Longing to be the Mountain: A Scoping Review about Nature-Centric, Health-Minded Technologies

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ABSTRACT

Engaging with nature enriches people's life greatly, and it is a particularly powerful wellbeing activity. Unsurprisingly, researchers in HCI and beyond seek to augment and extend the relationship people have with nature through technology, to positively enhance their health as a result. In this paper, we report on a scoping review that examines research exploring health, nature, and technology research. By charting 29 papers from the last five years, we produce a situated snapshot of the current research landscape and identify three trends within the paper pool: Despite the potential for rich, experiential engagements, human-nature interaction is often understood as an endeavour that is 1) universal, 2) flattened and 3) disconnected from everyday life. We reflect on our findings to outline design opportunities for human-nature interaction that extend and re-orientate it; to design for multi-dimensional caring experiences that allow for a more-than-just-human understanding of nature.

CCS CONCEPTS

• **Human-centered computing → HCI theory, concepts and models**.

KEYWORDS

scoping review, human-nature interaction, wellbeing, wellness, health, nature, environmentalism, ecology, climate change, sustainability

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1 INTRODUCTION

We are living through tough, concerning ecological times; irreversible climate change seems imminent [42], the Amazon forests continue to shrink [90] and all of earth's rainwater now contains *forever chemicals* making it unsafe to drink [40]. While humankind's relationship with nature could be described as *strained*, beingin and connecting with nature are important aspects of the human experience [55, 72], and of fundamental importance for *"human flourishing"* [112]. We have gone beyond simply encountering nature as individuals; our relationship with nature is increasingly mediated by and through technologies in a wide variety of ways. People navigate the outdoors with GPS trackers [67], engage in gamified jogging through parks [117], track associated health metrics [92], or move through urban green spaces with games such as Pokémon Go [94, 143]). As a result, the field of human-computer interaction (HCI) and related fields have shown substantial interest in the relationship between humans, nature, and technology [66, 81, 115, 137] Researchers and developers alike seek to reconfigure and investigate how we might want to use technology with, in *and* around nature, in applied or abstract ways: Examples for such endeavours include using video games as a medium for nature conservation [53], developing experiences to engage people with their local plants [23, 132] or birds [160], and using technology to educate children about environmental issues [5]. The interest in *"human-nature interaction"* (HNI) [98] as a rich design space has also moved towards creating health and/or well-being experiences. Being with and in nature can enrich our well-being and health tremendously [72], on all levels; mentally and physically [55], spiritually [85], and creatively [124, 129]. For the purpose of this paper, we define health-minded technologies as *affective health technologies [145] that seek to influence someone's health and well-being in some way, shape or form, but excluding strictly medical interventions.* This definition is broad rather than dogmatic, including all conceptualisations of health and how one may approach and care for it.

As researchers in HCI and beyond seek to engage with nature and health in the technologies we create, we need to construct, codify and formalise how we understand these concepts. While every person has their own *"subjective nature experience(s)"* [79] (vice versa for health experiences [169]), both nature and health are multidimensional aspects of human life that are influenced by forces beyond the individual's personal perception. These wider determinants of health [9, 109] include local considerations—e.g., a person's local climate and physical location [105] and their general

access to green spaces [13, 91]—but also global phenomena like climate change [125]. Therefore, we understand nature and health in personal, cultural or societal contexts. As a result, designers and developers imbue health-minded, nature-centric technologies (NCT) *naturally* with implicit and explicit values, assumptions, narratives and expectations: *When it comes to **health**, do they present it as an individualistic pursuit of well-being [168], based on improving health metrics [167]? Do they frame looking after one's health as a moral duty [102]? Or do they showcase well-being as an experiential and relational quality that touches on all aspects of people's lives [83]? Do they see **nature** as a convenient, resourceful backdrop to exercise in, or as a space for meaning-making and building kinship with the wider world that we live in [99]? How does **technology** support, contest or inhibit these orientations?*

The answers to these—and many more—questions directly influence technologies and the people who use them in a variety of ways: NCTs may therefore shape people's opinions of nature and health (and vice versa). Beyond tools for an individual's encounter with nature and health, NCTs are therefore active *"shapers"* of individual, cultural and societal attitudes. This paper seeks to make these underlying patterns and trends within current health-minded NCTs visible, and to investigate them through a scoping review. Our research questions are:

- **RQ1: What have studies on health-minded NCTs focused on over the last five years?**
- **RQ2: How do these studies make sense of technology, health and nature?**

The structure of this scoping review is as follows. First, we examine a snapshot of the research on current health-minded technology-facilitated experiences that make use of nature—both in-situ and virtually. We continue by positioning the work within related literature: We lay out how nature, human-computer interaction and health technologies can overlap. After establishing these connections, we turn to outline our methodology, particularly our search strategy and charting table. Then, we showcase our findings: First, by introducing the papers within our data set in general terms, and second, by reporting on their traits and attributes captured through charting—focusing on *technology, nature and health* respectively. Finally, we discuss the set of papers as a whole and sketch out commonalities and differences among them. We arrive at an understanding that health-centric technologies in HNI are pluralistic and heterogeneous, but that they also tend to frame nature in ways that 1) assume universality 2) flatten experience and 3) disconnect nature from the everyday. Based on these trends, we begin to sketch out a set of design opportunities to provide a counterweight to them, and suggest how HNI for health and well-being could be extended beyond the status quo.

2 RELATED WORK

As mentioned in the *Introduction*, engaging with nature and health through technology requires designers, developers, and researchers alike to define these concepts and determine how to implement them in practical ways. Applications implementing these concepts therefore unavoidably carry the designers' values, judgements, biases, and understandings of *what* nature, health and technology are and should be like—conceptions that can be supportive, but also potentially harmful.

2.1 Conceptualising Human-Nature Interaction

For the sake of this paper[1], we draw from humanistic geography to define *"nature" as a socially constructed interpretation of places [147] that feature elements of the "natural world"—including plants, non-human animals (flora and fauna) and other organisms such as mushrooms—prominently [152]*. We extend this definition through *"ecological realism"*, to understand people not as privileged others set apart from nature, but as distinct parts and actors within it [141]. With a working definition of *nature* in place, we can now conceptualise HNI on a spectrum; one that ranges from people considering themselves to be on the top of the food chain [41] to understanding humankind as intrinsically connected to nature, and as an equal part of it [78].

We start our mapping exercise with the concept of ***people as dominators over nature***. In this interpretation of nature/culture dualism [65], people perceive themselves as being above or beyond nature. Nature becomes a subservient, utilitarian place disconnected from people [118]—a distinct *other* [99]. As a consequence, nature is perceived as something in need of *taming*, both to provide natural resources and to be used, augmented and improved by people [99, 161]. This construction of nature undergirds (other) systems of domination that are based on human superiority [38], which affect human and non-human life alike, e.g. through imperialist and colonialist violence [186].

Still human-centred, but more relational is the idea of ***people as managers of nature***. In this middle-ground understanding, nature is still subservient to people, but humans approach it with a sense of responsibility and accountability [51, 155], as human beings have irreversibly shaped *all* ecosystems on planet Earth (*"Anthropocene"* [41]). In this framing, people approach nature as both space and capital that needs to be *"managed"* [51] and *"protected"* [190]. In practise, such a stance translates to local and international policies that seek to limit the harm done to the environment—e.g. the European Union's goal to be carbon-neutral by 2050 [131]—and an interest in animal welfare [28], sustainability [180], environmentalism [70, 116] and the conservation of biodiversity [84].

