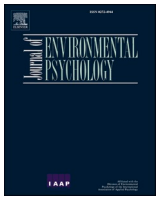
Journal of Environmental Psychology 84 (2022) 101884

Contents lists available at ScienceDirect

Journal of Environmental Psychology

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



Restorative effects of exposure to nature on children and adolescents: A systematic review

Adrián Moll [a], Silvia Collado [b], Henk Staats [c], José A. Corraliza [a,*]

[a] Department of Social Psychology and Methodology, Universidad Autónoma de Madrid, 28049, Madrid, Spain
[b] Department of Psychology and Sociology, Universidad de Zaragoza, 44003, Teruel, Spain
[c] Centre for Energy and Environmental Research, Social and Organizational Psychology, Leiden University, Wassenaarseweg 52, 233V, Leiden, the Netherlands

ARTICLE INFO

Keywords:
Exposure to nature
Restorative effects
Adolescent
Child
Systematic review

ABSTRACT

One of the most documented effects of exposure to nature is physical and psychological restoration. Restoration refers to the recovery or strengthening of adaptive resources (e.g., attentional capabilities, positive emotions, etc.) that are being spent in meeting the demands of everyday life. The restorative process has been widely studied in adults, but less is known about the restorative effects that exposure to nature has for children and adolescents. To fill this gap in the literature, we conducted a systematic review aiming at systematically summarizing the accumulated evidence about the restorative effects of nature exposure on children and adolescents and reporting the main findings in terms of the restoration of (1) cognitive, (2) emotional, (3) social or (4) behavioural resources. To conduct the study, we followed the PRISMA procedure. Databases were extracted from Web of Science, PUBMED, and SCOPUS. Studies were selected if (a) they included non-adult participants, (b) they included empirical results at least for one of the four selected variables, (c) the study was published in English and (d) the study had been peer-reviewed. According to these criteria, 30 studies were finally selected. Selected studies were categorized in terms of sample size, duration of the intervention (if applicable), and quality of the study (following the National Heart, Lung, and Blood Institute assessment tool). Results show that exposure to nature has significant restorative effects, but the effects differ across the selected variables. Due to methodological limitations, such as a lack of measurement standardization, and the scarcity of experimental and longitudinal studies, caution should be exercised when interpreting the available results. Suggestions for future lines of research in this area are provided.

Many people today live in urbanized environments (Cohen, 2006; Ritchie & Roser, 2018). Living in cities certainly has several advantages over living in a rural area, such as accessibility to educational, health, and entertainment resources. However, it also has disadvantages in terms of health, including an increased risk of chronic stress (Gidlow et al., 2016; Lederbogen et al., 2011) and depression (Romans et al., 2011). For many years, people have had the intuition that the experience of nature can alleviate some of the negative symptoms of urban life. Such intuition has been scientifically supported by studies conducted within research areas as environmental psychology, public health, and outdoor recreation (Collado et al., 2017; Hartig, 2021; Martin et al., 2020). Nature exposure has been associated with lower psychological distress (Astell-Burt et al., 2013), higher positive emotional states (Corazon et al., 2019) and improved attention (Berto, 2005; Ohly et al., 2016) in adult population. Positive linkages have also been found between contact with nature and children's physical and psychological health. Higher levels of direct exposure to nature as a child are linked to lower overweight rates (Crawford et al., 2010), better cognitive development (Dadvand et al., 2015), higher school performance (Kuo et al., 2021) and lower emotional problems (Chawla et al., 2014), among others, even when controlling for confounders as socio-economic status.

In spite of the recognition of the benefits children and youth obtain from contact with nature, there is a downward trend in children's exposure to nature (Hofferth, 2009; Larson et al., 2019; Soga & Gaston, 2016). Children spend more time indoors than their counterparts from previous generations and the reasons for this shift are diverse, including parental concerns about safety of outdoor environments (Carver et al., 2008), a tight daily schedule and academic pressures (Dowdell et al., 2011; Skar et al., 2016), and availability of screen devices (Larson et al., 2019). Given the recognized benefits of nature exposure for children's

* Corresponding author.
E-mail addresses: adrian.moll@uam.es (A. Moll), scollado@unizar.es (S. Collado), staats@fsw.leidenuniv.nl (H. Staats), josea.corraliza@uam.es (J.A. Corraliza).

https://doi.org/10.1016/j.jenvp.2022.101884
Received 15 December 2021; Received in revised form 30 September 2022; Accepted 30 September 2022
Available online 5 October 2022

development, these trends towards an alienation from the natural world are troubling. Studies examining the positive outcomes of children's contact with nature have multiplied in the last few years (Bento & Dias, 2017; Luís et al., 2020; Song et al., 2020; Wade et al., 2020), and their collective findings suggest that this progressive detachment from the natural world can be detrimental for children and youth in terms of health.

The majority of studies examining the positive effects that nature exposure has for children have been conducted within the realm of psychological restoration research. Extant evidence shows that nature exposure increases some transient outcomes as children's ability to concentrate (Oh et al., 2019) or improvement of their mood (Li et al., 2018) and the sense that the natural environment provides opportunities to get away from every day's worries and demands (Bagot et al., 2015). Although efforts have been made to gather information about the mental health benefits of children's interactions with nature (Tillmann et al., 2018), the empirical evidence supporting that nature exposure is restorative for children and adolescents has not been conclusive up to now. The aim of this systematic review is to fill this gap in the literature.

Restoration refers to the process of renewal or recovery of adaptive resources that are being spent in meeting the demands of everyday life (cf. Hartig, 2004). The two major theoretical frameworks that have led restoration research are attention restoration theory (ART; Kaplan & Kaplan, 1989), which concerns the renewal of a capacity for directed attention, and psychoevolutionary theory (SRT; Ulrich, 1983; Ulrich et al., 1991), which concerns stress reduction. ART proposes that, as directed attention is not needed in restorative environments, it can be restored. SRT proposes that, as a result of stress recovery, people show more positive emotions and fewer negative emotions, as well as some decline in physiological measures indicative of arousal and stress (e.g., blood pressure; Ulrich et al., 1991). Even though the two theories specify different antecedent conditions from which the person becomes restored, their integration has long been recognized (Collado et al., 2017; Hartig & Evans, 1993; Kaplan, 1995; Ulrich et al., 1991), and many of the studies about the restorative potential of nature exposure simultaneously consider cognitive, affective and sometimes physiological benefits (e.g., Taylor & Kuo, 2009).

An environment can be considered restorative when it imposes relatively few demands on depleted resources and has positive features that enable a fast and complete renewal of resources spent (see Hartig, 2021). Both theories predict that, in general, safe natural environments will be more restorative than non-natural environments. In line with these two theories, restoration research conducted with children has traditionally focused on studying the beneficial effect of exposure to nature on restoring cognitive resources such as concentration (Oh et al., 2019) and spatial working memory (Flouri et al., 2019), as well as on the recovery of emotional resources, like positive emotional well-being (Huynh et al., 2013) and mood (Li et al., 2018). Overall, the extant findings are in line with these two theories. However, there is a call to move the field forward by extending restoration theory and research concerned with the benefits of exposure to nature beyond the proposals of ART and SRT (Collado et al., 2017; Hartig, 2021; Hartig & Jahncke, 2017; Stevenson et al., 2018). There are already some studies suggesting that the restorative effects of nature surpass those proposed in ART and SRT. For instance, there is growing evidence about the positive effect of nature exposure on behavioural resources, such as gross and fine motor development (Kabisch et al., 2019), and on the promotion of daily physical activity (Remmers et al., 2019). There is also some evidence about the effects of nature exposure on children's sociability (Balseviciene et al., 2014). In line with this latter idea, Hartig (2021) proposes that the restoration theoretical framework could be extended to include the restoration of resources as held within closer relationships such as family cohesiveness or enhanced communication and as held collectively by members of a population, such as collective optimism or mental health of a population.

While the evidence about the restorative benefits of nature exposure for children is escalating, it is quite diverse. There is also plenty of variability in the measures used to study the restorative effects of nature exposure on children, which makes it difficult to generalize the results and conclusions of specific studies. We also know very little about what types of children's nature interactions are more effective in the promotion of restoration. Given the above, we deem it necessary to critically review and synthesize the linkages between nature experiences and restoration in this population group. Prior systematic reviews about the effects of nature exposure on health have focused on the general population (Ohly et al., 2016), on adults (Corazon et al., 2019), and/or on the general mental health effects that nature interactions have for children (Gill, 2014; Mnich et al., 2019; Oswald et al., 2020; Roberts et al., 2020; Tillmann et al., 2018).

