

Indoor nature exposure (INE): a health-promotion framework

J. MCSWEENEY^{1*}, D. RAINHAM², S. A. JOHNSON³, S. B. SHERRY³
and J. SINGLETON⁴

¹Interdisciplinary Phd Programme, Dalhousie University, Halifax, NS, Canada, ²Environmental Sciences, Dalhousie University, Halifax, NS, Canada, ³Department of Psychology, Dalhousie University, Halifax, NS, Canada and ⁴Leisure Studies, Dalhousie University, Halifax, NS, Canada

*Corresponding author. E-mail: jmmcswee@dal.ca

SUMMARY

Engaging in outdoor nature-based spaces has significant positive physiological and psychological health benefits. Although the integration of nature into indoor spaces is rarely considered a health-promoting tool, it may be an effective method for increasing nature engagement in a largely urbanized world. This paper presents an overview of indoor nature exposure (INE) by summarizing the current evidence of INE through the use of a scoping methodology. Results show that INE can be a health-promoting

tool through the interaction of nature-based stimuli and individual characteristics (e.g. gender, age). Moreover, the results of the current literature need to be interpreted with consideration to methodological issues, such as the lack of participant characteristics, the issue of exposure realism and little qualitative data to highlight individual experiences. The scoping review process allowed for the summation of results and for a framework to be created in order to better understand how INE is facilitated.

Key words: nature; health promotion; environment

INTRODUCTION

In nature and the language of the sense

The anchor of my purest thoughts the nurse

The guide, the guardian of my heart and soul
(Wordsworth, 1798)

The healing properties of nature have long been expressed in writing, as seen by the extract from *Lines Written Above Tintern Abbey* by Wordsworth (1798) and the literature from Muir (1901), Thoreau (1854) and Emerson (1836). (Nature has typically been a broad and encompassing definition that has a variety of meanings. Due to the vastness and ambiguity of the term, this article defines nature as outdoor spaces that

incorporate a range of plants, animals, landscapes and water features.) Recent evidence supports the claim that spending time in nature provides a range of positive physical, psychological and social health benefits (Ohtsuka *et al.*, 1998; Cimprich and Ronis, 2001; Wu and Lanier, 2003; Loeffler, 2004; Wichrowski *et al.*, 2005; Boniface, 2006; Berman *et al.*, 2008; Park *et al.*, 2010; van den Berg and Custers, 2011). These health-promoting properties are purportedly linked to humans' adaptive connection to nature. During the course of evolution, outdoor environments provided humans with food, security and a place of restoration, which resulted in positive physiological and psychological benefits (Ulrich, 1983; Wilson, 1984; Kellert and Wilson, 1993; Lorh and Pearson-Mims, 2000). The *biophilia*

hypothesis describes this innate affiliation with nature as an adaptive behavior passed on through evolution (Wilson, 1984). However, the landscape of 21st century is a drastic change from the natural environments from which humans evolved in.

Nature is beneficial for our health and well-being, and yet increasingly people spend less time outdoors. Currently, over 50% of the world's population is living in urban areas and has limited our opportunity to engage in nature (Zipperer and Pickett, 2012). People are now functioning largely within built spaces, despite their physiological and psychological functions evolving from nature (Ulrich, 1983; Wilson, 1984; Kellert and Wilson, 1993). Data now suggest this rapid change and nature deficit is linked to the growing mortality and morbidity rates associated with chronic stress and poor mental health (Garling and Golledge, 1993; Maller *et al.*, 2005; Louv, 2008; Selhub and Logan, 2012). While urbanization has drastically changed the appearance of outdoor environments, the ability to adapt built environments offers the opportunity to facilitate nature interaction within indoor spaces and provide restorative and health-promoting indoor environments.

Time-use data show that in North America, most adults spend ~90% of their time indoors (Klepeis *et al.*, 2001; Leech *et al.*, 2002; Setten *et al.*, 2013), where interior design features define the environment, and directly or indirectly (e.g. perceptions of environmental characteristics) influence an individual's wellbeing (Hedge *et al.*, 1989; Aries *et al.*, 2010). Through ambient (e.g. art) and architectural properties (e.g. windows), indoor built spaces can incorporate natural light, plant-based features and organic textures, sounds and aromas to replicate nature. Considering the potentially healing properties of nature, exposing individuals to natural elements through indoor environmental characteristics may be a means of improving health and creating health-promoting environments.

Reviews summarizing the effects of nature contact have not focused on indoor nature exposure (INE). Instead, the current work on nature and health has typically focused on outdoor nature (e.g. mountainous landscapes or forests) or urban environments. Little work has been done to understand how these two environments can merge to create restorative nature-based spaces within built environments. The present review outlines the current evidence on INE.

