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The empowering variability of affordances of nature: Why do exercisers feel better after performing the same exercise in natural environments than in indoor environments?

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ABSTRACT

Objectives: Evidence suggests that 'green exercise' (defined as physical activity in nature's environments) provides an important context for health-enhancing physical activity (HEPA), offering opportunities for (mental) health and well-being outcomes, compared to urban/manufactured environments. Theoretical explanations for HEPA tend to emphasize either nature's characteristics, or mental constructs, without explaining *why* similar behaviours have different outcomes in nature. Here, we discuss how an ecological dynamics rationale for this phenomenon simultaneously includes the environment and the individual.
Design: A narrative position statement, based on a critical evaluation of the literature, and an ecological dynamics conceptualisation, was undertaken.
Methods: The dominant theories were critically reviewed, and an ecological conceptualisation was proposed to highlight current limitations.
Results: An ecological dynamics perspective adopts as its unit of analysis the person-environment system, where individuals and environments co-influence each other in a relational, *transactional* manner, rather than existing independently. An emphasis on the person-environment system suggests how elucidation of psychological processes needs to incorporate aspects of the environment. Thus, explanations of HEPA behaviours cannot be limited to processes considered to occur *solely within* the individual, implying the need for consideration of different affordances (behavioural opportunities) offered by a particular environment.
Conclusions: Affordances in nature's environments are different from affordances in manufactured/urban contexts. Realizing such nature-based affordances implies perceptual and action variability that draws individuals to become, and remain, physically, psychologically and/or emotionally embedded in the natural environment.

1. Introduction

It is widely accepted that prolonged experience of physical activity (PA) promotes physical and mental health across the life span (Breda et al., 2018). The natural environment may influence how physically active an individual is by offering suitable contexts for certain types of activities. Nature provides readily accessible locations for PA and attracts people outdoors because of the unique experiences offered, compared to PA in urban or manufactured settings. Research shows that people who live near natural settings undertake higher levels of PA. Moreover, people with higher levels of PA tend to visit natural spaces more frequently and for longer durations (Shanahan, Franco, Lin, Gaston, & Fuller, 2016).

However a key question is whether, and how, benefits of health enhancing (HE) PA are improved by natural settings. Insights on how benefits of PA are enhanced by a natural setting have been provided by studies assessing how measures of well-being in individuals are influenced by experimentally manipulated environments (Shanahan et al, 2016; Twohig-Bennett & Jones, 2018). For example, a systematic review by Coon et al. (2011) found evidence that psychological well-being benefits of exercise reported by adults was higher following practice in natural versus indoor locations, with well-being effects felt in as little as 5 min (Barton & Pretty, 2010). It was observed that, compared with indoors, exercising in natural settings was associated

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with greater feelings of revitalization and engagement, and reduction in tension, anger and depression. Exercisers reported greater enjoyment and satisfaction with outdoor activity and declared a greater intent to repeat the activity again. These clear effects on psychological and emotional well-being, immediately following exercise in nature, not observed following the same exercise load indoors, have been confirmed in later research (e.g., Loureiro & Veloso, 2014; Puett et al., 2014; Rogerson, Gladwell, Gallagher, & Barton, 2016).

In short, research highlights the augmented benefits of engaging in PA in natural settings, with some studies advancing the idea of a synergistic effect, instead of merely accumulative effects. For example, Astell-Burt, Feng, and Kolt (2013) found that reductions in distress were associated with proximity to natural environments, and this association was increased in adults who undertook physical activity. Following this line of evidence, the aim of this article is to consider the questions: Why does the same exercise régime have different effects in different contexts? How can the augmented benefits of nature-based PA be theoretically explained? To address these questions we review existing theories seeking to explain observed nature-based PA effects, identify some limitations, and present an ecological dynamics framework that provides a different rationale.

2. Theoretical explanations of the enhanced benefits of nature-based physical activity

Nature-based PA occurs in the presence of nature and is sometimes referred to as *green exercise*. The term *green* in this context refers to spaces characterized by a topography dominated by natural features such as trees, trails, icefalls, rocks, beaches, oceans, bushes and lakes. Typical green activities include walking, cycling and running, aquatic activities such as sailing and surfing, and outdoor undertakings like mountaineering, skiing, snowboarding and kayaking.

Nature-based PA research focuses on enhancing human health and well-being and brings together two distinct fields of research with specific theories: 1) exercise psychology, and 2), analyses of mental health benefits from exposure to nature. From an exercise psychology perspective, the natural environment promotes uptake and adherence to PA (e.g., Duncan et al., 2014). However, research in this area is continuing to be developed and there may be differences in uptake between populations such as adults and children, or due to ethnicity (Reed et al., 2013). Proponents of green exercise argue that exposure to nature enhances health and well-being and provides *additional* benefits to those gained from exercise in indoor and urban (manufactured) settings (e.g., Pretty, Rogerson, & Barton, 2017; Lawton, Brymer, Clough, & Denovan, 2017; Yeh, Stone, Churchill, Brymer, & Davids, 2017).

