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The impact of the natural environment on the promotion of active living: An integrative systematic review

Giovanna Calogiuri^{1*} and Stiliani Chroni²

Abstract

Background: An understanding of how the living environment influences physical activity (PA) is of great importance for health promotion. Researchers have reported increased PA when there is a greater availability of nature within people's living environment. However, little has been said about underlying motivational processes. The aim of this study was to review the existing literature on the relationship between the natural environment (NE) and PA, integrating it into a conceptual model that depicts the motivational process underlying this relationship.

Methods: Through a systematic literature search in line with PRISMA guidelines, peer-reviewed articles were sought using PubMed (search updated to October 2013) and scrutiny of reference lists. In addition, we contacted experts within our network. We reviewed papers in which the research question(s) concerned: 1) Effects of PA in NE on individuals' feelings and beliefs; 2) Relationships between PA and availability of NEs; and 3) Motivational processes underlying visits to NEs in association with PA. Analysis and integration of the 90 selected studies were performed using the theory of planned behaviour (TPB).

Results: People's experiences in using the NE can enhance attitudes toward PA and perceived behavioural control via positive psychological states and stress-relieving effects, which lead to firmer intentions to engage in PA. Individual and environmental barriers, as expressions of social support and actual behavioural control, impact the process via subjective norm and perceived behavioural control. Instrumental beliefs such as a desire to enjoy nature and the expected health benefits also influence the process via attitudes. Different patterns have been identified for neighbourhood-based PA and outdoor recreations that take place in a NE.

Conclusions: The availability of a NE and attractive views of nature within an individual's living environment are important contributors to PA, yet attention should focus on personal characteristics and environmental barriers. Policy and infrastructural interventions should aim to guarantee access and maintenance of the NE, as well as information and programming of social activities. Social campaigns via media and health institutions should highlight how nature can be a source of motivation for maintaining a PA routine, reducing stress and achieving aesthetic and health goals.

Keywords: Natural environment, Health promotion, Physical activity, Attitude, Motivation, Exercise

Background

The benefits of physical activity (PA) in promoting health are well known. Despite this, a large portion of the population still does not meet the minimum recommended levels for PA, to the point that inactivity has been identified as the fourth leading factor in mortality

worldwide [1]. An increase in PA levels among the population is therefore a priority for public health. Policies that aim to encourage active lifestyles must act at a multilevel scale, targeting both the individuals and the living environment to induce behavioural changes in the population [2]. Mode of transport and recreation are two vital domains for an active lifestyle, but their sustainability on an everyday basis is strongly linked to motivational processes as well as environmental characteristics. For example, it has been reported that just the availability

* Correspondence: giovanna.calogiuri@hihm.no

¹Department of Dental Care and Public Health, Hedmark University College, Elverum, Norway

Full list of author information is available at the end of the article

of PA facilities, such as walking/cycling paths, is not sufficient to encourage people to embrace an active lifestyle [3]. Characteristics of the environment can influence PA behaviours by encouraging or discouraging a person to use the environment for PA purposes, however it is important to take into account *how* an individual's decision to be active is influenced by a supportive physical environment [4]. In recent years, the attention paid to the role of nature and natural environments (NEs – including green open spaces, neighbourhood gardens and attractive views of nature) that positively impact on PA behaviours has grown. NEs provide opportunities for individuals to engage in PA, so promotion of their importance for health through land-use planning has been advocated [5-7].

Systematic reviews of literature supported the view that the availability of NEs within people's living environment is generally positively related to more PA [8,9]. However, contrasting findings have also been reported, because some studies found weak or no associations between the availability of NEs and PA. Furthermore, concerns about the methodologies used have been expressed (e.g. inability to exclude confounding variables and reverse causality) and researchers pointed out the need to identify the motivational processes underlying the relationship between NE and PA for better planning of interventions [4,9]. Remarkably, systematic review studies [10,11] supported the finding that, when compared with PA taking place indoors or in urban settings, PA that is in touch with nature provides the individual with more pleasurable experiences, i.e. positive psychological states as well as psychological effects and, to a lesser extent, physiological effects on stress. So far, the 'behavioural' and 'psycho-physiological' outputs associated with the *PA-NE relationship* have been considered only independently of each other. Although integration of the two perspectives has been proposed, in the attempt to identify possible motivational processes [12-14], solid systematic methodologies and evidence-based approaches are still missing.