However, there are also understandings of nature that displace people as an actor that is superior, and conceptualise humankind as existing as one of many parts of nature; ones that view ***people as kin of nature***. Fundamental aspects of this relational understanding are (mutual) co-existence and connectedness with nature [78], as well as recognising the autonomy and agency of non-human life alike [173]; an acknowledgement of nature being an actor in itself [3, 141]. This line of thought—mutual co-existence with nature—is practised in the expertise, lived experiences and practises of native and Indigenous peoples, and it stands in direct opposition with the way of treating nature in the Global North [25, 46, 144]. A kinship-oriented understanding of nature can also extend to a *"more-than-human"* framing that critically deconstructs the image of the human being as the paternalistic gardener who seemingly needs to keep nature in check [30]. Instead, a *more-than-human*

[1]It is important to stress that our definition is one of many possible definitions and is not absolute.

orientation seeks to *de-centre* the *"human being"* as the common focal point, to shift it towards non-human actors: *"In uncovering the 'affordances' of nonhumans and not-quite human things, [more-than-human] work refutes the anthropocentric exclusivity of a humanist conception of agency as a rational consciousness directing all else"*, as described by Anderson [3, p. 5]. Examples for such inquiries include challenging the dichotomy of *"human/animal"* [54, 173], engaging with planetary health through relational, Indigenous epistemologies [82], and learning with and from plants as distinct and important actors in local ecosystems [128].

Having mapped out this potential spectrum, we see that designing for HNI is a complex process that can lean on ecology [22], environmentalism [45], sustainability [44, 93] and more. Examples for the plurality of HNI research include Rodgers et al., who map out how technology for the garden could be approached [137]; Jones et al., who explore the design for physical activities outdoors [81]; Häkkilä et al., who investigate how to design technology that does not distract from the nature experience in itself [66]; or Ferreira et al. and Thomas et al., who investigate how technology could help mitigate the harm of climate change [52, 175]. Examples for kinship-based or *more-than-human* research endeavours in HCI include Sondergaard et al. using eco-feminism as a fundamental value to design and research with [159] or Mencarini et al. who explore how we can build kinship with nature through and with technology [115]. In summary, researchers and designers both design for both micro- and macro-level understandings of nature in a rich design space full of competing attitudes and tensions.

2.2 Making Sense of Health-Minded Technology

At first glance, designing technology for health and well-being may seem like a unilaterally positive undertaking. It is, however, a tricky endeavour, since health can be considered an experience [121] that is constrained and shaped by many factors, including personal needs [111], wider determinants of health [9], access to (health)care [7], cultural and societal assumptions [29, 74] (including health-related stigmas [148]), wider systems of power [38, 39] and more.

This complexity means health-minded technologies have the potential to influence people on a very deep, personal level—in positive or supportive *and* disruptive or harmful ways—as they seek to augment a person's relationship with self and all of its tensions [75]. There is substantive scholarship in HCI and beyond that seeks to deconstruct and expose these values, norms and universal assumptions—and their consequences. One example of such scholarship is Spiel et al., who describe how technologies that are ostensibly *for* autistic children tend to focus more on their social networks—e.g. their parents, guardians or caregivers. This skewed alignment causes technology to enforce and perpetuate a narrow set of normative, socially acceptable behaviours for said children, instead of providing meaningful interactions *for* them [164]. Keyes et al. surveyed how HCI makes sense of the concept of *"women's health"*: They showcase that HCI features a pluralistic overview of experiences and interventions, but they also arrive at an understanding that gender (and its construction) in technology still tends to be limiting and *essentialist*. As a result, interventions are being designed in very opinionated ways of *who* a woman is, and *what* she needs for her health [89]. Similarly, Pendse et al. demonstrate how the construction and treatment of *"mental health"* within HCI can reinforce colonial, marginalising views by assuming what *"good"* mental health looks like, in normative, reductionist terms, and by failing to engage with the problematic history of how *"mental illness"* was and still is used as coercive, punitive tool [126]. Beyond overlooking systemic issues, technology may also propagate its own potentially harmful messages. To this end, Spors et al. investigated a set of commercial self-care apps in the Google Play Store to map out the narratives and assumptions in their store descriptions. They concluded that apps showcase self-care as an easy, universally available and linear self-improving activity that guarantees well-being—as long as the person engaging with it is compliant with the app in question. This presentation is disconnected from the reality of requiring care as relational negotiation and connection, and it does not take people's individual needs into consideration [168]. Similar concerns about normative design assumptions apply to health-aligned technology that engages with ageing [59], menopause [35], self-tracking for fitness [167], and reproductive functions of the body [31, 103], but they also apply to the populations HCI *generally* tends to design for, and by proxy, whose dis/ability and body/mind [60, 163, 165].

When we consider all theseconcepts and ways of understanding nature and health, it becomes clear that both health and HNI within HCI are heterogeneous fields full of tensions. With this review, we hope to add to understanding this interdisciplinary plurality.

3 METHODOLOGY

3.1 Scoping Review

As outlined in the *Introduction*, this paper seeks to investigate health-minded NCTs to understand how they shape people's understandings of health, technology and nature. We provide a *snapshot* of the current scholarship in the field, which we conceived as a scoping review, based on Arskey & O'Malley [6]. As such, the paper sets out to *map* a certain area of academic interest, to *"clarify a complex concept and refine subsequent research inquiries"*, as described by Levac, Colquhoun & O'Brien [96]. This review's goal is not a comprehensive overview; instead, it showcases a focused, specific *snapshot* of the current landscape of nature-focused, health-oriented technologies within HCI and beyond to make sense of current trends and patterns. We adopted Levac, Colquhoun & O'Brien's six-stage approach to scoping reviews, which includes defining a clear research question (1), defining a balanced breadth of papers to be included (2), iteratively assessing the paper pool (3), charting data (4), reporting it (5) and considering wider impacts of the review's findings (6) [96].

3.1.1 Development of Search Strategy. We conducted initial pilot searches in Google Scholar, Scopus and ACM DL to establish a preliminary set of keywords, which we iteratively refined. Given that Google Scholar has problems with reproducibility due to its personalised search results, it was only used as a piloting database to help us to identify relevant keywords and potential papers [64]. The search strings were iteratively refined, in several rounds. As we set out to define a set of keywords that were broad, yet specific

enough to enable us to construct a meaningful, *general* snapshot of the field, we encountered several constraints we had to balance:

(1) **Multi-purpose terms:** Many of the concepts that this scoping review looks at are used in a wide variety of contexts, e.g., papers using *"the nature of x"* as a generalised phrase or the plethora of words used to describe technology, e.g., *"tool", "experience", "intervention", "app"* etc.
(2) **Triangulating health, nature and technology:** As we were interested in the overlap of health and nature and technology, we had to calibrate our search terms carefully to avoid skewing the paper pool towards any potential combination of only 2 of the 3 concepts in question, such as a bias towards papers discussing nature and technology, without focusing on health. We had to make several opinion-based decisions for counterbalancing: We purposely chose not to include any *specific* health- or well-being-related concepts to avoid skewing our initial paper pool towards a specific orientation or technique, such as mindfulness. Similarly, we omitted specific terms, descriptors or words for specific species or groups of non-human life, which led us to discard all non-human–life and animal-related keywords, as we encountered too many false positives focusing on animal well-being or cultivation practises such as how to grow mushrooms. We were also careful to limit the number of *false positives* of ecology- and systems-oriented papers, such as those investigating the *"health"* of ecosystems; this limitation led to discarding all *"eco-"* prefixed terms and the removal of *"green spaces"* from our initial roster of keywords. To this end, our set of keywords therefore leans more towards nature as *flora*, as a green space.

