Human-nature connectedness as a pathway to sustainability: a global meta-analysis

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Running title: Human-nature connectedness and sustainability

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Abstract

Internationally-agreed sustainability goals are being missed. Here, we show how the extent to which humans see themselves as part of nature –known as *human-nature connectedness* (HNC) –can be used as a leverage point for reaching sustainability. We conduct the first global meta-analysis of the HNC literature. Meta-analysis of 147 correlational studies documents that individuals with high HNC had more pro-nature behaviours and were significantly healthier than those with low HNC. Meta-analysis of 59 experimental studies documents no effect of environmental education on HNC while HNC significantly increased after manipulations involving contact with nature and mindfulness practices. Thus, HNC is positively linked to mindsets that value sustainability and behaviours that enhance it. Further, we show that HNC can be enhanced by interventions and we identify techniques most likely to succeed. These results suggest that enhancing HNC, via promotion of targeted practices, can improve sustainability and should be integrated into conservation policy.

1. Introduction

Anthropogenic climate change and biodiversity loss are major threats not only to non-human living beings but also to our own survival (Pachauri & Meyer 2014; Brondizio et al. 2019; Díaz et al. 2019; Shukla et al. 2019). Despite there being apparent international consensus to better preserve nature (e.g., the Convention on Biological Diversity and Aichi Biodiversity Targets (CBD 2011)), to limit global warming to 2°C (e.g., the Paris Agreements) and to create a sustainable, equitable world (e.g., the Sustainable Development Goals - SDGs), actions remain limited and sustainable targets have failed to be achieved (Adenle 2012; Buchanan et al. 2020). Why do citizens and governments still find it hard to consider the health and well-being of humans as dependent upon the health of the natural world (Pachauri & Meyer 2014; Brondizio et al. 2019; Shukla et al. 2019)?

One possible explanation is cultural. Monotheist religions (Rolston 2013; Collins & Press 2018) and influential modern philosophers (e.g., Kant 1784) advocated a discontinuity between the inner-worlds of humans and those of other living beings, which has led people to consider themselves disconnected from, and dominant over, the rest of nature (the modern “Western” worldview). Another explanation is the increased urbanization of the world’s human population. Today, more than 55% of people live in urban areas, and this proportion is expected to increase to 68% by 2050 (<https://www.un.org/en/sections/issues-depth/population/index.html>). A major consequence is the increased disconnection of people from experience of natural habitats (Miller 2005). The combination of both psychological and physical disconnects from the natural world can result in devaluation of nature, thereby legitimizing and facilitating destructive practices towards nature by individuals and societies (Figure 1).

What can be done to modify these destructive trends? International scientific assessments, such as the MA, IPCC and IPBES, indicate that healthy natural systems are crucial to reach sustainability (Watson & Zakri et al. 2005; Brondizio et al. 2019; Shukla et al. 2019). The IPBES further claims that sustainable goals will not be achieved without a “transformative change” including an increase in “awareness of connectivity in the environmental crisis and new norms regarding interactions between humans and nature” (Figure 1). A key societal trait that is relevant to achieving sustainability is Human-Nature Connectedness (HNC), which has been described (Schultz 2001) and defined in different, often complex, ways (Supplementary information (SI) Appendix 1). We define HNC as the extent to which humans include the natural world in the self or see themselves as part of nature. A number of recent studies found that estimates of HNC were positively correlated both with pro-environmental behaviour (Mackay & Schmitt 2019; Whitburn et al. 2020) and with human welfare (Capaldi et al. 2014; Pritchard et al. 2020).

Due to paucity of data, prior synthetic analyses of the roles of HNC were forced to lump studies with disparate methodologies, whether they be experimental or correlational, and whether or not they used metrics of HNC that had been validated by methods that we describe in SI Appendices 2 and 3. Here, we take advantage of the rapidly-increasing literature to restrict our database to studies using at least one of the validated quantitative metrics of HNC (Dunlap et al. 2000; Schultz 2001; Clayton & Opatow 2003; Mayer & Frantz 2004; Nisbet et al. 2009) and to separate experimental from correlational studies. Thus, we provide, for the first time, a robust, coherent and global synthesis of the HNC literature with separate meta-analyses of experimental and correlational studies (Figure S1 and Table S1). This allows us to identify practices that have the potential for increasing HNC, and investigate whether HNC is a key element of sustainability, in particular nature conservation and human welfare.

2. Results

Experimental studies

Existing experimental studies are strongly biased towards adults and towards high-income, industrialized countries with a "Western" worldview (Figure S2). Among them, we identified 6 types of experimental designs: (1) *exposure to real nature*: direct contact with nature, either outdoors or indoors; (2) *exposure to virtual nature*: videos or pictures of nature; (3) *mindfulness*: focusing one's attention on one's inner self and one's environment in the present moment; (4) *environmental education*: exposure to naturalist, scientific and ecological knowledge of the natural world; (5) *combination of exposure to real nature + environmental education* and, (6) *combination of exposure to real nature + mindfulness*.

We combined two types of comparison: (1) sequential comparison of trait measurements made on the same participants before and after experimental treatment and (2) simultaneous comparison of control and treatment groups (see Methods and SI Appendix 4).

All experimental designs, except environmental education, affected HNC significantly and positively (Figure 2 and Table S2). The clearest positive effects on HNC were those of mindfulness, with or without experience of real nature, while estimated positive effects of environmental education were low. These analyses of experimental studies show that exposing individuals to nature, either real or virtual, does improve HNC. They also suggest exciting lines of future research to improve the efficiency of experimental programs designed to raise HNC by including mindfulness practices and/or by trying less anthropocentric transmission of scientific information.

