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Review article

Nature-based biopsychosocial resilience: An integrative theoretical framework for research on nature and health

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ABSTRACT

Nature-based solutions including urban forests and wetlands can help communities cope better with climate change and other environmental stressors by enhancing social-ecological resilience. Natural ecosystems, settings, elements and affordances can also help individuals become more personally resilient to a variety of stressors, although the mechanisms underpinning individual-level nature-based resilience, and their relations to social-ecological resilience, are not well articulated. We propose 'nature-based biopsychosocial resilience theory' (NBRT) to address these gaps. Our framework begins by suggesting that individual-level resilience can refer to both: a) a person's set of adaptive *resources*; and b) the *processes* by which these resources are deployed. Drawing on existing nature-health perspectives, we argue that nature contact can support individuals build and maintain biological, psychological, and social (i.e. biopsychosocial) resilience-related resources. Together with nature-based social-ecological resilience, these biopsychosocial resilience resources can: i) reduce the risk of various stressors (*preventive resilience*); ii) enhance adaptive reactions to stressful circumstances (*response resilience),* and/or iii) facilitate more rapid and/or complete recovery from stress (*recovery resilience*). Reference to these three resilience processes supports integration across more familiar pathways involving harm reduction, capacity

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building, and restoration. Evidence in support of the theory, potential interventions to promote nature-based biopsychosocial resilience, and issues that require further consideration are discussed.

1. Introduction

Academic and policy interest in the potential health and well-being benefits of natural environments has grown rapidly in recent years (WHO, 2021; Zhang et al., 2020). Regarding more "macro-level" benefits, there is recognition that natural settings, such as woodlands and wetlands, can help mitigate the impact of climate change-related stressors by, for instance, reducing the severity of urban heat island effects and flood risk (Cohen-Shacham et al., 2019; van den Bosch and Sang, 2017). These 'nature-based solutions' (Castellar et al., 2021)[1] are especially effective when they are developed in collaboration with affected communities (Seddon, 2022), enhancing community-level 'social-ecological resilience' (Adger et al., 2005; Folke, 2006; Lafortezza et al., 2018). At the "micro-level", nature contact can also help individuals within communities cope with acute and chronic stress by improving emotional states and cognitive performance in the short-term (Collado et al., 2017; McMahan and Estes, 2015), reducing the risk of chronic conditions such as cardiovascular disease, stroke, diabetes, and depression in the longer term (van den Berg et al., 2015; van den Bosch and Meyer-Lindenberg, 2019), and ultimately reducing mortality risk (Rojas-Rueda et al., 2019). Although the notion of resilience has also been applied to these more individual-level nature-based processes (e.g. Marselle et al., 2019; Wells, 2021), the underlying mechanisms are yet to be fully articulated and integrated. The aim of the current paper is to address this gap.

Drawing on existing perspectives on nature-health relations (e.g. Hartig et al., 2014; Frumkin et al., 2017; Markevych et al., 2017; Marselle et al., 2021), and evidence from qualitative experiential (e.g. Lovell et al., 2015), experimental (e.g. Corazon et al., 2019), and epidemiological (e.g. Yuan et al., 2021) research, we outline how nature contact can promote individual-level health and well-being by helping individuals build and maintain different types of resilience-related resources that can be deployed at different stages in the stress response-recovery process. We adopt a broad definition of nature contact (Holland et al., 2021) to include incidental exposure such as residential proximity, relatively passive exposures such as nature documentaries, active engagement such as recreational visits and gardening, and interventions that use nature to promote health and well-being such as 'green care' and nature-based social prescribing initiatives (van den Berg, 2017).[2] Widely used terms, such as nature exposure, nature engagement, nature experience and nature contact, all have their merits and drawbacks. We prefer the term nature contact over nature exposure for current purposes because exposure implies a relatively passive relationship on the part of an individual, whereas we also want to recognise the active role individuals have in seeking out nature. The terms nature engagement and nature experience highlight important subjective characteristics of person-nature transactions (two people with identical exposure or contact can still have very different experiences), but some nature-based biopsychosocial resilience processes do not require such subjective awareness (e.g. gut microbial diversity). We thus prefer the term nature contact because it can span both conscious and non-conscious exposures.

Our ideas build on earlier suggestions that nature might support processes that 'inoculate' (Hartig et al., 1991), 'immunise' (Parsons et al., 1998) or 'buffer' (Cartwright, et al., 2018; Høj et al., 2021; Wells and Evans, 2003; van den Berg et al., 2010) people against stress and help people cope with both acute and chronically challenging circumstances (Korpilo et al., 2021; Li et al., 2021; Roe et al., 2017; Takayama et al., 2019; Wells, 2021). We innovate here by bringing these ideas together into a unified framework that not only explains what happens at an individual level but also identifies where synergies might exist with the social-ecological resilience focus of nature-based solutions. Our framework makes three core contributions.

First, we draw on a stocks-and-flows metaphor (Graham and Oswald, 2010) to suggest that resilience is a collection, or stock, of adaptive resources. These resources can be deployed to help mitigate stress (i.e. outflows), but their use may deplete existing stocks. In turn, these stocks of adaptive resources can be restored and maintained through a variety of inflows including, but not limited to, nature contact.

Second, we identify three types of resilience resource or stock that could be built and maintained by nature contact: (a) biological resilience (e.g. better immune functioning), (b) psychological resilience (e.g. more effective emotion regulation), and (c) social resilience (e.g. enhanced social empathy). Collectively these three types of adaptive resource are referred to as biopsychosocial resilience (Davydov et al., 2010). To date, research on biopsychosocial resilience has tended to neglect environmental factors in general and nature contact in particular, instead focusing more on other determinants which build and maintain these resources such as genetic inheritance, socio-demographic factors, personality, health-related behaviours, and resilience training (Bennett et al., 2018, Kalisch et al. 2017). Nature-based biopsychosocial resilience thus provides an important addition to the resilience field by highlighting the role of the environmental contexts within which many of these other factors operate.

Third, we identify three key phases in the stress process where communities and individuals commonly deploy nature-based resilience resources to cope with potential stressors. Building on the World Health Organisation's (WHO, 2020a) climate-resilience report for health services, we propose that nature-based resilience can be used in: (a) a prevention/preparedness phase, (b) a response phase, and (c) a recovery phase. At a population level, community-integrated ecological approaches guiding nature-based solutions build stocks of social-ecological resilience, which serve to prevent, or at least mitigate, environmental shocks (i.e. preventive resilience). However, at an individual level, many sources of stress cannot be prevented or mitigated by specific nature-based solutions. Stressors are not just environmental but also financial, social, psychological, and so on. We argue that nature contact at the individual level can still help reduce the risk of even these stressors (i.e. preventive resilience) as well support more adaptive initial reactions to a stressor (i.e. response resilience) and/or enhance the extent and speed of recovery (i.e. recovery resilience). We develop a set

[1] Although the term 'nature-based solutions' (NBSs) has been used in various ways, we adopt the International Union of Conservation of Nature definition: "actions to protect, sustainably manage, and restore natural or modified ecosystems, that address societal challenges effectively and adaptively, simultaneously providing human well-being and biodiversity benefits" (https://www.iucn.org/commissions/commission-ecosystem-management/our-work/nature-based-solutions). NBSs may involve protecting and restoring a range of natural habitats including forests, wetlands, coral reefs, and mangroves. Here however, our interest is primarily in NBSs that focus on incorporating natural elements (e.g. street trees, green roofs, reed beds) within urban settings.

[2] Widely used terms, such as nature exposure, nature engagement, nature experience and nature contact, all have their merits and drawbacks. We prefer the term nature contact over nature exposure for current purposes because exposure implies a relatively passive relationship on the part of an individual, whereas we also want to recognise the active role individuals have in seeking out nature. The terms nature engagement and nature experience highlight important subjective characteristics of person-nature transactions (two people with identical exposure or contact can still have very different experiences), but some nature-based biopsychosocial resilience processes do not require such subjective awareness (e.g. gut microbial diversity). We thus prefer the term nature contact because it can span both conscious and non-conscious exposures.

of propositions here that together form a new, integrated framework: nature-based biopsychosocial resilience theory (NBRT).

The paper continues as follows. Section 2 provides short outlines of the key concepts of stress and resilience and Section 3 clarifies what we mean by nature and nature contact. Section 4 presents an overview of our theoretical approach and discusses how it relates to three general perspectives on human adaptation represented in the nature-health field. Section 5 presents evidence in support of the theory by examining selected experiential, experimental, and epidemiological nature-health research through the lens of biopsychosocial resilience. Section 6 considers how different interventions might help to build and maintain nature-based biopsychosocial resilience and Section 7 discusses limitations and gaps in our approach as well as potential next steps for future research.

2. Stress and resilience: An outline of key concepts

2.1. Homeostasis, stress and allostatic load

To understand how nature contact might contribute to biopsychosocial resilience, we begin by discussing stress, homeostasis, and allostatic load. A simplified schematic of these processes can be seen in the top section of Fig. 1, with stress processes reflected in red, and recovery and homeostatic processes in dark blue with the flow proceeding in an anti-clockwise direction. In general, homeostasis refers to a state of balance or equilibrium in an organism when available resources suffice for meeting situational demands, and stress involves a disruption of homeostasis (McEwen and Stellar, 1993). Sources of stress include a range of environmental, socio-economic, and personal stressors. Environmental stressors can be natural (e.g. earthquakes, microbial pathogens, allergens, Nuzzo et al., 2019), anthropogenic (e.g. air, noise and chemical pollution, Landrigan et al., 2018), or a combination of both (e.g. droughts, floods, wild-fires caused by human-induced climate and land-use change). While recognising that nature, and human-caused environmental degradation, can be an important source of stress, these issues are well documented elsewhere (e.g. Whitmee et al., 2015) and are not the focus of the current paper. Rather, our focus is on the positive role nature can play in helping individuals build and maintain resilience to various stressors. These include the socio-economic challenges of inequalities linked to income/status (Marmot et al., 1991), gender (Marmot, 2020), and race (Jackson et al., 2010) and personal stressors such as painful memories (Ottaviani et al., 2016), relationship worries (Bradbury et al., 2000), and goal failure (Covington, 2000). However, personal stress is not always involuntary and merely negative. People may choose to "leave their comfort zone" (e.g. run a marathon) in order to achieve personally meaningful goals (Inzlicht et al., 2018; Oishi and Westgate, 2022).