From a health-promotion perspective, understanding the link between nature-based indoor environments and health is important for the incorporation of nature into health sustaining and promoting ventures in a largely urbanized world.

METHODS

This study adopted a scoping method outlined by Arskey and O'Malley (Arskey and O'Malley, 2005), that allowed for the identification of a variety of evidence from various disciplines, regardless of the methods or study designs applied (Arksy and O'Malley, 2005; Badger *et al.*, 2000). Unlike systematic reviews, scoping studies do not address specific or narrow research questions, nor do they assess the quality of the included studies (Arksy and O'Mally, 2005).

The scoping study began by using a comprehensive strategy which used evidence (quantitative and qualitative) from a variety of sources. Articles were identified through electronic databases (including EBSCO, Cumulative Index to Nursing and Allied Health Literature (CINAHL), ProQuest, PubMed, Science Direct and Web of Science) and reference lists of reviewed articles. Key search words were selected from two broad areas: health and nature (Table 1).

The literature was included if it made theoretical or empirical assessments of INE, evaluated a physical, biological, psychological and/or social component of health, examined INE in an adult population with no indications of ill-health (i.e. chronic disease), was published in English, was peer-reviewed, and was published within the last 20 years. (The review focused on the literature looking at INE outcomes in healthy adult populations for three specific reasons. First, the purpose of the review was to understand the *health-promoting* and *health-sustaining* properties of INE rather than the *healing* properties. Secondly, pediatrics is a distinct and separate

Table 1: Search terms used in electronic databases

Nature search terms	Health search terms	
Natur ^a	Healing	Therap ^a
'Nature assisted'	Health	Attention
'Nature based'	Psycholog ^a	Mood
Indoors	Wellbeing	Stress
Plant ^a	Restorati ^a	Physical
	Cognitive	

^aIndicates multiple endings possible.

facet of health research. It is unknown if the health-promoting properties of INE are similar or distinctly different in a younger population, thus the authors did not want to risk comparing health outcomes across these two distinct populations. Thirdly, methodological issues arise when comparing differences in health outcomes across samples with significantly different health statuses at baseline; therefore, samples with existing health issues were excluded.) The data were organized by key themes (e.g. study results, definition of indoor nature) into a chart for synthesis (Table 2) and then summarized.

RESULTS AND DISCUSSION

The initial search resulted in 4573 articles. After assessing the title and abstracts of articles, a final total of 51 articles met the inclusion criteria. The articles used a wide range of self-reported and objective physical and psychological measures and provided evidence that INE promotes health and wellbeing (Table 2). A synthesis of the results is presented in Figure 1, illustrating the health-promoting features of INE through the interaction of environmental and individual characteristics.

Methods used to study INE

The reviewed literature consisted of cross-sectional ($n = 11$) and experimental ($n = 40$) study designs. All studies used quantitative measures to examine the relationship between INE and health. Self-reported measures were the only source of data in 49% of the studies, only objective measures (e.g. blood pressure, temperature) were used in 18%, and a combination of both were used in 33%. Only one study (Larsen *et al.*, 1998) used mixed methods and investigated how people perceive INE. Future research should consider the use of qualitative methodologies in order to understand how individuals develop personal connections with their environment when engaging with nature. Understanding this relationship will clarify how nature influences health and will strengthen the interpretation of statistical associations in the literature.

The study designs mainly focused on short-term one-time encounters with INE, making it difficult to generalize to longer and continual exposures (Berto, 2005; Barton and Pretty, 2010; Bratmann *et al.*, 2012) and to understand the

potential long-term impacts of INE (Hansen-Ketchum *et al.*, 2009). Future studies should consider using longitudinal studies that track changes over time, assesses the length of health effects after exposure and the accumulative effect from repeated interactions (Barton and Pretty, 2010). Work on INE should clearly describe their methodology choices, and consider the implications of study design, measurement and exposure lengths on their results. The nature-health literature tends to be optimistic towards the evidence of INE, overlooking the fact that much of this work has design flaws.

