cognitive benefits and effect sizes (Hedges' g)
Mygind et al. (2018)	Denmark	Within-subjects quasi-experimental design	N = 62 4th graders Attention data available for N = 46 M _{age} = 10.9	After 60' sitting in a forest to read quietly, a session of 20' with instructions, load-demand adaptation exercise, a short break, and the d2	Sitting in the classroom Sitting in a forest	d2 test of attention Heart rate variability (HRV) _{as} vagal tone ^c	No - No greater scores in the d2 test after sitting in nature for the symbols processed (0.41), errors (0.09), and symbols processed minus the errors (0.43)

Note. ^aEffect size (ES) calculated by subtracting the pre-ES from the post-ES, following the guidelines suggested by Durlak (2009)

^b(Italian version, Pasini et al., 2009)

^cVagal tone reflects the activity of the parasympathetic nervous system. At rest, higher vagal tone indices a larger individual resource for adapting to the demands of a situation, that is, higher physiological self-regulation. During a stressful event, a vagal withdrawal occurs and heart rate variability decreases. Severe stress exposure limits top-down processes, for example directed attention, disrupting the neurobiological connection between the activated subcortical region of the amygdala and the prefrontal cortex, a region with neural circuits involved in directed attention and executing functioning. Studies have linked vagal tone at rest with cognitive performance as postulated by the visceral integration model of emotion and cognition (Thayer et al., 2009)

^d=Incomplete statistical information

Table 2 Summary of the selected studies with secondary school students

Authors	Country	Study design	Participants' grade level and age	Context of short-term exposure to nature	Comparison conditions	Cognitive performance	Other measures	Cognitive benefits and effect size (Hedges' g)
Li and Sullivan (2016)	USA	Between-subjects experimental design	$N=94$ high schoolers Age = not available	After 30' classroom activities also including a modified Trier Social Stress Test (TSST) to fatigue attention and induce stress, a 10' break in a classroom with windows open on to green space	Staying in classroom with no windows Staying in classroom with window opened on to build spaces Staying in classroom with window opened on green space	Forward and backward DST	HRV (pNN50 and LH/HP) ^b Skin conductance level (SCL)	Yes - Greater scores (accuracy) in the DSTs after the break in the classroom with a green landscape view than in the other two conditions (^d)
Wallner et al. (2018)	Austria	Within-subjects experimental design	$N=64$ Age = 16–18 years Data available for $N=60$ $M_{\text{age}}=16.6$ years	After a heavy half-school day, 1 hour break with lunch, a walk together, and a brief relaxation for a total of 45' to recover	Walking and staying in a small urban park surrounded by streets and residential areas Walking and staying in a large urban park Walking and staying in forest	d2-R test ^c of attention	Wellbeing: self-condition scale	Yes - Greater scores (accuracy and time) in the d2-R test after returning from the larger park than the small urban park (0.74 ^b) and forest (0.90 ^b)

Table 2 (continued)

Authors	Country	Study design	Participants' grade level and age	Context of short-term exposure to nature	Comparison conditions	Cognitive performance	Other measures	Cognitive benefits and effect size (Hedges' <i>g</i>)
Stevenson et al. (2019)	Denmark	Within-subjects quasi-experimental design	<i>N</i> = 33 Data available for <i>N</i> = 30 <i>M</i> _{age} = 12.03 years	After forward and backward DST to induce cognitive fatigue, a 30' walk in a rural area	Walking in rural area Walking in an area adjacent to town	Attention network task (ANT) child-friendly version	Eye movements PRS	Yes/no - Greater scores (response times, 0.38) and improved stability, 0.48) in the ANT after walking in nature - No greater scores in the ANT for executive attention (0.23) and accuracy (0.12) after walking in nature

Note. *Effect size (ES) calculated by subtracting the pre-ES from the post-ES, following the guidelines suggested by Durlak (2009)

^bNN50 measures the number of pairs of successive normal inter-beat intervals that differ by more than 50 ms; a smaller value indicates more stress and anxiety. LF/HF ratio is the ratio between the low frequency band power (0.04–0.15 Hz) and the high frequency band power (0.15–0.4 Hz); a larger value indicates increased acute stress and anxiety (Li & Sullivan, 2016, p. 152)

^cRevised form (Brickenkamp et al., 2010)

^dIncomplete statistical information

DST = digital span test; HRV = heart rate variability; PRS = perceived restorativeness scale