In our systematic review, we attempt to reflect on the heterogeneous situations in which restoration might be operating, while also taking the complexity of the restoration concept into account. This complexity has not always been explicitly considered in the empirical literature. For example, in ART, Kaplan and Kaplan (1989, pp. 196–197) describe the process of restoration as consisting of four phases: 'clearing the head', leading to 'cognitive quiet', allowing to consider 'matters on one's mind', finally leading to 'reflection on one's life, priorities, possibilities, actions and goals. The richness of this model of the restorative process is seldom completely investigated (but see Herzog et al., 1997; Staats et al., 2003). It is however conceivable that in some situations, and therefore in some research designs, restoration may actually cover more of these phases, while in other studies the experimental design only allows assessing the initial short-term effects, which is often considered the authentic effect of a restorative situation, as it allows the direct demonstration of nature's restorative effect. However, we find this narrowing of the restoration concept to these direct effects arguable. As Hartig (2007) says, we could also take into account the instorative effects. These effects refer to the beneficial changes promoted by exposure to certain environments that strengthen the resource pool when there is no antecedent condition of complete depletion. Another complexity of restorative situations has to do with adaptation, in our case getting used to environments that permanently allow brief moments of micro-restoration through, for example, the presence of green views (Kuo & Sullivan, 2001) or the daily commute through a natural area (Zijlema et al., 2018). Whether this might dampen the restorative effect, reinforce it, or prevent the depletion of resources, is a question that has not been systematically addressed. To do justice to these and possibly other ways in which restoration is a function of the environment, the frequency and duration of exposure, as well as the initial mental state, we have applied a comprehensive perspective in charting multiple situations and research designs that attempt to shed light on outcomes that could be taken to reflect restoration.

To provide a general framework we argue that all psychological effects of nature exposure can be traced to either restoration in the classical sense of compensating for resource depletion, and instoration, as building stronger resources. We consider the combined processes as the psychological intermediary, the internal state, between exposure to nature and different kinds of outcomes like e.g., improved cognitive functioning, improved social behavior, the ability to reflect on life, ultimately leading to improved health. Similar arguments on the possibility of generalizing restoration have been voiced previously (see Hartig & Staats, 2003, Note 1) and coincide with theories in social psychology about ego strength as the mental capacity instrumental in the performance of many behaviors (Baumeister et al., 2018). We have to state in advance that the studies we retrieved in our systematic review did not allow a study of processes, but were focused on outcomes. Therefore, the conceptual framework we propose serves to explain the inclusion of studies that relate nature exposure to different kinds of outcomes. In so doing we make the distinction between direct effects of restoration and the indirect effects. We acknowledge that some researchers might see these indirect effects as a "black box" approach to restoration, as certainly, the mechanisms that theoretically underlie

indirect restoration are difficult to corroborate. In line with this view, some authors (Hartig & Jahncke, 2017; Stevenson et al., 2018) argue that restoration should be studied by employing research designs that introduce a state of fatigue for the experimental group, and compare outcomes to those of a control group, while empirically following the process of restoration. In fact, we believe that this perspective is the most appropriate for new experimental studies. However, due to the fact that restoration has been studied scarcely in the non-adult population and that this systematic review tries to synthesize the evidence accumulated up to now with children and adolescents, it is necessary to include all those studies that have studied restoration from a general point of view. Regarding direct effects of restoration we pay special attention to those studies that examine restoration in a short time frame, which is a relevant aspect of the restoration process (Hartig, 2021) and have explicit measures of restoration as outcome variables. And regarding studies that, in our framework, have processes of restoration or instoration as (unmeasured) intermediaries, we report the studies that focus on variables further in the process, that ultimately may improve health.

To the best of our knowledge, this is the first systematic review to synthesize the broad research outcomes about the restorative effects of nature exposure on children and adolescents. By children and adolescents, we refer to people from 0 to 19 years of age. In our endeavour, we consider the cognitive and emotional benefits of exposure to nature but also expand our research to the possible restorative effects of nature interactions on children's behavioural and social resources. We also dedicate a separate section to the possible different restorative effects that various types of contact with nature may offer.

1. Method

This systematic review started by determining relevant search terms related to children's and adolescents' restorative experiences in nature. These terms were first identified by the first author and discussed with the rest of the authors in search of an agreement (Table 1). We used three different bibliographic databases: Web of Science, PUBMED and SCOPUS. For each database, we screened and selected all English papers published from 1981, when Ulrich and Addoms first examined the restorative process, until April 2021.

1.1. Review process

This systematic review followed PRISMA guidelines and each step is represented in Fig. 1. The reviewing process was divided in three steps: title screening, abstract screening and full-text screening. First, databases outputs were downloaded and managed on EndNote citation program (X9). A total of 19134 articles were included. Duplications were removed and the title and abstracts of the remaining articles (n = 15979) were screened. From these, a total of 466 were identified for further review. Inclusion criteria for selecting the articles were that (a) the study included empirical results associated with the restoration of cognitive, emotional, behavioural or social resources through nature exposure; (b) the study had been peer-reviewed; (c) the study was published in English; (d) the study included children and adolescents. Full-text of the remaining articles was screened, leading to a total of 24 articles. To ensure a more complete coverage, we also checked the references of included studies, previous systematic reviews on related topics, and studies relevant to the review that we as authors were aware of. This led us to six additional articles that were manually selected. Thus, 30 articles were included in the systematic review.

Table 1
Database search terms.

	Search terms
Population	child OR adolescent OR teens OR infant OR babies OR teenagers
Intervention	exposure to nature OR contact with nature OR green OR nature interactions OR park OR forest OR garden
Outcome	attention OR emotions OR mood OR cognitive OR behaviour OR social OR physiological OR restoration OR restorative

1.2. Data extraction

Relevant data from the 30 selected articles were identified and compiled in Table 2. This information includes key characteristics of each selected study, including the study's core variables, major findings, sample size and design. If one study included more than one outcome variable, and each outcome variable was relevant to the systematic review, they were all included in Table 2. For each variable significance/non-significance is reported separately. From these 30 studies, we extracted all the effect sizes (Cohen's d) of eight articles that studied restorative processes in a short period of time, the 'classical' perspective of restoration (Hartig, 2021; Hartig & Jahncke, 2017; Stevenson et al., 2018). Effect sizes were considered negligible if they were lower than 0.20, small if they had values that were between 0.20 and 0.49, medium between 0.50 and 0.79, or large if they were equal or higher than 0.80.

1.3. Assessing bias

Following the approach of previous systematic reviews about the positive effects of contact with nature (Tillmann et al., 2018), we assessed the quality of the included studies with the National Heart, Lung, and Blood Institute (NHLBI) quality assessment tool. This was done to enhance comparability among studies. To assess the risk of bias, this quality assessment tool has developed different guidelines specific to the study design (e.g., cross-sectional, experimental). Each study was separately assessed and rated by two of the reviewers. Whenever there was a disagreement between the two reviewers, a third reviewer assessed the study and the majority rate was considered. Each study was then classified as having a high risk of bias (H) if less than 50% of criteria were met, as acceptable risk of bias (A) if 50%–75% of criteria were met or as low risk of bias (L) if more than 75% of criteria were met.

2. Results

Of the 30 included articles, 7 were conducted in the USA, 4 in Canada, 4 in Australia,3 in the UK, 2 in The Netherlands, 2 in Korea, 1 in Italy, 1 in Lithuania, 1 in Denmark, 1 in Portugal and 1 in Germany, 1 in Iran, 1 in New Zealand and 1 in China. The studies included children and adolescents from 3 years to a maximum of 19 years old (see Table 2).

The restorative outcome variables were classified in 1 of 5 categories. The first category was cognitive outcomes (registered in 12 papers), including mental processes or functions, such as attention, memory, and concentration. The second category was emotional outcomes (registered in 12 papers). These outcomes were captured through emotional variables, such as mood or positive emotions. The third category was behavioural outcomes (registered in 11 papers) and included variables registering children's and adolescents' behaviour (e.g., impulse control, hyperactivity, and physical activity). The fourth category was social outcomes (registered in 6 papers). It included variables registering direct interaction with other people (e.g., parent-child communication). Last, we included a fifth category called complex outcomes (registered in 7 papers). This category contained variables that fit in multiple categories (e.g., mental health contemplates cognitive, emotional, and behavioural aspects), thus being a multidimensional outcomes category. Table 3 shows the number of studies included in each category classified according to their risk of bias. As some studies examined more than one outcome variable, there are more than 30 entries (a total of 75 entries).