Correlational studies

Like experimental studies, correlational studies are strongly biased toward adults from industrialized countries. Meta-analysis of their results shows that HNC is negatively correlated with materialism/consumerism and political conservatism and positively correlated with the following suite of behaviours, opinions and personality traits: naturalist knowledge; time spent in natural outdoor spaces; engagement in mindfulness practices; pro-environmental values; humanistic values; happiness and good health.

In sum, individuals with high HNC had deeper knowledge of nature, spent more time in natural outdoor spaces, engaged more in mindfulness practices and were happier and healthier than those with low HNC. It is not surprising, then, that high HNC individuals displayed more pro-environmental values, expressed as concern and attitudes toward the ecological environment. They were also more humanistic, in the sense of more strongly expressing their moral responsibilities to other humans, and their sense of being part of communities within society (Figure 2; see Methods, SI Appendix 4 for detailed categories, Table S3 and Figures S3 to S6).

Additionally, one-third of the correlational papers (26 out of 108) addressed causal hypotheses using either structural equation models or path analysis. Although these approaches have limited ability to infer causality, these studies nonetheless suggest impacts on HNC of both contact with nature and mindfulness, in agreement with results from experimental data (Figure 2 and Table S2). In the opposite direction of causality, they also suggest impacts of HNC on pro-environmental values, human well-being and health and pro-environmental behaviours.

Taken together, correlational data support conclusions from experimental studies but also add to them, showing HNC to be positively linked to values and behaviours that enhance ecological sustainability and well-being, and negatively linked to non-environmental or anti-environmental values. Future experimental research is needed to test causal relationships, particularly the hypothesis suggested by our meta-analysis that raising HNC would enhance both human welfare and conservation of nature.

3. Discussion

Our meta-analyses robustly show that the extent to which people feel part of the natural world can be enhanced by very simple interventions involving contact with nature and mindfulness practices, at least for industrialized cultures that form the bulk of studies. They also show that validated HNC indices are positively linked to human welfare and nature conservation. Thus, improving HNC through contact with nature and mindfulness can be a valuable way to help individuals to understand and experience how much human welfare and nature conservation are interconnected (Rabinowitz et al. 2018). As an example, “greening” schoolyards could improve citizens’ HNC and well-being and thereby foster support for sustainable policies, adding to its known positive effects on urban biodiversity and climate adaptation (the virtuous circle in Figure 1).

Surprisingly, we found little impact of environmental education on HNC, and we hypothesize that this is due to the traditional anthropocentric transmission of scientific knowledge. While this result remains to be further tested, studies in non-industrialized populations (Atran et al. 2002) and children (Moore & Marcus 2008) suggest that modifying the way scientific information is transmitted using non-anthropocentric knowledge about non-human species can have a positive impact on HNC. Examples of non-anthropocentric approaches include focusing on similarities between humans and other species (Plotnik et al. 2006; Genty et al.

2009; Clay & de Waal 2013; Mancuso & Viola 2015; Yokawa et al. 2019) and taking the perspectives of other species and empathizing with them (Berenguer 2007).

If we are to develop efficient research and conservation programs aimed at simultaneously protecting humans and nature worldwide (Rabinowitz et al. 2018), we urgently need longitudinal studies in children and in non-industrial traditional cultures. Children from industrialized societies are known to show a strong affinity for non-humans (Moore & Marcus 2008), which tends to fade with age (Liefländer et al. 2013; Hughes et al. 2019) and develop into low ecological concern at adulthood (Windhorst & Williams 2015; Rosa et al. 2018) along with the acquisition of anthropocentric cultural norms (Wilks et al. 2020). We know much less about equivalent developmental changes in traditional societies, although pro-environmental behaviours may be more likely to persist into adulthood in societies with a high interdependency between humans and nature (Atran et al. 2002). Accumulation of knowledge about cultural and developmental norms and values in diverse societies, both traditional and industrial, should assist in building international environmental and educational policies and empowering citizens and governments to take actions and achieve sustainable targets at a global scale.

4. Methods

Data search and inclusion

We followed the PRISMA guidelines to conduct the systematic review (O'Dea et al. 2021). We searched previous papers assessing HNC on Web of Science (WoS) and PubMed from 1900 to 2020 with search terms corresponding to the different HNC scales used in previous published reviews, opinions and meta-analyses (see details in Table S1) and we obtained 2098 citations (see Figure S1 for PRISMA flow diagram).

Only *empirical, quantitative and peer-reviewed published* papers, which were *written in English* were made eligible for inclusion. In addition, we focused on explicit psychological HNC, also called “HNC as mind” (Ives et al. 2017), which refers to as validated and repeatable psychometrics questionnaires developed by psychologists, economists and social scientists to measure HNC. Specifically, we focused on the five more widely used scale (for a detailed description of HNC scales see SI Appendix 2 and 3): The New environmental paradigm (NEP; Dunlap et al. 2000), the Inclusion of Nature in the Self (INS; Schultz 2001), Environmental identity scale (EID; Clayton & Opatow 2003), the Connectedness to nature scale (CNS Mayer & Frantz 2004) and the Nature relatedness scale (NR; Nisbet et al. 2009). As such, papers measuring *at least one widely used and repeatable HNC measure (NEP, INS, EID, CNS and NR)* and *at least one factor* (correlational and/or experimental studies) were included.