Despite these calibrations, our initial paper pool was still broad enough to encompass 3110 papers, which will be explained in detail next.

3.1.2 Search Strategy and Keywords. We searched both ACM DL and Scopus in April 2022, in Finland with the following keywords:

- **Nature-specific keywords:** nature, outdoor*, outside, flora, greenery, forest, meadow, park
- **Technology-specific keywords:** tech*, app*, experience, gami*, game*
- **Health-minded keywords:** health, well-being, "well being", well-being
- **Exclusionary keywords:** review, survey, meta*, gamet*, algo*, olymp*, hunt*
- **Time frame:** Past five years (2017-2022).

The concrete search strings follow below:

- **ACM DL:** *[[Abstract: nature] OR [Abstract: outdoor*] OR [Abstract: outside] OR [Abstract: flora] OR [Abstract: greenery] OR [Abstract: forest] OR [Abstract: meadow] OR [Abstract: park]] AND NOT [Abstract: review] AND NOT [Abstract: survey] AND NOT [Abstract: meta*] AND [[Abstract: tech*] OR [Abstract: app*] OR [Abstract: experience] OR [Abstract: intervention] OR [Abstract: gami*] OR [Abstract: game*]] AND [[Abstract: health] OR [Abstract: well-being] OR [Abstract: "well being"] OR [Abstract: well-being]] AND [Publication Date: Past 5 years]*
- **Scopus:** *(((TITLE-ABS-KEY (game*) OR TITLE-ABS-KEY (gami*) OR TITLE-ABS-KEY (app*) OR TITLE-ABS-KEY (tech*) OR TITLE-ABS-KEY (experience) OR TITLE-ABS-KEY (intervention) AND TITLE-ABS-KEY (outside) OR TITLE-ABS-KEY (outdoor*) OR TITLE-ABS-KEY (nature) OR TITLE-ABS-KEY (flora) OR TITLE-ABS-KEY (forest) OR TITLE-ABS-KEY (meadow) OR TITLE-ABS-KEY (park) AND NOT TITLE-ABS-KEY (theory) AND NOT TITLE-ABS-KEY (review) AND NOT TITLE-ABS-KEY (survey) AND NOT TITLE-ABS-KEY (meta*) AND NOT TITLE-ABS-KEY (gamet*) AND NOT TITLE-ABS-KEY (algo*) AND NOT TITLE-ABS-KEY (olymp*) AND NOT TITLE-ABS-KEY (hunt*)) AND PUBYEAR > 2017 AND PUBYEAR < 2023)) AND TITLE-ABS-KEY (well-being) OR TITLE-ABS-KEY (wellbeing) OR TITLE-ABS-KEY ("well being")*

This resulted in 1110 papers for ACM DL and 3,898 potential papers for Scopus. Given that this is a scoping review and not a systematic review, we included the first 2000 papers from Scopus, sorted by relevance, in the pool of papers. Given that Scopus indexes papers from all research fields, this specific search string required excluding additional keywords, e.g., cumulative research like meta-analysis, or specific research about, for instance, algorithms, hunting, Olympic games, and reproductive biology. In total, we ended up with 3110 papers to be examined prior to the removal of duplicates, with 2000 papers from Scopus and 1110 papers from ACM DL. We used VOSViewer—a bibliometric visualisation tool [181]—to ensure that we did not miss any substantial research strands in these 3110 papers, by mapping out the author-given keywords included in this pool. As this examination revealed no omitted relevant research streams, we continued to further process the sample of studies.

3.1.3 Procedure of In- and Excluding Papers. We set the following five criteria for including and excluding papers:

- **Time frame:** The paper was published in the last five years (2017-2022).
- **Language:** The paper is written in English.
- **Academic rigour:** The paper is peer-reviewed and communicates the undertaken research clearly and consistently; we excluded grey literature, editorials and other non-peer-reviewed work.
- **Thematic focus:** The paper is centred on technology to inform or deliver health-minded experiences that feature nature. For the purpose of this paper, we defined well-being in open, agnostic terms, e.g. we included all research that sought out to enrich someone's experience.
- **Not Meta-Research:** The paper is excluded if it is a review, a survey, or a meta-analysis of existing research.

An overview of in- and excluding papers is showed in Figure 1, as a *PRISMA flow chart* [170]. After removing all duplicates (98 removed), we assessed the remaining 3012 papers based on their title and abstract, and applied the above specified criteria (2918 excluded). At this step, only those studies that clearly did not meet the inclusion criteria were discarded in order to avoid false negatives. Then, we investigated the full text of the remaining 94 papers, applying the same criteria as in the previous step, excluding 63. We

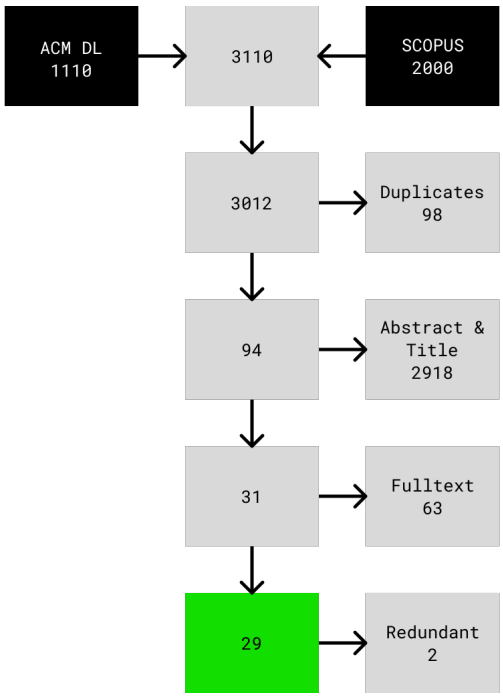

Figure 1: Overview of in/exclusion of papers, illustrated as a *PRISMA* flow chart.

conducted ancillary searches based on the potential full text papers' references, but we did not end up adding any additional papers to the paper pool. We removed two papers out of the remaining 31 papers as three papers reported on the same invention (*"Shmapped"* by McEwan et al. [113]). Finally, we charted 29 papers, which are included in the evaluation presented in this study.

3.1.4 Pool of Papers. *Table 1* showcases an overview of all included papers:

Papers (continued)	
van Houwelingen-Snippe, Allouch, van Rompay [182]	Reetz et al. [134]
Navarrete-Hernandez, Laffan [120]	Lee et al. [95]
McEwan et al. [113]	Graf, Liszio, Masuch [61]
Bandukda, Holloway [10]	Eftekharifar, Thaler, Troje [50]
Bates et al. [12]	Hitron et al. [76]
Browning et al. [26]	van Renswouw et al. [183]
Zabini et al. [191]	Adhyaru, Kemp [108]
Lundstedta et al. [100]	Luo et al. [101]
Reese, Stahlberg, Menzel [133]	Cochrane et al. [37]
Torrado et al. [177]	Schutte et al. [151]
Smith, Getchell, Weatherly [156]	Anderson [4]
Vella, Polderer, Brereton [184]	Seo et al. [153]
Petersen, Martin [127]	Sansom, See [146]
Chan et al. [33]	Bakolis et al. [8]
Wan [185]	

Table 1: Overview of all included papers in this review.