2.1. Most popular PA theories in exercise psychology

In exercise psychology, generally, cognitions related to motivation to exercise have been central in investigations into understanding how to promote behaviour changes. Buchan, Ollis, Thomas, and Baker (2012) identified Self-Efficacy Theory (SCT), Theory of Planned Behaviour (TPB), and Self-Determination Theory (SDT) as the most prominently utilised to study PA behaviours.

Self-Efficacy Theory (SCT). Self-efficacy is an individual's belief in his/her ability to achieve goals (Bandura, 1982). The PA-related research has utilised the construct of self-efficacy as an antecedent, outcome, or process variable when trying to understand motivations for PA behaviours. Self-efficacy is proposed to influence goal-setting, the ability to persist in the face of obstacles, and the capacity to cope with setbacks and stress, in directly influencing PA engagement. A criticism of this theory is that it lacks accuracy in the assessment of self-efficacy in relation to specific PA behaviours. Williams (2015) argued that self-efficacy is a broad marker of motivation, but fails to specify the numerous underlying factors that determine each individual's motivation to act.

The Theory of Planned Behaviour (TPB). This theory makes links between individuals' reported beliefs and their behaviours (Ajzen, 1991). It is argued that individuals engage in a behaviour when they evaluate it positively, believe that significant others want them to engage in it, and conceive it to be under their control. These factors shape an individual's behavioural intentions and increase the likelihood of HEPA behaviours. The theory has been criticised for its exclusive focus on rational reasoning, excluding unconscious and affective influences on behaviour (Sheeran, Gollwitzer, & Bargh, 2013). Moreover, the static explanatory approach of the TPB fails to explain the evidenced effects of actual behaviours on cognitions and future behaviours (McEachan, Conner, Taylor, & Lawton, 2011).

Self-Determination Theory (SDT). Self-Determination Theory provides a macro analysis of human motivation that highlights the inherent need for growth in humans and their innate psychological needs. It is concerned with the motivation behind choices that people make without external influences and interference. The model focuses on the degree to which an individual's behaviour is self-motivated and self-determined (Ryan & Deci, 2017). Significant attention is paid to processes through which a person acquires the motivation for initiating and maintaining PA behaviours over time. The theory assumes that individuals by nature are self-motivated, and search for attaining their own goals. Concretely, SDT proposes that behavioural regulation towards an activity varies in the extent to which it is: 1) autonomous (self-determined), which involves behaving with volition and choice, or 2), controlling, which implies behaving with the experience of pressure and demand toward specific outcomes that comes from external social forces. Such autonomous motivation, however, has been criticized for diminishing the role of the environment, as at best, a mere backdrop (e.g., Cameron, 2001).

These three models have contributed to explanations of the adoption and maintenance of PA behaviours. However, they follow a rationale where the main focus is on how to predict and explain internal regulation of behaviours (cf., Glass & McAtee, 2006). They share the belief that behaviour can be explained as a linear process whereby the measurement, and accumulation of cognitions, reported as attitudes, efficacy, beliefs, and intentions over time, will determine PA behaviours (Buchan et al., 2012). However, this approach over-prioritises internal regulation and fails to appreciate that behaviours emerge from the subtle interplay of many factors and levels of influence in a non-linear manner over time (Resnicow & Page, 2008; Sallis, Owen, & Fisher, 2008). Importantly these three exercise psychology models are not able to explain why PA behaviours in natural environments have different consequences than those in indoor environments. In the past decade, research has been revealing that the impact of contact with nature is complex, dynamic, with multiple levels of reciprocal influences, which Hartig and colleagues call "pathways" (Hartig, Mitchell, de Vries, & Frumkin, 2014). These pathways are mainly related to air quality, physical activity levels, social cohesion, and stress-reduction and emphasize different aspects of nature: such as physical environment, behaviour setting, and experience. Now we turn to those models which relate contact with nature to human mental health and well-being.

2.2. Theories linking contact with nature to health enhancing PA

The main frameworks employed in explanations of green exercise effects include: 1) evolutionary theories such as Biophilia, and 2), psychological restoration theories such as Attention Restoration Theory (ART) and Stress Reduction Theory (SRT) (see Barton, Wood, Pretty, & Rogerson, 2016).