At the end of the screening, 124 publications met the eligibility criteria. For all studies, we extracted the *number of participants, region* (Africa, Asia, Europe, North America, South America and Oceania), *country, gender ratio* (more than 60% female, between 40 and 60 % Female, less than 40 % female) and *age group* (below 18 years-old, between 18 and 25 years old, between 26 and 40 years old, more than 40 years old). For correlation studies (107 individual papers), we extracted zero-order Pearson correlations between HNCs and factors while means and standard deviations of HNC metrics between each condition (i.e., treatment vs. control or pre vs. post treatment) were extracted for experimental studies (35 individual papers). When correlations, means or SDs were missing from the paper, we emailed the corresponding author. Overall, we obtained a total of 1080 effects sizes from 198 studies from 124 individual papers done by 69,763 participants to perform the meta-analyses.

Statistical analysis

All statistical analyses were performed in the R (4.0) environment. For experimental data, we performed the meta-analysis on Standardized Means Difference (SMD; Hedges' g). For correlational data, meta-analyses were done on Pearson correlations after Fisher transformations. All estimates were calculated for each factor with the `rma.mv` function from the `metaphor` package (Viechtbauer & Viechtbauer 2015) in R, which permits to fit meta-analytic multivariate fixed- and random/mixed-effects models with or without factors via linear (mixed-effects) models. Since there were sometimes several measures of HNC and factors in one individual paper and/or one study, we included random effects including lab (multiple data from the same individual paper) and study (multiple data points from the same subjects) to take non-independence of data into account.

Since heterogeneity of the true effects within a study (within a lab) could be (or not be) identical, we added a higher-level random effect at the estimate level so that random effects = $\sim 1|lab/study/estimate.id$. Then, we transformed the estimates (SMD and Fisher's Z) into R estimates. Z tests and omnibus tests were performed when appropriate. We provided additional methods and results in SI (i.e., funnel and forest plots in Figure S4 and Appendix 4 to 6 in SI).

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Figure 1. Hypothetical representation of a vicious circle generated by a detrimental worldview (left) and a virtuous circle generated by a sustainable worldview (right). We assess whether and how human-nature connectedness can be used to switch from a detrimental to a sustainable worldview at both individual and societal levels.

254x134mm (150 x 150 DPI)

Figure 2. Results from meta-analyses of experimental (blue background and text) and correlational (green and orange backgrounds and text) studies. Each dot represents the average R estimate for each factor obtained after transforming averaged standardized effect sizes (Fisher's Z for correlational data and Hedges' g for experimental data) with n, k and s referring to the number of individual papers, number of effect sizes and number of participants, respectively. Horizontal lines indicate the 95% confidence intervals for each factor and cross the vertical dot lines when non-significant (i.e., environmental education in experimental studies). Single-headed arrows refer to causal relationships while double-headed arrows refer to correlational links. Overall R estimates from each broad category are in bold. Details are provided in Methods summary, Methods, Extended data Tables 2 and 3 and Extended data Fig. 4. Experimental studies show that exposure to nature and mindfulness practices improve HNC. Correlational studies confirmed experimental studies and show that HNC is positively linked to nature conservation and human welfare and negatively linked to non-environmental values. **: $p<.001$; ***: $p<.0001$.

195x190mm (150 x 150 DPI)

Supplementary information

Appendix 1. Definitions of HNC

Leopold, a philosopher and ecologist (Leopold 1989), gave the first a representative definition of HNC when saying “we abuse land because we regard it as a commodity belonging to us. When we see land as a community to which we belong, we may begin to use it with love and respect.” For Leopold, it is necessary to understand a) “how humans see themselves as equal members of a large natural community”, b) “feel a sense of kinship with it”, c) “consider themselves as belonging to the natural world as much as it belongs to them”, d) and “consider their welfare as related to the well-being of the natural world”.

More recent definitions built upon Leopold’s definition and theoretical framework, have been proposed. Opatow (1996) defined HNC as “the degree of similarity we perceive between ourselves and other components of the natural world, and whether we consider nature and non-human natural entities to have standing as valued components of our social and moral community”. Schultz (2001) who introduced the term nature connectedness defined HNC as “the extent to which individuals include nature as part of their identity”.

Finally, Mayer and Frantz (2004) recently defined HNC as “individual’s affective, experiential connection to nature” including “sense of kinship with plants and animals, sense of oneness with the natural world, and sense of equality between nature and the self”.

Several authors tried to describe the different facets of HNC. Schultz (2001) describes a *cognitive* component which refers to the extent to which humans integrated themselves in nature; an *affective* component which refers to ones’ sense of care for nature and a *behavioural* component which refer to one’s commitment to protect nature. Similarly, Ives et al. (2017) proposed five HNC categories including the *philosophical* connection (i.e. world view of what is nature and why it matters), the *emotional* connection (i.e. attachment or empathy for nature), the *cognitive* connection (i.e. knowledge or awareness of the environment), the *experiential*

connection (i.e. contact with nature) and the *material* connection (i.e. consumption of goods/materials from nature).

However, those different categories changed from one study to another. Indeed, these categories are somehow subjective and arbitrary since one's could pull some of them together (e.g., cognitive and philosophical both refers to knowledge individuals have about nature). In addition, items in the HNC measures (see below) often tackle more than one component of HNC and those measures also correlate with each others (Mayer & Frantz 2004). This suggests that HNC is a broad concept including interrelated sub-categories. As such, we define HNC in its broader sense as *the extent to which humans include the natural world in the self or humans see themselves as part of nature*.