Why does nature make us 'feel good'?

The physiological stress response is a general mobilization of the organism, and involves hormonal and behavioural responses for facing a situation perceived as demanding or threatening to the individual; this can be influenced by physical and social environments [15]. Some psychoevolutionary approaches postulate that human beings are still innately linked to the NE as its natural ecosystem and are not fully adapted to the modernized urban setting, so that an environment devoid of nature may have negative consequences via activation of stress responses (see for example Grinde and Patil [7]). The absence of a NE would be associated with increased stress, and the presence of nature would reduce stress. According to Ulrich's stress recovery

theory [16], recovery from stress is facilitated by exposure to scenes that elicit feelings of mild-to-moderate interest, pleasantness and calmness. The theory assigns a restorative advantage to NEs and features of nature over artificial environments [16]. In other theories such as the attention restoration theory of Rachel and Stephen Kaplan [17], cognitive stress occurs primarily as a result of prolonged focus on tasks that are not perceived as interesting (e.g. repetitive work, paying attention to the traffic). Restoration can occur through a form of attention that is spontaneous and 'effortless'. Environments and experiences that provide such resources would produce opportunities for recovery from mental stress. NEs not only provide such opportunities, but also elicit *soft fascination* processes, which are especially effective at mitigating and preventing stress [17].

The exact mechanism underlying an individual's responses to nature has not yet been conclusively explained. Many theories assign the main effect of exposure to nature to visual 'recognition' [7], an assumption that is also supported by studies using images of nature (e.g. pictures/videos displayed on a screen) [16,18] and views out of windows [19,20]. A recent study identified the colour green as a 'primitive visual feature' of NEs that may contribute to the positive psychophysiological responses to being in touch with nature [21]. Other authors have postulated that some effects of exposure to NEs are induced by substances present in the air – wood essential oils, called phytoncides, produced by trees [22]. Alternatively, it has been suggested that NEs can reduce stress through social support [23,24]. Either way, several studies have shown that exposure to nature can elicit recovery from mental and physiological stress. Furthermore, as stress is tightly linked to psychological states [15], exposure to nature has been shown to provide vitalizing effects and enhanced psychological states, such as improved mood and positive affect [10,11]. The processes of stress recovery occurring to people walking in natural environments have recently been displayed by field measurements using a portable electroencephalograph (EEG) [25]. In addition, observational studies have revealed that residential proximity to NEs was associated with (1) reduced levels of perceived stress, possibly due to restorative opportunities eliciting coping mechanisms [26], and (2) biological indicators of stress such as cortisol production [27].

Motivation and active living: How can nature help?

Ajzen's theory of planned behaviour (TPB [28]) is suggested as one of the psychobehavioural models suitable for explaining motivational processes that underlie the relationship between environments and PA [4]. According to the TPB, behaviour is mainly driven by *intention*. In turn, intention depends on three psychological components: *attitude toward the behaviour*, *subjective norm*

and *perceived behavioural control*; these are linked to the person's *behavioural, normative* and *control beliefs*, respectively. *Intention* captures a person's motivation and indicates willingness to perform a given behaviour. *Attitude* refers to a person's favourable or unfavourable evaluation of the behaviour. *Subjective norm* refers to the social pressure placed on the person to perform or not perform the behaviour. *Perceived behavioural control* refers to beliefs about the ease or difficulty of performing the behaviour and reflects past experiences, along with obstacles inhibiting the person from performing the behaviour.

According to Ajzen et al. [29]: 'the more favorable the attitude and subjective norm, and the greater the perceived behavioral control, the stronger should be the person's intention to perform the behavior in question.' However, an *intention-behaviour gap* may occur. In line with the TBP, subjective norm and perceived behavioural control may have a direct effect and weaken the intention-behaviour prediction, even when there is a favourable attitude to engage in a certain behaviour. *Actual behavioural control* (i.e. the extent to which a person has the skills, resources and other prerequisites needed to perform a given behaviour) also has an important double-sided influence on behaviour by influencing perceived control over the behaviour, as well as the possibility of putting intentions into action [30]. The TPB has shown a strong prediction in determining whether a person will take action in a diverse array of domains. In the context of PA, it has been shown to predict walking where an NE was available [31], as well as participation in outdoor recreation [32].