Evolutionary theories. This framework argues that people across cultures, individuals, and generations retain adaptations to the environments of human evolution (e.g., Kellert, 2016). It is, therefore, beneficial for humans to encounter environments, such as nature, to which they remain innately adapted. Biophilia is an evolutionary

concept first introduced by Erich Fromm (1964) to describe attraction to life. Following this idea, Wilson (1984) argued that humans have an affinity for life and life-like processes that motivates continuous contact with nature. The proneness to affiliate with other forms of life is considered to have genetic determinants, originated in the long–term adaptation to particular environmental conditions that provide a higher survival rate and opportunities for greater reproductive success. However, there have been several criticisms of the Biophilia hypothesis.

A line of argumentation (e.g., Topophilia hypothesis, e.g., Tuan, 1974) emphasises that an individual's response to a particular environment, at a specific time, varies as a function of learning within a particular sociocultural context. Unique individual experiences further shape whether and how nature is beneficial, as well as choices of activities through which an individual comes into contact with nature (Kuo, 2015). Another line of argumentation, sustains that evolutionary conceptions emphasize a uniform positive response to nature, yet individual differences in connections with the natural environment might be an important factor when studying the effects of PA in such settings (Hartig, et al., 2010; Zelenski & Nisbet, 2012). A study of regular exercisers found that well-being benefits for those who combined outdoor and indoor exercise were predicated on feelings of connectedness to nature (Loureiro & Veloso, 2014). A third line of argumentation, emphasises that the hypothesis of a positive response to nature contrasts with research that shows that nature can also prompt fearful, biophobic, responses. Biophilia and biophobia can be viewed as examples of biological predispositions to emotionally respond to nature (Hartig et al., 2010).

Psychological restoration theories. Restoration refers to processes through which personal resources (physiological, psychological, social) depleted in meeting everyday demands, can be recovered. People need to restore, otherwise they could develop burn-out or mental health issues. While some environments have neutral, or even adverse, effects on health and well-being, therapeutic environments, such as nature, support restoration. For example, research has shown a direct link between the richness of biodiversity (range of plant and animal species) in the immediate environment and psychological health benefits (Fuller, Irvine, Devine-Wright, Warren, & Gaston, 2007). Restorative environments facilitate a sense of psychological distance from stressors and distractions (as proposed in Stress Reduction Theory); and enjoyable experiences that offer effortless attention and positive emotions (as proposed in Attention Restoration Theory).

The Stress Reduction Theory (SRT) argues that enhanced health and well-being benefits emerge as certain restorative natural environments stimulate stress recovery from the impacting conditions of daily life (e.g., Ulrich, 1983). For a person experiencing acute stress, contact with natural environments can immediately evoke positive affect, which dissipates negative thoughts and feelings and fosters reduction of physiological activation (Honold, Lakes, Beyer, & van der Meer, 2016). Such responses are thought to be genetically determined and mediated by affective or emotional changes (Ulrich, 1999). Evolutionary theories have influenced the development of SRT, although it has a predominant psychosocial tone (Hartig et al., 2010). For example, evolutionary tendencies may mean that individuals are predisposed to engage in opportunities for restoration. Critically, there is an absence of empirical and conceptual support for the notion that health and well-being benefits stem from an evolved adaptive trait (Joye & van den Berg, 2011).

For Attention Restoration Theory (ART), everyday life is predicated on a notion of directed attention, defined as effortful mental processes required to attend to relevant stimuli while avoiding distraction by irrelevant stimuli (Kaplan, 1995). People must inhibit task-irrelevant stimuli as they direct their attention at work and in many daily circumstances, resulting in mental fatigue. However, as with SRT, certain environments and experiences provide opportunities for effortless attention, which supports restoration. The main argument is that these environments help to relieve the overloaded individual, protect him/her from perturbations, and stimulate soft and unconstrained attentiveness in the present, all without imposing any additional self-regulation needs (Lymeus, Lindberg, & Hartig, 2018). Support for this argument emanates from research with stressed and fatigued individuals (see Hartig et al., 2014; Ohly et al., 2016).

However, a recent meta-analysis illuminated a trend that contradicts the core supposition of ART (McMahan & Estes, 2015). The findings suggested that engagement with the natural world was associated with *increased positive affect*, as opposed to *decreased negative affect*, predicted by ART (Capaldi, Dopko, & Zelenski, 2014). Moreover, research investigating PA in hostile or extreme environments has shown that many benefits of PA in the presence of nature do not fit with hypotheses of traditional theories (Brymer & Schweitzer, 2013a; Holmbom, Brymer, & Schweitzer, 2017). Participants of activities undertaken in extreme environments such as climbing, mountaineering, and surfing report the development of a profound positive relationship with nature where the activity is described as 'dancing with nature' (Brymer & Gray, 2009). For many participants, health and well-being outcomes stemmed for transformations experienced from participating with nature that facilitated flourishing in everyday life (Brymer & Schweitzer, 2013b). The notion of being afraid and anxious while participating in extreme environments has been described as vital to transformations in everyday life (Brymer & Schweitzer, 2013a). Participants described feeling as if they were floating or flying and experienced their senses as being "more alive" (Brymer & Schweitzer, 2017; Holmbom et al., 2017).