The 30 studies considered in this systematic review were also classified into four categories according to the type of nature exposure they considered (Table 2 and 3): 1. Residential greenspace, which included studies assessing the restorative effects of nature exposure within the residential area; 2. School greenspace, which referred to exposure to

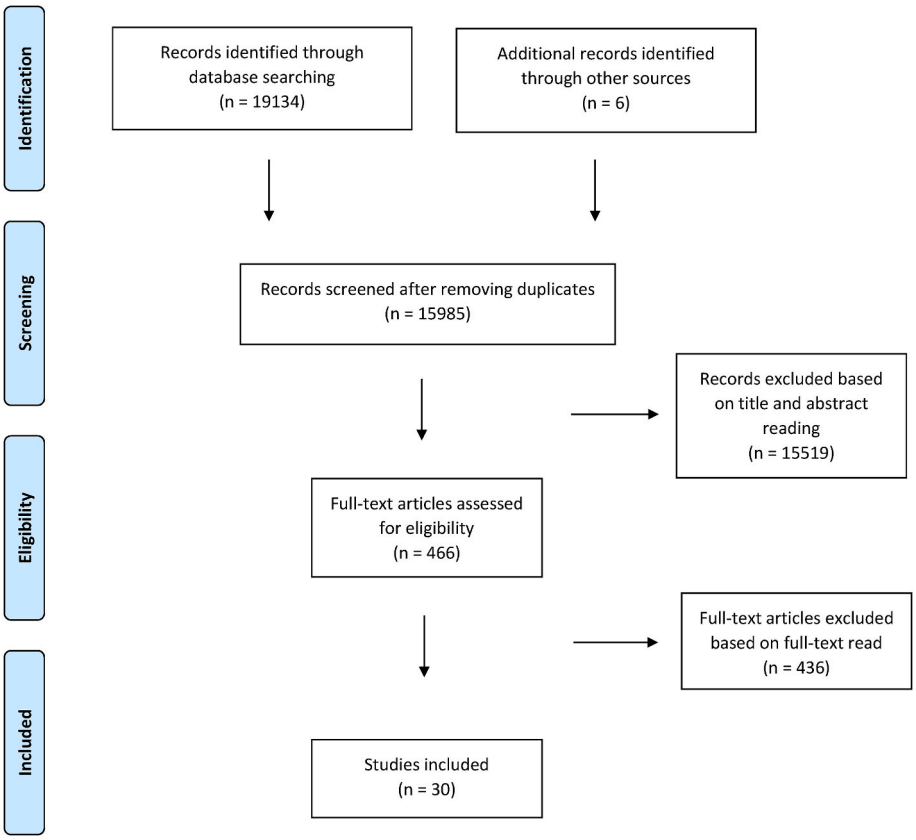


Fig. 1. PRISMA flow diagram selection process.

nature in educational environments (e.g., in the schoolyard); 3. Parks/forests. This category considered interactions with nature at parks or forests (forest activities, exercise in natural environments other than schools and residential areas, etc.) that are outside the residential and school areas; 4. Simulated nature. This last category included studies examining the restorative effects of exposure to simulated nature, such as natural soundscapes (e.g., bird songs, fountains, etc.) and visual stimuli (e.g., images of natural landscapes or plants in close up).

As displayed in Table 3, the 30 studies reported a total of 75 individual findings on the relation between children's and adolescents' exposure to nature and restorative outcomes. More than half of the findings (52) showed statistically significant positive relations between nature exposure and restorative outcomes, whereas 22 individual findings were non-significant. Also, one study reported significant negative relations between children's experiences in nature and restoration (i.e., a negative effect of exposure to nature). The specific results for each restorative outcome category (i.e., cognitive, emotional, behavioural, social, complex) are described below. We also provide information about the restorative effects of the different types of nature exposure.

2.1. Cognitive outcomes

We found 21 results related to cognitive outcomes, being attention, memory and concentration the most frequently studied. Among these, 17 significant and four non-significant results were found, suggesting a positive relation between nature exposure and cognitive recovery. All included articles were rated as low or acceptable risk of bias.

2.2. Emotional outcomes

We registered a total of 16 outcomes related to emotional restorative effects. Seven of these results showed a positive significant relation between emotional outcomes and exposure to nature. We found one significant, negative relation between exposure to nature and emotional outcomes, and eight non-significant effects. The most frequently studied variables in this category were positive mood, emotions, and self-esteem. Eleven out of twelve studies were rated as having low or acceptable risk of bias. After removing one study rated as with high risk of bias, the significant negative relation between nature exposure and emotional outcomes disappeared, and six positive significant and five non-significant effects remained.

2.3. Behavioural outcomes

We observed a total of 14 outcomes related to behavioral restorative effects. Of these, 11 significant positive results were found. Only three observed effects were not significant. The most frequently studied variables in this category were hyperactivity, impulse control and physical activity. All included studies were rated as having low or acceptable risk of bias.

2.4. Social outcomes

Among the 30 selected studies, 11 social outcomes were registered and only one result was not significant. The most frequently studied variables in this category were social interaction and prosocial behaviour. Four out of six studies were rated as having low or acceptable risk of bias. After removing the two papers rated as having high risk of bias, only five effects remained, and they were all positive and significant.

2.5. Complex outcomes

We found 13 effects that included outcomes combining two or more of the above-mentioned outcomes in more general concepts (e.g., mental health includes cognitive, emotional and behavioural aspects, so it would fit in multiple categories). Seven of these effects were statistically

Table 2
Characteristics and data of included studies.

Main Author, Year	Country	Age	Sample size (N)	Type of nature exposure	Restorative outcome	Nature exposure duration	Study design	Assessment quality
Sprague, 2021	USA	9–15	362	Nature-based education (School)	Emotional health functioning (E)*, physical activity (B)*, social functioning (S)*	15 weeks	Intervention	A
Kuo, 2021	USA	11–12	49255	School greenness (School)	School performance (C)*	–	Cross-sectional	A
Wade, 2020	Australia	14–15	90	Exercise in natural environment (Park/forest)	Perceived stress (O), positive affect (E), vitality (O)*, attention (C)*, cognitive arousal (C)* and spatial woking memory (C)*	20 min	Intervention	A
van den Borgerd, 2020	The Netherlands	12–18	213	School greenspace (School)	Well-being (E), health complaints (O), attention (C)*, lecture evaluation (C)*	7 weeks	Longitudinal	A
Main Author, Year	**Country**	**Age**	**Sample size (N)**	**Type of nature exposure**	**Restorative outcome**	**Nature exposure duration**	**Study design**	**Assessment quality**
Taylor, 2020	Canada	4–5	381	School greenspace (School)	Self-regulation (B)*	4 months	Intervention	L
Song, 2020	Korea	12	8	Forest activities (Park/forest)	Restoration (O)*, perceived health (O), self-steem (E), depression (O), perceived stress (O), behavior problems (B)	8 weeks	Intervention	A
Luís, 2020	Portugal	8–14	132	School greenspace (School)	Restorativeness (O)*, social competences (B)	–	Cross-sectional	A
Putra et al., 2020	Australia	4–15	4969	Greenspace quality (Residential)	Prosocial behavior (S)*	10 years	Longitudinal	A
Johnson, Snow, Lawrence, & Rainham, 2019	Canada	8–15	60	Nature walk (Park/forest)	Endogenous attention (C)*, exogenous attention (C)	30 min	Intervention	A
Main Author, Year	**Country**	**Age**	**Sample size (N)**	**Type of nature exposure**	**Restorative outcome**	**Nature exposure duration**	**Study design**	**Assessment quality**
Dadvand et al., 2019	Iran	10–18	10586	Time spent in green spaces (Park/forest)	Self-satisfaction (E)*, social contacts (S)*	–	Cross-sectional	A
Dopko, 2019	Canada	10	80	Natural school (School)	Positive affect (E)*, negative affect (E)*, vitality (E), pleassant affect (E), fun today (E), pro-sociality (S)*	4 h	Intervention	H
Flouri, 2019	UK	11	4758	Neighborhood greenspace (Residential)	Spatial working memory (C)*	9 months to 14 years	Cohort	A
Kabisch, 2019	Germany	4–7	60578	Greenness (Residential)	Gross motor development (B)*, fine motor development (B)*	–	Cross-sectional	A
Mavoa et al., 2019	New Zealand	12–19	4575	Neighborhood greenery (Residential)	Emotional health (E)*	–	Cross-sectional	A
Main Author, Year	**Country**	**Age**	**Sample size (N)**	**Type of nature exposure**	**Restorative outcome**	**Nature exposure duration**	**Study design**	**Assessment quality**
Raney, 2019	USA	6–11	437	Green playground (School)	Physical activity (B)*, social interactions (S)*	4 months	Intervention	A
Reuben et al., 2019	UK	5–18	1658	Neighborhood greenery (Residential)	Cognitive ability – IQ (C)	13 years	Longitudinal	L
Remmers, 2019	The Netherlands	10–12	255	Greenspace concentration (Residential)	Physical activity (B)*	7 days	Longitudinal	L
Shu, 2019	China	8–12	a)46 b)45	Natural soundscapes (Simulated)	a)attention (C)*b)memory (C)*	1 h	Cohort	A
Stevenson, 2019	Denmark	10–14	33	Natural environment (Park/forest)	Executive attention (C), accuracy (C), mean reaction time (C)*	30 min	Intervention	L
Oh, 2019	Korea	11–13	23	Natural visual stimuli (Simulated)	Attention (C)*, and positive mood state (E)*	30 min	Cohort	A
Main Author, Year	**Country**	**Age**	**Sample size (N)**	**Type of nature exposure**	**Restorative outcome**	**Nature exposure duration**	**Study design**	**Assessment quality**
Amicone, 2018	Italy	a) 10 b) 10	a) 82 b) 36	Natural environment at school (School)	a) attention (C)*, working memory (C)*, impulse control (B), perceived restorativeness (O)* b) attention (C)*, perceived restorativeness (O)*	1.5 h	Pre-post	A