Experimental studies have shown that positive experiences in PA can positively impact on people's attitudes toward PA and perceived behavioural control, leading to firmer intentions to engage in PA in the future. In turn, the environment in which PA takes place can play an important role when it comes to people's emotions in response to PA. For instance, it was found that walking outdoors, compared with walking indoors on a treadmill, was associated with more enjoyment and positive emotions, as well as a greater intention to engage in PA in the future [33,34]. Thus the positive experiences in NEs may lead to increased engagement in PA via attitudes and perceived behavioural control. However, the impact of the other constructs, such as subjective norm and perceived behavioural control, and other behavioural beliefs (e.g. expected health effects or feelings about nature) must be taken into account.

Objectives

Using an integrative review of the literature, the current study attempted to find an explanation for how availability of NEs within people's living environment can have a

positive effect on PA behaviour. The existing knowledge, approached here through the lens of TPB, provides us with multiple variables on which we may act to motivate people toward healthier active lifestyles.

Methods

The integrative review method, although criticized as less rigorous than other literature review methods (i.e. systematic reviews and meta-analysis), provided us with the opportunity to incorporate diverse methodologies (i.e. observational and experimental studies) to capture the context, processes and subjective elements of the topic better, and create new knowledge and perspectives [35].

Conceptual criteria

The term 'natural environment' is used throughout the paper to define open outdoor spaces that allow the individual to be surrounded by the elements of nature (trees, plants, grass, mountains, water, etc.) while engaging in PA. The term also includes outdoor built environments that are rich in vegetation or offer views of nature (*green neighbourhoods*). In accordance with the definition of PA by the World Health Organization (WHO) [1]: '... includes leisure time physical activity, transportation (e.g. walking or cycling), occupational (i.e. work), household chores, play, games, sports or planned exercise, in the context of daily, family, and community activities.' In an attempt to avoid confounding effects caused by actual inability to engage in PA, the current study was restricted to the 'healthy, non-athletic, adult population. An age cut-off of 16 years was chosen because it was found to be a cut-off age used in several studies. The literature search aimed to include peer-reviewed articles, in which the research question concerned:

1. Effects of PA in an environment of nature on individuals' feelings and beliefs
2. Relationships between PA levels and availability of NEs within the living environment
3. Motivational processes and reasons underlying visits to NEs in association with PA.

Literature search

Attention paid to search methodologies can enhance an integrative review's scientific validity [35]. As such, the literature search was based on a systematic review methodology, in line with the PRISMA statement [36]. Sources included databases and scrutiny of reference lists. In addition, we contacted behavioural and environmental psychology experts within our network (searches were guided by experts in the field of behavioural and environmental psychology who were known to the authors). At first, a literature search was performed on PubMed. Keywords used for the search were: *green space**, *natural*

*environment**, *outdoor**, *park* or *parks*, in combination with *exercise* or *physical activity*. Keywords were chosen on the basis of previous studies and through a preliminary investigation of the relevant literature. The combinations of keywords resulted in a total of 1273 titles (updated to October 2013), applying the filter *'field search for abstract/title'* and considering publications only in English with an abstract. Twenty-nine additional publications were identified through our network. Throughout the scrutiny process, 73 studies were included (Figure 1). Reasons for excluding papers were:

1. The presence and independent effect of NEs was not clearly stated
2. There was no measure of PA
3. PA was occupational or had athletic/competitive purposes
4. Although PA and NEs were measured or clearly reported, the study did not fall within one of the three above-mentioned *inclusion* criteria.

Studies that were considered to be duplicates or redundant were also excluded. The literature search was

then extended to the reference lists of the selected publications, identifying 17 additional publications. A review protocol was not registered.