In general, nature-health link models contribute to understanding of the health benefits of *any* activity in nature, such as contemplation. However, as Brymer and colleagues, on extreme sports practiced in natural environments, indicate (e.g., Brymer & Schweitzer, 2017) evolutionary and restorative theories do not explain specific consequences of nature-based exercise. For the health-nature link theories, PA is, at best, a consequence for people who seek, and remain inside, a natural environment for restoration. The health benefits derive from being in contact with nature, not specifically from PA engagement. However, there are additional benefits of nature-based PA, which are absent when just contemplating nature, and which are not effectively explained by the presented health-nature link theories (see Shanahan et al., 2016).

Attempts to fill this theoretical gap have spawned theorising from green exercise researchers. Specifically, Pretty et al. (2017) introduced the Green Mind theory (GMT) to help understand how brain and body are linked to engagement with natural and social environments. They clarify that the aim of GMT is not to provide a comprehensive description of complex brain-body interactions. Instead, their goal is to develop pathways and interventions for better health by means of contact with nature. They present a metaphor where the calming 'blue brain' drives the parasympathetic nervous system (PNS), and is influential in 'rest-and-digest' behavioural responses. The 'red brain' is activated by the amygdala, mainly during emotional changes, drives the sympathetic nervous system (SNS), and influences fight-and-flight behavioural responses. Furthermore, the term green mind suggests "an optimal mixed mode of mainly activated PNS, interest and excitement-associated mild SNS stimulation, and the presence of only occasional SNS spikes for alarm response" (p.4). However, Pretty and colleagues' highlighting of the term "green", still internalise their explanation of behaviour in the brain, as if it were the *cause* of the person's experiences in nature. More than environments which are immersive and involve focused attention for an individual engaged in PA, "it is the immersion and activation of the Parasympathetic Nervous System that is the key mechanism" (p.6). As long as the PNS is immersed and activated, the person will feel restored. The (green) environment and the person (and all dimensions beyond the PNS) have a secondary (interactive) role in the explanation.

For the most part, current theories developed to explain green exercise effects either focus on internal psychological processes or separate environmental features, such as the quality of air or the presence of

life. Problems with these approaches include low levels of empirical and conceptual support, and the realization that the mechanisms might be more complex than currently appreciated, as we highlight next.

2.3. Criticisms of existing theories of green exercise

Exercise psychological theories argue that PA behaviours are predicated on t understanding mental processes (self-efficacy, intrinsic motivation, pre-determined intentions) that select PA behaviours from among other behaviours. For this approach an important question is how exercisers acquire these processes, with a reduced emphasis on the role of natural environments in the acquisition of such mental constructs. Nevertheless, current conceptualisation that relies on mental processes cannot explain why undertaking same PA régime has different psychological and emotional consequences and effects in nature compared to indoors. These rationales only indicate that such mental processes contribute to adopting and maintaining PA behaviours. In other words, these theories cannot explain the research findings suggesting that, independently of self-efficacy, self-determination and expressed intentions, individuals report feeling better when exercising in contact with nature.

In turn, nature-health link theories view humans as composed of a profile of genes that provides them with innate preferences for natural environments. Their main research effort is directed towards identification of characteristics of nature that have shaped behavioural preferences since the origins of Homo Sapiens. This approach does not account for PA behaviour, because humans can be attracted to nature just to contemplate it. Moreover, after more than a few hundred thousand years, humans are adapted and attracted to other environments too, as highlighted by Topophilia hypothesis. Also, there is evidence for biophobias which can also be seen as an innate preference resulting from contact with nature. Another important point is that evolutionary theories tend to see contact with nature mainly as restorative and healing. The underlying assumption follows the medical model where nature tends to have a recuperative or curative role mainly for when the person and his/her resources are decompensated or depleted. Therefore, the role of environment is not considered as to provide a preventative advantage, or to empower humans, but simply to make restitution for what was depleted (e.g., Bell, Foley, Houghton, Maddrell, & Williams, 2018). Maybe this is due to the conception of 'organism' that these theories share. This approach conceives an organism based on its genes and psychological need for restoration, due to a limited capacity of its internal resources. Therefore, although the theories suggest that the environment has a crucial role, their proponents seem to point to the environment, not because of its inherent value, but due to the organism's internal challenges (genes and depletion of resources). From this perspective the environment is merely seen as a backdrop for the organism's effective functioning. These approaches end up displaying an *organismic asymmetry*, as with dominant exercise psychology theories (see Davids & Araújo, 2010).