(*continued on next page*)

Table 2 (*continued*)

Main Author, Year	Country	Age	Sample size (N)	Type of nature exposure	Restorative outcome	Nature exposure duration	Study design	Assessment quality
Cameron-Faulkner, 2018	UK	3–4	18	Natural park (Park/forest)	Number of utterances (S)*, length of connected communication (S)*, levels of responsiveness (S)*, levels of grammatical complexity (S)	15 min	Intervention	H
Li, 2018	USA	13–19	155	Concentration of nature (Residential)	Mood (E)*	4 days	Longitudinal	L
Main Author, Year	**Country**	**Age**	**Sample size (N)**	**Type of nature exposure**	**Restorative outcome**	**Nature exposure duration**	**Study design**	**Assessment quality**
Feng & Astell-Burt, 2017	Australia	4–5	4968	Green space quantity (Residential)	Internalizing problems (E)* and externalizing conduct problems (B)*	8 years	Longitudinal	L
Bagot, 2015	Australia	8–11	550	Playground naturalness (School)	Perceived restorativeness (O)	Not specified (1 day)	Pre-post	A
Balseviciene, 2014	Lithuania	4–6	1468	Residential greenness (Residential)	Emotional problems (E), hyperactivity (B)*, conditional problems (B)*, prosocial behavior (S)*, peer relationship problems (S)*	–	Cross-sectional	L
Huynh, 2013	Canada	11–16	17249	Natural space (Residential)	Positive emotional well-being (E)	–	Cross-sectional	A
Wells & Evans, 2003	USA	9	337	Naturalness (Residential)	Stress (O)*, distress (O)*	–	Cross-sectional	A
Main Author, Year	**Country**	**Age**	**Sample size (N)**	**Type of nature exposure**	**Restorative outcome**	**Nature exposure duration**	**Study design**	**Assessment quality**
Taylor, 2002	USA	7–12	169	Near-home nature (Residential)	Concentration (C)*, inhibition of impulses (B)*, delay of gratification (B)*	–	Cross-sectional	A
Wells (2000)	USA	7–12	17	Naturalness (Residential)	Attention (C)*	1 year	Pre-post	A

Note. Study assessment quality: (L), Low risk of bias; (A), Acceptable risk of bias; (H), High risk of bias. Restoration outcome: (C), Cognitive variable; (E), Emotional variable; (B), Behavioural variable; (S), Social variable; (O), Complex outcomes. Type of nature exposure: (School), School greenspace; (Residential), Residential greenspace; (Park/forest), Interactions with nature at parks/forests; (Simulated), Simulated nature.
* Statistically significant ($p < 0.05$).

Table 3
Findings by restorative outcome variable, type of nature exposure and study quality.

		Restorative outcome variable														
		Cognitive			Emotional			Behavioural			Social			Complex outcomes		
Bias	Type of nature exposure	P	N	NS	P	N	NS	P	N	NS	P	N	NS	P	N	NS
Low risk of bias	School greenspace	–	–	–	–	–	–	1	–	–	–	–	–	–	–	–
	Residential greenspace	–	–	1	2	–	1	5	–	–	1	–	–	–	–	–
	Parks/forests	1	–	2	–	–	–	–	–	–	–	–	–	–	–	–
	Simulated nature	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	Total	**1**	**0**	**3**	**2**	**0**	**1**	**5**	**0**	**0**	**1**	**0**	**0**	**0**	**0**	**0**
Acceptable risk of bias	School greenspace	6	–	–	1	–	1	2	–	2	2	–	–	3	–	2
	Residential greenspace	3	–	–	1	–	1	4	–	–	1	–	–	2	–	–
	Parks/forests	4	–	1	1	–	2	–	–	1	1	–	–	2	–	4
	Simulated nature	3	–	–	1	–	–	–	–	–	–	–	–	–	–	–
	Total	**16**	**0**	**1**	**4**	**0**	**4**	**6**	**0**	**3**	**4**	**0**	**0**	**7**	**0**	**6**
High risk of bias	School greenspace	–	–	–	1	1	3	–	–	–	1	–	–	–	–	–
	Residential greenspace	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	Parks/forests	–	–	–	–	–	–	–	–	–	3	–	1	–	–	–
	Simulated nature	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	Total	**0**	**0**	**0**	**1**	**1**	**3**	**0**	**0**	**0**	**4**	**0**	**1**	**0**	**0**	**0**
Total sum		**17**	**0**	**4**	**7**	**1**	**8**	**12**	**0**	**3**	**9**	**0**	**1**	**7**	**0**	**6**

Note. P: positive significant effect of exposure to nature ($p < 0.05$); N: negative significant effect of nature ($p < 0.05$); NS: non-significant effect of nature.

significant. The most frequently studied variables in this category were depression, stress and perceived restoration. All included articles were rated as low or acceptable risk of bias.

2.6. Type of exposure to nature

The restorative effects of residential greenspace were the most commonly studied (13 papers). This category included 19 positive significant results and three non-significant results. Nine studies considered the effects of exposure to nature at school (i.e., school greenspace). Among these studies, 17 positive significant results, one negative significant result (i.e., negative effect of nature exposure) and eight non-significant results were observed. Six papers were included in the category parks/forests. Within this category, we observed 12 positive significant results and 11 non-significant results, which indicates that the effects of exposure to nature are not unequivocal but may be relevant only in some conditions. Finally, two papers were included in the category simulated nature and all four observed effects showed a positive significant relation between nature exposure and restorative outcomes.

2.7. Risk of bias

The quality assessment process revealed seven studies classified as low risk of bias, 21 studies as acceptable risk of bias and two as high risk of bias. After removing findings from studies rated as high risk of bias, there were 47 significant results (previously 52) and 18 non-significant results (previously 23). In the high risk of bias studies, we found four significant effects of nature exposure on children's restoration and one negative effect. This indicates that there is a substantial amount of evidence supporting the restorative effects of exposure to nature exposure on children and adolescents.

2.8. Effect sizes

We calculated the effect sizes of the restorative effect of eight articles (Table 4) as they studied the restorative process during a short time period, that compared scores on several variables directly before and after a single instance of nature exposure. We also explored if they included a condition of depletion or fatigue. Only two of these studies contemplated this antecedent condition (Amicone et al., 2018; Shu & Ma, 2019).