The disruption of homeostasis caused by stressors can be acute (relatively short-term) or chronic (over a longer period). Acute stress can occur when a person is faced with an event or circumstances where the currently available resources are insufficient for meeting the situational demands, resulting in biological, psychological and social stress responses. In terms of biological reactions, stress is associated with a heightened state of arousal ('fight or flight' mode) through activation of the sympathetic nervous system (Chrousos, 2009). Sympathetic activation triggers an endocrine response such as increases in catecholamine

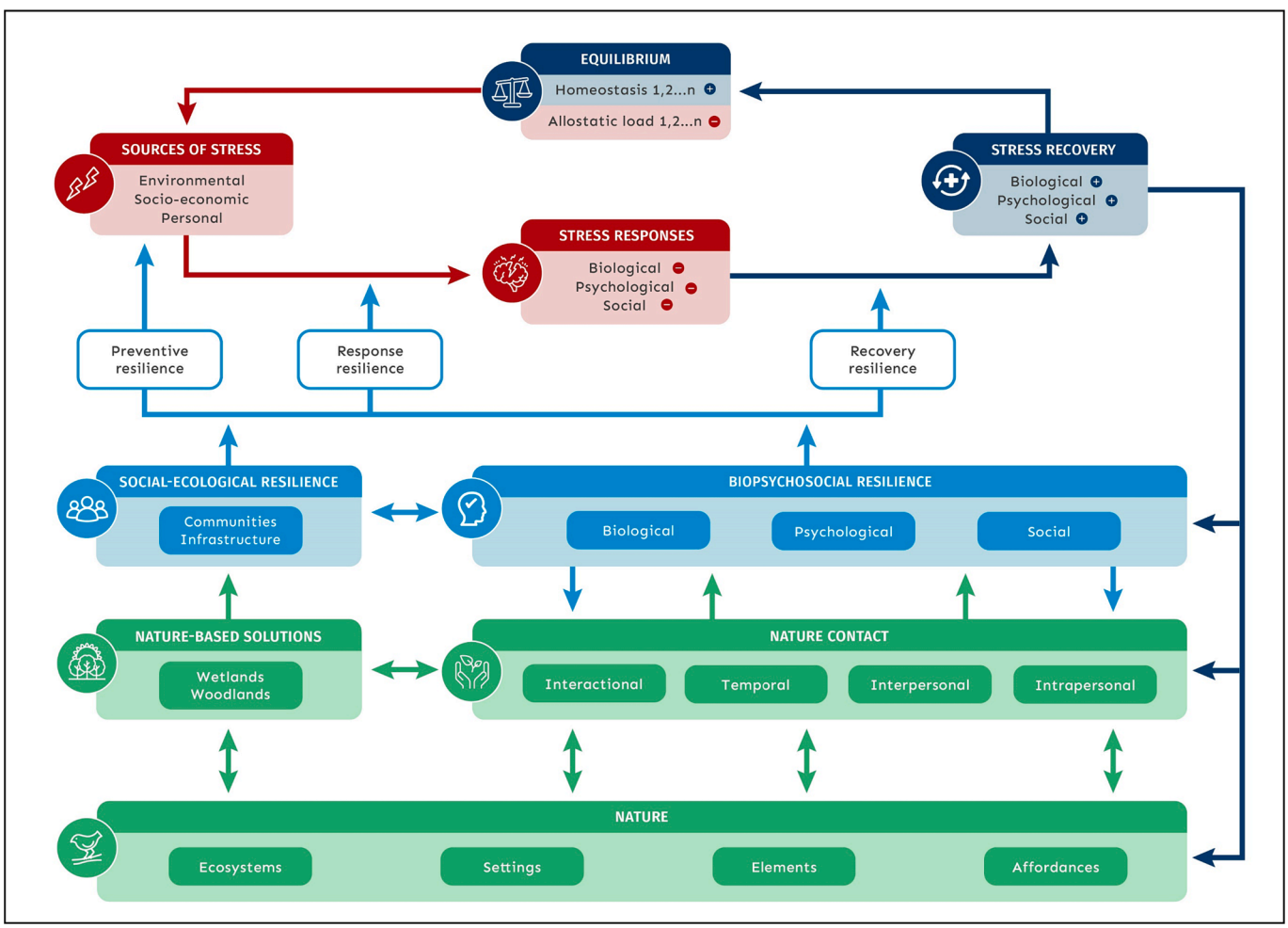

Fig. 1. The full schematic view of nature-based biopsychosocial resilience theory (NBRT).

levels (adrenaline and noradrenaline), followed by neuroendocrine-triggered glucocorticoid release from the adrenal gland (Russell and Lightman, 2019). Acute stress can also be associated with psychological reactions including emotions such as anxiety and confusion, which in turn can impair cognitive functions such as attention and decision making (McEwen and Sapolsky, 1995). Acutely stressed individuals can also become irritable and angry and show less empathy, impacting social relationships (Nitschke and Bartz, 2022; Sandi and Haller, 2015).

When the danger or challenge is assessed as having passed, the parasympathetic nervous system is activated, telling the body to "stand down" its heightened activation levels (Cohen et al., 2007). In terms of stress recovery, the speed and completeness of recovery of biological, psychological, and social functions will in part depend on the strength and character of the stress-related biopsychosocial reactions (e.g., Linden et al., 1997) and the circumstances and settings in which recovery occurs (Geurts and Sonnentag, 2006). For instance, signalling distress socially may lead to tend-and-befriend responding by others (Taylor et al, 2000). Over time a system may return to its pre-event state (Homeostasis 1 – in Fig. 1), but it may also settle at some new point of equilibrium.

The new equilibrium (Homeostasis 2…n – in Fig. 1) may be better in some respects than the previous one, for instance reflecting the acquisition of new coping strategies (Richardson, 2002). However, it may also be worse in some respects. For instance, if the individual is faced with repeated stressors and insufficient recovery opportunities this cumulative wear and tear on the body's systems can lead to a poorer equilibrium, with the combined burden known as allostatic load (McEwen, 2000; Allostatic load 1…n – in Fig. 1). In such chronic stress situations, stress-signalling pathways can become overstrained, fail in their adaptive function and become damaging (Dhabhar, 2014), leading to cardiovascular, metabolic, and neurodegenerative disorders (Lovallo, 2015). Bio-physiological changes seen in chronic stress have also been linked to neurobehavioral outcomes with implications for emotional, cognitive, and social functioning (Herman and Tasker, 2016; McEwen, 2007; Sharp, 2017), including attentional control and emotion regulation as well as social emotions and behaviours (Sandi and Haller, 2015).

2.2. Resilience

Although various definitions of individual-level resilience exist, a common theme is the ability "*to withstand or recover quickly from difficult conditions*" (Fletcher and Sarkar, 2013, p.14). Others emphasise "*faring better than expected given adversity*" (Troy et al., 2023, p547) or even the opportunity for growth or shifting to a more positive equilibrium: "*resilience can be viewed as a defence mechanism which enables people to thrive in the face of adversity*" (Davydov et al., 2010, p.479; Joseph and Linley, 2006). More broadly, resilience is portrayed as both: (a) a set of adaptive resources that could be drawn upon in times of stress, describing a higher or lower level of resilience in general (Fletcher and Sarkar, 2013); and (b) as a process related to the deployment of these resources in times of stress, with people showing more or less resilience in their ability to "withstand or recover" from a specific stressor (Fletcher and Sarkar, 2013; Troy et al., 2023). In this sense, there are parallels with seeing resilience as both a 'stock' of adaptive resources and a 'flow' of adaptive processes (Graham and Oswald, 2010). In this paper we explore both the resource/stock and process/flow aspects of biopsychosocial resilience.

2.2.1. Resilience as stocks of adaptive resources

While Graham and Oswald (2010) focus on 'hedonic capital' as a resilience-related stock, reflecting their interest in emotional states, we extend the metaphor here to refer to a broader range of resources that can help mitigate the impact of a stressor on biological, psychological, and social processes (i.e. biopsychosocial resilience, Bennett et al., 2018; Davydov et al., 2010). Stocks of biological resilience resources may include healthy immune, endocrine, neurological, and autonomic nervous systems and greater cardiovascular fitness (Dedoncker et al., 2021). Stocks of psychological resilience resources may include personality factors such as openness to change, dispositional mindfulness, and optimism (Fletcher and Sarkar, 2013). Stocks of social resilience might include personality factors such as extraversion and agreeableness, dispositional empathy, and generalised trust (Davydov et al., 2010). The combined stocks of biopsychosocial resilience resources are represented in Fig. 1 by the shaded light-blue box middle-centre. Some of these resources will have a genetic component (Feder et al., 2019), while others will be affected by circumstances (e.g. living in poverty), experiences (e.g. learning from past challenges), lifestyle (e.g. exercise, good diet, healthy sleep), and training (e.g. Cognitive Behaviour Therapies, Berking and Lukas, 2015). A central argument of the current paper, expanded in later sections, is that natural environments may also play a role in helping to build, restore, and maintain stocks of these biopsychosocial resilience resources.

Although we are primarily interested in individual-level biopsychosocial resilience processes, Fig. 1 also includes stocks of social-ecological resilience resources (Folke, 2006), reflecting more macro-level issues (light blue box middle-left). At this level, stocks of social resilience resources may include the formal and informal social networks underpinning 'social capital' (Aldrich and Meyer, 2015) as well as formal structures of 'planning and preparedness' (WHO, 2020a). Successful community-level social resilience tends to involve multi-level governance structures and the meaningful involvement of potentially affected communities (Adger et al., 2005). Stocks of ecological resilience can be considered a subset of 'natural capital', or the total stocks of all abiotic (e.g. water, air, minerals) and biotic (all living organisms) natural resources (Costanza et al., 1997). A bi-directional arrow in Fig.1 between the social-ecological and biopsychosocial resilience boxes reflects their interconnectedness especially where social processes are involved. For instance, strong social networks can help both whole communities and specific individuals cope better with stressful circumstances.