Here, we argue that both perspectives are overly-focused on the organismic side of the organism-environment system, and, in explanations of human behaviour, considering the individual in isolation from the environment. Exercise psychology and evolutionary approaches are founded on the separation of the exerciser from the PA context, the subjective (individual's psychology) from the objective (nature's features), and exercisers' behaviours from those situations in which they behave. When discussing green exercise, both approaches tend to locate distinguishing constructs of green exercise effects in the minds or cells of those engaged in PA. This dualistic view encourages conceptual divisions in science (e.g. a theory of the environment and a separate theory of the organism) from which unresolvable problems may arise. These become apparent as soon as questions are raised about how the processes under analysis are connected. For example: how are nature's features connected with mental processes? How are mental constructs derived from nature's features? How can mental constructs, such as self-efficacy, self-determination or intentions, specify PA behaviours and experiences in natural environments? More generally, how are internal (organismic) processes derived from external (environmental) processes, and vice-versa?

To overcome these theoretical problems a different kind of conceptualisation is needed for explaining behaviours, experiences and psychological processes. The dualistic viewpoint separates psychological processes from context, as if they function independently of circumstances, proscribed in the meta-theory of *interactionism* (Altman & Rogoff, 1987; Heft, 2013). In the remainder of this paper we lay out an alternative conceptualisation, explaining how nature's influences cannot be disentangled from psychological processes. We propose how they are intertwined in ongoing person-environment relations, which are constitutive of individual experiences and behaviour (Heft, 2013). This alternative framework stresses both the environment and the person, but it should not be conceived of as an instance of interactionism. Rather, the ecological dynamics framework has a transactional metatheoretical foundation (e.g., Altman & Rogoff, 1987; Dewey & Bentley, 1949; Heft, 2013; see also Gibson, 1979/1986). According to this perspective, animal and environment are interdependent, i.e., they continuously (re)define each other. For example, whether a plant is edible (is food for an animal) depends on the relationship between the evolving properties of the plant and the digestive system of the animal. By defining the environment in terms of the human (or any other animal), the transactional approach provides a meaningful description of the environment, capable of capturing characteristic relational properties of human experience.

As Heft (2013) compellingly demonstrated, we nowadays find many descriptive references to properties of the environment that are reproducibly measured, but lack psychological meaning (e.g., the wavelength of sound or light). Or, they may be meaningful, but difficult to ground in some measurable manner (e.g., the verbalised meaning of exercising in nature). Each of these descriptions is psychologically limited by their failure to capture the fundamental basis of the environment-person relationship. Physical treatments of the environment (e.g., space or time) or individual (e.g., mental information processing in a blue brain) are reductionist and, thus, "remote from human experience" (Heft, 2013, p. 23). The transactional approach, which Heft called "the third way" (ibid.), offers an alternative view that points to the meaningful engagement of a person with his/her environment.

3. The ecological dynamics approach to nature-based PA behaviour

The ecological dynamics approach, rooted in transactional thinking, has already been considered in green exercise research (e.g., Brymer & Davids, 2013; Davids, Araújo, & Brymer, 2016; Yeh, Stone, Churchill, Brymer, & Davids, 2016; see also; Appleton, 1996). Like other Gibsonian ecological perspectives (e.g., Heft, 2013; Richardson, Shockley, Fajen, Riley, & Turvey, 2008; Turvey, 2009), this approach takes as its unit of analysis the person-environment dynamic system. In the present paper, three, related, tenets of this approach are highlighted. First, the ecological dynamics approach conceives the person as an agent. Individuals are not passive receivers of stimuli that subsequently produce a reactive response, as many behaviourists asserted; rather they are inherently active organisms, scanning the ambient energy patterns, and continually adjusting their goal-directed behaviours to cope with, or devise, changes in the environment. Second, the ecological dynamics framework holds that experience resides in the person-environment relationship. Perceiving is a "keeping in touch" with the environment (Gibson, 1979/1986, p. 239). That is, experience of a natural environment is not mental and subjective; rather it can only be understood relationally. Third, the environment inhabited by humans, and other animals, is meaningful and consists of *action possibilities* or what Gibson called "affordances". These are properties of the environment that have functional significance for an active individual. In line with

transactionalist logic, Gibson claimed that an affordance is a psychological property of the environment taken with reference to the functional capabilities of an agent. Thus, affordances are relational, cutting across such an objective-subjective divide that has dominated psychology since the 17th century (Gibson, 1979/1986, p. 129).