Table 3 Summary of the selected studies with university students

Authors	Country	Study design	Participants grade level and age	Context of short-term exposure to nature	Comparison conditions	Cognitive performance	Other measures	Cognitive benefits and effect size (Hedges' <i>g</i>)
Hartig et al., (1991, Study 2)	USA	Between-subjects experimental design	$N = 34$ $M_{\text{age}} = 20$ years	After 40' of tasks to induce cognitive fatigue, a 40' walk in a park	Passive relax on a comfortable chair in a lab Walking in urban area Walking in a park	Proofreading (misspellings, typographical and grammar errors)	PRS Zuckerman Inventory of personal reactions (ZIPERS) Overall happiness Heart rate (HR) Systolic and diastolic blood pressure	Yes - More errors detected after walking in nature than in the other two conditions (°)
Berman et al., (2008, Study 1)	USA	Within-subjects experimental design	$N = 38$ Data available for $N = 37$ $M_{\text{age}} = 22.6$ years	After a DST and a 35' task to induce cognitive fatigue, a 50/55' walk in an arbo- return	Walking in down-town Walking in arbo- return	Backward DST	Positive and negative affect schedule (PANAS)	Yes - Greater scores (accuracy) in the DST after walking in nature (0.46°)

Table 3 (continued)

Authors	Country	Study design	Participants grade level and age	Context of short-term exposure to nature	Comparison conditions	Cognitive performance	Other measures	Cognitive benefits and effect size (Hedges' <i>g</i>)
Han (2017)	Taiwan	Between-subjects experimental design	$N = 116$ $M_{age} = 20.8$ years	15' walk along a natural route (400m back and forth) in the campus	Walk along a built route (40% visible greenness rate) Walking along a natural route Jogging along a built route Jogging along a natural route	Backward DST Forward spatial span test (SST)	Actigraph data Movement velocity Profile of mood state, short form (POMS-SF)	Yes - Greater scores (accuracy) in the DST after green exercise along both routes than before (4.40) - Greater scores (accuracy) in the SST after green exercise than before (2.95)
Bailey et al. (2018)	USA	Within-subjects experimental design	$N = 10$ $M_{age} = 20$ years	After performing two cognitive tests to induce cognitive fatigue, a 30' walking in a natural campus trail	Walking in an aquatic recreation center Walking along a natural campus trail	Color Stroop test Backward DST	EEG	Yes - Greater scores (response time) in the Stroop test after walking in nature (0.64 ³) - No greater scores (accuracy) in the DST after walking in nature (0.00 ³)

Table 3 (continued)

Authors	Country	Study design	Participants grade level and age	Context of short-term exposure to nature	Comparison conditions	Cognitive performance	Other measures	Cognitive benefits and effect size (Hedges' g)
Crossan and Salmoni (2019)	Canada	Within-subjects experimental design	$N=22$ $M_{age}=23$ years	After 20' Stroop test to induce cognitive fatigue, a 10' simulated walk in a forest (180-degree screen)	Walking on a treadmill (blank white screen) Simulated nature walking (forest on a 180-degree screen Simulated perturbed nature walking on bumpy and hilly path (forest with birds flying toward the participant)	Backward DST Necker cube test	PANAS	Yes - Greater scores in the DST (incorrect responses) after simulated walking in nature than walking on a treadmill (0.63 ^a) and in simulated nature with perturbation (0.41 ^a) - No greater scores (orientation changes) in the Necker test after simulated walking in nature than walking on a treadmill (0.16 ^a) and in simulated nature with perturbation (0.28 ^a)

Table 3 (continued)

Authors	Country	Study design	Participants grade level and age	Context of short-term exposure to nature	Comparison conditions	Cognitive performance	Other measures	Cognitive benefits and effect size (Hedges' g)
Chen et al. (2020)	China	Between-subjects experimental design	$N = 32$ $M_{\text{age}} = 20.6$ years	20' sitting in a small wooden garden by a pond at a 15' walking distance	Sitting in a traffic island of a heavily trafficked road Sitting in a small wooden garden	Necker cube ^b	EEG POMS	No - No greater scores in the Necker test after sitting in nature (0.16)

Note. ^aEffect size (ES) calculated by subtracting the pre-ES from the post-ES, following the guidelines suggested by Durlak (2009)

^bSpecifically, the Necker cube pattern control test

^cIncomplete statistical information

Characteristics and results of the studies are also narratively presented in chronological order in the next sections. The topic is novel in the educational psychology literature; thus, it is relevant and useful to make the investigations more completely understandable in terms of what has been done and why in this fascinating area of research that also deserves attention by scholars interested in learning and instruction.