Health outcomes of INE

The review illustrates the physiological and psychological mechanisms present in the INE–health relationship. INE promotes health when individuals are presented with nature-based stimuli that they perceive as attractive, pleasing and pleasant to all their senses. A range of physiological and psychological health benefits were identified (Table 2), such as:

- a decrease in physiological stress indicators (e.g. a reduction in heart rate, blood pressure, skin temperature) [see examples (Lorh *et al.*, 1996; Parsons *et al.*, 1998; Li *et al.*, 2012a,b)];
- increased comfort (i.e. individuals felt INE created a reflective, restorative, relaxing, peaceful and pleasing environment) [see examples (Kaplan, 2001; Shibata and Suzuki, 2002; Han, 2010)];
- improved health (e.g. a reduction of headaches, itchy skin, dryness, sick leave and increased energy) [see examples (Fjeld, 2000; Pretty *et al.*, 2005; Gladwell *et al.*, 2012)];
- higher pain tolerance [see examples (Lorh and Pearson-Mims, 2000; Vincent *et al.*, 2010a,b)];
- improved facets of mood such as increased relaxation and happiness, and decreased anger and frustration [see examples (Tennessen and Cimprich, 1995; Larsen *et al.*, 1998; Kweon *et al.*, 2008)];
- higher self-rated quality of life and wellbeing [see examples (Dravigne *et al.*, 2008; Kweon *et al.*, 2008; Vincent *et al.*, 2010a)];
- better cognitive function (e.g. increased task performance, attention, memory) [see examples (Tennessen and Cimprich, 1995; Lohr *et al.*, 1996; Shibata and Suzuki, 2001)].

Only one study examined social aspects of health in the context of INE (Hartig and Staats, 2006),

Table 2: Overview of the literature

Author	Nature definition	Health measurement	Discipline	Study outcomes
Aries et al. (2010)	Sunlight and view of nature (undefined)	Attractiveness, mood, restorativeness	Psychology	View, view quality and people sharing a window influenced discomfort. Nature reduced discomfort through office impression, but increased discomfort directly
Adachi et al. (2000)	Flowers and potted plants	Mood	Horticulture	Flowers improved mood and affected women positively. Foliage increased temper, but affected males positively
Berman et al. (2008)	Scenery undefined nature	Cognition	Psychology	Nature improved cognitive functions and task performance, was more refreshing, enjoyable and likable.
Berto (2005)	Photos of landscapes	Restorativeness	Psychology	Nature improved attention and were viewed longer
Bringslimark et al. (2009)	Potted plants	Cognition, perceived stress	Psychology	View or presence of plants reduced sick leave and productivity, and was positively correlated with stress
Cackowski and Nasar (2003)	Pictures of trees	Cognition	Psychology	Nature improved cognition
Chang and Chen (2005)	A window with a view of a tree and potted plants	BVP, brain activity, mood	Horticulture	Nature increased brain activity and reduced anxiety. Just a nature views impacted BVP more than a view of nature and a plant, and a view of a city and a plant
Chang et al. (2008)	Photos of landscapes	BVP, brain activity, restorativeness	Planning and design	Nature increased restorativeness, brain activity and lowered BVP
Coleman and Mattson (1995)	Potted plant and a photograph of a plant	Temperature	Horticulture	Nature lowered stress more than non-nature
de Kort et al. (2006)	A video of landscapes, animals and plants	Mood, presence, SCL	Psychology	Nature reduced stress and improved affect
Dijkstra et al. (2008)	Potted plant	Attractiveness, perceived stress	Medicine	Nature reduced perceived stress through the perceived attractiveness of the room
Dravigne et al. (2008)	Potted plant and a window with a view of greenspace (undefined)	Attractiveness, job satisfaction	Horticulture	Nature increased job satisfaction and wellbeing. Men had the highest satisfaction with plants/no window, and the lowest with no plants/windows
Felsten (2009)	Images of landscapes	Restorativeness	Psychology	Nature increased restorativeness
Fjeld (2000)	Potted plants and sunlight (manmade)	General health	Horticulture	Nature improved health, discomfort, neuropsychological symptoms (fatigue and headache) and mucous membrane symptoms (dry and hoarse throat)
Fjeld et al. (1998)	Potted plants	General health	Planning and design	Complaints of cough, fatigue, dry/hoarse throat and dry/itching facial skin decreased in nature
Gladwell et al. (2012)	Photos of nature (not defined)	BP, HR, general health	Psychology	No significant cardiovascular or respiratory differences. Viewing nature increased parasympathetic activity
Han (2010)	Photos of landscapes	Attractiveness, restorativeness	Psychology	Preference mediated scenic beauty and restoration
Hartig et al. (1996)	Photos of a dirt path in a forest	Cognition, mood	Psychology	Nature resulted in less error, positive affect was more relaxing and increased wellbeing
Hartig and Staats (2006)	Photos of a forest	Attractiveness, mood, restorativeness, social stimulation	Psychology	Nature increased attitudes, recovery, reflection and social stimulation
Herzog et al. (2003)	Photos of a field or a forest	Restorativeness	Psychology	Nature was more restorative and preferred