Appendix 2. Measures of HNC

In 2002, Dunlap and Jones (Dunlap n.d.) estimated that at least several hundred measures of human-nature connectedness have been developed since the 1960s across various research fields. Indeed, human nature connectedness has been used synonymously with nature connection, nature relatedness, love and care for nature, inclusion of nature in the self, connectedness to nature, connectivity with nature, empathy for nature, environmental identity, environmental concern, etc.

Among numerous measures, five major scales have been used more widely than others (see Appendix 1 for detailed items of the questionnaires). The **New Ecological Paradigm** (Dunlap et al. 2000), first labelled as New Environmental Paradigm (NEP), is the oldest and the most widely measure of environmental concern in the world. The NEP scale consists of 15 items and shows strong psychometrics and theoretical backgrounds. The original version of the NEP focuses on three components of HNC including beliefs about humanity's ability to upset the balance of nature, the existence of limits to growth for human societies, and human domination of nature. The revised version includes five components: the reality of limits to growth, anti-anthropocentrism, the fragility of nature's balance, rejection of exceptionalism and the possibility of an eco-crisis. A recent meta-analysis reviewing 69 studies from 36 countries (including 58,279 participants from 139 samples) shows that variations in population type and selection of specific items in the NEP scale (i.e. sub-scales) have a significant effect on NEP scores suggesting that using all items from the scale is particularly important for reliability (Hawcroft & Milfont 2010).

In 2001, Schultz developed the **Inclusion of Nature in Self (INS)**, a single-item measure that tackles self-identification with nature. Although very simple and easy to administrate, this scale nonetheless presents limits in its predictive validity (Martin & Czellar 2016). However, the INS test-retest correlations nonetheless present very high reliabilities

between measurements of individual differences in connectedness with nature (Schultz et al. 2004).

The **Environmental Identity** scale (**EID**; Clayton et al., 2003) is composed 24 items and is known to have good psychometrics properties (Olivos et al. 2011). The EID takes into account multiple components of HNC including a) individual's interactions with nature, b) self-identification (e.g. humans as part of nature), c) ideology measured by support for environmental education and a sustainable lifestyle, d) positive emotions through aesthetic appreciation ("I would rather live in a small room or house with a nice view than a bigger room or house with a view of other buildings") and e) autobiographical component, based on memories of interacting with nature (e.g. childhood exposure).

Similarly, the **Connectedness to Nature Scale** (**CNS**; Mayer & Frantz, 2004) is composed of 14 items, has good psychometric properties since it correlates with related variables (e.g., correlations with the NEP scale) but not with confounding factors such as verbal ability or social desirability (Mayer & Frantz, 2004).

The most recent "classical" scale is **Nature Relatedness** (**NR**; Nisbet et al., 2009) which is composed of 21 items measures people understanding of interconnectedness between humans and other living beings.

All five scales measure the philosophical and cognitive components described by Ives et al. (2018) while the NR and the CNS also tackle the emotional and experiential components.

In parallel, other research areas from social sciences (e.g., geography) develop their own measurement of HNC that they called place attachment, sense of place or place identity (e.g., Jorgensen & Stedman, 2001). Place attachment measures multidimensional constructs including a) beliefs about the relationship between self and place; b) feelings toward the place; and c) the behavioural exclusivity of the place in relation to alternatives. However, contrary to classical scales described above, PA is always associated with a specific place (e.g., specific

lake) implying repeatability issues. For instance, as extensively described in a recent review on HNC(Ives et al. 2017), methodology and statistical analysis that have been done in studies measuring PA are not as “rigorous” as studies measuring classical scales. Similarly, sub-scales (e.g. selected items from classical scales) or other adapted scales focusing on specific non-human animals (e.g. spider or dolphin) or event (e.g. earth quake) have also been used, but selection of sub-items as well as generalization from one species or event to one another can also induce reliability issues (Hawcroft & Milfont 2010).

Other scales have been developed recently. For instance, the Dispositional Empathy for Nature scale tackles the emotional aspects of HNC(Tam 2013) but only focus on the emotional aspects which do not corresponds to our definition of HNC. Finally, different other connection-with-nature scales including Disposition to Connect with Nature (Brügger et al. 2011), Commitment to Environment (Davis et al. 2009), implicit connection with nature have been developed (e.g. Implicit Associative Task (IAT) have also been used.

Appendix 3. Detailed items from the 5 classical scales

1. New Ecological Paradigm (NEP, Dunlap et al., 1978, 2000)

Instructions: Listed below are statements about the relationship between humans and the environment. For each one, please indicate whether you STRONGLY AGREE, MILDLY AGREE, are UNSURE, MILDLY DISAGREE or STRONGLY DISAGREE with it.

1.1 New Ecological Paradigm (original version) : 12 verbal items*

1. We are approaching the limit of the number of people the earth can support.
2. The balance of nature is very delicate and easily upset.
3. Humans have the right to modify the natural environment to suit their needs.
4. Mankind was created to rule over the rest of nature.
5. When humans interfere with nature it often produces disastrous consequences.
6. Plants and animals exist primarily to be used by humans.
7. To maintain a healthy economy we will have to develop a “steady-state” economy where industrial growth is controlled.
8. Humans must live in harmony with nature in order to survive.
9. The earth is like a spaceship with only limited room and resources
10. Humans need not adapt to the natural environment because they can remake it to suit their needs.
11. There are limits to growth beyond which our industrialized society cannot expand.
12. Mankind is severely abusing the environment.

*Agreement with 3, 4, 6, and 10 indicate anti-NEP responses.