Effects of Short-Term Exposure to Nature in Elementary School Students

Based on Kaplan's (1995) attention restoration theory (ART), Berto et al. (2015) performed a study aimed at examining the effects of different environmental conditions on fourth and fifth graders' attention, perception of environmental restorativeness, environmental preference, and connectedness to nature. Students were assessed in the classroom after a training of Mindful Silence held by their teacher, in the school courtyard after the play time during the daily break, and in the alpine wood closest to the school after a walk. Before and after the treatment of each condition, attentional performance was measured by means of the continuous performance test (CPT), which is a paper-and-pencil test including three sub-tests with long strings of letters that differ for the order of the letters that appear in the string, their size, and space between them. Children were asked to identify three given contiguous letters in each string (Cornoldi et al., 1996). Results indicated that the students gave a significantly higher number of correct responses in the attentional test and were faster after walking in the natural environment. The alpine wood was also perceived as more restorative and appealing than the other two settings. Moreover, heart rate and blood pressure were lower after walking in the forestry and practicing mindfulness silence than playing in the courtyard. Findings were interpreted with reference to Kaplan's (1995) theory of attention restoration.

Taking into account both the attention restoration theory and the stress reduction theory, Schutte et al. (2017) investigated whether the positive impact of urban nature also emerges for executive functioning in younger children attending preschool and students of the first years of elementary school. With the experimenter, they walked through a university campus, or an urban walk along busy streets in a downtown area. After walking, the preschoolers completed tests to measure spatial working memory, directed attention (CPT), and inhibition (Go-no-Go test), while elementary school students also completed a backward digit span test (DST) that combines attention and working memory. Specifically, in the spatial working memory test, children had to remember the location of a target (e.g., treasure) while ignoring a distractor that also appeared on the screen periodically. In the inhibition task, a fish or shark appeared on the screen and children had to press the bar to capture a fish when they saw it. They should not press the bar—a dominant response—when a shark appeared. The backward DST required children to listen to sequences of numbers whose length ranged from two to eight digits and to repeat them in the reverse order. As regards attention, results revealed faster reaction times after walking in nature than in the downtown area, with older children faster than the younger. Data regarding spatial working memory only indicated that in preschoolers, it remained

stable after the natural walk. No beneficial effects emerged for inhibition skills and performance in the backward DST.

Amicone et al. (2018) carried out two studies to examine the effects of green breaks on the restoration of attention. In Study 1, they compared fourth and fifth graders' sustained and selective attention before and after a morning recess in the built environment of the school courtyard, or in a correspondent green area of the schoolyard. Participants were collectively administered three paper-and-pencil measures of selective and sustained attention, working memory, and inhibition immediately before and after their break. The Bells test was used to assess sustained and selective attention (Biancardi & Stoppa, 1997). In this standardized test, children are asked to mark in 120 s all the bells that are embedded in distracting stimuli presented in four sheets that have 35 bells each. Working memory was measured by the DST, both forward and backward of the Wechsler Intelligence Scale for children (Wechsler, 2003). Inhibition skill of a dominant response was measured using a Go-no-Go task taken from an Italian battery (Marzocchi et al., 2010). Results showed that only after the break in the garden, students restored their attention as the scores for sustained and selective attention were significantly higher after the contact with greenness. Similar results were reported for working memory, while no effects emerged for inhibition skill. The green break also led students to perceive the garden as more restorative than the courtyard.

Study 2 involved only fifth graders in free play during a recess time after lunch. Attention was measured after the break using the same test used before but with different stimuli (birds not again bells) to prevent learning effects. Findings confirmed the benefits of exposure to nature on students' attention restoration and perception of the restorative quality of the natural environment. Both studies were grounded in the ART (Kaplan, 1995) and the results were interpreted in relation to this theoretical approach.

Mygind et al. (2018) examined the effects of the physical environment on stress response during rest and cognitive performance in fifth and fourth graders. Comparison conditions were a forested area not far from the school and the classroom environment. Selective and sustained attention was measured using a paper-and-pencil letter cancellation test, the d2 (Brickenkamp, 1994). It requires the identification of the letter d with two dashes among a number of distracting letters in 20 s for each of the 14 rows in which the letters appear. After controlling for a number of variables, results showed no beneficial effects of the forestry environment on cognitive performance in d2 test as children had better scores the second time they executed the test, regardless of the environment in which it happened. Similarly, no differences emerged for stress response during the d2 test. Surprisingly, neither ART nor SRT has been mentioned in the article.

To sum up, in the four selected articles involving elementary school students (Table 1), four quasi-experimental and one experimental studies were reported. All but one had a within-subjects design. Mental fatigue was "naturally" induced by regular school activities before the examined break took place, or expressly induced by asking participants to perform activities that tax directed attention. Together with attention using typical tests (CPT, Bells test, and d2), also working memory and executive functions (inhibition) were measured in two investigations. In all but one

study, results reveal the restorative advantages for attention and working memory of short-term breaks in green spaces when students' attention has depleted. In the developmental step in which students' attention seems characterized by a plateau after a fast development in the previous years (from 5–6 to 8–9 years), the opportunity of its relatively quick restoration, after being fatigued, is important to sustain classroom engagement.