Effect sizes were then categorized and ranged considering the type of restorative outcome that the variables were assessing (i.e., cognitive, emotional, etc.; see Table 5). Results show that there is a vast difference between the observed effect sizes, but that the majority of them comprised small and medium effect sizes (between 0.20 and 0.80).

Table 4
Effect sizes of studies conducted in a short time frame.

Main Author, Year	Mean difference Cohen's d
Wade, 2020	Stress: .26; Affect: .26; Vitality: .39*; Attention: .59*; Cognitive arousal: .45*; Spatial working memory: .31*
Johnson et al., 2019	Endogenous attention:1.45*; Exogenous attention:
Dopko, 2019	Possitive affect: .28*; Negative affect: .44*; Vitality: .11; Pleassant affect: .13; Fun today: .21; Prosociality: .32*
Shu, 2019	Attention: .34*; Memory: .69
Stevenson, 2019	Executive attention: .22; Accuracy: .11; Mean reaction time: .38*
Oh, 2019	Attention: *; Mood state (comfort): .72*
Amicone, 2018	a) Attention: 0.40*; Working memory:0.68*; Impulse control:0.03; Perceived restorativeness:0.81* b) Attention: 0.81*; perceived restorativeness:1.09*
Cameron-Faulkner, 2018	Number of utterances: 0.62*, Length of connected communication: 1.34*, Levels of responsiveness: 1.44*, Levels of grammatical complexity: 0.21

* Statistically significant ($p < 0.05$).

Table 5
Effect sizes range considering restorative outcome categories.

Variable	N articles	N effects (N significant effects)	Cohen d range	Cohen d range without non-significant effects
Cognitive	6	14(11)	−.22–1.45	.31–1.45
Emotional	3	7(3)	.11–.72	.28–.72
Behavioral	1	1(0)	.03	–
Social	2	5(4)	.21–1.44	.32–1.44
Complex outcomes	2	4(3)	.26–1.09	.39–1.09

When non-significant effects were excluded from the analysis, all effects could be classified as, at least, small size effects except for the effects included in the behavioural category.

The most studied outcomes concerned were cognitive variables, (14, of which 11 significant) and emotional ones (seven, of which three were significant). The cognitive, social and complex outcomes categories registered large effects (greater than 0.80), the largest being found in a cognitive variable (endogenous attention: 1.45). However, caution should be taken when interpreting these effect sizes as the number of observed outcomes is not large enough to be generalizable, especially with behavioural, social and complex outcomes categories.

3. Discussion

This systematic review is based on 30 papers with a variety of study designs. It revealed a significant number of positive findings on the relation between children's and adolescents' exposure to nature and restoration for all five contemplated outcomes (cognitive, emotional, behavioural, social and complex outcomes). In accordance with previous literature reviews about the benefits of contact with nature, both with adults (Ohly et al., 2016) and children (Gill, 2014; Mnich et al., 2019; Oswald et al., 2020; Roberts et al., 2020; Tillmann et al., 2018), our results show that exposure to nature provides a wide range of benefits to children. Moreover, among all the contemplated studies, only one negative significant effect of exposure to nature on restorative outcomes was observed. Specifically, Dopko et al. (2019) reported a negative relation between nature exposure in a nature school and positive emotions that could be traced back to the fact that some children described being scared of seeing snakes, bears and wolves. This is in line with previous studies' findings suggesting that nature can be scary and uncomfortable for children (Larson et al., 2011). We paid special attention to those studies that researched restoration within a short time span, before and after exposure to a natural environment. Only two of those studies included an antecedent condition of fatigue. The combined findings of the eight studies revealed that there is a vast variety in terms of the observed effect sizes but, overall, the effects were positive.

For the 30 studies, there were several differences in relation to the results found in each of the restorative outcomes' categories. First, the ratio between positive significant and non-significant findings varied across categories. The most frequently studied variables were the ones included in the cognitive restorative outcomes category (e.g., attention, memory). Given that ART (Kaplan & Kaplan, 1989) focuses on diminished attentional resources, and considering the popularity of this theory in restoration research (Hartig, 2021), this result is not surprising. Of the 21 results reported in this category, only four were non-significant regardless of the risk of bias. According to our results, exposure to nature helps children improve attention (van den Bogerd et al., 2020), working memory (Amicone et al., 2018) and concentration (Taylor et al., 2002). Three of the four non-significant results dealt with nature exposure in parks/forests. One explanation could be that, in the studies that we reviewed, compared to the daily exposure to nature at school and residential areas, exposure to nature in parks and forests tends to be shorter in time. Hartig (2007) observed that longer exposure to nature provides stronger restorative effects. While frequent visits to parks and

forests may provide cumulative positive effects of repeated restorative experiences (Collado et al., 2017; Hartig, 2007), the studies included in this literature review only considered the possible restorative impact of single visits (Cameron-Faulkner et al., 2018; Stevenson et al., 2019).

A similar pattern was observed for behavioural outcomes (e.g., impulse inhibition, hyperactivity). Only three of the 15 registered findings that considered behavioural outcomes were non-significant. According to these results, exposure to nature helps children inhibit impulses (Amicone et al., 2018), reduces hyperactivity (Balseviciene et al., 2014) and promotes physical activity (Raney et al., 2019), among others. Similarly, results included in the social category, although scarcer than the ones registered in the cognitive and behavioural categories, showed a clear restorative benefit from exposure to nature, with all the findings except one (Cameron-Faulkner et al., 2018), being positive and significant. This is in consonance with recent calls to extend restoration theory beyond ART (Kaplan & Kaplan, 1989) and SRT (Ulrich, 1983) and, specifically, to contemplate the restorative effects that nature exposure has on social resources (Hartig, 2021; Kaplan, 1995). For instance, Sprague and Ekenga (2021) observed that after a 15-week nature-based education program students showed an improvement in social functioning whereas students in the control group, who did not participate in any program, showed a decline. However, effects of participation in a differently oriented program as a comparison group would have been a useful complement. These results are in line with the relational restoration theory (RRT; Hartig, 2021). RRT proposes that the resources that are depleted on a daily basis and so need restoration extend beyond those proposed in ART and SRT (i.e., cognitive, emotional and physiological). Specifically, social resources (e.g., friends' support) can also be restored through people-environment transactions. Hartig (2021) suggests that people-environment transactions that support restoration can also improve the inclination to exchange social support. RRT is a relatively new theory and, to our knowledge, there are no specific studies inspired by it. Yet, our findings indicate that nature exposure helps improve children's social resources (Balseviciene et al., 2014; Cameron-Faulkner et al., 2018). However, the number of findings for this restorative outcome is low, when compared to other variables (cognitive, emotional and behavioural), and none of them includes an antecedent condition to recover from. So, although promising, more research about the social aspects of restoration is needed.

The scenario was quite different for the two remaining categories (i.e., emotional resources and complex outcomes). Although significant results were observed for emotional variables (7 out of 16) there was also an important number (more than 50%) of non-significant results. We also found one negative significant effect of exposure to nature on children's emotions (Dopko et al., 2019). This does not necessarily imply that children's positive emotions cannot be restored through exposure to nature. According to SRT (Ulrich, 1983), for emotional recovery to occur, the individual must first experience stress. Maybe the stress experienced was too low to find substantial recovery through a nature experience. Thus, further examination of the restorative effects in relation to emotions that exposure to nature has on children and adolescents is required. In light of our results, we encourage researchers to examine the whole process of restoration as described by Ulrich (1983) and, as such, consider not only positive emotions but also stress reduction.

With regards to the complex outcomes category, the ratio of positive significant results was close to 50% (7 out of 13 findings). In other words, exposure to nature does not always appear to have a clear positive effect on children and adolescents on variables that fit in several of our categories. One reason for these findings may be that nature exposure has a clear effect on single outcome variables (e.g., attention) but the effects on variables including more than one dimension (e.g., those including cognitive and behavioural aspects) are more difficult to capture and disentangle. This would be the case for those studies examining the possible restorative effects of nature exposure on perceived health (Song et al., 2020), perceived stress (Wade et al., 2020) or health complaints such as fatigue, headaches or irritation of eyes (van den Bogerd et al., 2020). Nevertheless, according to our results, variables including more than one restorative outcome are the least frequently studied and, in our view, their inclusion in future investigations should be more strongly justified.