1.2 Revised NEP : New Environmental Paradigm (Dunlap et al., 2000) : 15 verbal items°

1. We are approaching the limit of the number of people the earth can support.
2. Humans have the right to modify the natural environment to suit their needs.
3. When humans interfere with nature, it often produces disastrous consequences.
4. Human ingenuity will insure that we do NOT make the earth unliveable.
5. Humans are severely abusing the environment.
6. The earth has plenty of natural resources if we just learn how to develop them.
7. Plants and animals have as much right as humans to exist.
8. The balance of nature is strong enough to cope with the impacts of modern industrialised nations.
9. Despite our special abilities humans are still are still subject to the laws of nature.
10. The so-called “ecological crisis” facing humankind has been greatly exaggerated.
11. The Earth is like a spaceship with very limited room and resources
12. Humans were meant to rule over the rest of nature.
13. The balance of nature is very delicate and easily upset
14. Humans will eventually learn enough about how nature works to be able to control it.
15. If things continue on their present course, we will soon experience a major ecological catastrophe.

°Agreement with the eight odd-numbered items and disagreement with the seven even-numbered items indicate pro-nature responses.

2. Inclusion of Nature in Self (INS ; adapted from Schultz, 2001) : 1 non-verbal item

Instructions : Please circle the picture below which best describes your relationship with the natural environment. How interconnected are you with nature ?

3. Environmental Identity (EID ; Clayton, 2003) : 24 verbal items

Instructions : Please indicate the extent to which each of the following statements describes you by using the appropriate number from the scale below.

- 1 2 3 4 5 6 7 with 1 : Not at all true of me 4 : neither true nor untrue 7 : completely true of me
- _____ 1. I spend a lot of time in natural settings (woods, mountains, desert, lakes, ocean).
 - _____ 2. Engaging in environmental behaviors is important to me.
 - _____ 3. I think of myself as a part of nature, not separate from it.
 - _____ 4. If I had enough time or money, I would certainly devote some of it to working for environmental causes.
 - _____ 5. When I am upset or stressed, I can feel better by spending some time outdoors "communing with nature".
 - _____ 6. Living near wildlife is important to me; I would not want to live in a city all the time.
 - _____ 7. I have a lot in common with environmentalists as a group.
 - _____ 8. I believe that some of today's social problems could be cured by returning to a more rural lifestyle in which people live in harmony with the land.
 - _____ 9. I feel that I have a lot in common with other species.
 - _____ 10. I like to garden.
 - _____ 11. Being a part of the ecosystem is an important part of who I am.
 - _____ 12. I feel that I have roots to a particular geographical location that had a significant impact on my development.
 - _____ 13. Behaving responsibly toward the earth – living a sustainable lifestyle – is part of my moral code.
 - _____ 14. Learning about the natural world should be an important part of every child's upbringing.
 - _____ 15. In general, being part of the natural world is an important part of my selfimage.
 - _____ 16. I would rather live in a small room or house with a nice view than a bigger room or house with a view of other buildings.
 - _____ 17. I really enjoy camping and hiking outdoors.
 - _____ 18. Sometimes I feel like parts of nature – certain trees, or storms, or mountains – have a personality of their own.
 - _____ 19. I would feel that an important part of my life was missing if I was not able to get out and enjoy nature from time to time.
 - _____ 20. I take pride in the fact that I could survive outdoors on my own for a few days.
 - _____ 21. I have never seen a work of art that is as beautiful as a work of nature, like a sunset or a mountain range.

- _____ 22. My own interests usually seem to coincide with the position advocated by environmentalists.
- _____ 23. I feel that I receive spiritual sustenance from experiences with nature.
- _____ 24. I keep mementos from the outdoors in my room, like shells or rocks or feathers.

4A. Connectedness to Nature Scale (CNS ; Mayer & Frantz, 2004)

Instructions: Please answer each of these questions in terms of the way you generally feel. There are no right or wrong answers. Using the following scale, in the space provided next to each question simply state as honestly and candidly as you can what you are presently experiencing.

1 2 3 4 5 with 1: Strongly disagree 3: Neutral 5: Strongly agree

- _____ 1. I often feel a sense of oneness with the natural world around me.
- _____ 2. I think of the natural world as a community to which I belong.
- _____ 3. I recognize and appreciate the intelligence of other living organisms.
- _____ 4. I often feel disconnected from nature.
- _____ 5. When I think of my life, I imagine myself to be part of a larger cyclical process of living.
- _____ 6. I often feel a kinship with animals and plants.
- _____ 7. I feel as though I belong to the Earth as equally as it belongs to me.
- _____ 8. I have a deep understanding of how my actions affect the natural world.
- _____ 9. I often feel part of the web of life.
- _____ 10. I feel that all inhabitants of Earth, human, and nonhuman, share a common 'life force'.
- _____ 11. Like a tree can be part of a forest, I feel embedded within the broader natural world.
- _____ 12. When I think of my place on Earth, I consider myself to be a top member of a hierarchy that exists in nature.
- _____ 13. I often feel like I am only a small part of the natural world around me, and that I am no more important than the grass on the ground or the birds in the trees.
- _____ 14. My personal welfare is independent of the welfare of the natural world.