Continued

Table 2: *Continued*

Author	Nature definition	Health measurement	Discipline	Study outcomes
Herzog and Chernick (2000)	Photos of landscapes	Attractiveness, restorativeness	Psychology	Restorativeness and environmental attractiveness increased depending on characteristics of the landscapes (e.g. danger vs. safe)
Hinds and Sparks (2011)	Photos landscapes	Mood	Psychology	Nature improved mood depending on previous nature experiences
Jin <i>et al.</i> (2009)	The scent of fresh flowers	BP, HR, SCL, temperature	Horticulture	Nature scents reduced physiological stress and increased temperature
Kahn <i>et al.</i> (2008)	A window view of a grass and trees	HR	Psychology	Nature increase in HR recovery
Kaplan (2001)	Picture or a window with a view of nature	Attractiveness, restorativeness	Psychology	Nature increased satisfaction with nature and neighborhood and improved restorativeness. A park view reduced satisfaction but a garden increased it
Kaufman and Lohr (2004)	Computer-generated photos of trees	Attractiveness	Horticulture	The color of nature influenced environmental attractiveness. Green and red trees had positive responses, purple and orange had negative. People also responded different to trees within the same color hue
Kim <i>et al.</i> (2010)	Photos landscapes	Brain activity, mood	Medicine	Nature improved mood
Kweon <i>et al.</i> (2008)	Photos of landscapes	Mood, perceived stress	Psychology	Males had more anger and stress to no nature and females had lowest anger and stress to nature
Larsen <i>et al.</i> (1998)	Potted plants	Attractiveness, cognition, mood	Psychology	Nature increased productivity and attractiveness. Open-ended comments were grouped into positive (e.g. lack of distraction); negative (e.g. blandness) and qualities (e.g. soothing)
Laumann <i>et al.</i> (2002)	A video of natural waterscapes and sounds of nature	BVP, cognition, HR	Psychology	Nature reduced HR
Leather <i>et al.</i> (1998)	A window with sunlight and a view of nature	Attractiveness, general health, job satisfaction, mood, perceived stress	Psychology	Sunlight and/or a nature view increased job satisfaction, reduced intention to quit and lower feeling worn out and uptight
Li <i>et al.</i> (2012a,b)	A window view of water or a grassy hill	Noise annoyance	Planning and design	Nature view reduced noise annoyance
Li <i>et al.</i> (2012a,b)	Computerized photos of various plantscapes	BP, HR, mood, SCL	Horticulture	The color of nature influenced stress and mood. Red, yellow and green reduced stress and improved mood
Lohr and Pearson-Mims (2000)	Potted Plants	BP, mood, pain tolerance, temperature	Horticulture	Nature was rated more positively, had higher levels of positive emotions and increased pain tolerance
Lohr <i>et al.</i> (1996)	Potted plants	BP, cognition, HR, mood	Horticulture	Nature increased performance and reduced stress
Ozdemir (2010)	A window view of trees and/or vegetation	Attractiveness	Planning and design	Nature increased view satisfaction
Parsons <i>et al.</i> (1998)	Photos of vegetation	BP, brain activity, HR, restorativeness, SCL	Psychology	Nature reduced BP and brain activity, improved mood and restorativeness
Pretty <i>et al.</i> (2005)	Photos of rural landscape (not clearly defined)	General health, mood	Medicine	Nature reduced BP and increased mood
Raanaas <i>et al.</i> (2011)	Potted plants	Cognition	Psychology	Nature improved task performance

Sakuragawa <i>et al.</i> (2005)	Wooden furnishings	Attractiveness, mood, restorativeness	Horticulture	Nature decreased BP for those who liked the environmental features. Non-nature was decreased environmental attractiveness and mood
Shibata and Suzuki (2002)	Potted plants	Attractiveness, mood	Psychology	Nature improved mood and was associated with a silent and small room
Shibata and Suzuki (2001)	A window view of vegetation and/or woods	Attractiveness, cognition, mood, restorativeness	Psychology	Plants increased female performance and was related to preference. Nature improved mood overall
Shibata and Suzuki (2004)	Potted plants	Cognition, mood	Psychology	Females felt the plant to be less distracting and had a greater feeling of familiarity than men, but did not impact performance
Staats <i>et al.</i> (1997)	Photos trees, fields and foliage	Mood	Psychology	Mood was influenced by nature-based features in photos (e.g. accessibility, density)
Staats <i>et al.</i> (2003)	Photos of forests	Attractiveness, restorativeness	Psychology	Nature was preferred, decreased fatigue and has greater restorativeness
Tennessen and Cimprich (1995)	Photos of trees, grass, bushes and lakes	Cognition, mood	Psychology	Nature increased attention, but did not impact mood or performance
Tsunetsugu <i>et al.</i> (2007)	Wooden furnishings	Attractiveness, BP, HR	Planning and design	The 45% room, decreased BP and increased HR, and was the most comfortable. The 90% room decreased BP, but caused a decrease in brain activity and increased HR
Valtchanov <i>et al.</i> (2010)	A virtual forest	Cognition, mood, SCL	Psychology	SCL and mood increased in nature. No differences in cognition
Vincent <i>et al.</i> (2010a)	Photos of landscapes	BP, HR, pain tolerance, presence	Medicine	Hazardous features of nature influenced pain tolerance and mood
Vincent <i>et al.</i> (2010b)	Photos of landscapes	BP, HR, pain tolerance	Medicine	Negative features (e.g. hazard) of nature influenced pain tolerance, stress and mood
White <i>et al.</i> (2010)	Photos of landscapes	Attractiveness, mood, restorativeness, presence	Psychology	Nature was preferred more. Increasing aquatic features increased preference and mood. Adding water to nature increased restorativeness, only aquatic reduced restorativeness