3.2 Data Extraction and Analysis

We created a charting table to investigate the pool of papers (n = 29) in a deductive manner. We divided this table into three thematic sections:

- **General Traits:** The first set of questions establishes a general idea of each paper and how the research presented in it was conducted, including such traits as publishing year, funding sources, country, intended audience for the theory or intervention shown and the paper's reason for using technology as a medium.
- **Health- and Well-being-Specific Traits:** The second set of charted traits centres around how papers made sense of health and well-being, e.g., did they apply a specific model for understanding health? Which aspects of well-being did they focus on? Which instruments and tools did they use to measure or assess health-related aspects?
- **Nature-Specific Traits:** The third and last set of traits to be charted focuses on how papers make sense of nature, and how the research engages with it and represents it. This set includes what aspects of nature are being shown and how, which nature-related theories or concepts the paper leans on and how people are framed within nature.

In terms of concrete procedure, VS created the first initial draft of the charting table and refined it based on discussions with the other authors. Then, VS did the first pass of data extraction and filled in the table preliminarily, with SL confirming that the data extracted was appropriately presented using accurate descriptions and terms. Finally, all authors discussed the charting table as a whole to construct understandings based on it. We make sense of the data extracted through the aforementioned charting process by synthesising it, akin to how it is practised in a narrative review [188].

3.2.1 Research Lens, Epistemology and Positionalities. We conceived the charting table to include questions and traits that required us to interpret data from papers to make sense of them as a whole. Given this process, it is important for us to highlight our approach to knowledge creation. We position ourselves within the third paradigm in HCI, as defined by Sengers et al., as creating *"phenomenologically-situated"* knowledge [71]. Concretely, this means that this paper, and the showcased work within it, does not seek to provide objective or absolute insights, but it acts within a more humanistic HCI framing [11]: Beyond providing facts about the papers included in this review, this paper sets out to inspire and challenge the reader and engage them in a critical reflection with the contents it presents.

For transparency's sake and to foster further understanding of our process of extracting, charting and interpreting, we outline our researcher positionalities. These profiles are not all-encompassing, but sketch out important key points in our understandings of technology, nature, and health: **VS** is a white, able-bodied and non-binary German person in their early thirties. They have a background in Graphic Design and HCI. Having grown up in a forest-dense country, being with and in nature is an important aspect of their personal self-care practice, and they make an effort to seek out nature-aligned spaces in their daily life. While technology has been enriching for their encounters with nature—e.g., by assisting in

identifying plants or providing information about hiking trails—VS is concerned about technology's potential to be disruptive to someone's health- and nature experience, e.g. through metrics-based *"Self-Surveillance"*, as described by Lupton [103].

SL is an able-bodied male from Finland, a Nordic country with a low population density, thousands of lakes and dense forestation. His work currently is primarily focused on location-based games and nature technologies. Since his childhood he has regularly visited Finnish forests and nature, due to living in proximity to a forest and being in Boy Scouts and later in the Finnish army. He regularly plays location-based games in natural environments in his free time, and visits nature periodically during summer and autumn to collect berries and mushrooms. He is concerned about the effects of human intervention on forest ecosystems.

OB is a researcher who works on gameful/playful technologies of all kinds with a specific focus on bodily technologies. He is an able-bodied man and is Turkish but has been living in a Nordic country for the last four years. OB enjoys nature, although being in nature is not an integral part of his life. Since he moved to the Nordic country, due to accessibility and the culture oriented around natural environments, he is more engaged with nature and takes regular trips to cottage houses almost every month. Lately, he has been realising the inherent conflicts in using the technology of daily life (e.g., laptops, mobile phones) in natural settings and he thus tries to understand how non-computational tech (e.g., fire tools, rowboats) feels more aligned with the dynamics of nature.

JH is a white, able-male-bodied person in their late thirties. After a childhood where the main stage of everyday life and play took place in forests and nature, JH has primarily been interested in crafted experiences (chiefly games) and technology. JH is holistically involved in research related to the relationship between humans and tech, especially in relation to leisure and motivational uses. Currently, JH is enthusiastic about different developments, practices, and cultures in which technology and nature come together. In terms of epistemology, JH tends towards overall scepticism in the short term and relativism and pragmatism in the long term, believing that across-disciplinary synthesis of approaches and methods leads to meaningful sense-making of reality). JH has been involved in conducting research in relation to human-technology research representing all common approaches from art and design to strictly controlled experiments.

4 FINDINGS

In this section, we first provide an overview of all papers to establish context for the following findings. Then, we outline themes that we identified in the data set. An overview table of all charted traits, questions and associated data can be found in the *Supplementary Material* of this paper.

4.1 Findings: General Overview of the Pool of Papers

4.1.1 Year of publication and country. More than half of all papers were published in the last three years, in 2022 (n = 7, e.g. [133]), 2021 (n = 8, e.g. [184]) and 2020 (n = 8, e.g. [191]), although this aspect is constrained by our search strategy. Our pool of papers showcases 14 different countries in which research was conducted, with most activities clustered around Europe: UK (n = 5, e.g. [10]), USA (n = 4, e.g. [4]), Australia (n = 4, e.g. [151]), Canada (n = 2, e.g. [134]), Germany (n = 2, e.g. [61]), Netherlands (n = 2, e.g. [183]), Chile [120], Hong Kong [185], Israel [76], Italy [191], Japan [101], Norway [177], Singapore [33], and Sweden [100]. One study was open worldwide [8] and one paper took part in Norway and Germany [127].

4.1.2 Implementation and research setup. Fifteen papers featured a concrete artefact/intervention that was studied empirically; examples include Vella, Polderer and Brereton, who provided a group of Australians with camera traps in order to make sense of their gardens and reflect on their relationship with it [184], and Wang, who developed the *"Nature Jar"*, an interactive object that encourages people living in urban environments to pay attention to nature in their everyday life [185].

The remaining 14 papers focus on exploring technology, nature, and health from a more theoretical and/or conceptual standpoint by sketching out potential interventions or laying the foundation for future research. Such projects include comparing forest-bathing in actual nature with experiencing a virtual forest, as investigated by Reese, Stahlberg and Menzel [133]. Almost all papers (n = 26, e.g. [33]) involved participants in their research (or planned to engage with participants, e.g. [133, 156]). The average number of participants was n = 60 (minimum n = 4 [37], maximum n = 240 [120]).

4.1.3 Duration of use and engagement. Most papers offered experiences that participants engaged with briefly (e.g. [33]). The average across all experiment papers was 15 minutes per individual session and/or engagement. The shortest engagement among the papers was four minutes (n = 4 [120]), as reported by Navarrete-Hernandez and Laffan, who engaged visitors of a cultural event with speculative urban planning [120]. The maximum engagement was being in nature for several hours, as described by Petersen & Martin, who designed photography field trips into German and Norwegian nature [127]. Repeated engagement with an experience was rare, as most research from our paper pool involved a single session (n = 17, e.g. [37]). Repeated engagements or sessions were predominantly defined by the researchers (n = 6), e.g., engaging in four sessions of digital forest-bathing lasting an hour each, as reported by Markwell & Gladwin [108]. Nevertheless, a substantial set of papers let participants decide how long they wanted to experience an intervention (n = 11, e.g. [100]).