4B. Adapted CNS for children: Connectedness to Nature Index (CNI ; Cheng & Monroe, 2012)

1. I like to hear different sounds in nature
2. I like to see wild flowers in nature
3. When I feel sad, I like to go outside and enjoy nature
4. Being in the natural environment makes me feel peaceful
5. I like to garden
6. Collecting rocks and shells is fun
7. Being outdoors makes me happy
8. I feel sad when wild animals are hurt
9. I like to see wild animals living in a clean environment
10. I enjoy touching animals and plants
11. Taking care of animals is important to me
12. Humans are part of the natural world
13. People cannot live without plants and animals
14. Being outdoors makes me happy
15. My actions will make the natural world different
16. Picking up trash on the ground can help the environment
17. People do not have the right to change the natural environment

5. Nature relatedness scale (NR; Nisbet et al., 2009): 21 verbal itemsNR-Self

Instructions: For each of the following, please rate the extent to which you agree with each statement, using the scale from 1 to 5 as shown below. Please respond as you really feel, rather than how you think “most people” feel.

1 Disagree strongly 2 Disagree a little 3 Neither Agree or disagree 4 Agree a little 5 Agree strongly

1. I enjoy being outdoors, even in unpleasant weather. _____
2. Some species are just meant to die out or become extinct. _____
3. Humans have the right to use natural resources any way we want. _____
4. My ideal vacation spot would be a remote, wilderness area. _____
5. I always think about how my actions affect the environment. _____
6. I enjoy digging in the earth and getting dirt on my hands. _____
7. My connection to nature and the environment is a part of my spirituality. _____
8. I am very aware of environmental issues. _____
9. I take notice of wildlife wherever I am. _____
10. I don't often go out in nature. _____
11. Nothing I do will change problems in other places on the planet. _____
12. I am not separate from nature, but a part of nature. _____
13. The thought of being deep in the woods, away from civilization, is frightening. _____ 14. My feelings about nature do not affect how I live my life. _____
15. Animals, birds and plants should have fewer rights than humans. _____
16. Even in the middle of the city, I notice nature around me. _____
17. My relationship to nature is an important part of who I am. _____
18. Conservation is unnecessary because nature is strong enough to recover from any human impact. _____
19. The state of non-human species is an indicator of the future for humans. _____
20. I think a lot about the suffering of animals. _____
21. I feel very connected to all living things and the earth. _____

Scoring Information Reverse scored items: 2, 3, 10, 11, 13, 14, 15, 18; NR-self items: 5, 7, 8, 12, 14, 16, 17, 21; NR-perspective items: 2, 3, 11, 15, 18, 19, 20; NR-experience items: 1, 4, 6, 9, 10, 13 Overall NR score is calculated by averaging all 21 items (after reverse scoring appropriate items). Scores on the 3 NR dimensions are also calculated by averaging appropriate items after reverse scoring. A short-form version of the NR scale (NR-6) consists of items: 4, 5, 7, 9, 17, 21. Items are averaged to create a score on the brief measure of NR. No items are reverse scored.

Appendix 4. Additional method

1. Data search and sources

A total of 1697 citations were found using database searching: Citations were imported from PubMed using R software while citations from Web of Science were imported through their web platform (see Table S1 for keywords details). Additional 401 citations found in references of previous meta-analyses and reviews were also added. Finally, we pulled 2098 citations together in a single excel file (Figure S1).

2. Eligibility criteria

After removing manually duplicates (387 over 2098 records), we performed a three-stage screening to assess the relevance of the paper for future meta-analyses. In the first screening phase, titles and abstracts of the remaining 1711 records were screened and only *empirical, peer-reviewed and English-written* studies measuring *at least one HNC* were made eligible for inclusion. We thus excluded 931 irrelevant papers (i.e., off-topic), 27 non-peer-reviewed and conference papers, 240 reviews, opinion or perspective papers, 6 meta-analyses, and 26 papers not written in English (Figure S1).

In a second stage, we screened abstract and full text when necessary, to include only papers measuring *at least one factor* (causes and/or consequences) in addition to HNC measure. As such, papers aiming at developing or validating HNC scales (without factors) or a new version of a scale were excluded (n=29). We thus obtained 452 empirical papers including 5 case studies, 98 qualitative studies, 316 quantitative studies and 33 studies with both quantitative and qualitative data.

Since only *quantitative studies* can be further used in meta-analyses, full texts of those 348 quantitative studies were assessed for the final stage before inclusion. Among the 348 papers, 60 records reported more than one study or more than one HNC classical scale *shown to be repeatable namely NEP, INS, EID, CNS and NR*. After contacting corresponding authors

to obtain missing data, we obtained 198 studies from 124 individual papers done by 69,763 participants.

3. Description of factors' measurements for correlational data

We calculated R estimates between HNC and nine factors which corresponds to 4 broader categories described in the main text: (1) pro-environmental behaviours (self-reported behaviours and pro-environmental intentions), (2) pro-environmental values (biospheric, altruistic and egoistic values (Schultz 2001), utilitarian value of nature, interest in nature, ecological and environmental values), (3) Human health (mental and physical health and well-being, reversed effect sizes were used for negative mental health (e.g. depression), negative personality trait (e.g. neuroticism) and negative physical health (e.g. physical stress), (4) Humanist values (social values, community values, moral values and humanist values), (5) materialistic values, (6) conservative (political) values, (7) environmental education (naturalist and scientific knowledge about nature), (8) exposure to real nature (time spent in nature, living close to nature, frequency of park visitation), and, (9) mindfulness (practicing mindfulness).

4. Description of factors' measurements for experimental data

We calculated R estimates between HNC and 6 factors: 1) environmental education (naturalist and scientific knowledge about nature), 2) exposure to real nature (outdoor natural activities, walk in the forest, walk in indoor garden), 3) participation in an environmental program involving both outdoor activities and environmental knowledge 4) virtual nature (exposure to videos or pictures of nature), 5) Mindfulness and 6) a combination of mindfulness and real nature.