It is remarkable that only two of the 30 selected articles (Amicone et al., 2018; Shu & Ma, 2019) studied restoration within a short time period and considered an a priori condition of depletion or fatigue which are especially relevant aspects (Hartig et al., 2017; Stevenson et al., 2018). Nevertheless, at least eight studies looked at the phenomenon of restoration in a time frame of less than one day and included a pre-post measure. When analysing these effects in greater depth, not only observing the significance, but also the size of the effects, we found that, overall, the effects could be categorized as small or medium. A possible explanation for these moderate restorative effects could be that no previous condition of fatigue induction was considered. In fact, Amicone et al. (2018) reported three large effects after analysing the restorative effects of natural environments at school after attending classes (i.e., antecedent condition). Cognitive variables were the most studied in these eight studies. Specifically, six out of eight studies included at least one cognitive restorative outcome and, when considering just significant effects, 11 effect sizes ranging from 0.31 (small) to 1.45 (large) were registered. Considering the emotion category, only small and medium effects were found. The restorative effects that could be found in the other three categories (i.e., behavioural, social, and complex outcomes) were also examined. However, within the eight studies in which effects sizes were analysed, these types of restorative outcomes were scarcely studied. Thus, the results obtained regarding these three categories cannot be generalized and should be considered with caution.

Our findings also showed that most restoration research with children and adolescents has been conducted in places close to children's daily activity, such as residential areas and schools, producing 47 of the 75 findings considered in this literature review. This is only logical considering that the mobility at this age range is limited, and hence most children spend their time at school and in their neighborhood (Carver et al., 2008). Overall, positive relations were found between school and residential greenspace, simulated nature and restorative outcomes. In these types of nature exposure, the number of positive significant results highly surpassed the non-significant ones. In contrast, exposure to nature at parks and forests had a lower ratio of significance as nearly half of the findings (11 out of 23 results) were non-significant. As indicated above, this might be due to the short time people tend to spend in parks/forests compared to home and school areas with the permanent presence of nature nearby (Carver et al., 2008).

Exposure to simulated nature was the less frequently studied category (only two out of the 30 studies included in this literature review considered this type of nature exposure). Interestingly, each of the effects reported in these studies was positive and significant. For instance, exposure to natural soundscapes (Shu & Ma, 2019) and to natural visual stimuli, such as pictures of plants (Oh et al., 2019) helped restore children's cognitive and emotional resources. Given the limited number of studies evaluating the restorative effects that simulated nature may have for children, future investigations should explore if our findings are exceptional or, on the contrary, restoration can indeed be promoted by simulating nature conditions.

Regarding the quality of the included studies, the vast majority of them were classified as with an acceptable risk of bias (21 out of 30) while seven of them were classified as with a low risk of bias. This pattern is similar to the one observed in previous systematic reviews using the NHLBI quality assessment tool (Tillmann et al., 2018). This provides reliability to the inferences extracted from this systematic review, suggesting that nature exposure offers restorative benefits to children and adolescents. Two of the studies did not meet the selected criteria (at least 50% of criteria NHLBI quality assessment tool is met), and were classified as with high risk of bias. In sum, the findings of this systematic review showed that nature exposure offers restorative benefits to children and adolescents, especially in terms of restoring

cognitive, behavioural and social resources. Thus, this systematic review supports the application of these findings in diverse forms of policy, such as redesigning school playgrounds and residences to make them greener, promoting nature-based education at schools, and considering outdoor experiences as a health priority. By promoting this kind of policies, children, adolescents and even whole communities could benefit from interacting with nature and its restorative effects.

3.1. Limitations of the study

This systematic review was exhaustive and comprehensive according to the standards developed by PRISMA. Nevertheless, there are a few limitations that need to be taken into account. First, compared to a meta-analysis, with a systematic review a statistical descriptor such as an estimated pooled effect or a funnel plot cannot be analysed. Conducting a meta-analysis was our first option, but was not possible due to the lack of homogeneity found in the studies' designs and the high variability of measures used in the reviewed articles. Specifically, there was a lack of standardization and wide variability regarding the observed variables (cognitive, emotional, behavioural, social or complex outcomes) that each selected study included. For instance, the emotional category included variables such as emotional health, positive and negative affect, and positive mood. It is important to notice that transient effects (e.g., mood) should be distinguished from durable effects (e.g., emotional health) as although both refer to emotions, they reflect processes at quite different levels. In addition, even when the same concept was considered in different studies (e.g., directed attention), different measures were used to register it, introducing even more variability in the findings and precluding generalizations. In line with previous systematic reviews about the benefits of nature exposure (Ohly et al., 2016; Tillmann et al., 2018), we believe there is a need for standardization from the scientific community to agree on what a restorative outcome is, and what it is not, so that similar variables, tools and experimental designs are used across studies.

A second limitation relates to how the restorative process is conceived in each of the studies. Restoration theories propose that for restoration to occur, a clear need for restoration should be specified (i.e., attentional fatigue). However, the inclusion of this antecedent condition in restorative research with children and adolescents is rare. Thus, while experimental studies have shown that exposure to nature is indeed restorative for children (Raney et al., 2019), and the results of the current systematic review point in that direction, efforts should be put into differentiating between restorative and instorative effects of nature exposure. Instorative effects refer to the beneficial changes promoted by exposure to certain environments (mainly natural ones) when the antecedent depleted condition is not necessarily present (Hartig, 2007). These beneficial effects are often smaller than restorative effects when assessed as short-term outcomes (Stevenson et al., 2018) although they may emerge as at least as robust and meaningful with repeated exposure over longer time spans. However, such complex and cumulative processes are difficult to control and measure. We did not differentiate between restorative and instorative effects in this systematic review. We actually made a plea to expand the restoration concept and make it comprehensive to include not only the 'classical' restorative effect -the short-term recovery after a depletion manipulation- but also what has been called the instorative effect by Hartig (2021) and the multiple recovery phases as described by Kaplan (1995).

One last limitation concerns the evaluation of risk of bias. In line with previous studies (Tillmann et al., 2018), there was a consensual agreement between three of the researchers involved in this systematic review to assess each study using the selected criteria. However, as this decision is left to the researchers, if a stricter perspective had been taken, some of the studies would have been classified as having a high risk of bias, and this should be considered when interpreting the results.

4. Conclusion

The main objective of this systematic review was to evaluate and synthesize the extant evidence about the effects of exposure to nature on restoring cognitive, emotional, social and behavioural resources for children and adolescents. Overall, our results reflect that nature exposure is restorative for this population group. We also found that the restorative benefits of exposure to nature are less obvious when outcome variables represent a combination of several possible restorative effects (e.g., cognitive, emotional and behavioural). Moreover, an effort should be made to assess restorative outcomes using standardized measures. This would enhance comparability across studies. There is also a need to look at how, why, for whom and under what circumstances different types of nature exposure offer restorative benefits to children. A deeper understanding of these specificities is needed not only to enhance scientific knowledge, but also to develop specific guidelines for health practitioners, parents and policy makers.

Funding

This work was supported by the Spanish Ministry of Science, Innovation and Universities (grant number: PGC2018-095502-B-I00).

Author statement

JC, SC, AM: Conceptualization. AM: Data curation, Formal analysis, Methodology. SC, JC, AM: Project administration, Visualization. AM: Writing - original draft. JC, SC, HS: Supervision, Validation, Visualization, Writing - review & editing. JC, SC: Funding acquisition. All authors have read and agreed to the current version of the manuscript.