4.1.4 Target audience(s). The intended audience for the experiences and interventions in the data pool was mostly the (unspecified) general adult public (n = 13, e.g. [191]), followed by more specified target groups. Papers specifying a target audience typically described and studied socially marginalised people who may reap health benefits from engaging with nature-centric technologies, especially vulnerable populations such as older people (n = 4, e.g. [61]) or people with disabilities and/or mental distress (n = 3, e.g. [177]). Other target audiences were young adults (n = 2, e.g. [185]), children [76], people visiting a cultural event [120] and healthcare professionals [1].

4.1.5 Research paradigms and methods. The majority of papers investigated how nature affected participants and their health through

targeted instruments like surveys and questionnaires to measure specific aspect and traits, embedded within mixed-methods research approaches (n = 24, e.g. [113]). We therefore encountered a diverse mix of standardised surveys, measures and instruments to make sense of nature/health experiences, particularly in research that engaged participants, e.g. [26, 191]. A minority of papers engaged in qualitative research (n = 5, e.g. [4, 146]), such as interviewing people about their experience of testing a prototype and/or organising a focus group [10].

4.2 Findings: Technology

In this section, we present our findings related to technology and showcase which technological choices and considerations papers described.

4.2.1 Encountered "tech stack". The technology and *"tech stack"* encountered in the data set was varied, yet most papers relied on virtual reality (VR) to facilitate their experiences (n = 11, e.g. [133]). The next biggest category of technology was smartphone apps (n = 4, e.g. [177]), combining video or audio with interaction with objects (n = 4, e.g. [95]) and tangible prototypes (n = 3, e.g. [183]). Other technology that papers deployed included an analogue camera [127], a scent diffuser [12], camera traps to capture photos of wildlife at night [184], a desktop game [134], an online platform to watch the livestream of a farm [4] or the use of audio for mediation [37].

4.2.2 Reasons for engaging with technology. The majority of papers (n = 15, e.g. [26, 191]) gave their reasoning for using technology as its presumed accessibility; that is, the papers made the case that nature is currently difficult to access and technology may aid access. This reasoning was followed by stating technology's ability to facilitate an engaging experience (n = 8, e.g. [4]). The remaining five papers referred to the possibility of attaining their research goals through the technology chosen, e.g. comparing and contrasting experiencing virtual nature with actual nature [151].

4.3 Findings: Nature

This section outlines our findings about how the paper pool encountered, approached and made sense of nature.

4.3.1 Nature as a research site. Although this review covers nature-centric technologies, only a minority of papers involved research going outdoors and/or engaging with nature in situ (n = 6; one example of this type involved the *"HikePal"* application developed by Torrado et al., which seeks to bring autistic people into nature [177]). An additional five papers showcased research that included indoor and outdoor aspects, such as Markwell Gladwin, who compared virtual and in situ forest-bathing as a well-being practise [108]. The remaining papers (n = 18, e.g. [61]) were designed for indoor use.. This means that most papers in the paper pool engaged with nature by simulating it (n = 12, e.g. [100, 133]).

4.3.2 Depiction and portrayal of nature. The focus on such immersive technologies as VR—*see 4.2.1*—coincides with many papers featuring simulated, virtual nature (n = 8, e.g. [100]). Where research projects engaged in showcasing virtual nature, the overwhelming majority of chose to present it in (hyper)realistic ways, for instance by using recordings of actual nature (e.g. [101]) or by using realistic-looking trees instead of stylised portrayals, engaging in a form of digital mimicry (e.g. [50]). It should be noted these presentations of virtual nature were often not described in detail or shown through images. Only a minority of papers made their experiences available publicly, either through images, downloads of the experiences (e.g. [134]) or videos (e.g. [33]). To the extent that we could glean an understanding from the papers, we found they presented nature in mostly non-specific ways: We encountered similar-looking bright green grass, leafy trees and shrubbery across the paper pool. As far as we can tell, the only exception to this trend seems to be Chan et al.: While they do not mention it explicitly, they have seemingly modelled their VR forest experience after trees found in Singapore [33].

We can therefore infer an absence of fantastical, comical, or stylised portrayals of nature: The effect of being with or in nature was often compared and contrasted to being in an *realistic "urban"* environments, or having been exposed to "urban" sounds, imagery or spaces prior to encountering the *"nature-based"* condition (e.g. [151]). What this *"urbanness"* entailed varied among papers, but common overlaps included car sounds (e.g. [134]) (audio) and densely built grey buildings without any visible greenery (e.g. [33]) (visual).

4.3.3 Modalities of encountering nature. Across the paper pool, most papers presented nature as *something*–a space, an environment, a backdrop—to be looked at and focused on through its visual aspects (n = 21, e.g. [37]). This circumstance applies to *both* papers that brought people into nature and those that featured experiences exploring virtual nature. Interactivity was often restricted by design or implementation choices, e.g. VR experiences featuring 360-degree videos [26]. Across all papers, only a minority of experiences included interactive aspects beyond looking around in the provided simulated space; for instance, Graf, Liszio and Masuch developed a VR application for older people, which included being able to move around and play cognitively stimulating mini games within the scene [61], or Bates et al. provided an audio-focused experience, that was complemented by scents and objects for participants to touch [12].

The influence of games was visible across the whole paper pool. In papers featuring virtual nature, the majority drew inspiration from video games, not least because game engines were often to used to develop the experiences (e.g. Unity [134]). Beyond facilitating the prototypes, common video games design practises or patterns also manifested themselves in the surveyed papers—particularly by 1) putting participants into scenes from a first-person perspective, such as traversing virtual nature as a camera placed at human eye height, slightly above the ground; and 2) through having gameful elements within the experiences, such as pointing and clicking to teleport around an island in VR [100] or planting plants in the environment [134]. Only one paper let participants take on the role of a non-human actor, or an unusual perspective that normally is not accessible to people: Reetz et al. had their participants embody *"wind"* in their gameful experience, so participant could *"fly"* through the provided 3D environment [134]. Animals and depictions of people were absent from most papers'

portrayals of nature, with Graf, Liszio and Masuch being the exception: They designed their VR scene to include a virtual companion dog [61]. Few papers explained this absence, though Chan et al. noted that depictions of animals or people could inhibit the well-being potential of the provided experience [33].

4.3.4 Understandings of nature. The majority of papers discussed nature as an unilaterally positive space (n = 23, e.g. [120] and as beneficial to humankind. The exceptions to this rule were six papers, including Bates et al. [12] and Wang [185], whose papers reflected on human-nature relationship as a contextual, multi-dimensional and complicated one.

4.4 Findings: Health and Well-being

Now we turn to report on our findings on how papers approached health and well-being.

4.4.1 Health and well-being activities. Across the paper pool, we encountered a very homogeneous approach to well-being activities a person could undertake with technology in nature. The most common proposed well-being activity was noticing nature, particularly by looking at it (n = 26, e.g. [101]). This orientation matches the previously described modalities of encountering nature *(see 4.3.3)*. Other proposed activities were meditation [37], physical exercise through walking [177] or engaging in social play [76]. Some studies included other people being present around the participant experiencing an intervention, both to help out and spectate (e.g. [100]), but all papers proposed and organised encountering nature on an individual level.