BP, blood pressure; BVP, blood volume pulse; EEG, electroencephalography; EMC, electromagnetic compatibility; HR, heart rate; SCL, skin conductance level.

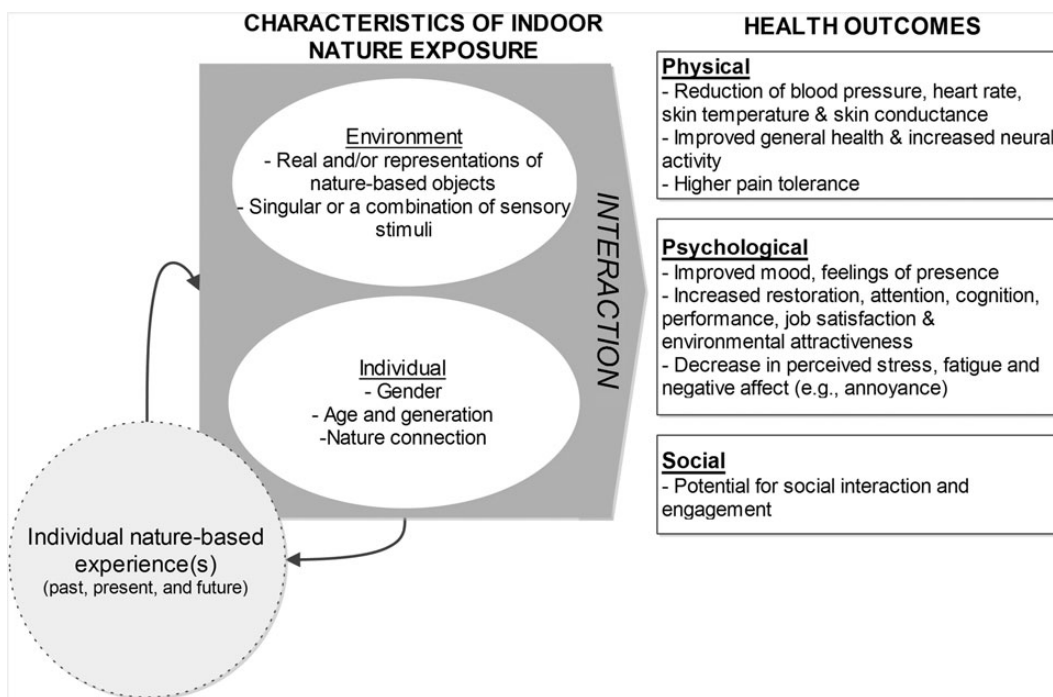


Fig. 1: Indoor nature exposure (INE) framework.

and found that photos of forest environments (nature) were significantly less socially stimulating than photos of urban environments. With such little research examining the social aspects of INE it is difficult to deduce the social benefits of INE; however, it is logical to assume that if there is similar physiological and psychological health benefits between outdoor and INE, similar social benefits would also exist. In the work by Lewis (Lewis, 1990, 1992, 1996) it is found that community gardens provide individuals with opportunities to socialize with local and fellow gardeners and community residents, which encourages community social cohesion through the elimination of prejudices (e.g. race, socio-economic standing) by working towards a common community goal. Armstrong (Armstrong, 2000) and Leyden (Leyden, 2003) found that urban parks facilitate social networks and the building of community and social contacts, which serve to enhance the safety and wellbeing of communities. Qualitative research shows that engaging in nature-based leisure (e.g. camping, hiking) encourages the formation of social bonds and gives individuals the opportunity for, and results in, shared experiences (Bricker and Kerstetter, 2002; Boniface, 2006; Garst et al., 2010). Future research

should consider the social benefits of INE, and the potential it has for creating communities within the built environment.