Since demographic information was often considered as a covariate to control, we did not include them as factor but performed appropriate statistics to investigate their impact on effect sizes (see SI Appendix 5 and Methods).

Appendix 5. Additional results

We investigated the effect of type of programs while controlling for gender ratio, experimental design, time of the post-test, duration of the program and age group on overall effect sizes of **experimental data**. To do so, we built a multivariate model with the five factors as fixed effects and lab and study and estimate ID as random effects (random = ~ 1|lab/study/estimate.id). We found an effect of the type of programs, the gender ratio and the duration of the program on the estimates (omnibus tests: program type: $QM(df = 5) = 19.42$, $P = 0.0016$; experimental design (pre-post vs. control/treatment) : $QM(df = 1) = 2.26$, $P = 0.13$; duration of the program (1 day or less; between 2 days and one month; more than one month): $QM(df = 2) = 7.43$, $P = 0.024$; time of the post-test (short term vs. retention): $QM(df = 1) = 0.46$, $P = 0.49$; age (children vs. adults): $QM(df = 1) = 3.65$, $P = 0.056$; gender ratio: $QM(df = 1) = 4.18$, $P = 0.041$; heterogeneity of the model: $QE(df = 82) = 212.95$, $P < .0001$; overall model: $QM(df = 11) = 43.38$, $P = 0.001$; see Figure 2, Methods, SI Appendix 5).

We also investigated the effect of categories, region, gender ration, age group and HNC metrics on overall effect sizes of **correlational data**. To do so, we built a multivariate model with the five factors as fixed effects and lab and study and estimate ID as random effects. We found a significant effect of the category (Figure 2) and of the HNC metrics on effect sizes (omnibus tests: categories: $QM(df = 3) = 179.83$, $P < .0001$; age: $QM(df = 1) = 0.48$, $P = 0.49$; gender: $QM(df = 2) = 0.86$, $P = 0.65$; region: $QM(df = 4) = 0.54$, $P = 0.97$; HNC metrics: $QM(df = 4) = 36.7$, $P < .0001$; heterogeneity of the model: $QE(df = 919) = 12588.43$, $P < .0001$; overall model: $QM(df = 14) = 221.01$, $P < .0001$ (see Methods, Figure 2 and Figure S3).

Appendix 6. Forest plots for experimental studies

Appendix 6.A Real Nature + Environmental education

Appendix 6.B Real Nature

Appendix 6.C Real Nature + Mindfulness

Appendix 6.D Environmental Education

Environmental Education

Appendix 6.E Virtual Nature

Appendix 6.F Mindfulness

Table S1. Number of papers by keyword from database searching over the 1900-2020 (May) period

Keywords	Pubmed	Web of Science/MedLine
Human nature connectedness	1	9
Human nature connection	3	17
Empathy nature	14	55
Emotional affinity nature	0	4
Inclusion nature self	0	4
Environmental identity	22	253
Connectivity nature	22	4
Nature relatedness	16	41
Connect nature	1	44
Love of nature/Love and care for nature	11	243
Commitment to natural environment	0	5
Environmental connectedness	33	33
New Environmental Paradigm	18	112
Anthropomorphism nature	0	6
Anthropomorphism animal	3	51
Biophilia	11	110
Human plant relationship	3	31
Human-animal relationship	75	390
Human non-human relationship	6	46

Table S2. Summary of meta-analyses from experimental data showing the R estimates, lower confidence interval at 95% (lCI), upper confidence intervals and 95% (uCI), number of individual papers n, number of effect sizes k, number of participants s, z and p values from the z-tests for each category as well as Q (residual heterogeneity) and its corresponding p value Qp for each model (one model per line) with lab and study as random effects.

Type of programs	R	lCI	uCI	n	k	s	z	p	Q	Qp
Contact with real nature	0.18	0.13	0.23	25	70	4773	6.5	<.00001	246	<.00001
<i>real nature + environmental education</i>	0.1	0.034	0.17	10	31	2352	2.9	0.004	109	<.00001
<i>real nature</i>	0.21	0.15	0.27	15	33	2290	7.1	<.00001	86	<.00001
<i>real nature + mindfulness</i>	0.34	0.19	0.48	4	6	220	4.3	<.0001	12	0.037
Other programs (without real nature)	0.19	0.089	0.30	14	24	2328	3.5	<.001	94	<.00001
<i>environmental education</i>	0.11	-0.016	0.24	6	10	909	1.7	0.085	26	0.0017
<i>virtual nature</i>	0.12	0.012	0.23	5	10	1113	2.2	0.03	13	0.17
<i>mindfulness</i>	0.43	0.26	0.58	3	4	306	4.7	<.0001	20	<.00001

Note. Real nature + Environmental Education: Outdoor activities including scientific knowledge. Real Nature: Outdoor programs or experimental manipulations using exposure to real nature; Virtual nature: videos or pictures of nature administered in an indoor setting. EE: educational programs or experimental manipulations involving transmission of naturalist or ecological knowledge in an indoor setting. Mindfulness: focusing on one self or surrounds in the present moment in an indoor setting; Real Nature + Mindfulness: practicing mindfulness in real nature.

Table S3. Summary of meta-analyses from correlational data showing the R estimates, lower confidence interval at 95% (lCI), upper confidence intervals and 95% (uCI), number of individual papers n, number of effect sizes k, number of participants s, z and p values from the z-tests for each category as well as Q (residual heterogeneity) and its corresponding p value Qp for each model (one model per line) with lab and study as random effects.