4.4.2 Conceptualisation of health and well-being. Given the focus of this review on health, nature and technology, unsurprisingly, the research focus of most papers was oriented towards nature due to its health benefits (n = 27, e.g. [113]). These benefits were often described in a generalised or universal ways, without being overly specific or concrete, such as assertions that being in nature affects people's well-being (e.g. Browning et al. stating that *"nature promotes human health and well-being by mitigating adverse environmental stressors"* [26]). Unsurprisingly, stress reduction through being in nature was a commonly encountered theme throughout the paper pool (e.g. [133]). One paper did not specify a concrete understanding of well-being [37]. Vella et al. stressed the benefit of kinship with nature through meaning-making in local green spaces [184]. Similarly, Bates et al. explained that a broadened understanding of nature may be beneficial for people [12]. Navarrete-Hernandez and Laffan mentioned the positive benefit of rejuvenating urban spaces in nature-aligned, equitable ways, thus focusing on a more societal, communal well-being benefit [120].

4.4.3 Theories and concepts for engaging with nature for health purposes. Our pool of papers features a small number of theories and concepts used to explain and justify why an engagement with nature makes sense for health purposes:

- **Nature connectedness** (n = 8, e.g. [151]), the philosophical concept of feeling connected to nature and relating to it [78].
- **Attention restoration theory** (ART) (n = 6, e.g. [101]), a theory developed by Kaplan and Kaplan [86], suggests that looking at and being in nature replenishes our attention and restores our concentration [123].
- **Stress reduction theory** (SRT) (n = 7, e.g. [50]), developed by Ulrich et al., seeks to explain how encountering nature reduces stress, based on psycho-evolutionary theory [179].
- **Biophilia** (n = 3, e.g. [134]) theorises that being in nature is positive for people because human beings are naturally attracted to it, based on hard wiring in our biology [63].
- **Mindfulness** (n = 3, e.g. [191]) is a wellness practise that encourages being present and grateful in the moment by being aware of your surroundings and yourself [154].
- **Shinrin-yoku** (n = 2, e.g. [133]), Japanese forest-bathing, is the practise of embedding yourself into the forest without a clear path, used for introspection and being present in the moment [69].
- **Kama Muta** (n = 1 [127]) is a concept developed by Schubert and Seibt, which literally translated means *"moved by love"* in Sanskrit [149]. *Kama Muta* describes the relational state of being deeply moved and feeling connected to yourself, others and the wider world [192].

Five papers did not specify any concept or theory, e.g. [100]. The rest of the papers expressed the general idea that being in nature is restorative and that nature is an environment to be active in, e.g. [156].

5 DISCUSSION

5.1 Paper Limitations

Before we discuss the data set as a whole, we outline the limitations of this review. A scoping review aims to provide a current, focused snapshot of a research area or field [6]. As such, this review showcases a limited number of papers that do not represent nature-centric, health-minded technology research as a whole.

It is likely that we missed other relevant papers due to our search strategy, chosen databases or time frame of conducting searches. As this scoping review is part of a greater set of research that explores technology in Finnish forests, we operate from a Western, Eurocentric standpoint. This circumstance is again reflected in our chosen keywords, e.g., *"forest"* and *"meadow"*, and surfaces again in the countries featured in our paper pool *(see 4.1.1)*. We particularly point out that we excluded papers written in languages other than English, and that we had to streamline our set of keywords due the sheer number of potential papers, as explained in *(see 3.1.2)*. Generating a broad, yet specific enough set of keywords for a scoping review necessarily meant finding common denominators that papers may use in describing nature, which may not represent or engage with nature's complexity and interconnectedness (such as showcasing people, animals and plants as distinct others instead of co-existing life forms, not considering mushrooms, and so forth). Although our initial pool was quite large—with more than 3000 papers—without those limitations, we would have reached a wider data set, which could have altered some of our findings and the trends we identified. Similarly, our framing of nature *(see 2.1)* and positionalities *(see 3.2.1)* have affected how we understood and charted the information found in the included papers—particularly due to all authors being based in the Global North. While we can

only speculate about other, additional external influences, we recognise that many papers in this review were written and published during the ongoing Covid-19 pandemic. Research has begun to indicate that access to outdoor spaces and urban greenery became an important *lifeline* for many during the pandemic [139, 158], which in turn may have influenced some of the papers,showcased in this review, as well as their research framing.

5.2 Identified Trends within the Pool of Papers

We now turn to showcase trends that we recognised across the pool of papers. Here, it is important to refer back to our epistemology and positionalities *(see 3.2.1)* to emphasise that the trends we construct are not absolute, but rooted within the *situated* work we undertook to chart and make sense of the paper pool. We are certain that different researchers would identify different trends, and we openly invite other researchers to use our data set to do so.

5.2.1 Nature and Health as Seemingly Universal Phenomenona. As we outlined in our findings—*see 4.3.2 and 4.3.4*—many of these papers did not showcase nature or describe it very very specifically. This circumstance gives the impression that some authors approached nature as a universal and ubiquitous phenomenon. We can speculate here that this trend is partially caused by research papers prioritising text and often being restricted in how many images an author can comfortably include. None of the papers we reviewed were pictorials or other visually focused publication formats. Similarly, this circumstance may also be exacerbated by researchers using pre-made 3D assets and/or ready-made design elements in their studies, which may contribute to a more homogeneous portrayal of nature. However, if we design for nature—and by extension for health—we need to specify *which* parts of nature, *where* and *who* we are designing for: Different climates, ecosystems, flora, fauna—and non-human life that eludes easy categorisation—offer different modes of engagement and contexts that need to be reflected. The same applies to people, local communities, and their access and understanding of nature. In the academic community we encourage a high degree of rigour and descriptive clarity when it comes to describing research setups, study decisions and methodologies; we should apply the same standards to our concepts of nature (and health). Here, we would also like to draw attention again to work that problematises other *"defaults"* within in HCI and beyond, as showcased in *Related Work (see 2.2)*: Just as there is not *one* universal *user*, there is also not *one* universal *nature*, or *health* experience. While a deep dive into the political *"nature"* of nature lies beyond of the scope of this paper, we have to be very clear that the images these concepts prompt are the result of human influences [114]:, including tourism [32], media representations [68] and hegemonic power [87]. These portrayals have societal and political weight, as they define what *"good"* and *"bad"* nature looks like [14, 20, 119]. Do we deem ourselves *dominator, manager* or *kin* of it *(see 2.1)*? What language, categories and taxonomies do we use to describe nature [47]? What narratives do we propagate? What do we perpetuate with terms we choose (e.g. prioritising imperialist terms over terms used by local, Indigenous communities [140])? What are the implications of these portrayals?

5.2.2 Risk of Flattening Health Experiences with Nature: Being in Nature is Good, Because Nature is Good? The papers we reviewed relied on several theories and concepts to explain their engagement with nature for health and well-being *(see 4.4.2 and 4.3.4)*. However, the resulting understanding of nature *(see 4.3.4)* and proposed well-being activities *(see 4.4.1)* were fairly homogeneous. To put it provocatively, the majority of the research we encountered *looking at nature, because being in nature is supposedly good for people*. This is a very passive framing of both concepts, and the person engaging with them. Here, we speculate that this circumstance is partially caused by studies wanting to limit interference and/or carefully control study conditions. Nevertheless, this orientation implies that nature is a means to a utilitarian (human) end: *Stress reduction*. However, being with nature is an embodied experience that is not only multisensory but also a multidimensional experience with mental, physical, emotional and spiritual aspects. Similarly, our experiences with nature are not static, evergreen *(see 4.3.2)*, or necessarily positive *(see 4.3.4)*. Instead they are influenced by local climates, the seasons and the cyclical nature of birth and death or growth and decomposition. Encountering nature may also be strenuous (e.g. climbing a mountain), painful (e.g. falling while climbing a mountain) or scary (e.g. looking down from the mountain just climbed). All of these factors mediate our relationship with nature, and are missed opportunities for technology to create and support encountering and meaning-making with nature.