References

Amicone, G., Petruccelli, I., De Dominicis, S., Gherardini, A., Costantino, V., Perucchini, P., & Bonaiuto, M. (2018). Green breaks: The restorative effect of the school environment's green areas on children's cognitive performance. *Frontiers in Psychology, 9*, 1579. https://doi.org/10.3389/fpsyg.2018.01579

Astell-Burt, T., Feng, X., & Kolt, G. S. (2013). Mental health benefits of neighbourhood green space are stronger among physically active adults in middle-to-older age: Evidence from 260,061 Australians. *Preventive Medicine, 57*(5), 601–606. https://doi.org/10.1016/j.ypmed.2013.08.017

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. https://doi.org/10.1016/j.jenvp.2014.11.005

Balseviciene, B., Sinkariova, L., Grazuleviciene, R., Andrusaityte, S., Uzdanaviciute, I., Dedele, A., & Nieuwenhuijsen, M. J. (2014). Impact of residential greenness on preschool children's emotional and behavioral problems. *International Journal of Environmental Research and Public Health, 11*(7), 6757–6770. https://doi.org/10.3390/ijerph110706757

Baumeister, R. F., Tice, D. M., & Vohs, K. D. (2018). The strength model of self-regulation: Conclusions from the second decade of willpower research. *Perspectives on Psychological Science, 13*(2), 141–145. https://doi.org/10.1177/1745691617716946

Bento, G., & Dias, G. (2017). The importance of outdoor play for young children's healthy development. *Porto Biomedical Journal, 2*(5), 157–160. https://doi.org/10.1016/j.pbj.2017.03.003

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

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

Cameron-Faulkner, T., Melville, J., & Gattis, M. (2018). Responding to nature: Natural environments improve parent-child communication. *Journal of Environmental Psychology, 59*, 9–15. https://doi.org/10.1016/j.jenvp.2018.08.008

Carver, A., Timperio, A., & Crawford, D. (2008). Playing it safe: The influence of neighbourhood safety on children's physical activity—a review. *Health & Place, 14*(2), 217–227. https://doi.org/10.1016/j.healthplace.2007.06.004

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

Cohen, B. (2006). Urbanization in developing countries: Current trends, future projections, and key challenges for sustainability. *Technology in Society, 28*(1–2), 63–80. https://doi.org/10.1016/j.techsoc.2005.10.005

Collado, S., Staats, H., Corraliza, J. A., & Hartig, T. (2017). Restorative environments and health. In *Handbook of environmental psychology and quality of life research* (pp. 127–148). Cham: Springer. https://doi.org/10.1007/978-3-319-31416-7_7.

Corazon, S. S., Sidenius, U., Poulsen, D. V., Gramkow, M. C., & Stigsdotter, U. K. (2019). Psycho-physiological stress recovery in outdoor nature-based interventions: A systematic review of the past eight years of research. *International Journal of Environmental Research and Public Health, 16*(10), 1711. https://doi.org/10.3390/ijerph16101711

Crawford, D., Cleland, V., Timperio, A., Salmon, J., Andrianopoulos, N., Roberts, R., … Ball, K. (2010). The longitudinal influence of home and neighbourhood environments on children's body mass index and physical activity over 5 years: The CLAN study. *International Journal of Obesity, 34*(7), 1177–1187. https://doi.org/10.1038/ijo.2010.57

Dadvand, P., Hariri, S., Abbasi, B., Heshmat, R., Qorbani, M., Motlagh, M. E., … Kelishadi, R. (2019). Use of green spaces, self-satisfaction and social contacts in adolescents: A population-based CASPIAN-V study. *Environmental Research, 168*, 171–177. https://doi.org/10.1016/j.envres.2018.09.033

Dadvand, P., Nieuwenhuijsen, M. J., Esnaola, M., Forns, J., Basagaña, X., Alvarez-Pedrerol, M., … Sunyer, J. (2015). Green spaces and cognitive development in primary school children. *Proceedings of the National Academy of Sciences, 112*(26), 7937–7942. https://doi.org/10.1073/pnas.1503402112

Dopko, R. L., Capaldi, C. A., & Zelenski, J. M. (2019). The psychological and social benefits of a nature experience for children: A preliminary investigation. *Journal of Environmental Psychology, 63*, 134–138. https://doi.org/10.1016/j.jenvp.2019.05.002

Dowdell, K., Gray, T., & Malone, K. (2011). Nature and its influence on children's outdoor play. *Journal of Outdoor and Environmental Education, 15*(2), 24–35. https://doi.org/10.1007/BF03400925

Feng, X., & Astell-Burt, T. (2017). Residential green space quantity and quality and child well-being: A longitudinal study. *American Journal of Preventive Medicine, 53*(5), 616–624. https://doi.org/10.1016/j.amepre.2017.06.035

Flouri, E., Papachristou, E., & Midouhas, E. (2019). The role of neighbourhood greenspace in children's spatial working memory. *British Journal of Educational Psychology, 89*(2), 359–373. https://doi.org/10.1111/bjep.12243

Gidlow, C. J., Randall, J., Gillman, J., Smith, G. R., & Jones, M. V. (2016). Natural environments and chronic stress measured by hair cortisol. *Landscape and Urban Planning, 148*, 61–67. https://doi.org/10.1016/j.landurbplan.2015.12.009

Gill, T. (2014). The benefits of children's engagement with nature: A systematic literature review. *Children, Youth, and Environments, 24*(2), 10–34. https://doi.org/10.7721/chilyoutenvi.24.2.0010

Hartig, T. (2004). Restorative environments. In *Encyclopedia of applied psychology* (pp. 273–279). Academic press. https://doi.org/10.1016/B0-12-657410-3/00821-7.

Hartig, T. (2007). Three steps to understanding restorative environments as health resources. In *Open space: People space* (pp. 183–200). Taylor & Francis. https://doi.org/10.4324/9780203961827-22.

Hartig, T. (2021). Restoration in nature: Beyond the conventional narrative. In *Nature and psychology* (pp. 89–151). Cham: Springer. https://doi.org/10.1007/978-3-030-69020-5_5.

Hartig, T., & Evans, G. W. (1993). Psychological foundations of nature experience. *Advances in psychology, 96*, 427–457. https://doi.org/10.1016/S0166-4115(08)60053-9. North-Holland.

Hartig, T., & Jahncke, H. (2017). Letter to the editor: Attention restoration in natural environments: Mixed mythical metaphors for meta-analysis. *Journal of Toxicology and Environmental Health, Part A B, 20*(5), 305–315. https://doi.org/10.1080/10937404.2017.1363101

Hartig, T., & Staats, H. (2003). Guest Editors' introduction: Restorative environments. *Journal of Environmental Psychology, 23*, 103–107. https://doi.org/10.1016/S0272-4944(02)00108-1

Herzog, T. R., Black, A. M., Fountaine, K. A., & Knotts, D. J. (1997). Reflection and attentional recovery as distinctive benefits of restorative environments. *Journal of Environmental Psychology, 17*(2), 165–170. https://doi.org/10.1006/jevp.1997.0051

Hofferth, S. L. (2009). Changes in American children's time–1997 to 2003. *Electronic International Journal of Time Use Research, 6*(1), 26–47. https://doi.org/10.13085/eijtur.6.1.26-47

Huynh, Q., Craig, W., Janssen, I., & Pickett, W. (2013). Exposure to public natural space as a protective factor for emotional well-being among young people in Canada. *BMC Public Health, 13*(1), 1–14. https://doi.org/10.1186/1471-2458-13-407

Johnson, S. A., Snow, S., Lawrence, M. A., & Rainham, D. G. (2019). Quasi-randomized trial of contact with nature and effects on attention in children. *Frontiers in Psychology, 10*, 2652. https://doi.org/10.3389/fpsyg.2019.02652

Kabisch, N., Alonso, L., Dadvand, P., & van den Bosch, M. (2019). Urban natural environments and motor development in early life. *Environmental Research, 179*, Article 108774. https://doi.org/10.1016/j.envres.2019.108774

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

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

Kuo, M., Klein, S. E., Browning, M. H., & Zaplatosch, J. (2021). Greening for academic achievement: Prioritizing what to plant and where. *Landscape and Urban Planning, 206*, Article 103962. https://doi.org/10.1016/j.landurbplan.2020.103962

Kuo, F. E., & Sullivan, W. C. (2001). Aggression and violence in the inner city. Effects of environment via mental fatigue. *Environment and Behavior, 33*, 543–571. https://doi.org/10.1177/00139160121973124

Larson, L. R., Green, G. T., & Castleberry, S. B. (2011). Construction and validation of an instrument to measure environmental orientations in a diverse group of children. *Environment and Behavior, 43*(1), 72–89. https://doi.org/10.1177/0013916509345212

Larson, L. R., Szczytko, R., Bowers, E. P., Stephens, L. E., Stevenson, K. T., & Floyd, M. F. (2019). Outdoor time, screen time, and connection to nature: Troubling trends among rural youth? *Environment and Behavior, 51*(8), 966–991. https://doi.org/10.1177/0013916518806686

Lederbogen, F., Kirsch, P., Haddad, L., Streit, F., Tost, H., Schuch, P., … Meyer-Lindenberg, A. (2011). City living and urban upbringing affect neural social stress processing in humans. *Nature, 474*(7352), 498–501. https://doi.org/10.1038/nature10190