2.2.2. Resilience as flows of adaptive processes

Although the notion of individual-level resilience resources is widespread in the literature (e.g. a resilient personality), the stocks of adaptive resources discussed above are perhaps more accurately described as having biopsychosocial resilience potential. Only when they are deployed to prevent, mitigate, or recover from stressors is this latent potentiality realised. As such, resilience should also be considered in terms of the processes by which these adaptive resources are utilised. This is somewhat analogous to discussions in the natural sciences concerning how and when the stock of natural capital supports a range of 'ecosystem services' (Díaz et al., 2018). According to the WHO's (2020) climate resilience report for health-care facilities, resilience processes can occur at three key phases in the stress response-recovery cycle: prevention/preparedness, response, and recovery, each of which is depicted in Fig. 1 by light-blue clear boxes (between the resilience resources and stress-response-recovery cycle).

The prevention/preparedness phase reflects the processes by which adaptive resources are drawn upon (i.e. flow) to reduce the risk and/or potency of a potential stressor. We refer to these processes as 'preventive resilience'. When preventive resilience has not been fully effective and the person is confronted with a stressor, the response phase refers to the initial reaction up to the point of maximum impact. 'Response resilience' reflects the utilisation of adaptive resources to limit this initial impact. Finally, after the point of maximum impact, an individual will tend to move to a new equilibrium, and in so doing will be drawing on a range of biopsychosocial resilience resources during the 'recovery resilience' phase.

To date, the distinction between resilience processes at these different phases has not always been clear. For instance, one of the most widely used measurement tools for psychological resilience, the 10-item Connor-Davidson Resilience scale (Campbell-Sills and Stein, 2007),

includes items such as 'I can stay focused under pressure' (response resilience) and 'I tend to bounce back after illness and hardship' (recovery resilience), but does not distinguish between them in terms of sub-scales. By distinguishing biological, psychological, and social resilience resources and the processes by which these resources might be drawn upon at three different phases in the stress-recovery cycle, our approach may thus enrich theory, research, and practice in the resilience field generally.

2.2.3. The interplay between resilience resources and processes

The interplay between biopsychosocial resilience resources and preventive, response and recovery resilience processes can be demonstrated using the example of ischaemic stroke (henceforth: stroke). Strokes occur when an artery gets blocked and blood supply to the brain is restricted. It is an interesting case in the context of resilience because: a) the disease has a high prevalence, being ranked as the– second leading cause of death (Feigin et al., 2021) and third leading cause of disability (Vos et al., 2020) globally; b) stress is both a risk factor for, and a consequence of, stroke (Huang et al. 2022); and c) the risk of developing a stroke (Valtorta et al., 2016) as well as the short-term (response phase, Wang et al., 2022) and long-term (recovery phase, Cooper et al., 2015) prognosis can be influenced by individual-level biopsychosocial resources. A schematic overview of the interplay between some of the hypothesised resilience resources and processes in the context of stroke is presented in Table 1. This is not meant to be systematic or definitive since the exact processes proposed in some of the cited papers are speculative and require further research. Instead, our aim is to help structure a discussion of how resilience resources and processes might combine, in this case to reduce the large global burden of stroke.

Table 1
Ischaemic stroke: Potential biopsychosocial resilience resources and preventive, response, and recovery resilience processes that reduce risk, aid prognosis and support recovery.

Resilience resources *Adaptive resources to support stroke risk/outcomes*	**Resilience processes** *Deployment of resilience resources at different phases of the stroke-related stress-recovery process*		
	Preventive resilience	**Response resilience**	**Recovery resilience**
Biological Resilience	***Lower stroke risk*** *Resource*: Cardiovascular fitness *Process*: Improved blood rheology reducing thrombosis risk (Prior and Suskin, 2018)	***Better stroke prognosis*** *Resource*: Healthy immune system *Process*: Lower inflammation following early signs reduces severity (Wang et al., 2022)	***Improved stroke recovery*** *Resource*: Healthy blood pressure *Process*: Aids neuroplasticity (neural regenesis) (Dobkin, 2008)
Psychological Resilience	***Lower stroke risk*** *Resource*: Optimistic outlook *Process*: Health protective behaviours and positive autonomic nervous system activity (Nabi et al., 2010)	***Better stroke prognosis*** *Resources*: Early symptom knowledge and attention capacities *Process*: Acting quickly reduces stroke severity (Sprigg et al., 2009)	***Improved stroke recovery*** *Resource*: Emotion regulation capacities *Process*: Supports positive social interactions & social resilience (Cooper et al., 2015)
Social Resilience	***Lower stroke risk*** *Resource*: Local social network *Process*: Engaging in socially supported physical activities (e.g. local park runs) supports health promotion (Valtorta et al., 2016)	***Better stroke prognosis*** *Resource*: Friend/ family network *Process*: "Stress buffering" from social relations improves prognosis by reducing early aggravation of effects (Ikeda et al., 2008)	***Improved stroke recovery*** *Resource*: Close personal relationships *Process*: Emotional support aids adherence to recovery activities and directly improves quality of life (Glass and Maddox, 1992)

Note. The resources and processes included in this table vary in terms of the quality of evidence currently supporting them, with authors often calling for more research. The summary is not meant to be definitive, exhaustive or exclusive, but rather aims to provide potential examples of how the different types of resilience resources and processes can be conceptualized.

With respect to preventive resilience processes, the risk of having a stroke can be reduced by, among other things: a) greater cardiovascular fitness (biological resilience resource) which may reduce thrombosis risk through improved blood rheology (Prior and Suskin, 2018); b) a more optimistic outlook (psychological resilience resource), which encourages more health protective behaviours (Nabi et al., 2010); and c) stronger social networks (social resilience resource) which can promote exercise through socially engaging activities (Valtorta et al., 2016).

With respect to response resilience processes, the prognosis of a stroke can be mitigated by factors associated with timely reactions to the initial onset. These include: a) a healthier immune system (biological resilience resource) which may help lower initial inflammation created by stroke onset (Wang et al., 2022); b) greater knowledge of early stroke symptoms and attentional capacity to notice them (psychological resilience resources) which increase the chances of taking immediate action such as calling an ambulance (Sprigg et al., 2009); and c) a strong friend and family network (social resilience resource) which can help "buffer" some of the stress caused by stroke onset and thus mitigate some of the neural impact (Ikeda et al., 2008).

Finally, with respect to recovery resilience processes, factors that may help recovery to be quicker and more complete include: a) healthy blood pressure (biological resilience resource) which may aid neural regenesis (Dobkin, 2018); b) better emotional regulation capacities (psychological resilience resource) that help maintain supportive relationships (a recovery resilience process with links to the social resilience resource; Cooper et al., 2015); and c) close interpersonal relationships (social resilience resource) which help adherence to recovery activities through emotional support (Glass and Maddox, 1992).

From these examples it should also be clear that the different resources and processes are deeply intertwined. For example, better social networks (social resilience resource) may reduce stroke risk by encouraging physical activity (preventive resilience process), which in turn aids cardiovascular fitness (biological resilience resource), and also by increasing self-esteem and an optimistic outlook (psychological resilience resource) which itself encourages more social activities and support (social resilience process).

Of particular interest here, stroke risk is lower among people living in greener neighbourhoods (Liu et al., 2022; Villeneuve et al., 2012) and many of the biopsychosocial resilience resources discussed in this context are related to nature contact (Section 5). In other words, to the extent that nature contact builds the biological, psychological and social resilience resources described above, it may also aid stroke prevention, stroke response and stroke recovery processes. Before we examine the evidence supporting the contention that nature contact plays a role in these kind of resilience resources and processes across a broad range of health and well-being outcomes, we first define what we mean by nature and nature contact and present an overall summary of our proposed framework.

3. Nature and nature contact

3.1. Nature

Many definitions of nature exist, with the one offered by the Cambridge Dictionary fairly representative: "*all the animals, plants, rocks, etc. in the world and all the features, forces, and processes that happen or exist independently of people, such as the weather, the sea, mountains, the production of young animals or plants, and growth*" (https://dictionary.

cambridge.org/dictionary/english/nature). To help structure this for current purposes we propose a three-level typology relating to the scope or scale of the natural aspects we address, ranging from the broadest and most encompassing (i.e. natural ecosystems), through lower-level more geographically-bounded contexts typical of much epidemiological nature-health research (i.e. settings), to more specific aspects of nature that often feature in experimental studies (i.e. elements).

Within this approach, our broadest category, 'natural ecosystems', are composed of abiotic and biotic elements and processes, and are often characterised in terms of different biomes, i.e. a large naturally occurring community of flora and fauna occupying a major habitat such as forests, grasslands, deserts, and inland and coastal waters, as well as combinations of these (Keith et al., 2020; Li et al., 2023). Due to anthropogenic influences, few if any ecosystems remain truly "natural", i.e. untouched by human interventions or influences, and are thus already socio-ecological systems. Consequently, they vary in terms of their functional integrity (Borja, et al. 2009), ecological richness/biodiversity (Marselle et al., 2021), presence/absence of pollutants (Francis et al., 2012), and their more instrumental value to humans (IPBES, 2022; Millennium Ecosystem Assessment, 2005) in terms of factors such as aesthetics (Grahn and Stigsdotter, 2010), accessibility (Seeland and Nicolè, 2006), and support for health-related processes such as psychological restoration (Bratman et al., 2012).

The interconnections between healthy ecosystems and healthy people are recognised through, for example, the One Health approach (WHO, 2022), but few, if any, empirical studies in the nature-health field consider the impact of whole ecosystems on health. Instead, they are more likely to focus on our second level of typology i.e. specific geographical 'settings' such as parks, beaches, gardens, neighbourhood greenspaces, rivers, or urban woodlands (Garrett et al., 2023a; Holland et al., 2021). These settings exist within broader ecosystems but are generally contained enough to observe an individual's personal contact with them. For instance, while it may be possible to identify how often an individual visited their nearest woodland or wetland in the last four weeks, it is much harder to quantify their contact with the broader ecosystem the woodland and wetland are part of. As with broader ecosystems, the quality as well as accessibility of settings (Nguyen et al., 2021) may be important for health by building and maintaining biopsychosocial resilience.