Extraction and integration of the studies

All records were screened for eligibility and then reviewed by the first author. Basic information was extracted from the included papers and reported on a standardized spreadsheet. Tables were created and used for analysis, which was performed by the first author. The analysis tables and notes produced were then reviewed by the second author and disagreements discussed until consensus was reached. As the reviewed studies used a large variety of research designs, we were unable to identify a standardized instrument that could have been appropriately applied to all individual studies for quality assessment purposes. Alternatively, we reported sample sizes and study design for all the papers included (see, for example, Des Jarlais et al. [37] and Lu et al. [38]).

Integration and theoretical framework

Major themes were created on the basis of recurrent issues emerging from the papers included [39], but special

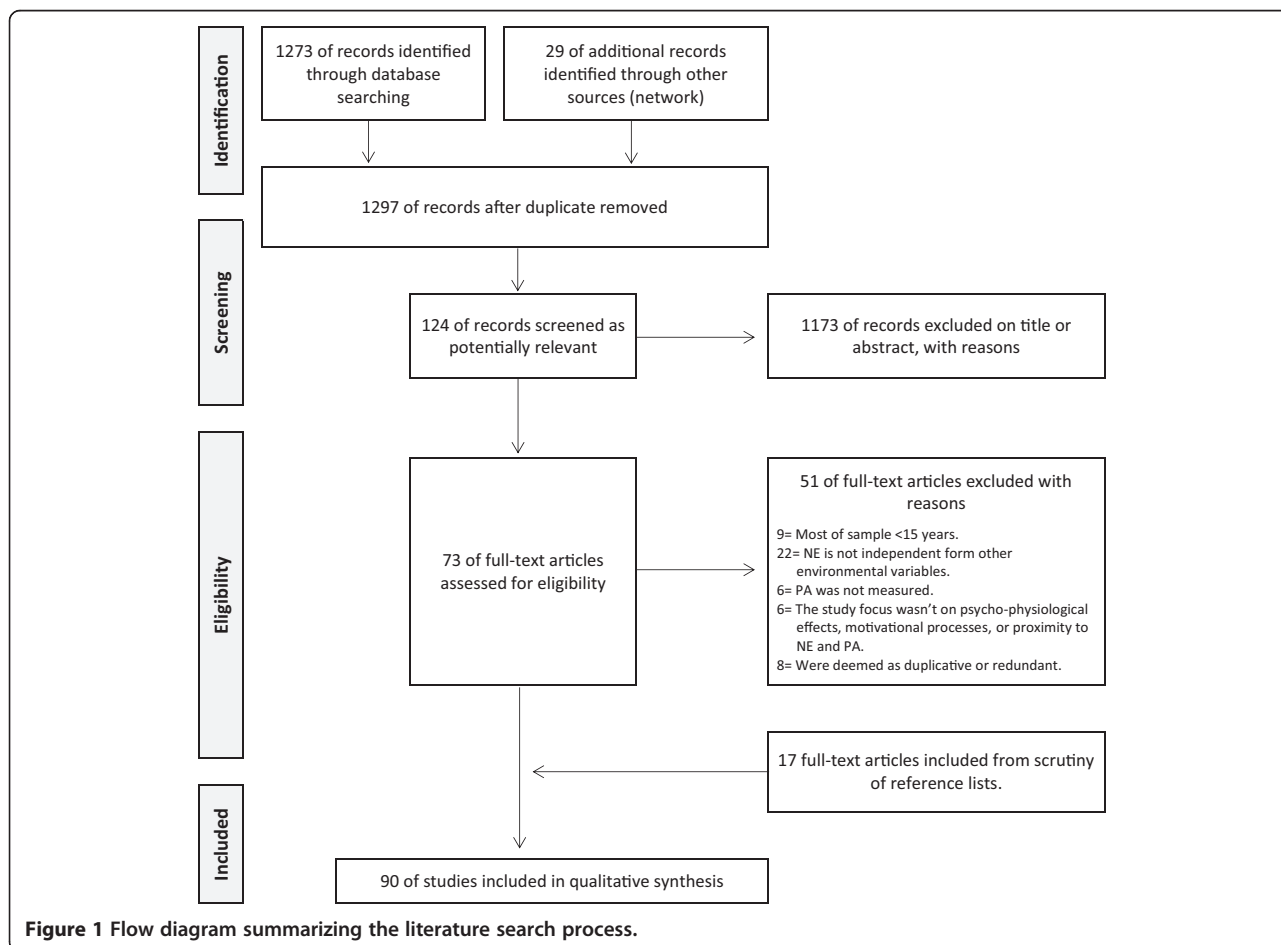


Figure 1 Flow diagram summarizing the literature search process.

attention was paid to organizing the themes in line with the TPB. Other theories used to inform our analysis and interpretations of the reviewed studies were Ulrich's stress reduction theory [16] and the Kaplans' attention restoration theory (ART) [17]. Last, the constructs identified in the reviewed studies that conceptually appear to fit the TPB model were portrayed graphically (Figure 2).