With these key concepts in place, we can see that the ecological dynamics framework implies a different view of what HEPA constitutes. Indeed, it entails not only perception of the environment in terms of affordances, but also the understanding of action as the realization of such opportunities. Importantly, to realize an affordance does not necessarily imply whole-body movement; it can be an affordance for contemplating or judgement behaviours, for example (Stoffregen, Yang, & Bardy, 2005). From an ecological perspective, behaviour is understood as self-organized and emergent under personal, environmental and task constraints, in contrast to organisation being imposed from inside (e.g. intentions emanating from the mind) or outside (e.g. reinforcement contingencies), nature triggers a reaction as a metaphorical 'pill' (Van Heezik & Brymer, 2018). Importantly, HEPA behaviour is not prescribed by internal or external structures, yet within existing constraints, there are typically a limited number of stable emergent outcomes that can be achieved (Araújo, Hristovski, Seifert, Carvalho, & Davids, 2017). In this view, within a HEPA environment, behavioural patterns emerge under constraints as less functional states of organisation are dissipated. Exercisers can exploit this tendency to enhance their adaptability and maintain PA behaviours under variations of the natural environment.

Understanding PA behaviours at the level of the *environment-agent system* entails some key points: 1) the environment is not a manifold of neutral affordances from which the exerciser chooses one to realize, but consists of (momentary) invitations to which exercisers functionally respond (e.g., Rietveld, 2008; Withagen, de Poel, Araújo, & Pepping, 2012); 2) exercisers are also capable of deliberately selecting and utilizing affordances, i.e., they modulate their coupling with the environment and thus constrain the dynamics of the person-environment relationship (i.e., behaviour may emerge, for example by not giving in to the demands of the environment; see Withagen, Araújo, & de Poel, 2017); and 3), whether an affordance invites an action of a particular exerciser is likely to depend on multiple organismic and environmental factors (e.g., Withagen et al., 2012). Hence, the degree to which an affordance solicits behaviours from an exerciser can momentarily and circumstantially vary, and might vary according to the individual. This is a very different consideration from a person deliberating an intention and imposing it on the environment via the mechanical body (see Withagen et al., 2017, for an explanation). The ecological dynamics perspective that we have sketched here points to different types of explanations for the benefits of physical activity in nature environments, the gist of which are discussed in the remainder of the paper. While the theoretical framework is powerful, it is important to emphasize that these initial explanations are tentative and emergent, requiring empirical and conceptual scrutiny in future research. They provide a platform for research in physical activity psychology and suggest alternative views that are worth exploring, in our opinion. Some ideas and related methods are discussed below.

3.1. Affordances of green versus manufactured environments

The understanding of the environment in terms of affordances offers the theoretical means to distinguish between the benefits of nature-based and manufactured environments. As Gibson (1979/1986) noted, each and every object provides numerous affordances. In a review of the ecological perspective, Cutting (1982) once enumerated about 30 affordances that a single piece of paper provides us, concluding that it was far from complete—"an infinity remain" (p. 216).

Although objects may be used in many different ways, we tend to use them in specific ways. The reason for this is that objects always exist in a sociocultural milieu. Ever since Costall's (1995) seminal paper on "socializing affordances", a growing number of authors have adopted and developed this perspective (e.g., Heft, 2001; Rietveld & Kiverstein, 2014; Van Dijk & Rietveld, 2016). The main tenet of this view is that we always act in a sociocultural environment in which there are normative ways of using objects. Costall (2012) introduced the concept of canonical affordances to capture this:

> Canonical affordances are conventional and normative. It is only in such cases that it makes sense to talk of *the* affordance of the object. Chairs, for example, are *for* sitting-on, even though we may also use them in many other ways (Costall, 2012, p. 85; emphases in original).

The equipment we encounter in a gym or in other places where people exercise, offer such canonical affordances. For example, a treadmill is *for* running and walking, although it, too, affords numerous other actions. The fact that such equipment is designed for certain purposes seriously constrains our behaviour (for a discussion of play elements with open functions see Withagen & Caljouw, 2017). Indeed, a person who tries to use gym equipment in a way for which it is not suited, as prescribed by equipment manufacturers, is likely to be admonished, if only, by the disapproving looks of his/her peers.

In the natural environment, such canonical affordances seem relatively absent. For instance, there is no specifically prescribed way in which we ought to engage with a tree trunk that we encounter in a forest. We can climb on it, jump from it, kick it, walk over it, hug it, push it, etc. It is even hard to think of a behaviour that is not in accordance with *the* affordance of the tree trunk—it simply does not have one. Hence, natural environments seem to allow and invite more diverse behaviours than manufactured ones. This hypothesis has been explored by Fjørtoft and colleagues (Fjørtoft, Kristoffersen & Sageie, 2009; Fjørtoft & Sageie, 2000) in the context of children's free play. Studying the playing behaviours of children in natural and manufactured play spaces, they suggested that the number of used affordances in the natural environment tends to be higher than that in the manufactured environment.