The third level of our typology focuses on specific 'elements' of nature. In many cases these elements reflect the individual building blocks that make up the settings and ultimately the ecosystems. The elements of a setting will include the dominant morphology of a site, as well as specific geological features (Li et al., 2023), plants (Taylor et al., 2015; Gobster et al. 2023), animals (Chandler, 2022), and some of their emergent properties in isolation or combination such as birdsong and broader natural soundscapes (Ratcliffe, 2021). Whereas geological features and plants are relatively stable elements of a given setting, wildlife elements may move between settings and ecosystems. Other features of nature that are even less geographically bounded, and more transient and ephemeral (e.g. sunsets and rainbows; Smalley and White, 2023) can also be considered as elements of a particular setting if they are experienced there at any given point in time. Elements may also be removed from, and experienced outside of, natural settings and ecosystems, for instance when they are placed in human-made buildings (e.g. houseplants and pets, Han et al., 2022), or observed in urban settings (e.g. a thunderstorm in the city; Smalley and White, 2023).

In addition to this relatively "bottom-up" typology of nature, we also consider nature in terms of how people interact with it. Building on the work of Heft (2010) and others, we recognise that different ecosystems, settings and natural elements have different 'affordances', in that they encourage or discourage particular behaviours (Heft, 2010; Ward Thompson, 2013). A lake can be paddled in, swum in, rowed over etc., and a fallen tree trunk can be sat on, climbed on, jumped over etc. Including the affordances nature offers in a typology of natural components is important for health and well-being, because different settings and elements may promote biopsychosocial resilience via, for instance, enhancing physical activity in adults (Araújo et al., 2019), play in children (Laaksoharju et al., 2012), and a deeper connection with the natural world (Rosa and Collado, 2019).

These four aspects of our approach to considering nature are represented in Fig. 1 in the centre-bottom green box. Fig. 1 also presents two inter-connected pathways through which nature can influence resilience-related resources and processes. First, natural ecosystems, settings and elements underpin the nature-based solutions (green box middle -left) that build and maintain community-level social-ecological resilience resources aimed at preventing, or mitigating, environmental stressors. Here, though, our primary focus is on how natural ecosystems, settings and elements can influence nature contact at the individual level through, for instance, the affordances they offer (green box middle-centre). Specifically, the arrows from the Nature box (and the Nature-based Solutions box) to the Nature Contact box, and in turn Nature Contact to Biopsychosocial Resilience box reflect the possibility that the types of contact people have with nature are a function of the natural ecosystems, settings, elements encountered, and affordances offered.

3.2. Nature contact

The degree to which nature can help build, maintain and restore stocks of adaptive biopsychosocial resilience resources will depend on several features of contact experiences. Here we focus on: interactional, temporal, interpersonal, and intrapersonal aspects. Interactional aspects of nature contact can be broadly classified as indirect, incidental, or intentional, with some overlap (Keniger et al., 2013). Watching nature documentaries is one of many forms of relatively indirect, yet intentional, digital nature experiences (Browning et al., 2020; Frost et al., 2022; Yeo et al., 2020). More direct, though not necessarily always intentional, may be seeing, hearing, and/or smelling nature from home (Hartig et al., 2014; Kaplan, 2001), while commuting to/from work (Zijlema et al., 2018), or while at work itself (Korpela et al., 2017). Intentional contact includes gardening and recreational visits to settings such as parks, woodlands, or the beach, and while motives will vary, the building of biological (e.g. fitness), psychological (e.g. emotional regulation strategies), and social (e.g. friendships) resources may all play a role (Knopf, 1987; Stigsdotter and Grahn, 2011).

Nature contact also varies in temporal terms ranging from a few minutes (e.g., Ulrich et al., 1991) or a couple of hours (White et al., 2019), to many years (Rojas-Rueda et al., 2019). Cumulative contact over time, including over the entire life-course, is key for building and maintaining some biopsychosocial resilience resources (Browning et al., 2022; de Keijzer et al., 2016; Li et al., 2021; Pearce et al., 2016). Foley (2017), for example, refers to cumulative nature exposures as an 'accretive practice', with each experience slowly building layer upon layer of possible protection, much as an oyster develops a "*series of layers*" that "*help build resilience in the maintenance and recovery of health*" (p.49). There may also be 'critical periods' in people's lives where nature is particularly important for building resilience (Li et al., 2021), including *in utero* (Akaraci et al., 2020), during childhood (Engemann et al., 2019; Ward Thompson et al., 2008; Vitale et al., 2022; Wells and Lekies, 2006), and transitions into adulthood or retirement (Rishbeth et al. 2019).

In terms of interpersonal aspects, people do visit nature alone, but much nature contact is a shared experience with others (Schipperijn et al., 2010; White et al., 2013). Social identities, norms, and expectations also structure nature contact (Oh et al., 2021), and can help or hinder access for different groups (Solecki and Welch, 1995), even across generations (Phoenix et al., 2020). Differences in use patterns and motivations have been observed for sociodemographic factors such as gender, race, and socioeconomic status (Boyd et al., 2018), and tensions can exist between social and ecological functions of natural settings, for example due to crowding (Shams and Barker, 2019). The double-headed arrow between the Nature Contact and Nature-based Solutions boxes in

Fig. 1 reflects these and other interactions.

Finally, intrapersonal aspects of nature contact, such as felt intensity and memories are an important, though often neglected, exposure mechanism (Völker and Kistemann, 2015). Particularly intense contact experiences, though brief in duration (Richardson et al., 2021), may be perceived of as magical in childhood (Chawla, 2007), spiritual in adulthood (Snell and Simmonds, 2012), and lead to long-term memories that affect both how new encounters are perceived (Smalley et al., 2022) and the emotions they generate (Smalley and White, 2023). A fleeting glimpse of dolphins jumping may last only a few seconds but the memory may last a lifetime and be repeatedly recalled and 'consumed' such that in the mind's eye the total nature contact duration far exceeds the original encounter (Knez and Eliasson, 2017). While recognising that what gets replayed in autobiographical memory is subject to a range of alterations from the original experience, this kind of 'contact' is rarely discussed by epidemiologists and ecological researchers in the nature-health field who tend instead to view nature exposure purely in terms of physical, rather than psychological, contact, and to focus on exogenous factors external to the person (e.g. de Keijzer et al., 2017).

Although our main focus is on how nature and nature contact may build, maintain and restore biopsychosocial resilience resources, we also recognise that resilience resources and processes may in turn influence nature and nature contact through reciprocal relationships and feedback loops. These are represented in Fig. 1 by: a) the light blue arrows from Biopsychosocial Resilience to Nature Contact; b) by the double headed green arrows between Nature Contact/Nature-based Solutions and Nature; and c) the dark blue arrows from the recovery process to Biopsychosocial Resilience, Nature Contact and Nature. For instance, if people are aware of nature's role in supporting their recovery processes (e.g. "that walk through the woods really helped me put things in perspective"), they may deliberately increase the amount of future nature contact to promote such benefits (Korpela et al., 2018; Tester-Jones et al., 2020). Such a realisation may alter not just how much but also how people interact with the natural world, perhaps treating it with more care and respect once they realise the opportunities it provides (Lee, 2011; Rosa and Collado, 2019; Smalley et al., 2022; Whitburn et al., 2020). While many feedback loops may be positive, for instance when greater contact is associated with greater support for proposed nature-based solutions (Ferreira et al., 2022), we also have to recognise that too much, and certain types of contact (e.g. careless mountain-biking) can negatively impact delicate ecosystems, settings, and elements (Pickering and Barros, 2015). Although these feedback loops, both positive and negative, are potentially important, detailed discussion of them is beyond the scope of this first iteration of the theory.

4. Nature-based biopsychosocial resilience theory (NBRT)

4.1. The theory in a nutshell

Bringing these various elements together, NBRT is built on the following propositions:

Stressors. Individuals are faced with multiple environmental, socio-economic, and personal stressors, which can disrupt their homeostatic equilibrium and negatively impact their biological, psychological, and social health/well-being, potentially increasing allostatic load.

Biopsychosocial resilience resources. At any point in time, individuals have a stock of biological, psychological, and social resources that can be used to mitigate the impact of stressors on their biological, psychological, and social health/well-being (i.e. biopsychosocial resilience). Many factors are involved in the building, maintenance and restoration of these different resources, but nature contact can also play an important role.

Biopsychosocial resilience processes. These biopsychosocial resources can be drawn upon at different phases in the stress response-recovery cycle to help individuals: (a) prevent, or reduce the risk or potency of, a stressor (preventive resilience); (b) reduce the initial impact of an experienced stressor (response resilience); and (c) recover towards a new equilibrium (recovery resilience). Drawing on these resources can deplete the available stocks, and nature contact can help restore them.

Nature and nature contact. The natural world can be considered in terms of ecosystems, settings, elements and affordances, all of which affect an individuals' contact with nature. The degree to which nature can help build and maintain stocks of adaptive biopsychosocial resilience resources will depend on several features of such contact, including interactional, temporal, inter-and intra-personal factors.

Feedback loops. The stress response-recovery process may itself build biopsychosocial resilience resources directly (e.g. through the acquisition of new coping strategies) and indirectly through nature by, for instance, leading to greater support for nature protection and more contact experiences.

Nature-based solutions and social-ecological resilience. The natural world also underpins nature-based solutions, which can help to build socio-ecological resilience resources that can be deployed to mitigate climate change-related and other environmental stressors (preventive resilience processes). Individual-level contact experiences and biopsychosocial resilience resources have a number of potential synergies and tensions with nature-based solutions and social-ecological resilience resources.