Effects of Short-Term Exposure to Nature in Secondary School Students

Of the three selected studies (Table 2), the Li and Sullivan (2016) investigation aimed to restore students' attention and reduce their stress level after a break with exposure to a green landscape from the classroom window. High school students were randomly assigned to one of three classrooms in their school: classroom without windows, classroom with built landscape windows, and classroom with green landscape windows. Attention was measured using the forward and backward DST, once after the stressful classroom activities and once after the break. Results revealed that there were no differences in attentional capacity (composite score of the two tests) across conditions at the end of the classroom activities when it declined. However, differences emerged after the break, as attentional performance in the classroom condition of green window view was significantly higher than in the other two window conditions combined, which did not differ each other. The same pattern of results was found for stress although with a smaller effect size, but stress recovery and attentional functioning were uncorrelated. Findings were interpreted in light of the two aforementioned theories: ART (Kaplan, 1995) and SRT (Ulrich, 1981).

The study by Wallner et al. (2018) examined high school students' cognitive and emotional effects of exposure to different urban green spaces. The study compared three environments: an urban small park with a few trees, surrounded by busy streets and dense residential areas; a large urban park with tree clumps; and a large, dense broadleaved forest with scattered meadows. The d2 test was used to measure attentional functioning. Results reported significantly greater students' cognitive performance in the attention test after staying in all green environments, but the highest increase after the break emerged for the larger park, not the forest that was supposedly a more unusual green space. In contrast, only the time spent in the forest sustained wellbeing which decreased the least compared to the other two conditions upon return to the classrooms and completing the attention test. Findings were interpreted in light of both the attention restoration theory and the stress reduction theory.

Stevenson et al. (2019) were interested not only in examining whether improvement of students' attentional functioning occurs thanks to exposure to greenness, but also in examining whether visual attention—as reflected in eye movements registered by mobile eye-tracking technology—differs depending on the environment, natural or urban. A child-friendly version of the attention network task (ANT) was used to measure three different attention systems: alerting, orienting, and executive or directed attention before and after walking. Results revealed that students exposed to the nature during a walk did not improve executive attention or accuracy of responses

in the ANT, but were significantly faster and more stable in responding and perceived the natural environment as more restorative than the urban. Moreover, eye-tracking data for a small subsample showed that the participants made a higher number of fixations per minute during the walk in the natural environment than in the built environment—likely reflecting intrinsic fascination and desire to explore the scene at no cost of directed attention—although the fixations did not differ in average duration across the environments and did not predict cognitive performance. Attention restoration theory was used to ground the study and interpret the findings.

To sum up, in the three selected articles involving secondary school students (Table 2), one quasi-experimental and two experimental studies were reported, all but one with a within-subject design. Mental fatigue was again induced by regular school activities, or other activities that deplete directed attention. The latter was measured by typical tests in two studies, while working memory measures were used in the other. Cognitive benefits clearly emerged in two investigations and partially in the other in terms of faster and more stable responses that were not more accurate. In the developmental step of adolescence in which students' attention grows rapidly because of neurobiological changes, green breaks for remediating its momentary depletion are substantially effective even when they take place indoor but in a classroom with windows opened on green space.

Effects of Short-Term Exposure to Nature in University Students

Hartig et al., (1991, Study 2) were pioneers in investigating the cognitive and emotional restorative effects of short-term experiences with green spaces. The authors based their experimental investigation on both theoretical frameworks that inspire research in this area, that is, ART and SRT. Specifically, the authors compared the impact of three different conditions: a walk in a park with flora, stream, and outcropping rocks; a walk in urban environment comprising a residential and commercial areas; and a relaxing pause on a comfortable chair to read magazines in a departmental lab. Cognitive functioning was measured using a proofreading task that required to identify spelling, typographical, and grammar errors. Results showed that after walking in the natural environment, students significantly detected more errors in the proofreading task than in the other two conditions and reported greater happiness overall, higher positive affect, and less anger and aggression. Physiological measures did not reveal differences across conditions and this outcome was interpreted with reference to the late final assessment of restoration which occurred around 50 min after completion of the tasks.

Berman et al. (2008) also investigated the effects of green contacts on cognitive functioning. Using the ART paradigm, they compared a walk in an arboretum near the campus and a walk in downtown along a very busy street. Backward DST was used to measure directed attention. Findings indicated that cognitive performance was higher after walking in nature than in town and this benefit was not related to mood improvement (Watson et al., 1988) due to the green environment.