Apart from providing a different approach to what an environment is, the ecological dynamics framework also entails a detailed account of action that initiates an alternative answer to the question why exercising in a nature-based environment brings augmented benefits.

3.2. The realization of affordances of nature imposes specific (psychological, physiological, social) experiences due to behaviour variability

Nature's environments present inherent variability, both for perception as well as for action. This is why it demands careful steps and movements, as well as absorbs human attention (through activities like contemplation). The distinct affordances of nature imply a more varied action for the exerciser. Individuals are able to uniquely and functionally adapt their movements during PA, exhibiting flexible, or more adequately, degenerate behaviours. Degeneracy signifies that an individual can vary movement (structurally) without compromising function (Edelman & Gally, 2001; Seifert, Komar, Araújo, & Davids, 2016), to satisfy interdependent personal, environment and task constraints (Davids, Button, Araújo, Renshaw, & Hristovski, 2006).

Research has demonstrated that degeneracy in perception-action systems provides the basis for diversity of experiences and actions required to negotiate information-rich and dynamic environments for task goal attainment (e.g., Cordovil et al., 2009; Seifert et al., 2014). These studies have shown that, more than simply ensuring stability against perturbations and adaptations to dynamic environments, the degenerate architecture of organisms can help individuals exhibit adaptability and creativity. Therefore, as proposed by Newell, Liu, and Mayer-Kress (2005), rather than being seen as a problem for HEPA behaviour, the many and diverse degrees of freedom of a perception-action system can provide a degenerate platform for the emergence and

adaptation of behaviours in a natural environment. Adaptive behaviours signify that perception-action systems are stable when needed, and flexible when relevant (in terms of enhancing functionality). In fact, although a perception-action system typically tends to seek relatively stable states for reasons of energy efficiency and economy (Sparrow & Newell, 1998), stability and flexibility are not opposites on a continuum. Notably, flexibility is not a loss of stability but, conversely, is a sign of adaptability, in order to facilitate changes in movement patterns, at the same time, maintaining functional behaviour (Warren, 2006).

Degeneracy, thus, would reflect each individual's actualization of an affordance through various movement solutions. Perceiving opportunities for specific actions requires perceptual attunement and calibration to relevant informational variables (Fajen, Riley, & Turvey, 2009). This key idea implies that exercisers detect a range of informational variables from different sources (haptic, kinesthesis, auditory, visual) that inform them about a functional property of PA in a natural environment. Manufactured environments tend to be more uniform, bland and monotonous (exemplified by manicured lawns and topiary or organised spaces, in comparison with a natural environment space). However the higher variability of a natural environment may often be beneficial in the detection of information (Dykman & McClintock, 1998). This effect of variability is found in many non-living systems allowing information signals surrounded by background noise to be transmitted without being highly degraded, through the simple mechanism of adding an intermediate level of background noise. In nature's environments during physical activity, the textured visual, auditory, olfactory, kinesthetic and haptic information may function to enhance perception of abundantly available affordances. Such affordances are realized by means of fine perceptual attunement and calibration, making each action or gesture unique. They invite continuous interactions through exploratory behaviours. In contrast, even though we cannot repeat the same movement identically (Bernstein, 1967), running on a treadmill, or cycling on a gym ergometer, induces "automatic" or mechanistic actions. In short, the psychological, physiological, and social experiences differ in these different settings.

Due to incessant variations in texture, gradients, curvature, surfaces, ledges and barriers, the natural environment solicits the whole individual in each stride. It demands embodied and embedded (ecological) cognition and emotion in each course of action. It requests, what some may call, 'mindful action' (Lymeus et al., 2018). More than simple immersion, restoration or healing, or a distraction from daily problems, nature-based exercise demands engagement with affordances of nature through exploration and discovery. The continuously varying affordances of nature's environments, entail challenging psychological engagement and attunement. Through these affordances, HEPA activity in natural environments promotes mental health and well-being, through active exploration and the acquisition of skills and mastery. Health and well-being benefits emerge through adaptation to the fundamental variability of the natural environment, which can be transferred to other contexts (see also Ewert & McAvoy, 2000). Engagement with affordances of nature empowers physically active individuals, driving them to leverage the challenge to enhance health, well-being and performance (Kiefer et al., 2018).