5.2.3 Nature-Centric Technology as Disconnected from Everyday Life. The last trend we identified in the data set relates to a lack of more mundane, everyday encounters with nature. Across the paper pool, *nature was treated as a positive, beneficial space for well-being, but one that seemed to be disconnected from participants' everyday life*. The majority of papers tended to characterise nature as ever more inaccessible, and proposed technology as a solution that could make nature more accessible *(see 4.2.2)*. We can speculate that this factor is influenced by a substantial number of papers engaging in comparison studies between *"real"* and *"virtual"* nature, e.g. Browning et al. investigating if engaging with recorded video of nature in VR is as effective as being in actual nature [26]. We would like to challenge this narrative. First, there is a missed opportunity to understand and augment common, everyday activities and encounters with nature and to understand what *"everyday"* means in different communities and places. Many of these engagements may already be focused on well-being, and/or may involve technology, such as going to a park to jog while listening to music; such encounters could be extended and built upon. We would also like to trouble the understanding of *inaccessible nature becoming accessible through technology*: Firstly, VR was one of the most featured technologies in this review. While VR has become and is still becoming more mainstream, it is far from being a truly accessible technology; both in terms of material costs and user experience, e.g. motion sickness [104]. Second, very few papers *(see 4.3.4)*, discussed the material, societal and cultural reasons for nature becoming (more) inaccessible. While an engagement with the current socio-political treatment of nature lies beyond the scope of most papers in the paper pool, it is important not to portray nature as existing within a vacuum, outside of human intervention or judgement: Concretely, access to green spaces is a privileged position of affluent people,

in higher social strata [80, 136], and the inaccessibility of nature is emblematic of disabled people being marginalised in society, and by extension through urban planning [13, 91]. This means access and accessibility are socio-cultural issues that cannot only be addressed by technological interventions [77]. As we seek to design for interdependent, sensitive contexts and spaces like nature and health, we need to examine our understanding of *what* gaps technology is supposed to bridge, and *if* technology is even the right way to address them (or if efforts could support policy-making and community endeavours [176]). To put it plainly, we must resist an ecological techno-solutionist approach [39, 88, 172].

6 DESIGN OPPORTUNITIES

In this section, we outline several high-level design opportunities based on our findings, identified trends in the paper pool and subsequent discussion. These opportunities are not to be understood in absolute terms, but as a set of many potential design orientations to kick-start wider discussions about HNI in HCI focused on health and well-being. We explicitly invite other people to augment, extend and/or challenge the following ideas, through their own lived experiences, expertise and situated knowledges.

6.1 Design Recommendations: Practicalities

First, we outline a set of pragmatic, practical design recommendations:

(1) **Specific, detailed descriptions of nature as a design space:** As discussed in *5.2.1*, we encourage researchers to describe the *"nature"* they design for in specific, concrete and detailed ways, both to counteract the narrative of *"nature"* as a homogeneous experience and to enhance HNI within HCI by grounding the work in specific, detailed contexts for additional rigour. These descriptions could contain, but are not limited to, 1) the targeted climate zone, 2) details about the local environment, 3) non-human life (plants, animals etc.), and 4) an overview description and/or a map of the environment, among other specifics. Similar research in HCI has already proposed such unifying endeavours; for instance, Gerling and Birk showcase how artefacts within experimental games research could be described [58]). We also advocate for presenting images and videos of the environments in which the research takes place or on which it is based. Where possible, digital and virtual experiences could be openly shared as supplemental materials, to be played or viewed by others. Similarly, the origin of certain assets should be included or listed. This is especially relevant if the presented aesthetics are a conscious design choice—that is, modelled or chosen for the project at hand—or the result of research constraints and/or convenience, as in the case of projects relying on royalty-free materials or nearby spaces.

(2) **Mapping of health, technology and nature through different research lenses:** We see the integration of wider understandings of nature into HNI as fundamental for its future development. There is a tremendous richness to draw from, as nature, health and technology can be understood from many angles. As outlined earlier *(see 5.2.3)*, we see an opportunity to ground health-minded HNI within HCI in wider discourses, to avoid a portraying well-being in a vacuum. Here, we would like to point to the extant critical HCI scholarship informed by disability studies [166, 171, 189], as well as the wider accessibility community in HCI [106] (and beyond). This scholarship can help us to collectively dig deeper into what design justice [39] and applied accessibility may mean [135], in nature-centric, health-aligned technology. There is a distinct opportunity to extend how we understand HCI by drawing from other fields and domains that engage with health *and* nature in nuanced, sensitive and critical ways—e.g. eco-feminism [27], critical sustainability studies [62, 142], human geography [3, 24] and Indigenous and native peoples' ways of creating knowledge [25, 30, 46]. Instead of seeking one unifying concept for hNCTs, we propose building an inter-relational network of situated knowledges, based on investigations of the existing scholarship through varied lenses.

(3) **Developing a shared, interdisciplinary vocabulary for HNI in HCI:** As we discussed regarding in our search strategy and resulting initial paper pool *(see 3.1.1 and 3.1.2)*, it was difficult to find keywords that were *both* broad and specific enough to encounter health-aligned NCTs in HCI and beyond. Here, there is an opportunity to develop an agnostic, shared set of interdisciplinary terms to aid the visibility of future work (and the potential of the aforementioned inter-relational network), and enable future work in this area to build more firmly on existing scholarship. To this end, we propose *Nature-Centric Technology* (NCT) and *health-aligned NCT* (hNCT) as potential field- and research-orientation-agnostic terms.

6.2 Potential Research Agenda: From being a "nature user" to becoming an interdependent part of it

In this section, we sketch several design opportunities to support potential synergetic avenues of health, nature and technology in HNI and HCI. We propose that the field move away from framing people as mere nature "users" and toward technology that supports people in relating and belonging to nature.

(1) **Engaging with all senses and multi-dimensional sense-making:** Most papers in this review focused on providing an experience of *looking* at nature, with the participant more passive active *(see 5.2.2)*; often with the goal of relaxation. Few papers explored nature through other senses, e.g. listening, taste, smell or touch. Here, we see a plethora of opportunities for design that strengthens our relationship to nature by making use of all available human senses, and drawing from related research that already explores them, through *multisensory HCI* [122]. Examples of relevant work in this area include Bertran et al. exploring the potentials of human-food interactions [2], Maggioni et al. outlining how smell-based experience design could be developed [107] or Hayes and Rajko showcasing the interdisciplinary potential of touch and technology [73]. Similarly, few papers engaged with knowledge creation in embodied, experiential ways that would respond to nature as a unique design space, such as

by employing common, universal approaches like observing participants, measuring attributes, and surveys *(see 4.1.5)*. However, NCTs could also benefit from embodied, integrated knowledge creation in nature. Examples for such approaches include employing multisensory ways of encountering one another and nature, such as through workshops while walking, called *("walkshops")* [187]; untangling the relationship between the self and natural places through design and video, as demonstrated by Bidwell and Browning [18]; or integrating Indigenous knowledge with technology through multisensory experiences, based on walking, listening and talking, as described by Bidwell and Winschiers-Theophilus [19]; or extrapolating knowledge from common, nature-centric activities like bird-watching, as demonstrated by Biggs et al [21].