Han (2017) used a pre-test and post-test before and after walking or jogging back and forth along a natural or urban road on campus. Of note is that even the latter

road had at least 40% of visible greenness rate. Based on both ART and SRT, the study examined the impact of physical activity in the two different environments on both cognition and emotion. Cognitive functioning was measured using the forward spatial span test and the backward DST of the Wechsler Memory Scale, third edition (WMS-III, 1997). Results showed that students had greater scores in both tests after green exercise than before, with no differences between the two roads, while their fatigue and nervousness decreased after being in the environment with higher visible greenness rate. Interestingly, walking as a low-level physical activity was more beneficial to improve attention and emotions than jogging as a relatively high-level physical activity, and this occurred without increased fatigue.

The study by Bailey et al. (2018) was carried out to compare both processes and outcomes of walking indoor and outdoor. Undergraduates wore a mobile Emotiv EEG headset to monitor their brain wave activity at baseline, pre-test, while walking along a natural trail of the campus and inside an aquatic recreation center, and at post-test. In accordance with the attention restoration theory, the findings showed that students performed better in the Stroop test after walking, but those who had the opportunity of a contact with nature were faster than those in the indoor walking condition, while no differences emerged for the backward DST that was performed after the Stroop test. Brain activity revealed that focus and stress were high during the Stroop tests, while meditative (frontal theta waves) and relaxed states (alpha waves) were high during the walk in both conditions. However, the outdoor walking in the nature produced a higher meditative state than the indoor walking. Moreover, the contact with nature made the relaxed and meditative states last even through the post-test Stroop, as they remained high following a linear trend.

The Crossan and Salmoni (2019) study tested Kaplan's (1995) ART in students by manipulating top-down processing in simulated conditions. A walk for 10 min was compared across three different conditions: control, nature, and perturbation. In the control condition, students were involved in a basic treadmill walk with a field view of a blank white screen. In the nature condition, they walked on the treadmill but with a field view of an unfolding, simulated nature walk through a forest on a 180° screen. The perturbation condition was similar to the nature condition except for two differences: (a) birds flew around the participants and (b) they wore biomarkers on the back of their hands, which were projected as two orbs on the screen in front of them. While walking through the simulated nature path, they were requested to use the orbs to hit the upcoming birds. In addition, this path required students' unexpected adjustments to their balance as it was bumpy and hilly. The nature condition was meant to involve only bottom-up processing that captures attention without effort. In contrast, the perturbation condition was meant to involve top-down processing that tax directed attention. Cognitive functioning was measured using a backward DST and the Necker cube test (Hurlbut, 2011). In the latter, participants had to observe the cube in a given orientation for 60 s and to tap the desk when the orientation of the cube appeared to switch. The frequency of the cube's switches is a measure of directed attention. Results confirmed the hypothesized restorative effect of simulated nature on cognitive performance for the backward DST (not for the Necker cube test) as in the nature condition students outperformed those in the

other two conditions. Of note is that this benefit could not be explained by changes in positive mood as the affective state did not differ across conditions.

Finally, also Chen et al. (2020) carried out a study to examine the neural mechanisms of the restorative effect of short-term exposure to nature. Like in the Bailey et al. (2018) investigation, students wore a mobile Emotiv EEG headset to register their brain activity in two different conditions while sitting: exposure to a small wooden garden by a pond and exposure to a traffic island in a heavily busy road. As measure of cognitive performance, the Necker cube was used, measuring the frequency of failures to maintain concentration. Findings showed a more efficient and stronger alpha-theta synchronization in the communicating brain network during the restorative green experience than the urban experience, which was accompanied by stronger alpha-theta oscillations in the occipital lobes. The latter indicate suppression of alertness, so cognitive resources might be saved for recovery from fatigue. In fact, a strong positive association emerged between alpha-theta oscillations in the occipital lobes and the perception of fatigue recovery. Of special interest here is the outcome that attention performance after the green experience was not greater than after the urban experience, although the trend was in the expected direction. Moreover, the perception of fatigue-vigor was related to cognitive performance in the attention test. Findings are interpreted in light of both attention restoration theory and stress reduction theory.

To sum up, in the six selected articles involving university students (Table 3), only experimental studies were reported. Three of them had a within- and three a between-subjects design. Mental fatigue before the break was expressly induced in four studies. Tests for specifically measuring directed attention (proofreading and Necker cube) were used in two studies, while all the others rely on the typical digital span tests for working memory. All but one study documented that cognitive functioning was greater after the short-term exposure to nature, which in an investigation was simulated by a 180° screen while walking on a treadmill. Attention continues to grow, even slowly, into adulthood and must be supported. When it depletes, green recesses may be a valid, useful, and costless opportunity to refresh it in young adults.