Results

Ninety papers were included in the current integrative review (Tables 1 and 2). Of these, 7 were reviews of literature (of which 4 used systematic methodologies – Table 2), 62 used observational design (4 were quasi-experimental and 4 prospective cohort studies), 1 was a report using meta-analysis for many studies and 20 reported experimental studies. All studies but one used quantitative methods. Overall, the studies included a total of 1,331,771 participants. Although many of them used generic samples of 'adults' (i.e. aged ≥16 or 18), some studies focused on age-specific groups, sampling a total of 15,060 adolescents, 1,176 young adults, 15,266 middle aged, and 5,173 older adults.

For the purposes of the current study dependent variables were classified as the four main constructs of the TPB: *behavioural beliefs* ('positive psychological states', 'stress relief', 'instrumental beliefs'), *normative and control beliefs* (including social support, and individual and environmental barriers), *intention* (including explicit environmental preference and motives for visiting NEs) and *PA behaviour* (Table 3). As *behavioural beliefs*, we classified positive psychological states that were mainly measured as 'mood' or 'positive affect' [21,40-55]. Other outcomes measured were 'enjoyment' [56], 'general happiness' [42] and 'self-esteem' [45,46,48]. One observational study also used indicators of mental health [57]. Stress relief was measured by both self-reported and biological indicators of stress. The former included mainly perceived stress [23,27,58] or the environment's perceived potential for restoration [42-44,59,60], whereas the latter included mainly measurements of stress hormones [22,27,40,54,55] and cardiovascular parameters [42,43,45,47,61]. Other biological measurements of stress included performance in attention tasks [42-44,52], brain waves on a mobile EEG [25] and salivary amylase [62]. Last, instrumental beliefs, such as perceived benefits