4.2. Relations to other perspectives on nature-health relationships

How do NBRT's propositions relate to existing general perspectives on how nature contact promotes health and well-being through adaptational processes (e.g. Markevych et al., 2017; Marselle et al., 2021)? Arguably, the three most frequently discussed in the literature are: (1) the mitigation perspective, which can broadly be characterized in terms of reducing exposure to the occurrence or intensity of environmental stressors; (2) the capacity-building (or instoration) perspective, which can be characterised in terms of strengthening and/or reinforcing physical and psychological resources that help people cope better with potential stressors; and (3) the restoration perspective, which can be characterised in terms of restoring emotional, cognitive and physiological capacities depleted as a result of stressful experiences (Hartig et al., 2008). Explicitly or implicitly, these perspectives are represented in a vast body of research on nature-health relationships and they have informed and are integrated within NBRT.

Work guided by the mitigation perspective has tended to focus on nature's macro-level abilities to reduce the strength of external stressors such as air pollution, flooding, and urban heat island effects, e.g. through greater tree coverage, provision of sustainable drainage systems, and green roofs. In NBRT, this perspective is reflected in the pathways in Fig. 1 from Nature, through Nature-based Solutions, Social-ecological Resilience resources and Preventive Resilience processes (Cohen-Shacham et al., 2019; Castellar et al., 2021; Lafortezza, et al., 2018; Seddon, 2022). The epidemiological literature is replete with studies that support this perspective. For instance, parallel mediation analysis of data from a large prospective cohort study by James et al. (2016) suggested that approximately 4–5% of the reduced mortality risk from living in neighbourhoods with greater greenspace was due to lower levels of air pollution (i.e. preventive resilience).

Work guided by the capacity-building perspective has emphasized the more proactive opportunities nature affords for developing biopsychosocial resources such as a healthy gut microbiome (Rook et al., 2017), motor skills and physical fitness (Hunter et al., 2015), positive self-esteem (Trzesniewski et al., 2006), and social contacts (Astell-Burt et al., 2022), which could be subsequently drawn upon when faced with a stressor. This perspective is related to NBRT's notions of a stock of biopsychosocial resilience resources and response resilience processes. The relative importance of these factors is also highlighted by James

et al. (2016), with meeting physical activity targets (biological resilience), not having depression (psychological resilience), and having frequent social engagements (social resilience) accounting for approximately 1–2%, 26–31% and 13–19% of the reduced mortality risk from living in neighbourhoods with greater greenspace, respectively.

Finally, research and interventions guided by the restoration perspective tend to emphasize ways in which nature contact can help individuals better recover from stressful situations (Ulrich et al., 1991) or fatigue of cognitive resources (Kaplan and Kaplan, 1989). As with the capacity-building perspective, it recognises that the adaptive resources needed for recovery can be biological (e.g. Yao et al., 2021), psychological (e.g. Stevenson et al., 2018), and/or social (e.g. Hartig, 2021; Izenstark and Ebata, 2017), that they can become depleted with use, and that they will need to be restored to support further coping. Furthermore, the cumulative effects assumption suggests that people build stocks of resilience resources by acquiring experience, knowledge, and skills related to the deliberate use of nature to serve recovery needs (e.g., Kaplan, 2001; Korpela et al., 2018; Lymeus et al., 2022; Tester-Jones et al., 2020). As such, there are clear parallels with NBRTs pathways from nature contact to biopsychosocial resilience as a set of resources and recovery resilience as a set of processes.

Given that the three perspectives cover the necessary phases of adaptation as a superordinate process linking people and nature, they are conceptually interdependent. A key contribution of NBRT is to elucidate how. This is done through the concept of resilience, which we argue can be applied to: (a) a set of adaptive resources at the community/ecological level (social-ecological resilience); (b) a set of adaptive resources at the individual level (biopsychosocial resilience); and (c) a set of processes that draw on these resources in order to reduce exposure to stressors (preventive resilience), reduce the initial impact of stressors (response resilience) and aid stress recovery processes (recovery resilience). By representing the conceptual interdependence of the three perspectives, NBRT provides an integrative theoretical framework for the nature-and-health field.

5. Evidence supporting NBRT

This section reviews selected experiential (e.g. based on self-reported experiences and qualitative research), experimental, and epidemiological evidence supporting NBRT. Table 2 provides examples of individual studies and multi-study reviews that link different biopsychosocial resilience resources to different stages in the stress-recovery process. Given that few studies have been designed to tease apart different resilience resources and processes, the categorisations summarised in Table 2, and described in the text, are not meant to be exhaustive or final.

Table 2
Example studies and reviews related to nature-based biopsychosocial resilience resources and processes.

Resilience resources *Adaptive resources supported through nature contact*		**Resilience processes** *Deployment of resilience resources at different phases in the stress-recovery cycle*		
		Preventive resilience	**Response resilience**	**Recovery resilience**
Broad type	**Examples**	*Reduced exposure to potential stressors (e.g. through greater greenspace exposure)*	*Less reactivity to a potential stressor (lower maximum point of reaction)*	*Faster and/or more complete recovery or improved equilibrium following a stress response*
Biological Resilience	Stronger immune, cardio-vascular, respiratory and musculoskeletal systems; more adaptive neurological responses	Longitudinal cohort study suggests that young adults have better lung function if spent childhood years in greener areas with (potentially) lower air pollution (Fuertes et al., 2020). Systematic review provides consistent evidence that stroke mortality risk is lower among cohorts with greater longitudinal neighbourhood greenspace exposure (and thus potentially fewer environmental stressors) (Yuan et al., 2021).	fMRI study found lower amygdala activity (which triggers HPA axis response) among people who grew up, and currently lived, in greener (i.e. less stressful) areas following a social stress test (Lederbogen et al., 2011). Systematic review provides qualified evidence that nature exposure can build anti-inflammatory immune-profile which can be used to fight infections (Andersen et al., 2021).	Randomized crossover study found that people watching natural vs. built scenes prior to a stressor showed faster stress recovery as indicated by more favourable autonomic activity (Brown et al., 2013). Systematic review and *meta*-analysis provides consistent evidence that nature (vs. non-nature) exposure is associated with decreased salivary cortisol and better cardio-vascular outcomes following stressors (Yao et al., 2021).
Psychological Resilience	Better emotional balance (more positive and fewer negative emotions); replenished attentional resources; more adaptive threat and coping appraisal mechanisms	Prospective cohort study found that people who had moved to greener areas (and possibly fewer environmental stressors) had lower risk of psychotic and mood disorders after 5 years (Kivimäki et al., 2021). Systematic review provides consistent evidence for an association between long-term exposures to greenspaces and better performance on a range of cognitive functions and lower dementia risk (Besser, 2021).	Experimental study found less negative emotional reactivity to a stressor after watching pictures of nature vs. urban environments (Michels et al., 2021). Systematic review provides strong evidence that nature can promote positive emotions which can aid coping appraisals and mechanisms in the face of threats (McMahan & Estes, 2015).	Cross-sectional study found children living in more (vs. less) natural neighbourhoods showed higher global self-worth following stressful life events (Wells & Evans, 2003). Systematic review and *meta*-analysis provides consistent evidence that nature prescription programmes associated with lower anxiety and depression scores than controls (Nguyen et al., 2023).
Social Resilience	Better interpersonal communication; enhanced interpersonal cooperation; lower aggression; greater social connections	Longitudinal cohort study reported less loneliness (a social stressor) among people living in greener areas, especially those who lived alone (Astell-Burt et al., 2022). Systematic review finds mixed (weak) evidence of more neighbourhood nature and pro-social behaviours in children and adolescents (Putra et al., 2020).	More ostracized participants reacted less 'aggressively' after viewing natural (vs. urban) scenes (Poon et al., 2016). Narrative review describes how nature can promote relational resources that can be drawn on in times of stress (Hartig, 2021).	Incidents of psychological aggression and physical violence in deprived (chronically stressful) neighbourhoods lower among those residing in houses with more trees/grass (Kuo and Sullivan, 2001). Systematic review finds consistent evidence that experimental nature exposure (vs. control) associated with more pro-social behaviors in younger children (Putra et al., 2020).

Note. Identification of specific studies and review findings with different resilience processes is suggestive only, since few studies are able to clearly untangle the processes and the same resources may be drawn upon at multiple stages in the stress recovery process.

5.1. Nature-based biological resilience

Nature contact can strengthen a range of biological resilience resources which subsequently aid response and recovery resilience processes. While recognising the interrelationships between different biological systems, research suggests at least five systems may benefit. First, although the relationships between green space and air pollution are complex (Diener and Mudu, 2021), there is general consensus that greener areas have lower particulate pollution levels (e.g. $PM_{10}/PM_{2.5}$) with epidemiological evidence identifying a range of potential benefits for lung function (Fuertes et al., 2020) and mortality risk (Crouse et al., 2019; James et al., 2016). These benefits are related to preventive resilience processes by reducing individuals' exposure to potential harms.

A second biological mechanism relates to an individual's anti-inflammatory immune-profile (Andersen et al., 2021). Exposure to biodiverse microbiota in soil, leaf litter, and the air can influence the gut and skin microbiome (Nurminen et al., 2018; Zhang et al., 2023) and the immune system (Roslund et al., 2020), which, in turn, can reduce the inflammation associated with chronic stress (Morey et al., 2015). Experimental research as part of Japan's Forest Bathing programme suggests benefits might include boosting the number of natural killer cells and anticancer proteins (Kamioka et al., 2012; Lee et al., 2014; Li, 2010). Aside from microbiota, studies also suggest that regular exposure to negative air ions produced by waterfalls can reduce pro-allergic cytokines such as interleukin (IL)-13 and IL-5, and induce anti-inflammatory IL-10 producing T cells in paediatric asthmatics, with lasting improvements in symptoms and medication use (Gaisberger et al., 2012). If nature contact can help improve immune functioning, then individuals will be better equipped to respond adaptively to various sources of inflammation (i.e. response resilience).