Environmental characteristics

INE consisted of real ($n = 27$) or representations ($n = 29$) of nature-based items (e.g. plants vs. a picture of a plant) that elicited at least one sensory response with participants. Real nature-based items were typically plants (59%) or windows with a view of nature (37%), and representations of nature were often photographs, paintings or videos of plantscapes (85%) and landscapes (44%). While representations may produce positive health outcomes, direct comparisons of the effects of these depictions and real nature-based stimuli are limited (van den Berg et al., 2003; de Kort et al., 2006; Kjellgren and Buhrkall, 2010). Kahn et al. (Kahn et al., 2008) found greater stress recovery in the presence of a window with a nature view than in the presence of a plasma screen (representation) with the same view. In the work by Kjellgren and Buhrkall (Kjellgren and Buhrkall, 2010) it is found that simulated nature-based environments were as effective at reducing stress as real environments, but were less preferred. Participants

felt that ‘there was something missing’ (p. 470) and left them ‘longing to be in real nature’ (p. 470), suggesting that representations may not be a preferred substitute for nature and raises questions of effectiveness and realism.

The majority of studies focused only on the impact of a single stimulus rather than the cumulative effect of a variety of sensory interactions. Two studies (Laumann *et al.*, 2002; Li *et al.*, 2009) evaluated non-visual experiences (e.g. sounds and scents) with nature-based items, whereas all others examined visual stimuli. The use of only a single and/or visual stimulus created an INE experience for participants that lacked rich sensory components that occur in outdoor environments, and likely limited an individual’s ability to feel a sense of ‘presence’ or connection to the exposure [(de Kort *et al.*, 2006), p. 312]. [Presence refers to an emotive state of existing or being present in a particular place and is linked to enhanced well-being and may be a critical component in the therapeutic benefits of nature exposure (van den Berg *et al.*, 2003; Sanchez-Vives and Slater, 2005; de Kort *et al.*, 2006).] In the anecdotal work by Burns (Burns, 1998) on nature-guided therapy it suggests that auditory and olfactory interactions are particularly influential in creating psychological and physiological responses with nature. Moreover, research shows that the integration of sound and aromatherapy into healthcare setting reduces pain and stress in patients (Dijkstra *et al.*, 2008), influences psychosomatic reactions (Hongratanaworakit, 2004; Edris, 2007) and boosts immunity (Li *et al.*, 2006). It is possible that presenting indoor nature stimuli that integrate visual, auditory and olfactory sensory experiences will better replicate the experience of being outdoors and, thus, enhance the therapeutic benefits of INE.

Through this review, we also determined that the amount (e.g. the number of plants present) and type (e.g. flowers vs. plants) of INE to which an individual was exposed impacted outcomes. In some studies the amount of nature present was positively correlated with stress and higher ratings of unattractiveness and negatively correlated with productivity (Larsen *et al.*, 1998; Tsunetsugu *et al.*, 2007; White *et al.*, 2010); the color of the nature-based stimuli influenced individuals’ preference for the object (Kaufman and Lohr, 2004; Li *et al.*, 2012a,b) and characteristics of a window view (e.g. park vs. garden) influenced satisfaction with surroundings (Kaplan, 2001; Fasten, 2009; Li *et al.*, 2012a,b). Careful

consideration should be made when developing health-promoting INE tools, as factors such as the amount, type and details (e.g. color) of the nature-based stimuli are likely to influence the therapeutic outcomes.

Individual characteristics

Studies largely used convenience samples of college or university students ($n = 37$), and office employees ($n = 8$). Over 45% of the studies had a sample between the ages of 18 and 29 years, except for 18 studies which did not identify the average age or age range of their sample. Little consideration was made to understand potential differences in health outcomes based on sex and/or age; however, data suggest that individual characteristics (i.e. sex, age and nature connection) may influence the health outcomes received from INE. Results showed that females, compared with males, have stronger preferences for nature and experience greater positive outcomes in the presence of nature (Shibata and Suzuki, 2001, 2002; Kweon *et al.*, 2008), indicating a potentially significant interaction between sex and INE. While most of the articles examined the nature–health relationship with a sample that contained both males and females, sex was rarely considered a potentially confounding variable. Females typically have more exposure to plants (Lohr *et al.*, 1996) and more familiarity with nature-based stimuli, which is associated with greater positive experiences with nature (Berto, 2007). Future research should consider how males and females interact with indoor nature-based stimuli and how these interactions impact the therapeutic outcomes.