Discussion

The general aim of this review was to understand if even short-term exposure to green environments can be beneficial for cognitive and academic performance at different educational levels, given the theoretical and practical significance of the issue. As the review was guided by three specific research questions, we will discuss the results in relation to each of them.

The Context of Short-Term Exposures to Nature

Our first research questions asked in what contexts students at various educational levels were briefly exposed to greenness. As previously mentioned when reporting

the general results, only in two studies (Chen et al., 2020; Mygind et al., 2018), students were not induced particular mental fatigue before the contact with nature. Interestingly, these studies did not reveal its benefits for cognitive functioning, meaning that attention must be depleted to be restored in a natural environment.

Specifically, when considering the green contexts, exposures to nature took place in forests not far from the school (Berto et al., 2015; Mygind et al., 2018), green area of the schoolyard (Amicone et al., 2018), small or large urban parks (Berman et al., 2008; Hartig et al., 1991; Schutte et al., 2017; Wallner et al., 2018), rural area (Stevenson et al., 2019), small wooden garden (Chen et al., 2020), or natural campus trail (Bailey et al., 2018; Han, 2017). Only one study examined the impact of the green landscape from the classroom window views (Li & Sullivan, 2016). Moreover, only one study used simulated immersive walking in a green environment while participants were on a treadmill (Crossan & Salmoni, 2019). The non-natural outdoor comparison conditions included school courtyards (Amicone et al., 2018; Berto et al., 2015) and urban routes (Berman et al., 2008; Han, 2017; Hartig et al., 1991; Schutte et al., 2017; Stevenson et al., 2019).

Non-green indoor environments used to contrast the natural outdoor ones were a usual classroom (Li & Sullivan, 2016; Mygind et al., 2018), a classroom with no windows (Li & Sullivan, 2016), an aquatic recreation center (Bailey et al., 2018), a lab (Hartig et al., 1991), and a standard treadmill walking situation (Crossan & Salmoni, 2019). In addition, a small park with a few trees surrounded by busy streets and dense residential areas was also used as the least green urban environment (Wallner et al., 2018).

In sum, across educational levels, various green conditions in schools or campuses, or at close locations, were used to investigate their effects on cognition and other dimensions of students' experience. Moreover, both indoor (mostly classrooms) and outdoor settings (mostly urban streets) served to contrast non-natural conditions. The variety of the contexts may be seen as a drawback because it makes hard to strictly compare the studies. However, the variety can also be considered as positive as it shows that several settings are available with no effort to those who seek to act at the level of the physical environment to improve students' cognitive functioning.

Measures of Cognitive Benefits

Our second research question asked how the cognitive benefits of short-term experiences with nature were measured. In accordance with the attention restoration theory, in more than half of the reviewed studies, cognitive performance across educational levels was measured at least by a test that specifically measures directed attention, like the continuous performance test (CPT; Berto et al., 2015; Schutte et al., 2017), the d2 test (Mygind et al., 2018; Wallner et al., 2018), the attention network task (ANT; Stevenson et al., 2019), the Bells test (Amicone et al., 2018), the Necker cube test (Chen et al., 2020; Crossan & Salmoni, 2019), and the proofreading task (Hartig et al., 1991).

In the other studies, typical measures of working memory (storage and manipulation of information) were used as the main variable (Bailey et al., 2018; Berman et al., 2008; Crossan & Salmoni, 2019; Han, 2017; Li & Sullivan, 2016), or in addition to attention assessment (Amicone et al., 2018). In fact, well-known tests like the backward or forward digit span tests depend on directed attention. We can indeed focus and manipulate information held in mind if we keep attention focused on that mental content (Diamond, 2013). Neuroscientific research has indicated that attention and working memory share the same neural basis as the prefrontal parietal system substantially supports both working memory and focused attention, allowing us to selectively attend to certain environmental stimuli and tune out the irrelevant (e.g., Gazzaley & Nobre, 2012). In this regard, it is relevant to point out that working memory was higher after exposure to nature than to an urban environment, as revealed by digit span tests (Amicone et al., 2018; Bailey et al., 2018; Berman et al., 2008; Crossan & Salmoni, 2019; Han, 2017; Li & Sullivan, 2016), or a spatial working memory task in the younger participants (Schutte et al., 2017).

In contrast, no improvement of inhibition, as measured by the Go-no-Go task, after contact with greenness emerged in the two studies that measured this executive function in elementary school students (Amicone et al., 2018; Schutte et al., 2017). These outcomes suggest that short-term exposure to nature may not have the same effect on inhibitory executive function as on attention and working memory in children. It may be that the Go-no-Go task is not optimally sensitive as it is not considered a paradigmatic example of when inhibition is required in the real world. The task requires to suppress a dominant response to a certain stimulus, whereas other typical inhibitory tasks require to inhibit that response and to substitute it with another (Diamond, 2013). The null effect of short-term exposure to nature on inhibition may also suggest that continual exposure to green space around home is required during the course of development, for inhibitory control to be positively affected (Schutte et al., 2017).