Category	R	lCI	uCI	n	k	s	z	p	Q	Qp
Nature conservation	0.36	0.32	0.39	84	404	51633	18	<.00001	9713	<.00001
<i>pro-environmental behavior</i>	0.35	0.32	0.39	54	168	36945	17	<.00001	2098	<.00001
<i>pro-environmental values</i>	0.36	0.31	0.41	52	231	33793	12	<.00001	8434	<.00001
Human welfare	0.23	0.20	0.27	50	477	30343	12	<.00001	3422	<.00001
<i>Human health</i>	0.22	0.19	0.25	47	430	28558	13	<.00001	2587	<.00001
<i>Humanist and social values</i>	0.28	0.10	0.45	8	38	3762	3	0.003	751	<.00001
Lifestyle characteristics	0.27	0.21	0.32	35	93	14335	8.8	<.00001	1508	<.00001
<i>Environmental education</i>	0.25	0.14	0.35	10	11	6570	4.5	<.00001	209	<.00001
<i>Real nature</i>	0.26	0.18	0.33	25	68	10304	6.7	<.00001	1149	<.00001
<i>Mindfulness</i>	0.32	0.21	0.43	9	14	2539	5.3	<.00001	89	<.00001
Non-environmental values	-0.23	-0.29	-0.17	7	12	3174	-7.3	<.00001	34	<.0001
<i>materialistic values</i>	-0.23	-0.31	-0.15	4	7	1324	-5.5	<.00001	11	0.082

Category	R	ICI	uCI	n	k	s	z	p	Q	Qp
Conservative political values	-0.23	-0.34	-0.11	3	5	1850	-3.8	0.0001	23	0.0001

Note. Nature conservation: pro-environmental values (ecological, personal interest and appreciation of nature) and pro-environmental behaviours (self-reported and observed pro-environmental behaviours as well as pro-environmental intentions). Human welfare: psychological health (mental health, positive personality traits, academic performance), social well-being (happiness, social and psychological well-being), physical health (vitality, mobility) and humanist values (value of human beings including human freedom and progress, individually and collectively namely social values, community values, moral values and humanist values). Reversed effect sizes were used for negative mental health (e.g., depression), negative personality trait (e.g., neuroticism) and negative physical health (e.g., physical stress). lifestyle characteristics: contact with real nature (e.g., time spent in nature), environmental education (scientific or naturalist knowledge) and mindfulness practices (focusing on the present moment). non-environmental values: materialistic and utilitarian values (values focusing on wealth, possessions, image, and status including consumerism) and conservatism (political values emphasizing traditional social institutions).

Figure S1. PRISMA flow diagram.

Figure S2. Description of all studies included in the review. A) Number of participants for children (<18 years old), young adults (18 to 25 years old), adults (26 to 40) and older adults (>40). B) Number of participants in function of HNC metrics. C) Number of participants by region is presented on the left while coloured map representing the number of participants by country, with grey referring to country without any data on the right. The EID scale was the least used scale. Most of the studies are strongly biased towards adults from industrialized countries.

Figure S3. R estimates from correlational data by HNC metrics. Each round represents the R estimate for each HNC metrics with n, k and s referring to the number of individual papers, number of effect sizes and number of participants respectively. Horizontal lines indicate the 95% confidence intervals for each factor and cross the vertical dot lines when non-significant.

Figure S4. Funnels plots from the meta-analyses of experimental studies. Each dot represents effect size from one individual study.

Figure S5. Funnel plots from the meta-analyses of correlational studies. Each dot represents effect size from one individual study.

Figure S6. R estimates for each sub-category from human welfare (human health include physical and psychological health and humanist values include social and moral values) and nature conservation (pro-environmental behaviour (PEB) include observed and self-reported PEB and pro-environmental intentions while pro-environmental values include nature for human interest, appreciation of nature and ecological concern). Each round represents the R estimate for each factor with n, k and s referring to the number of individual papers, number of effect sizes and number of participants respectively. Horizontal lines indicate the 95% confidence intervals for each factor and cross the vertical dot lines when non-significant.

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For Peer Review

Figures

Figure 1

Hypothetical representation of a vicious circle generated by a detrimental worldview (left) and a virtuous circle generated by a sustainable worldview (right). We assess whether and how human-nature connectedness can be used to switch from a detrimental to a sustainable worldview at both individual and societal levels.

Figure 2

Results from meta-analyses of experimental (blue background and text) and correlational (green and orange backgrounds and text) studies. Each dot represents the average R estimate for each factor obtained after transforming averaged standardized effect sizes (Fisher's Z for correlational data and Hedges' g for experimental data) with n, k and s referring to the number of individual papers, number of effect sizes and number of participants, respectively. Horizontal lines indicate the 95% confidence intervals for each factor and cross the vertical dot lines when non-significant (i.e., environmental education in experimental studies). Single-headed arrows refer to causal relationships while double-headed arrows refer to correlational links. Overall R estimates from each broad category are in bold. Details are provided in Methods summary, Methods, Extended data Tables 2 and 3 and Extended data Fig. 4. Experimental studies show that exposure to nature and mindfulness practices improve HNC. Correlational studies confirmed experimental studies and show that HNC is positively linked to nature conservation and human welfare and negatively linked to non-environmental values. **: $p < .001$; ***: $p < .0001$.

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- [Extendeddata.docx](#)
- [SIConservationLetters.docx](#)