Third, nature contact can also strengthen adaptive nervous system responses to non-pathogenic stressors (e.g. social stressors). Nature contact can reduce activity in the sympathetic nervous system (Jimenez et al., 2020; Lanki et al., 2017); increase activity in the parasympathetic nervous system (Annerstedt et al., 2013; Brown, Barton, and Gladwell, 2013); and deliver a better balance in the hypothalamic–pituitary–adrenal (HPA) axis, as reflected in healthier patterns of cortisol release (Antonelli et al., 2019; Yao et al., 2021). These outcomes may begin with early threat processing in the brain. For instance, Lederbogen et al. (2011) found that individuals who lived in rural, compared to city, areas showed less activity in the amygdala, a part of the limbic system that responds quickly to external stressors, during a socio-cognitive stress task. Given that the amygdala has an activating influence on the HPA axis (Ulrich-Lai and Herman, 2009), lower amygdala activity as a result of an individual's greater cumulative nature contact may thus reflect response resilience processes given the speed with which these activations occur. As little as 60 min of nature (vs. urban) contact can reduce immediate amygdala activity during stress tasks (Sudimac et al., 2022), and watching 10-minute nature (vs. control) videos prior to a social stressor results in lower heart rate and blood pressure (Wells, 2005), suggesting that even short nature-contact experiences can help build nervous system-related biological resilience resources that can then be deployed during the response resilience phase.

A fourth biological resource concerns cardiovascular fitness. Experimental research (Hamer et al. 2006) suggests that just 30-minutes of moderate-intensity activity can buffer against blood pressure responses to psychosocial stress (i.e. response resilience), while epidemiological research indicates that physical activity reduces the risk of a number of chronic non-communicable diseases and premature mortality (WHO, 2020b). Although the evidence is mixed, systematic reviews suggest that neighbourhood greenness and closer access to public green spaces are associated with higher levels of active commuting and overall levels of physical activity, respectively (Jing et al., 2021), with associated improvements in cardiovascular fitness and reductions in stroke risk (Yuan et al., 2021), obesity, and Type 2 diabetes (de la Fuente et al., 2021). Many natural settings afford physical activity (Section 3.1) and people may be more willing to engage in informal nature-based physical activity than formal/indoor exercise (White et al., 2016), and for longer durations (Elliott et al., 2015), with potentially important cumulative cardiovascular resilience-related benefits at the population level (Hug et al., 2009).

Finally, nature contact can support the musculoskeletal system. Walking or jogging on uneven terrain, more commonplace in natural than urban settings, induces a more complex movement pattern with potential benefits for the musculoskeletal system. A trial with older adults showed that a week's mountain hiking improved static balance, gait speed, and muscle mass, compared to a standard holiday control group (Prossegger et al., 2019). If sustained over time this could help reduce the risk of falls (Ambrose et al., 2013). Research has also shown sustained benefits of 'green exercise' for chronic lower back pain (Huber et al., 2019), a key cause of disability globally. Finally, epidemiological research suggests that those in greener (vs. less green) urban neighbourhoods report fewer musculoskeletal complaints (Maas et al., 2006), possibly due to greater levels of physical activity requiring more complex bodily movements.

Of note, at least three of these types of biological resource, namely immune function, cardiovascular fitness, and an adaptive nervous system were discussed in Section 2.2.3 as potentially important for the stroke example (Table 1). Since, stroke risk is lower among those with greater nature contact (Liu et al., 2022; Villeneuve et al., 2012), and nature contact can support all of these mechanisms, these pathways may help account for some of the reduced risk and better response and recovery processes.

5.2. Nature-based psychological resilience

Nature contact can also support psychological resilience. Although we discuss emotional and cognitive functions separately below, as with biological resources we recognise their inter-relatedness.

5.2.1. Emotional resilience

One of the most consistent findings in the field is that nature contact can promote positive emotions such as joy and vitality and reduce negative ones such as anxiety and anger (Corazon et al., 2019; Thompson Coon et al., 2011). Experience sampling protocols have found that people report greater happiness (MacKerron and Mourato, 2013) and less tension (Beute and de Kort, 2018) in natural vs. built environments. Experimental studies show both that people exhibit more muted emotional reactions to stressors directly after nature vs. non-nature contact (Michels et al., 2021, i.e. response resilience) and report more positive emotions and fewer negative emotions following nature vs. non-nature contact (McMahan and Estes, 2015; i.e. recovery resilience). In the longer-term, epidemiological studies generally find that more natural features within individuals' residential environments (e.g. neighbourhood greenspace, coasts) are associated with both higher subjective wellbeing (Houlden et al., 2018; Garrett et al., 2019; White et al., 2021), lower psychological distress (Nutsford et al., 2016; Dzhambov et al., 2019), a reduced risk of mood disorders (Kivimäki et al., 2021), and better self-reported health (Elliott et al., 2023; Geiger et al., 2023) even after a range of socio-economic and potential life stressors are controlled for. These studies have, however, not unpacked whether this might be due to the psychological resilience resources built by extended nature contact being deployed at the response phase, recovery phase, or both.

The more positively balanced emotional states associated with living in more natural settings can also be drawn upon in times of both acute stress and during longer periods of chronically challenging life circumstances (Wells, 2021). Wells and Evans (2003), for instance, found that children who had more (vs. less) 'natural' home environments were less distressed and maintained higher self-worth despite experiencing stressors such as bullying at school. Similar results were found in adults

following stressful events such as divorce (van den Berg et al., 2010), and one longitudinal study reported that while stressful life events were associated with worsening mental health trajectories overall, this effect was attenuated for individuals living in greener areas (Høj et al., 2021).

Other studies report more mixed results. While Flouri et al. (2014) found that children with more (vs. less) nature contact had fewer emotional, conduct, and peer problems, there was no evidence that greater nature contact reduced the effects of adverse life events on later emotional reactions. This seems to suggest that nature contact may have helped build emotional resilience resources, which did not then transfer into useful deployment of these resources in adverse circumstances. Similarly, although Marselle et al.'s (2019) quasi-experimental study found that taking part in group-based nature walks was associated with positive emotional outcomes, there was no evidence that they reduced the impact of stressful life events. Given the relatively short exposures of this latter study, perhaps it is expecting too much of nature contact to build sufficient emotion-related resilience over such a time frame, but this begs the question of how much exposure is needed to build sufficient resilience to respond to which types of shock.

5.2.2. Cognitive resilience

With respect to nature-based cognitive resilience, we draw on two core aspects of cognitive psychology: attentional focus (Logan, 2004) and appraisal theories of emotion (Clore and Ortony, 2008; Scherer, 1999). First, attentional focus is necessary for various executive functions (e.g. planning and decision making) and self-regulation mechanisms (e.g. the ability to resist impulses and delay rewards). However, consistent with a stocks and flows metaphor, attention is seen as a limited resource that can be depleted (Kaplan, 1995). Activities in complex urban settings (Kaplan, 1995), long periods of concentration (Felsten, 2009), and pressures that activate repetitive self-focused negative thought patterns (i.e. rumination, Bratman et al., 2021; Lopes et al. 2020) are among factors that can deplete attentional capacity. This depletion may in turn impair a range of cognitive processes (Kaplan and Berman, 2010). According to attention restoration theory (ART; Kaplan and Kaplan, 1989), nature-contact can help replenish depleted attentional resources, and other cognitive resilience resources associated with a person's "mental bandwidth" (Basu et al., 2019), by shifting the focus of attention away from external demands and internal concerns, to intrinsically and 'softly' fascinating stimuli such as swaying plants and moving water which can hold attention in a non-demanding and relatively effortless way. This can in turn provide people with an opportunity to collect their thoughts and reflect on unresolved issues or future goals (Herzog et al., 1997), all useful when subsequently faced with a new stressor.

Experiential evidence suggests that potential cognitive benefits (e.g. 'space to think') are a key motive for nature visits (Peschardt et al., 2012), and such visits are often perceived as successful in restoring depleted attention capacity (Wyles et al., 2019). Experimental studies have shown that walks in natural (vs. urban) settings reduce rumination (Berman et al., 2012; Bratman et al., 2021) and aid subsequent performance on some directed attention and working memory tasks (Ohly et al., 2016; Stevenson et al., 2018). Laboratory studies suggest that even simulated nature (e.g. photos) can benefit attention and working memory and reduce subsequent impulsive decision making (Berman et al. 2008; van der Wal et al., 2013; Berry et al., 2014). Applied field studies suggest that indoor plants or lunch-time nature walks can improve worker concentration and productivity levels on returning to work (Gilchrist et al., 2015; Sianoja et al., 2018). Finally, studies have suggested living in greener (vs. less green) neighbourhoods may be linked to higher attentional functioning (Kuo, 2001) lower impulsivity (Taylor et al., 2002), better cognitive maturation in children (Dadvand et al., 2015), better self-assessed psychological resilience in young adulthood (Dzhambov et al., 2019), and slower rates of cognitive decline in later life (Cherrie et al., 2018). Combined, the results support Wells and Evans' (2003) suggestion that improvements in cognitive processes following nature contact help people "*resist the inclination to react to certain stressors or potential distractions*" (p.325; i.e. response resilience).

How might nature contact free up attentional resources that contribute to response and/or recovery resilience in practice? In an early articulation of stress reduction theory, Ulrich (1983) argued that the unfolding of stress responses depends on how the stressor is cognitively appraised. Two aspects of appraisal are key here: a) primary appraisal which assesses the extent of the threat, and b) secondary appraisal which assesses one's ability to cope with the threat (Moors et al., 2013). Fear, for example, might be a reasonable response to a threat that is appraised as high, but for which there is minimal coping capacity (e.g. a forest fire). However, theories within the field of cognitive behavioural therapy (CBT) suggest that many situations people fear or worry about are not as intrinsically threatening as believed, and/or that an individual has more resources to cope with and manage the threat than they realise (Brewin, 1996; Britton et al., 2011). Supporting people to develop strategies to make more accurate threat and coping appraisals is effectively helping them to build cognitive resilience resources that can then be drawn upon in times of potential stress at both the response and recovery stages (Padesky and Mooney, 2012).