Worth noting is that all the cognitive measures used in the reviewed studies are typically of basic research on attention and working memory. No measures of academic performance were used, although the latter requires a considerable amount of mental resources in terms of attention and working memory. Reviews on long-term contacts with natural environments nearby schools or campuses have highlighted their effects on academic achievement in terms of scores in math, reading, and writing standardized tests, and the American College Test (ACT) administered at the end of high school to assess preparation for college studies (Browning & Rigolon, 2019; Kuo et al., 2019). However, even short-term exposures to nature produce positive effects on attention and working memory, which are required in academic tasks. In other words, if brief contacts with greenness cannot be related to overall achievement in the main school subjects, they can support engagement in the classroom and performance in academic tasks immediately after the contacts (Kuo et al., 2018a, b). In this regard, the use of tasks that are more similar to everyday school activities to assess the cognitive benefits of green breaks would represent a relevant step forward in this field of research.

Conditions for the Cognitive Benefits of Short-Term Exposure to Nature

Twelve out of 14 reviewed studies documented across educational levels restorative effects of nature on students' performance in the tasks used to assess attentional capacity, in accordance with Kaplan's ART (1995). The sequence order of exposure to the natural or built environments was counterbalanced in within-subjects designs, except in the Mygind et al. (2018) study. Thus, the first outcome of this review concerns a general condition for the emergence of the positive relation nature-cognitive functioning, that is, even a short contact with greenness can act as a powerful resource at all educational levels, from elementary school to university. At various ages, students are sensitive and able to take advantage from a passive and short-term contact with nature.

Mygind et al. (2018) did not find any improvement as effect of contact with a natural environment in elementary school students. However, it should be noted that this study differs from the others as students did not spend a recess time after intense mental fatigue or stress. They spent an hour sitting in a forest to read quietly and then performed the attention test. In other words, the usual methodological paradigm—fatiguing school activities, recess time, and attention task—was not fully adopted. As the authors noted, it may be that stress-buffering effects of greenness accumulate during breaks after intense mental effort, which was not the case in this study. Elementary school children spent an hour in nature to read quietly and then did not perform better in an attention task than in the classroom setting (Mygind et al., 2018). While participants were in the forest, in fact, they had higher level of vagal tone, indicating better physiological self-regulation, but during the demanding cognitive tasks afterward, their stress response and cognitive performance was not different from those registered in the classroom environment. This review can therefore point out that a second essential condition for attention renewal benefits to occur and be detectable is to use contact with greenness after intense mental effort.

The other study with university students by Chen et al. (2020) did not document a significant improvement in the Necker attention test even if the usual ART paradigm was used. Worth noting is that also Crossman and Salmoni (2019) did not find the attention restoration effect when using the Necker test. It might be possible that this test is less appropriate than others to detect aspects of attention that can be influenced by the restorative characteristic of a green environment. In the study by Stevenson et al. (2019), even if participants were not more accurate in executive attention, they were faster in providing correct responses and more stable in their execution.

A third condition for revealing attention restoration effects after short-term exposures to nature is to rely on relative short tests of attention, or attention and memory, as these effects may dissipate soon (Berman et al., 2008; Mygind et al., 2018). This review highlights that the cognitive advantages of short-term exposure to greenness in terms of restored attention seem short-term as well and their duration is an open issue worth of investigation. It might be that frequent green breaks during a school day may transfer their cognitive effects to tasks that are more similar to those used for learning in educational contexts, providing therefore a contribution to academic achievement.

A fourth condition for the positive relation nature-cognitive performance seems related, to some extent, to light physical exercise in the natural environment. In the two studies that did not find the hypothesized cognitive benefits of short-term contact with nature (Chen et al., 2020; Mygind et al., 2018), participants did not walk in the greenness during the recess time but were seated as neural or physiological measures were registered. It is well known that physical activity has positive impact on physical and mental health (e.g., Kim et al., 2012). Likely, the combination of light leisure exercise and a green environment might be an optimal condition to produce the attentional advantage observed in 12 out of the 14 studies.