Generation and age may also influence the relationship between INE and health. Research examining the restorative properties of nature indicates significant differences in preference and familiarity between older adults and adolescents, indicating that adolescents are less familiar with and less in favor of nature-based environments. Hinds and Sparks (Hinds and Sparks, 2011) also found that individuals raised in rural settings or with greater experience with nature-based environments reported more joy and less apprehension to nature experiences than participants from urban childhood locations or with less experience with nature. The studies sample a range of individuals from 18 to 61 years of age; however, much like sex, age was never considered a potentially mediating variable.

The literature largely ignored the impact of individual factors on health outcomes. While studies often provided a breakdown of sex and age demographics, no studies indicated the ethnicity or cultural backgrounds of participants. Future work should take into consideration individual factors, as an individual factor may significantly influence how an individual perceives, experiences and engages with nature.

Individual nature-based experiences

The heavy focus of psychology-based studies (Table 1) may account for the lack of qualitative results that are able to address socially, culturally and individually constructed meanings of nature. Research has primarily focused on exploring the experience of nature through emotions and physical feelings, and has revealed much about the diverse experiences individuals have when engaging with nature. While peoples' experiences are varied, the focus of this work has been on a common natural environment that is shared across and between groups of people. Regardless of similarities, experiences with nature can be, and are, personal and distinctive. Patterson *et al.* (Patterson *et al.*, 1998) stated that an experience is 'influenced by individuals' unique identities, their current personal projects, past experiences and situational influences' (p. 244); this suggests that an individual's experience with nature is idiosyncratic, dynamic and varies across the life course.

Neurobiological research indicates that an individual's previous interactions with nature-based environments will influence their experience with INE. Biederman and Vessel (Biederman and Vessel, 2006) suggest that visual stimuli associated with semantic memories (e.g. facts or knowledge) and episodic memories (e.g. personal experiences) will be more pleasing and interesting than stimuli associated with fewer memories. This is because triggering memories releases endorphins that create positive and pleasant feelings. Nature-based stimuli associated with more memories and experiences are thus likely to lead to greater positive feelings (Shibata and Suzuki, 2002; Biederman and Vessel, 2006). INE research to date has focused on the strength and impact of the nature–health relationship, rather than on how an individual develops relationships with nature-based places over time (Boniface, 2006). One study in this review (Larsen *et al.*, 1998)

focused on how people perceive INE and highlights this significant gap in the literature.

INE: a health-promotion framework

The collation and summarization of the literature allowed for themes to be structured in a way that highlights the interaction between environmental and individual factors that create health outcomes, and the various ways INE can promote physical and psychological health (Figure 1). INE occurs within indoor environments that contain real or representations of nature-based stimuli that engages a variety of senses (e.g. sight, hearing). Variations in the environment (e.g. real or representations of nature) and the individual (e.g. sex, age, nature connection) will impact the health outcomes observed and influence the therapeutic benefits and experience an individual receives from INE. Additionally, nature-based experiences across the life course will also impact the current and future INE experiences, indicating that INE experiences move and change across an individual's life time.

This framework presents a starting point for the integration of INE into daily lives and is supported by the Ottawa-Charter's call to create supportive and healthy environments for all populations (WHO, 1986). However, this review suggests that there are inherent challenges to this, as individual characteristics likely influence nature preferences and health outcomes. While individual characteristics have not been investigated as mediating factors in the INE–health relationship, it is important to consider their potential influence and resulting implications on the therapeutic benefits of INE.

One clear finding is that the physiological and psychological benefits of INE are often facilitated through stress reduction and stress recovery, and suggest that this is a fundamental pathway in the nature–health relationship. These benefits have been examined through several nature-based theories including the Attention Restoration Theory (ART) (Kaplan, 1987; Kaplan and Kaplan, 1989) and the psychoevolutionary theory (PET) (Ulrich, 1983; Ulrich *et al.*, 1991). The proponents of ART suggest that restorative settings remove an individual from their daily tasks, contain features that hold their attention with little effort (e.g. clouds, rustling leaves) and restores their ability to concentrate, allowing them to recover from

stress (Kaplan, 1987). It is argued that these aspects are more likely to occur within a natural setting where one can have the sense of being removed from the everyday (i.e. urbanized) world, feel a part of a larger process, be in an environment that is rich in elements and stimuli that allow for recovery from mental fatigue and be in harmony with an environment humans are pre-disposed to feel comfortable in. Through the PET, Ulrich (Ulrich, 1983) and Ulrich *et al.* (Ulrich *et al.*, 1991) propose that our bodies create physiological reactions when presented with stressful environments that threaten our health (i.e. urban areas). Recovery from stress can occur in environments that are pleasant, calm and moderately interesting to an individual by replacing negative affect (generated from stress) with positive affect, and reducing autonomic arousal (e.g. blood pressure). Much like ART, PET suggests that nature-based environments encompass features that promote and enhance stress recovery.