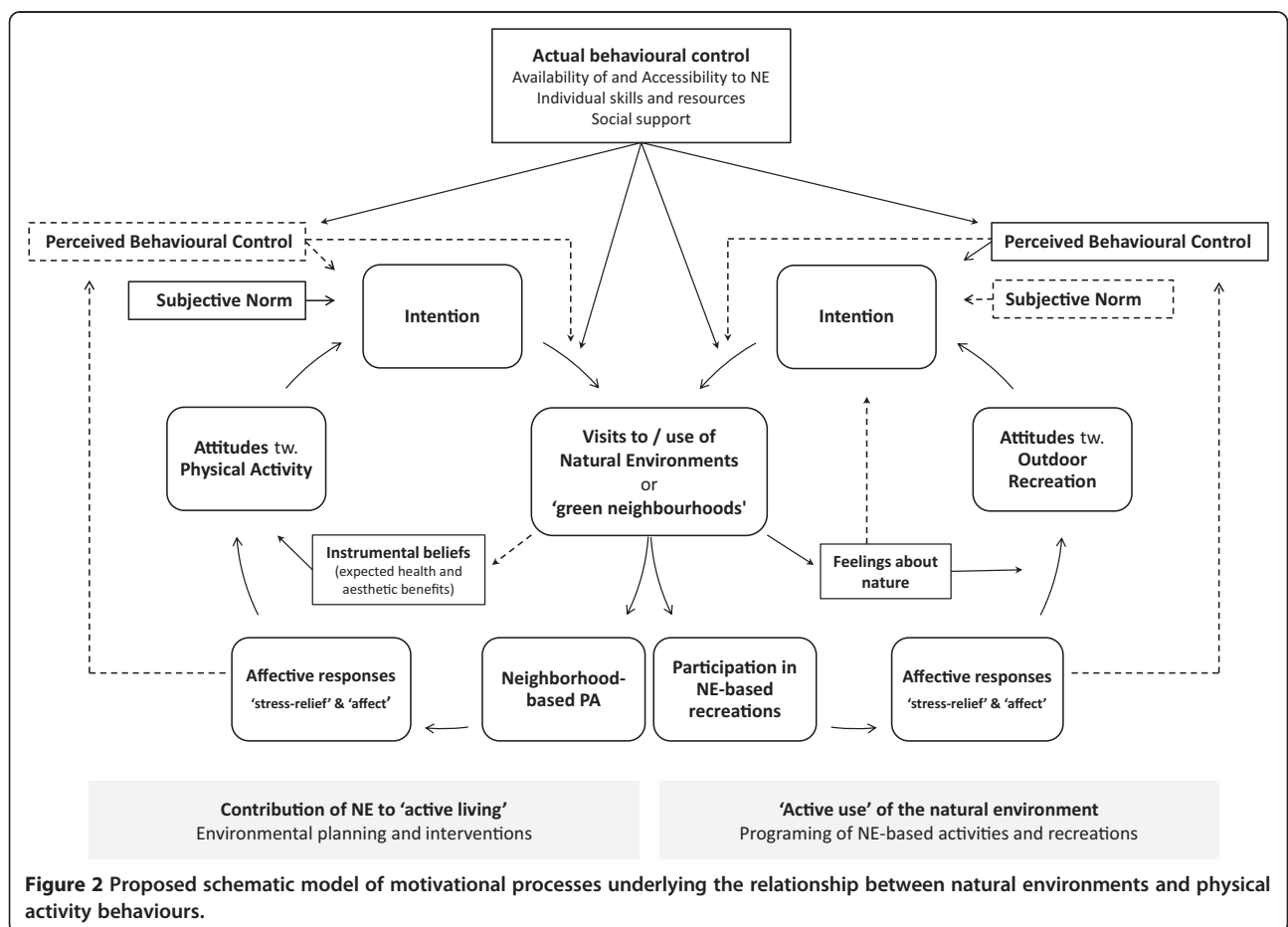


Table 1 Summary of papers included that report original research

| AUTHORS | SAMPLE SIZE | STUDY DESIGN | EXPERIENCE OF THE NATURAL ENVIRONMENT (NE) | TYPE OF PHYSICAL ACTIVITY (PA) | SUMMARY OF FINDINGS |
|-----------------------------|--|---|---|---|---|
| Akers et al. (2012) [21] | 14 young male adults | Experimental trial, with pre-test measurements and within-subjects, non-counterbalanced design. No control group. | Exposure to colour-manipulated videography of NEs. Standardized setting | Cycling. Standardized activity | The colour green was associated with greater improvements of post-exercise total mood and lower ratings of perceived exertion while exercising. |
| Anderson et al. (2008) [91] | 446 adults, 'proximate/resident' and 'distant/non-resident' visitors | Cross-sectional study (random sampling) and onsite survey (purposeful sampling). | Visitation of naturalistic parks (lake area). Standardized setting | Outdoor recreation such as fishing, camping, and motor boating. Self-reported | Important benefit factors to NEs visitors were 'enjoy nature', 'mental and physical health', and 'social interaction'. For people living nearby a NE, 'solitude' and 'learning' were also important benefit factors. |
| Aspinall et al. (2013) [25] | 12 adults | Experimental, within-subjects, non-counterbalanced design. No control group. | Experience of PA in an urban green-area (park). Standardized setting | Walking. Standardized activity | Measurements of brain-waves activity by a mobile EEG showed stress recovery mechanisms in line with Attention-Restoration Theory (Kaplan & Kaplan, 1989). |
| Bai et al. (2013) [65] | 893 adults living nearby parks | Cross-sectional study among residents within .5 miles from 60 parks | Availability and perceived quality of urban parks. Self-reported | Overall moderate to vigorous PA and park-based PA. Self-reported | There was a strong agreement among residents that having neighbourhood parks is a benefit. Perceived quality of parks was positively associated with overall and park-based PA. |
| Barton & Pretty (2010) [48] | 1,252 adults overall | Meta-analysis of 10 studies with matching measurements. Individual studies used pre-measurements with non-randomized allocation (self-selecting). | Experience of PA in different NEs. Standardized setting | Various green exercise activities. Standardized activity | A dose-response effect of green-exercise on mood and self-esteem. All types of NEs elicited greater post-exercise improvements, with different patterns identified for subjects' age, time of exposure and PA intensity. |
| Berman et al., 2008 [52] | 37 young adults (study 1) | Experimental trial using mixed design with counterbalanced cross-over. Random allocation. | Experience of PA in an arboretum/park. | Walking. Standardized activity | When compare to walking in an urban setting, walking in a NE after a mental-fatiguing-task was associated with improved performance in an attention task, which was not driven by changes in mood. |
| Bjork et al. (2008) [92] | 24,819 adults | Cross-sectional study using stratified random sampling design. | Availability of NEs with high recreational and restorative value in suburban and rural areas. Objective measure | Genial PA. Self-reported | Residential proximity to NEs was associated with neighbour satisfaction, time spent on PA and normal or low BMI. A positive effect on vitality in women was also found. |
| Bodin & Hartig (2003) [44] | 12 experienced runners | Experimental trial with pre-test measurements and counterbalanced cross-over design (two treatments). Random allocation (method not described) | Exposure to a NE (natural reserve). Standardized setting | Running. Standardized activity | PA in the natural environment was associated with greater potential for restoration, while statistically significance was not achieved for affective responses and attention performance. The subjects reported to prefer running in the natural environment. |