(2) **Designing hNCTs in specific, contextualised and localised ways:** As we have begun to outline in *5.2.1* and *6.1*, only a few papers we encountered in our paper pool described *the* nature they engaged with in great detail. We would like to expand our previous guideline in 6.1 to encourage researchers and designers to resist treating nature as universal greenery, and to think, design and develop for *specific*, localised contexts—including meaningful engagement with the local environment. Instead of seeing this circumstance as a hurdle, we see a tremendous amount of potential richness to design for by valuing and contextualising each engagement with nature and health *uniquely*: What does it mean to walk through *this* forest; on *this* day, in *this* state of mind? What approach to nature is being taken *(see 2.1)*? Here, we would like to point to existing work within HCI and beyond that deals with shifting normative, universal assumptions towards specific, situated design contexts *(see 2.2)*, e.g. Spiel et al. deconstruct how common self-tracking devices enforce a *"normative ontology"* that values quantified metrics over lived experience, such as by coercing people into walking more steps for the sake of it [167]; Keyes et al. showcase how neo-liberal tendencies are prominent in HCI through anarchist thought [88], and Pendse et al. outline how current mental health research in HCI is prone to reproduce colonial categories, and approaches [126].

(3) **Making use of and extending technological affordances for HNI:** Most papers in our pool tried to portray nature as it is in reality by engaging in simulation and mimicry *(see 4.3.2)*. We see this only as *one* of many potential ways of portraying nature, as creative technologies do not need to be faithful to nature on earth. We see this realism as a missed opportunity, since immersive technologies—like VR and mixed reality [162] in general—offer the potential for meaningful interactivity. In this context, technology could make use of critical, speculative design [48, 157] to imagine what nature could be like, drawing from science fiction and beyond. Similarly, there is a distinct potential to extend human capabilities through technology, by implementing pervasive or ubiquitous computing in HNI, such as through sensors, wearables or the development of dedicated HNI-contextualised hardware and gadgets. Examples of work that may inform this area further include Marquez et al., who draw from the expertise of LARP players to design social wearables embedded in environmental, embodied contexts [110]. The design, use and understanding of wearables can also include ecological considerations, as demonstrated by Duval and Hashizume [49]. Similarly, these gadgets may be built with nature-based resources in mind, bringing in different temporal, haptic and aesthetic qualities; see, for example, Genç et al. who explore mushroom mycelium as a component for electronic prototyping [57].

(4) **Going beyond disconnected, *"feel good"* experiences:** Most papers focused on stress reduction and how to provide a calming, positive experience *(see 4.4)*. There is an opportunity to extend HNI beyond this status quo, to engage with the full spectrum of human emotions and to employ pluralistic understandings of well-being. Technology could provide a safe, affective environment to make sense of emotions and engage people beyond pacifying or pleasant engagements *(see 5.2.3)*. Here, we see the potential to also design intimate [138, 150], ambiguous [56], meaningfully uncomfortable [16] and/or challenging design experiences [17, 174]. These directions may be of particular interest considering the state of ecosystems on earth [40, 42, 90], the rise of climate anxiety [36] and the need for a pluralistic understanding of nature *(see 2.1)*.

(5) **Resisting human-centredness as the assumed default:** All experiences and interventions in the papers we charted, focused on the human being as the *most* important actor, as the centre of the scene, with other people and non-human animals absent *(see 4.3.2)*. This orientation is emblematic of living through the human-centred *"Anthropocene"* [97] era. We encourage researchers and designers to resist assuming the *human as the default*, and to explore design modalities and discourses that contest, interrogate and reframe people's relationship with nature. Specifically, we see an opportunity to engage with non-human actors, their lives, ways of being and narratives—similar to Reetz et al. exploring what it would be like to be *"wind"* [134]—and to explore HNI from a *more-than-human* perspective [3]. We deem it fundamentally important to move towards a socio-ecological understanding of HNI, as Cibin et al. propose [34], and to recognise that nature is not a single actor, but multifaceted. We make this suggestion to inspire HNI engagements creatively—*What would it be like to exist as a mushroom, to traverse a garden as an ant or to be a mountain that is massive and centuries old? What would it feel like to embody the hole in the ozone layer?*—but also to understand HNI as a design space that requires distinct moral, ethical and justice-oriented considerations and choices. Does technology in HNI reproduce the assumption that non-human life is less valuable than human life, and a mere resource to be exploited? Or can we use HNI to ask important questions about co-existence, responsibility and mutuality in the environments we inhabit and influence?

(6) **Recognising nature and health as a relational, interdependent design space:** As we have begun to explore in both the *Related Literature (see 2)* and *Findings (see 4.2, 4.3 and 4.4)* sections, designing for health and nature demands a clear awareness of values and norms to avoid presenting

health, nature and technology in universal ways *(see 5.2.1)*. Most experiences and interventions encountered in this review focused on the individual, but seemed disconnected from their everyday life *(see 5.2.3)*. We see potential to develop nature-centric, health-aligned technologies that are relational and that integrate contexts beyond the personal. *First,* we state provocatively that such a direction necessarily requires recognising nature not as *"just"* as an aesthetics-driven design space, but as an interdependent and complex one. Here, we advocate for an engagement with nature as a place of complicated and often violent politics [141], with a far reach into the lives of its dwellers, human and non-human alike. We urge that designers avoid reinforcing discriminating, marginalising or oppressive attributes [39]. *Second,* we propose an understanding that hNCTs could thrive as relational technologies that let people engage with other people, non-human animals, environments and the wider world t in interconnected *and* careful ways [43]. Within this pluralistic frame, we see great potential to design for non-normative spatial, temporal and aesthetic encounters with nature. Examples of applying such a design orientation could include the design of technologies that support people in acquiring a nature-related skill, and then fade into the background over time; technologies that integrate themselves in local communities, drawing from localised environmental or ecological knowledge; or technologies that encourage habit- and ritual-building to build and maintain a relationship to nature as a place (e.g. as *trajectories* [15]). Here, we would like again to emphasise existing nature-centric activities, and to recognise their richness—for instance, we can understand dog walking as a co-located encounter [178]— or augmenting nature-centric encounters through technology, such as by teaching people about (urban) foraging [130]. We also see potential in meaning-making through technologies that are not directly focused on fostering kinship with nature as their main goal. Here, we would also like to call back to to the potential of playful and gameful technologies and technology-facilitated experiences that include nature by proxy, but engage people with it nevertheless, such as Pokémon Go [94, 143].

7 CONCLUSION

This scoping review has focused on a selection of papers that engage with nature, health and technology from the last five years. By charting these 29 papers, we showcased a snapshot of current technologies that centre on both nature and health, resulting in an overview of a heterogeneous, pluralistic set of experiences and approaches. By considering the paper pool as a whole, we identified three trends: Nature is often described and approached in ways that are 1) assumed to be universal, 2) flattened and 3) seemingly disconnected from everyday life. We developed a set of nature-, technology- and health-centred design opportunities to kickstart counterbalancing these aforementioned tendencies, and to extend human-nature interaction in HCI beyond them.

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