Li, D., Deal, B., Zhou, X., Slavenas, M., & Sullivan, W. C. (2018). Moving beyond the neighborhood: Daily exposure to nature and adolescents' mood. *Landscape and Urban Planning, 173*, 33–43. https://doi.org/10.1016/j.landurbplan.2018.01.009

Luís, S., Dias, R., & Lima, M. L. (2020). Greener schoolyards, greener futures? Greener schoolyards buffer Decreased contact with nature and are linked to connectedness to nature. *Frontiers in Psychology, 11*, Article 567882. https://doi.org/10.3389/fpsyg.2020.567882

Martin, L., White, M. P., Hunt, A., Richardson, M., Pahl, S., & Burt, J. (2020). Nature contact, nature connectedness and associations with health, wellbeing and pro-environmental behaviours. *Journal of Environmental Psychology, 68*, Article 101389. https://doi.org/10.1016/j.jenvp.2020.101389

Mavoa, S., Lucassen, M., Denny, S., Utter, J., Clark, T., & Smith, M. (2019). Natural neighbourhood environments and the emotional health of urban New Zealand adolescents. *Landscape and Urban Planning, 191*, Article 103638. https://doi.org/10.1016/j.landurbplan.2019.103638

Mnich, C., Weyland, S., Jekauc, D., & Schipperijn, J. (2019). Psychosocial and physiological health outcomes of green exercise in children and adolescents—a systematic review. *International Journal of Environmental Research and Public Health, 16*(21), 4266. https://doi.org/10.3390/ijerph16214266

Oh, Y. A., Kim, S. O., & Park, S. (2019). Real foliage plants as visual stimuli to improve concentration and attention in elementary students. *International Journal of Environmental Research and Public Health, 16*(5), 796. https://doi.org/10.3390/ijerph16050796

Ohly, H., White, M. P., Wheeler, B. W., Bethel, A., Ukoumunne, O. C., Nikolaou, V., & Garside, R. (2016). Attention restoration theory: A systematic review of the attention restoration potential of exposure to natural environments. *Journal of Toxicology and Environmental Health, Part A B, 19*(7), 305–343. https://doi.org/10.1080/10937404.2016.1196155

Oswald, T. K., Rumbold, A. R., Kedzior, S. G., & Moore, V. M. (2020). Psychological impacts of "screen time" and "green time" for children and adolescents: A systematic scoping review. *PLoS One, 15*(9), Article e0237725. https://doi.org/10.1371/journal.pone.0237725

Putra, I. G. N. E., Astell-Burt, T., Cliff, D. P., Vella, S. A., & Feng, X. (2020). Association between green space quality and prosocial behaviour: A 10-year multilevel longitudinal analysis of Australian children. *Environmental Research, 196*, Article 110334. https://doi.org/10.1016/j.envres.2020.110334

Raney, M. A., Hendry, C. F., & Yee, S. A. (2019). Physical activity and social behaviors of urban children in green playgrounds. *American Journal of Preventive Medicine, 56*(4), 522–529. https://doi.org/10.1016/j.amepre.2018.11.004

Remmers, T., Thijs, C., Ettema, D., de Vries, S., Slingerland, M., & Kremers, S. (2019). Critical hours and important environments: Relationships between afterschool physical activity and the physical environment using GPS, GIS and accelerometers in 10–12-year-old children. *International Journal of Environmental Research and Public Health, 16*(17), 3116. https://doi.org/10.3390/ijerph16173116

Reuben, A., Arseneault, L., Belsky, D. W., Caspi, A., Fisher, H. L., Houts, R. M., … Odgers, C. (2019). Residential neighborhood greenery and children's cognitive development. *Social Science & Medicine, 230*, 271–279. https://doi.org/10.1016/j.socscimed.2019.04.029

Ritchie, H., & Roser, M. (2018). *Urbanization. Our world in data.* September https://ourworldindata.org/urbanization.

Roberts, A., Hinds, J., & Camic, P. M. (2020). Nature activities and wellbeing in children and young people: A systematic literature review. *Journal of Adventure Education and Outdoor Learning, 20*(4), 298–318. https://doi.org/10.1080/14729679.2019.1660195

Romans, S., Cohen, M., & Forte, T. (2011). Rates of depression and anxiety in urban and rural Canada. *Social Psychiatry and Psychiatric Epidemiology, 46*(7), 567–575. https://doi.org/10.1007/s00127-010-0222-2

Shu, S., & Ma, H. (2019). Restorative effects of classroom soundscapes on children's cognitive performance. *International Journal of Environmental Research and Public Health, 16*(2), 293. https://doi.org/10.3390/ijerph16020293

Skar, M., Wold, L. C., Gundersen, V., & O'Brien, L. (2016). Why do children not play in nearby nature? Results from a Norwegian survey. *Journal of Adventure Education and Outdoor Learning, 16*(3), 239–255. https://doi.org/10.1080/14729679.2016.1140587

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

Song, M. K., Bang, K. S., Kim, S., Lee, G., & Jeong, Y. (2020). Effects of an urban forest-based health promotion program on children living in group homes. *Journal of Psychosocial Nursing and Mental Health Services, 58*(6), 18–29. https://doi.org/10.3928/02793695-20200406-01

Sprague, N. L., & Ekenga, C. C. (2021). The impact of nature-based education on health-related quality of life among low-income youth: Results from an intervention study. *Journal of Public Health*, 1–8. https://doi.org/10.1093/pubmed/fdaa243

Staats, H., Kieviet, A., & Hartig, T. (2003). Where to recover from attentional fatigue: An expectancy-value analysis of environmental preference. *Journal of Environmental Psychology, 23*(2), 147–157. https://doi.org/10.1016/S0272-4944(02)00112-3

Stevenson, M. P., Dewhurst, R., Schilhab, T., & Bentsen, P. (2019). Cognitive restoration in children following exposure to nature: Evidence from the attention network task and mobile eye tracking. *Frontiers in Psychology, 10*, 42. https://doi.org/10.3389/fpsyg.2019.00042

Stevenson, M. P., Schilhab, T., & Bentsen, P. (2018). Attention restoration theory II: A systematic review to clarify attention processes affected by exposure to natural environments. *Journal of Toxicology and Environmental Health, Part A B, 21*(4), 227–268. https://doi.org/10.1080/10937404.2018.1505571

Taylor, A. F., & Butts-Wilmsmeyer, C. (2020). Self-regulation gains in kindergarten related to frequency of green schoolyard use. *Journal of Environmental Psychology, 70*, Article 101440. https://doi.org/10.1016/j.jenvp.2020.101440

Taylor, A. F., & Kuo, F. E. (2009). Children with attention deficits concentrate better after walk in the park. *Journal of Attention Disorders, 12*(5), 402–409. https://doi.org/10.1177/1087054708323000

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

Tillmann, S., Tobin, D., Avison, W., & Gilliland, J. (2018). Mental health benefits of interactions with nature in children and teenagers: A systematic review. *Journal of Epidemiology & Community Health, 72*(10), 958–966. https://doi.org/10.1136/jech-2018-210436

Ulrich, R. S. (1983). Aesthetic and affective Response to natural environment. In I. Altman, & J. F. Wohlwill (Eds.), *Behavior and the natural environment. Human behavior and environment* (pp. 85–125). Springer. https://doi.org/10.1007/978-1-4613-3539-9_4.

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

Wade, L., Lubans, D. R., Smith, J. J., & Duncan, M. J. (2020). The impact of exercise environments on adolescents' cognitive and psychological outcomes: A randomised controlled trial. *Psychology of Sport and Exercise, 49*, Article 101707. https://doi.org/10.1016/j.psychsport.2020.101707

Wells, N. M. (2000). At home with nature: Effects of "greenness" on children's cognitive functioning. *Environment and Behavior, 32*(6), 775–795. https://doi.org/10.1177/00139160021972793

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

Zijlema, W. L., Avila-Palencia, I., Triguero-Mas, M., Gidlow, C., Maas, J., Kruize, H., … Nieuwenhuijsen, M. J. (2018). Active commuting through natural environments is associated with better mental health: Results from the PHENOTYPE project. *Environment International, 121*, 721–727. https://doi.org/10.1016/j.envint.2018.10.002