Table 1 Summary of papers included that report original research (Continued)

| | | | | | |
|-----------------------------------|-------------------------------|---|---|---|---|
| Boone-Heinonen et al. (2010) [83] | 10,773 adolescents | Cross-sectional study (sampling technique reported elsewhere). | Amount of green spaces and availability of parks in urban areas.. Objective measure | Wheel-based activities, active sports and exercise. Self-reported | Associations between availability of NEs and PA were found, especially in girls. |
| Butryn & Furts, 2003 [50] | 30 female experienced runners | Experimental trial using mixed design with counterbalanced cross-over. Random allocation not specified. | Experience of PA in an urban park | Running. Standardized activity | There were no differences in affective responses after running in the two environments, despite most of runners reported to prefer the NE. Safety issues may influence the experience of PA in the NE and consequent affective responses. |
| Cerin et al. (2008) [56] | 2,650 adults | Cross-sectional study using two-stage stratified sampling design. | Availability of different types of NEs in urban areas, including beaches/coasts trails and open spaces. Self-reported | Leisure time physical activity. Self-reported | PA was positively associated with perceived access to beaches/river/lakes, while significance was not achieved for open spaces such as parks and trails. Self-efficacy did not mediate the relationship. |
| Cerin et al. (2013) [75] | 484 older adults | Cross-sectional using stratified random sampling design. | Presence of nature elements within the neighbourhood in urban area. Self-reported | Leisure time walking and other PA Self-reported | Availability of NEs within the neighbourhood was associated with PA. Other attributes of the environment such as noise/air pollution, availability of spaces for walking and safety, were also predictors of PA. |
| Cohen et al. (2007) [76] | 1,318 adults | Direct observation and onsite interviews. | Availability of urban parks. Objective measure (onsite observation) | Park-based PA. Assessed through direct observation | The NE was an important source for PA opportunity for the users. Furthermore residential proximity to NEs was associated with frequency visitation the NE and PA. Men used the NE for PA purposes more often than women. |
| Coogan et al. (2009) [93] | 20,354 Afro-American women | Prospective cohort study. Recruitment based on subscription to a magazine. | Availability of urban parks. Objective measure | Utilitarian- and, exercise-walking. Self-reported | A weak association was found between distance to NEs and PA. Other factors associated with PA related to housing density, bus availability and access to transit. |
| Coombes et al. (2010) [94] | 6,821 adults | Cross-sectional study using single stage sampling based on electoral wards (equal size populations selected). | Availability of urban green-spaces. Objective measure | General PA. Self-reported | Residential proximity to NEs, especially those classified as 'formal green spaces', was associated with higher PA and lower probability to be overweight or obese. |
| Coutts et al. (2013) [95] | 67 counties | Cross-sectional study. Sampling technique not reported. | Availability of green-spaces within counties. Objective measure | Moderate to vigorous PA. Self-reported | Overall amount of NE within the county was positively associated with PA. |
| Cummins & Fagg (2012) [96] | 79,136 adults | Cross-sectional study over two time-periods. Sampling technique not reported. | Availability of nature elements within the neighbourhood in urban and rural. Objective measure | General PA. Self-reported | Mixed results were found in the relationship between obesity/overweight and residential proximity to NEs, with PA not mediating the relationship. Living in urban or rural areas was instead a relevant factor. |