Early work from Ulrich (Ulrich, 1979; 1981) and Ulrich *et al.* (Ulrich *et al.*, 1991) on PET confirmed that physiological changes occur when an individual is exposed to nature. When viewing nature-based scenes, participants experienced increased alpha wave amplitudes, which is often associated with increased serotonin production (a neurotransmitter that is a primary target of anti-depressants and anti-anxiety medications). Selhub and Logan (Selhub and Logan, 2012) also suggest that exposure to INE can increase dopamine production, which elicits feelings of well-being, positive mood and the perception of less stress. Thus, much like outdoor nature, INE can facilitate physiological changes in individuals that enhance both physical and psychological health.

Limitations of the review

This review provides a valuable synthesis of the nature-health research within an indoor setting, but is not without limitations. First, while the framework presents an overview of the INE–health relationship, interpretation and application should be done with consideration to variations in INE definitions, methodological differences across studies and limitations in the literature which may make it difficult to generalize. Secondly, it is possible that we missed relevant articles, as some databases have poor indexing. Thirdly, the comprehensive process for the review (e.g. using snowballing to find additional sources in article

bibliographies) can make replicating the search results difficult. Fourthly, the restriction to articles published in English excluded relevant work done in Japan, China and Korea ($n = 6$), which may have contributed to alternative evidence. Fifthly, by limiting the selection of literature to published peer-review journals, the study may be susceptible to publication bias (Rosenthal, 1979). It is possible that the effectiveness of INE is exaggerated as studies showing negative results are less likely to be published. Lastly, the scoping study methodology does not allow for the critical appraisal of evidence quality, as its goal is to evaluate the breadth of knowledge rather than its depth (Arskey and O’Mally, 2010). A critical appraisal of the INE literature would help clarify the quality of existing evidence, how limitation in the methods impact the interpretation of the INE–health outcomes and help further the understanding of the INE–health relationship.

CONCLUSION AND FUTURE DIRECTIONS

This review synthesizes existing results and presents additional evidence to support the use of indoor nature as a health-promoting resource through physiological and psychological channels (Figure 1). The literature presented supports INE as a health-promoting mechanism; however, inconsistencies in definitions and issues with methodology (e.g. study design, sample descriptions) should be taken into consideration when applying the INE framework. The benefits of nature have been recognized for centuries; however, the value of nature and place as a health-promotion tool has been lost. However, the ability to adapt our surroundings, particularly indoor environments, offers a means of integrating nature into spaces we live in and engage with, and INE may be a way to use the built environment to enhance our health and wellbeing.

The breadth of the scoping review allowed for the identification of gaps in the current literature across a variety of disciplines (Table 2), but also highlights a growing field that presents further opportunities for understanding the pathways between INE and health outcomes (Figure 2). It is hoped that the framework can begin to facilitate the integration of interdisciplinary approaches to understanding INE and serve as a meeting grounds for future discourses. Creating interdisciplinary research agendas for INE may help refine the

<p><i>Stimuli</i></p> <ul style="list-style-type: none"> • What is the strength of the relationship between real and representations of natural stimuli and therapeutic health outcomes? <p><i>Sensory interactions</i></p> <ul style="list-style-type: none"> • What are the therapeutic benefits of non-visual interactions with INE? • Is there an accumulative impact of sensory interactions that facilitate a sense of presence that is derived in an outdoor environment? <p><i>Health and INE</i></p> <ul style="list-style-type: none"> • What are the social benefits of INE? <p><i>Defining INE</i></p> <ul style="list-style-type: none"> • How does the characteristics of INE (e.g., colours) impact the therapeutic benefits? • How can INE be re-defined to incorporate sensory interactions? <p><i>Methodological Considerations</i></p> <ul style="list-style-type: none"> • Can the incorporation of qualitative work be used to understand the meaning individuals develop with nature, and how these meanings impact therapeutic benefits? • How does age and gender impact the therapeutic benefits? • How does an individual's generation and connection with nature impact the therapeutic benefits one receives from INE?

Fig. 2: Future research considerations.

existing knowledge and would highlight the complexity of nature-based health-promotion mechanisms. Creating indoor spaces rich in nature may provide an effective means of promoting health inside and out and embracing the proverbial ‘roots’ of medicine.

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