3.3. Methods for understanding the empowering variability of affordances of nature

The human capacity to coordinate actions with the environment is predicated on the dynamic organisation of adaptive behaviours (see Araújo, Davids, & Hristovski, 2006 for a detailed explanation in sport psychology). Dynamics is a large and diverse set of concepts and methods, and consequently there are many different ways that psychological phenomena can be understood dynamically (Richardson, Dale & March 2014). Importantly, goal-directed behaviour can be modelled by eco-physical variables (variables that express the fit between the physics of the environment and an individual's adaptations, such as perceiving time-to-contact with a surface), normally from time series data (Araújo et al., 2017, 2006; Correia, Araújo, Vilar, & Davids, 2013). The modelling process is a matter of clarifying the phenomena to be understood, obtaining the time-series data, developing a model, and interpreting whether the model can explain a significant proportion of the data. When conducted successfully, the modelling process yields not only precise descriptions of existing data, but also predictions which can be used in evaluating the model (e.g., Araújo, Diniz, Passos, & Davids, 2014). A misunderstanding that might arise from the modelling emphasis on eco-physical variables, is that it cannot elucidate the psychological processes involved in regulating behaviours. However, psychological measures of goal-directed behaviour can be obtained by analysis of physical variables that capture the emergent ecological interplay of a person with key objects, events and others in a given environment. Moreover, environmental properties may directly inform an individual what he/she can and cannot do. For example, the rate of dilation of the image an approaching object on an individual's retina can provide time-to-contact information without the need to mentally compute either distance or speed of the object to intercept it (Lee, Young, Reddish, Lough, & Clayton, 1983). Therefore, the emphasis on eco-physical variables avoids the traditional tendency to search for variables putatively located *inside of the organism* that are deemed to 'cause' behaviour (i.e., in the mind as captured by self-reported intentions, self-efficacy, or motivations). Additionally, this emphasis avoids a behaviourist tendency to search for explanatory variables in the environment (e.g., the contingencies of reinforcement of behaviour) without considering the organisation of behaviour itself (see also Warren, 2006).

In addition to modelling, nonlinear methods are also vital to capturing the propensity for human behaviour to be multi-stable (i.e., two or more stable behavioural states are simultaneously possible, given the same situational factors) and degenerate. Interestingly, the use and development of nonlinear modelling and time-series analysis techniques within the psychological sciences has steadily risen over the past several decades (Richardson, Dale, & Marsh, 2014). For example, time series data for nonlinear analysis techniques include measurements of heart rate, movement, running speed, or verbalizations in a conversation recorded over seconds, minutes or hours. These techniques have allowed researchers to begin to investigate how human physiological, psychological and social behaviours emerge from the complex, interrelated processes of development, practising and everyday activity (Van Orden, Kloos, & Wallot, 2011).

A recently documented exploratory study offers a preliminary step in approaching HEPA behaviours from an ecological dynamics perspective. Testing the idea that more complex variability is needed when acting in unfamiliar running routes, Exel and colleagues (2017) quantified the type of variability (or more precisely, entropy which quantifies the regularity and/or complexity of a behavioural time-series, Fonseca, Milho, Passos, Araújo, and Davids (2012) investigated associations between heart rate and running speed of three recreational middle-distance runners in familiar and unfamiliar running routes, for the same task (45 min running at similar paces). They found that speed and heart rate variability presented a more complex structure in unusual routes, revealing more varied behaviours. This result is aligned with the hypothesis that exercise in a natural context provides more varied experiences. These experiences can be healthier, as demonstrated by empirical research that has contrasted indoor and green exercise environments) due to the empowering variability of affordances of nature. Moreover, future research can use eco-physical variables for running in nature, measuring variables such as stride length and duration, steps per minute, duration of foot contact with the ground, which express the continuous embodiment and embeddedness of psychological, physiological and social experience. The use of eco-physical variables in research and practice enables understanding of how psychological processes (such as approaching a goal, and avoiding

repelling zones, following Lewin, 1936; Kadar & Shaw, 2000), might be predicated on continuous, emergent, performer-environment interactions in physical activity.

In comparison to the existing theoretical approaches discussed earlier in this article, the theoretical framework of ecological dynamics offers a more parsimonious explanation in addressing the question: 'Why do exercisers feel better after performing the same exercise in natural environments than in indoor environments'? The 'empowering variability of affordances of nature' is a compelling explanation to account for the findings from the existing large body of empirical research simultaneously capturing the influence of individuals and nature, offering new paradigms for research. Our explanation of the unique benefits of nature-based exercise is centred on notions of affordances and variability. First, nature's affordances are less constrained than manufactured affordances. Second, the variability presented by nature's environments (and not genes, mental constructs, such as intention, self-efficacy or motivation; or specific brain areas) solicits immersive interactions and attention. Third, acting in nature's environments, due to their variability, demands the holistic involvement of an individual, where PA behaviour is cognitively and emotionally embodied and embedded (and not only when restoration, therapy, or stress reduction is needed). Fourth, the experience of nature-based HEPA provides an opportunity to develop expertise in dealing with challenging situations. Most probably, the unique benefits of green exercise and physical activity are predicated on nature's invitations for immersive, embodied engagement of the individual Consequently, individual-nature interactions in HEPA can be modulated by skill and personal characteristics when solicited by affordances of nature.

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