Nature contact can positively influence threat and coping appraisals, and thus build cognitive resilience, through at least two pathways. With respect to threat appraisals, Fredrickson's broaden-and-build theory (2001) posits that negative emotions can limit people's abilities to think laterally and creatively in challenging situations, decreasing the chance that a potential threat will be accurately appraised. By contrast, positive emotions can broaden a person's attentional perspective and build their creative, problem-solving orientations and behavioural repertoires, increasing the chance of accurate threat appraisal (Fredrickson and Branigan, 2005). Because nature contact can reduce negative emotions and promote positive ones (McMahan and Estes, 2015), this suggests it can also help build cognitive resources and so enable more appropriate appraisals of threat, mitigating potential stress responses (Meuwese et al., 2021; i.e. response resilience).

With respect to coping appraisals, experiential research suggests that spending time in nature can build people's self-esteem or global sense of self-worth (including coping self-appraisals, Masten and Reed, 2005). Marselle et al. (2019), for instance, summarized a longstanding rationale for wilderness camping programmes studies by stating that they "*may promote resilience, as the experience provides the opportunity to engage in activities and to develop new skills that develop feelings of self-esteem, competency, self-confidence, or self-efficacy*" (p.2, for a review see Levitt, 1988). People report increases in self-esteem after even relatively short nature visits (Barton and Pretty, 2010) and self-esteem improvements are often reported in 'green/blue care' interventions (Garcia-Llorente et al., 2018) and forest schools (O'Brien and Murray, 2007). Increases in self-esteem and self-efficacy from nature contact can thus have a double benefit, being deployed to reduce the impact of potential stressors on the stress response through the power of positive coping appraisals (i.e. response resilience), as well as supporting the acquisition of new skills and competencies that help individuals more quickly down regulate any stress responses that do occur (i.e. recovery resilience).

5.3. Nature-based social resilience

Wells and Evans (2003) also identified social support as a "*possible candidate for a mechanism to explain the moderating function of nearby nature*" on stressful life events (p.324, see also Wells, 2013). Although people may turn to nature for time alone to ease pressure in social relations (Korpela and Hartig, 1996; Korpela and Staats, 2021), as noted above, most voluntary visits to nature are with others (White et al., 2013) and a key motivation is to spend time with friends and family (Knopf, 1987). Laboratory and field experiments suggest people are more pro-social (Zelenski et al., 2015; Weinstein et al., 2009), generous (Zhang et al., 2014), and helpful (Guéguen and Stefan, 2016) following nature contact, as well as less aggressive in response to provocation

(Poon et al., 2016; i.e. response resilience). Epidemiological research suggests living in greener versus less green neighbourhoods and/or visiting nature for recreation more frequently tends to have higher levels of social cohesion (Dzhambov et al., 2018; Weinstein et al., 2015, Liu et al., 2020) and pro-social behaviours (Putra et al., 2020), less loneliness (Astell-Burt et al., 2022; Pasanen et al., 2023), and fewer anti-social behaviours such as crime (Kuo and Sullivan, 2001). Interventions that promote nature-based neighbourhood social contact through community co-designed urban planning initiatives or shared activities, such as social gardening (Teig et al. 2009), can improve community health (Litt et al., 2015; Litt et al., 2023), psychological well-being (van den Bogerd et al., 2021), and reduce aggression (Branas et al., 2011).

How do these processes help build social resilience resources? Relational restoration theory (RRT; Hartig, 2021) suggests the sharing of social support between close others relies on relational resources such as trust and respect, which may be promoted through nature contact. Wilderness experiences (Holland et al., 2018) can build social resilience by encouraging communication and cooperation within groups (Ewert et al., 2011). Everyday nature contact can build parent–child resilience through improved communication (Cameron-Faulkner et al., 2018) and establishing positive bonds through play and the sharing of pleasant activities (Ashbullby, et al., 2013; West, 1986). Nature visits are perceived as more positive by adolescents when accompanied by a friend (Greenwood and Gatersleben, 2016), potentially reflecting enhanced coping appraisal processes. For instance, Schnall et al. (2008) found that grassy (natural) slopes are appraised as less steep and easier to walk up (i.e. response resilience) if one is accompanied by, or even merely imagines being accompanied by, a friend. Such observations have informed interventions including outdoor programme activities for parents and children (Davidson and Ewert, 2012) and nature-based therapies for couples (Burns, 2000).

6. Interventions to build and maintain nature-based biopsychosocial resilience

Indeed, many nature-based interventions may "work" by helping to build and maintain biopsychosocial resilience resources. Using the health promotion/disease prevention pyramid analogy (Frieden, 2010), such interventions can occur at the primary, secondary, and tertiary prevention levels (Fig. 2; Table 3). At the base of the pyramid, primary prevention interventions tend to target populations in general rather than specific groups, and often involve physical/infrastructural changes. Hunter et al.'s (2015) review of interventions to promote physical activity in urban green space identified four types: parks, greenways/trails, urban greening (e.g. greening vacant lots), and green-built (e.g. green roofs). Broadly speaking, such interventions appear to 'bring nature closer to people' and/or make it more accessible. Although such interventions are often designed to promote social-ecological resilience, and thus come under the umbrella of nature-based solutions, they may also help build and maintain biopsychosocial resilience-related resources, especially if they use evidence-based design practices sensitive to how nature contact can benefit individuals directly (Grahn and Stigsdotter, 2010; Mishra et al., 2023; Palsdottir et al., 2018; Skärbäck et al., 2014).

In the middle of the pyramid, secondary prevention interventions focus on at-risk populations, such as individuals who are physically inactive or groups living in chronically stressful conditions (e.g. deprivation, Evans and Kim, 2007; Wells, 2021). Such interventions often focus on increasing physical nature contact, and/or promoting a deeper psychological connection to the natural world. Examples include forest bathing (Li, 2010), wilderness therapies (Anderson et al., 2018), green care, allotment/community gardens, urban farms (Litt et al., 2018; Litt et al., 2023), nature group walks (Faber Taylor and Kuo, 2009), forest schools (Roe and Aspinall, 2011), and park prescription programmes (Razani et al., 2018). Razani et al. (2019), for instance, conducted a

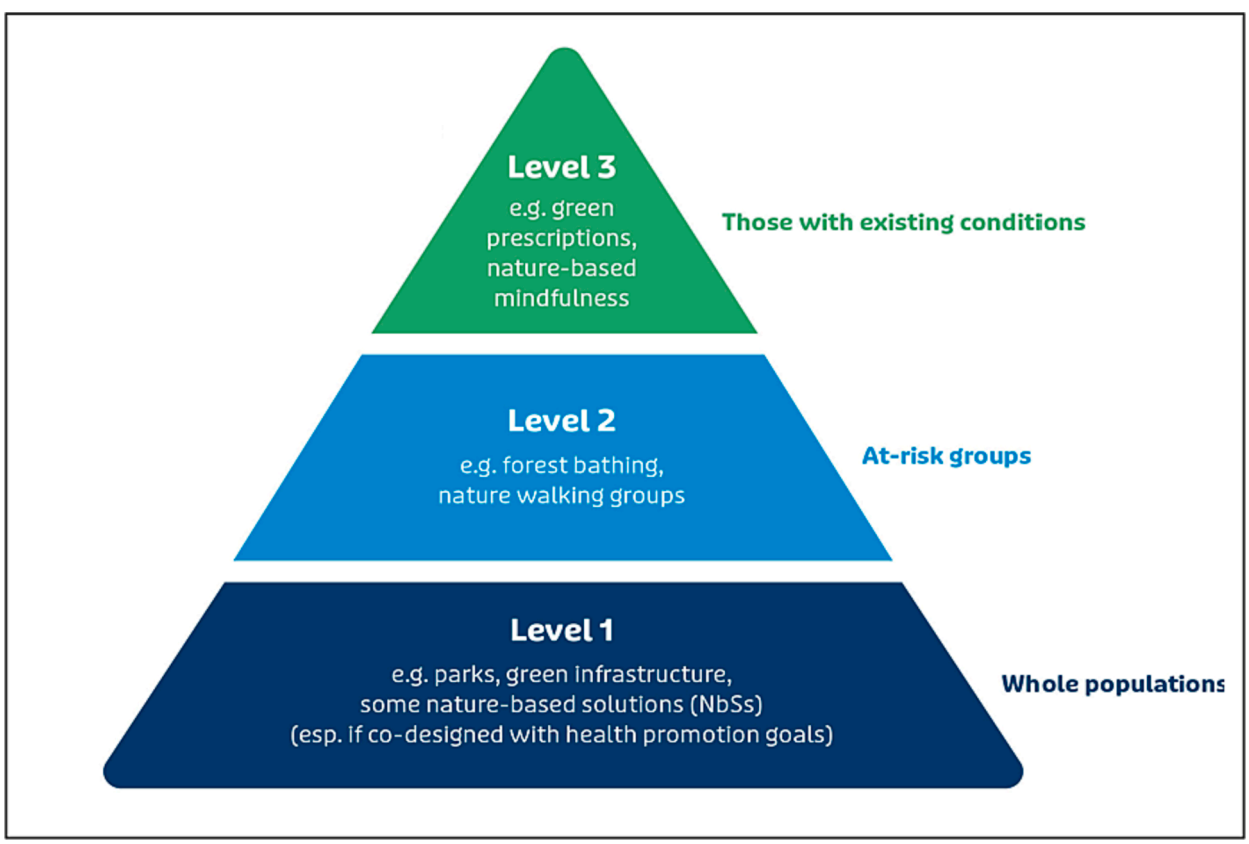

Fig. 2. Health promotion/disease prevention pyramid applied to nature-based interventions.

Table 3
Examples of primary, secondary, and tertiary prevention interventions that build and maintain biopsychosocial resilience resources through nature contact.