With reference to the attention restoration theory (Kaplan, 1995), this review is focused on the beneficial cognitive effects of short-term exposures to greenness. However, in most of the reviewed studies, other outcome variables were taken into account across educational levels. Specifically, participants' perception of the restorative quality of the environments they were exposed to, affective states, or wellbeing were assessed in 10 out of the 15 studies across educational levels. Moreover, two investigations registered neural activity through EEG (Bailey et al., 2018; Chen et al., 2020), while three studies registered physiological measures as blood volume pulse, blood pressure, heart rate variability, or skin conductance (Berto et al., 2015; Li & Sullivan, 2016; Mygind et al., 2018), and one study recorded eye movements using portable eye-tracking glasses (Stevenson et al., 2019).

When it emerged, the positive relation nature-cognitive functioning was interpreted in light of Kaplan's (1995) ART. However, when also affect was considered in three studies, Ulrich et al.'s (1991) SRT was a theoretical reference as well. The conceptually legitimate link between attention restoration and stress reduction did not emerge in the Crossan and Salmoni (2019) and Li and Sullivan (2016) studies as improvement in attention performance could not be explained by changes in positive mood. However, in Chen et al.'s (2020) investigation, the perceived degree of recovery from fatigue was positively related to improved attentional performance.

Future Directions

The review identifies some important issues that need to be considered in future research. First, an issue pertains to the transfer of the cognitive benefits to academic tasks (Norwood et al., 2021). We do not know whether the effects of short-term exposure to green breaks can also be detected on typical tasks used in the educational context. Future studies can rely on both attention and memory tests typically used in basic research and tasks frequently used in the classroom, which involve these fundamental cognitive functions, for example, text comprehension or calculation. As the restorative effect of short contacts with greenness is subject to rapid decay, the order of basic and academic tasks administration can vary to see if the outcome is related to the type of test or the time elapsed from the break to the assessment. The longevity of the restorative impact is certainly a related issue to explore (Bailey et al., 2018).

Second, we also need to know whether a typical classroom lesson in an outdoor green environment (e.g., green schoolyard or a nearby park), which usually lasts less

than an hour, can accumulate the same mental restorativeness like in a recess, so that the lesson causes less mental fatigue than in the indoor environment of the classroom, with positive effects on performance in a subsequent task. It should be taken into account, however, that academic performance is based not only on sustained attention and other cognitive mechanisms but also on motivation and engagement (Martin, 2009).

Third, in-depth research is needed to shed more light on the theoretically possible moderating or mediating role of stress reduction in the link between exposure to nature and refreshed attentional functioning. The conceptual link between ART and SRT did not emerge in two of the three studies that examined the relationship between the cognitive and affective dimensions. It would be a step forward for theoretical and practical implications not only to document that nature improves affect and cognition separately (Bratman et al., 2015), but also to provide evidence that the attention and stress paths meet at some point, in line with current approaches on warm cognition which do not separate cognitive and emotional components of our mental functioning (e.g., McGaugh, 2015).

Implications for Practice

The practical implications of this review are quite clear. Short breaks in a green environment after cognitive effort are a low-to-zero cost type of intervention to help students refresh attention and improve their cognitive functioning, which is essential for academic tasks. It is also interesting and relevant that even exposure to nature through a window view of a classroom can be restorative compared to an urban landscape window view, or that a simulated contact with nature can also refresh cognitive resources. In addition, short-term exposures to nature support students' perception of the restorative "affordance" of a green environment and their emotional wellbeing that is also crucial for cognitive functioning. Furthermore, we did not find differential effects due the educational level of the participants involved in the studies. Our results indicate that short-term exposures to nature can and should be used after demanding lessons in school or college.

Conclusions

Since various systematic reviews have documented the positive impact of long-term exposure to nature, the additional scientific contribution of the current review is the accumulated evidence, with convincing effect sizes, that even brief contacts with natural environments, after intense mental effort, are powerful to sustain cognitive functioning, specifically attention and working memory in students across educational levels. These are fundamental functions at the basis of engagement, on-task behavior, and performance in academic tasks. The powerfulness of brief experiences with greenness can therefore be considered even more compelling than that regarding long-term experiences, which has been widely documented. For the latter, in

fact, it becomes more difficult to specify the causal relation between exposure to nature and attention or academic performance, as multiple concurrent factors, which may be not all controllable, play a role in longer periods of time. In contrast, if students' performance in an attentional task is better after a short contact with greenness, such causal relation emerges much more clearly, meaning that nature can really restore a fundamental cognitive function in a short time frame.

This review therefore indicates that short-term experiences in green environments are optimal to refresh students' "batteries." Breaks are necessary to prevent deterioration of cognitive performance due to depletion of mental resources. Today, children, adolescents, and young people spend much less time in natural environments than in the past for various reasons. This reduced contact with nature may have relevant consequences for their cognitive functioning and health in general. As even short-term exposures to nature are beneficial for cognitive performance, they represent a great and no-cost opportunity to support students' cognition across educational levels.

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*Indicates an article included in the review.

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