Level	Focus	Target	Selected Examples
Primary prevention (Level 1)	Physical and infrastructure resources. Bringing nature closer to people.	Broad groups within population.	Various nature-based solutions including parks, greenways/trails, urban greening, green-roofs/walls etc. (Hunter et al., 2015; Palsdottir et al., 2018).
Secondary prevention (Level 2)	Changing behavior, bringing people closer to nature.	At risk groups, e.g. physically inactive, lonely/isolated, living in deprived areas.	Forest bathing, wilderness therapy, urban farms, vacant lot community gardens, forest schools, group nature walks, park prescription programs (e.g. Leavell et al., 2019; Litt et al., 2023; Razani et al., 2019; Roe & Aspinall, 2011).
Tertiary prevention (Level 3)	Nature-based approaches integrated with existing medical or psychological treatments.	Individuals with physical and/or mental health issues e.g. chronic stress.	Talking therapies outdoors, meditative/mindfulness practices in nature (e.g. Lymeus et al., 2018; Nguyen et al., 2023; van den Berg & Beute, 2021).

longitudinal trial with families from low income areas including those where children had experienced neglect and/or violence. Intervention families received help to visit local parks over a three-week period with results showing a significant positive association between the number of visits and improvements in the children's psychological resilience. Broadly speaking, the aim of secondary level interventions appears to be to 'bring people closer to nature', especially those who might benefit most.

Finally, at the top of the pyramid, tertiary prevention interventions target individuals with existing physical and/or mental health issues (e.g. cardiovascular disease, depression), integrating elements of nature contact into established medical or psychological treatments (Beute and de Kort, 2018; Gonzalez et al., 2010; Leavell et al., 2019; Nguyen et al., 2023). These natural elements may enhance conventional treatment in several ways. First, they may increase willingness to engage and participate in treatment programmes. Many established treatments for chronic illness, including exercise prescriptions (Sherwood and Jeffery, 2000), cognitive behavioural therapy (Meichenbaum, 2017), and mindfulness training (Baer, 2003), hinge on motivating people to engage with demanding therapeutic procedures (cf. Sekhon et al., 2017) and, if nature can support this challenge, then it becomes an important part of the programme. For instance, mindfulness exercises are easier to learn and practice in non-distracting natural settings (Lymeus et al., 2018), with consequently greater compliance with the training programme (Lymeus et al., 2019; 2022), and therapeutic progress may be faster in talk-based therapies conducted outdoors (van den Berg and Beute, 2021) via mechanisms including higher self-disclosure, incorporation of nature-based metaphors, and increased therapist well-being (Cooley et al., 2020).

Regardless of which part of the pyramid an intervention is targeting, many of the most successful are those that have a core social element, including community engagement in green-infrastructural design (Hunter et al., 2015), group-based nature activities (Barton et al., 2012), and therapeutic programmes (Gonzalez et al., 2010) and interventions (e.g. Razani et al., 2018) involving close relationships.

7. Conclusions, remaining issues, and next steps

The natural world can be a source of stress, exacerbated by human-caused changes in climate, land use, and biodiversity (Whitmee et al., 2015), and a growing detachment and false dichotomy between people and the natural world (Konijnendijk et al. 2023). However, human society has developed in part through learning how to cope with these challenges and there is also growing evidence that nature can promote human health and well-being, especially when aided by well-designed interventions. We argue that this is in part because nature can help to build and maintain social-ecological and biopsychosocial resilience resources that can be deployed to reduce the risk and/or severity of stressors (preventive resilience), mitigate stress responses (response resilience), and help people recover more quickly and fully from stressful situations and challenges (recovery resilience). These resilience processes help individuals achieve more positive homeostatic equilibria following acute and chronic stress, and potentially reduce allostatic load. While recognising nature's potential to build and maintain macro-level stocks of social-ecological resilience resources (e.g. through nature-based solutions), our focus has been on the more micro-level pathways by which nature contact influences individual's stocks of biological, psychological, and social resilience resources and how these can be used to mitigate the impact of potentially stressful circumstances and challenges. We noted that nature contact is underpinned by ecosystems, natural settings, natural elements, and affordances, and that contact experiences can vary in terms of interaction type, duration and time frame, inter-personal aspects, and under-researched forms of intra-personal processes such as memories.

Synthesising these observations, we introduced nature-based biopsychosocial resilience theory (NBRT), which integrates three general perspectives on nature-health relations within a single framework by distinguishing three phases when resilience resources are deployed (i.e., prevention, response, recovery). Evidence from experiential, experimental and epidemiological research highlighted how nature contact can build and maintain different resilience resources: (a) biological – by strengthening respiratory, immune, neurological, cardio-vascular, and musculoskeletal systems; (b) psychological – by promoting positive and reducing negative emotions, shifting the focus of and replenishing attentional resources, helping to establish more adaptive threat and coping appraisals and building self-esteem, new competencies and skills; and (c) social –through the benefits of shared experiences and aiding communication, support and cooperation. Finally, we identified nature-based interventions at all three levels of the health promotion/disease prevention pyramid which may help build and maintain biopsychosocial resilience resources.

Although we are not the first to discuss resilience-related resources and processes in nature-health relations (e.g. Dzhambov et al., 2019; Flouri et al., 2014; Hartig et al., 1991; Høj et al., 2021; Marselle et al., 2019; Parsons et al., 1998; Razani et al., 2018; van den Berg et al., 2010; Wells and Evans, 2003; Wells, 2013, 2021), NBRT offers a far more integrated conceptual foundation than has previously been provided. It thus provides guidance for a new research agenda, new hypotheses, and new interventions. Nevertheless, several unresolved issues will need to be addressed in future theorizing and research.

First, we have said relatively little about how social-ecological and biopsychosocial resilience pathways interact. For instance, as well as building individual level biopsychosocial resilience, nature contact is also associated with more sustainable attitudes and behaviours (Mackay and Schmitt, 2019; Rosa and Collado, 2019; Whitburn et al., 2020), which can in turn promote social-ecological resilience through better nature protection and management. Since people derive more benefits from higher quality natural settings (Wyles et al., 2019) a virtuous cycle

can ensue (Bowler et al., 1999). Further research is needed to explore these synergistic opportunities as well as the more diverse set of positive and negative feedback loops that might occur.

Second, we have also said relatively little about the interdependencies between biological, psychological, and social resilience resources. Previous, non-nature-based, studies, and our own discussion of how resilience resources and processes can support stroke, demonstrate that biological aspects of resilience such as adaptive cortisol responding to stressors are influenced by a variety of psychological and social processes including coping, emotion regulation strategies (Hori et al., 2010; Höhne et al., 2014; Jentsch and Wolf, 2020; Troy et al., 2023), and social support (Heinrichs et al., 2003; Kirschbaum et al., 1995; see also Bennett et al., 2018; Davydov et al., 2010; Kalisch et al., 2017). There is thus every reason to suppose that nature influences multiple resilience resources concurrently, and future research may use NBRT's perspective to examine these interdependencies in more detail.

Third, we recognize that, while there appears to be relatively strong evidence that nature contact can build and maintain biopsychosocial resilience resources, identifying exactly when these resources are used in terms of prevention, response, and recovery resilience processes is challenging. In part this could be addressed using different study designs (e.g. experiments that track the time-course of stress responses and recovery, Troy et al., 2023). However, this will remain challenging because it is likely that different resilience processes operate on different time scales (from moments to years). Further developments of NBRT could say more about these temporal issues.

Fourth, in focusing on individual level biopsychosocial resilience we have also said little about distributional issues, equity and fairness. Many investigations suggest nature contact is inequitably distributed, with wealthier (versus poorer) individuals and communities having access to both more and better-quality natural spaces (Buckland and Pojani, 2023; Sun et al., 2022; although see Fian et al., 2023). Although such inequalities may exacerbate health and well-being inequalities, several studies suggest that nature contact benefits may actually be stronger for socio-economically disadvantaged individuals/neighbourhoods (Garrett et al., 2023b; Rigolon et al., 2021), a so-called 'equigenic' effect (Wang et al., 2022). Future work exploring these relationships through the lens of biopsychosocial resilience resources and processes may shed greater light on when, why, and for whom nature contact may exacerbate or mitigate such inequalities.

Fifth, the evidence presented here in support of NBRT has been selective. The growing number of systematic reviews in the nature-health field are often cautious in their conclusions due to issues of study comparability and quality (Yang et al., 2021). Evidence in support of reduced physiological reactions to stressors following nature exposure, for instance, has primarily been provided by researchers in the Shinrin-yoku (Forest Bathing) field. Here, unequivocal replications are rare (Corazon et al., 2019; Jones et al., 2021), potential placebo effects a standing concern (Antonelli et al., 2019), and clearly identifying the impact of the environment versus, for example, guided behaviours and demand characteristics, has been challenging. However, our aim was not to establish the size and extent of any relationships. Rather we have used available knowledge to develop a novel integrative theoretical perspective for testing in future research. It remains to be seen how well the theoretical propositions outlined in Section 4.1 stand up to empirical scrutiny.

Finally, is NBRT a theory? Although NBRT might instead be considered a conceptual model or framework, it meets the criteria for a theory in that it builds on evidence to articulate a series of propositions, which explain current phenomena and predict future ones which can be tested and falsified by subsequent research. We would argue that in this sense it as much a theory as attention restoration theory (Kaplan and Kaplan, 1989), stress reduction theory (Ulrich, 1987), or relational restoration theory (Hartig, 2021), and in some respects incorporates core elements of all three. Theories adapt and develop in response to new evidence, and although our proposals can serve as a useful first step, we fully expect NBRT to change over time as new thinking and evidence emerges. This first iteration of NBRT is thus set up to encourage discussion and research and is open to challenge and further development, and as such we hope it will undergo further refinements and improvements.

To conclude, natural environments are often seen as a risk factor for human health and well-being, but contact with nature offers an abundance of resilience building opportunities which can also reduce risk and help people cope with the inevitable challenges life brings. By highlighting the resilience-related mechanisms by which nature can support these positive outcomes we hope NBRT will contribute to an improved understanding of the many ways in which our own health and well-being is intricately bound up with the health of the planet as a whole.

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CRediT roles, all authors: Conceptualization, Funding acquisition, Writing – original draft; Writing – review and editing; Vizualisation. This paper was co-ordinated by the first author with all co-authors writing original drafts of specific sub-sections related to their area of expertise. These were subsequently synthesised before going through several rounds of revisions. Revisions were coordinated by a core authorship team (MW, TH, LM, SP, AEvdB, NW) with subsequent authorship in alphabetical order. We would like to thank the anonymous reviewers for some extremely insightful suggestions for improvements to an earlier version of the manuscript.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

No data was used for the research described in the article.

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