Table 1 Summary of papers included that report original research (Continued)

| | | | | | |
|----------------------------------|-------------------------------------|--|---|--|---|
| Day (2008) [90] | 45 older adults | Qualitative, case study. Purposeful snowball sampling design. | Availability of nature elements (e.g. presence of gardens, sea view, trees, etc.) within the living environment. Self-reported and direct observation | Walking and general PA habits. Self-reported | NE was an important motivational factor to engage in PA for pleasure. Cleanliness, aesthetic, and restorative potential were environmental characteristics encouraging older people to go outdoors, for walking and socializing. Among the physical barriers, quality of the pavement was the most important. |
| Duvall & Young (2013) [89] | 62 experienced walkers | Observational study using a purposeful sample. Subjects recruitment through announcement. | Use of nearby nature. Self-reported | Walking. Self-reported | To set health goals and using good walking paths, especially using nearby nature, were the most useful strategies to sustain walking routines among experienced walkers. Social support was the least useful strategy, although it was associated with other types of PA. |
| Fan et al. (2011) [23] | 1,544 adults | Cross-sectional study (three-stage random sampling technique) and definition of a conceptual model. | Availability of vegetation and parks within the neighbourhood. Objective measure | Moderate to vigorous PA. Self-reported | PA was directly associated with availability of NEs and indirectly associated with reduced stress via improved social support. NE was positively associated with reduced stress, although different components of neighbourhood green had different influences on stress mitigation. |
| Foster et al. (2004) [77] | 4,157 adults | Cross-sectional study using multi-cluster random sampling design. | Availability of parks and open spaces within the neighbourhood (urban and rural areas). Self-reported | Walking. Self-reported | The availability of NEs was associated with PA in men, while walking behaviour in women was more influenced by perceived safety. |
| Foster et al. (2009) [97] | 13,927 middle-aged and older adults | Cross-sectional study. Recruitment through approach by general practitioner. | Availability of urban green-spaces (nature reserve, river walk, or public park). Objective measure | Different types of PA, for leisure or transportation purposes. Self-reported | There was no association between availability of NEs and PA. Traffic intensity had a negative impact on cycling. |
| Gatersleben & Andrews, 2013 [60] | 34 adults (study 2) | Experimental trial with counterbalanced cross-over design and control group (indoors with no PA). Random allocation not specified. | Exposure to actual and 'virtual' NEs with different characteristics. | Walking. Standardized activity | Compared to a NE with low prospect/ accessibility and high refuge characteristics, a NE with high prospect/ accessibility and low refuge were associated with greater improvement of mood. On the other hand low prospect/ high refuge certain types of NEs may be responsible for more stress due to increased fear. |
| Gomez et al. (2010) [78] | 1,966 older adults | Multi-level cross-sectional study using a two-stage randomized sampling design. | Availability of urban parks within the neighbourhood. Objective measure | WalkingSelf-reported | Associations between availability of NEs and PA were found. Other factors influencing PA behaviour were safety from traffic, pavement slope and connectivity. |

Table 1 Summary of papers included that report original research (Continued)

| | | | | | |
|-------------------------------|---|--|--|---|---|
| Gomez et al. (2010) [84] | 1,315 adults | Multi-level cross-sectional study using stratified and cluster sampling design. | Availability of urban parks within the neighbourhood. Objective measure | Leisure time PA. Self-reported | The availability of NEs predicted irregular and regular PA. Other environmental factors predicting PA were better connectivity and smaller pavement slope. |
| Harte & Eifert (1995) [40] | 10 male adults | Experimental trial with counterbalanced cross-over design (three exercise-treatments and a control). Randomized allocation (method not described) | Garden of a University Campus and indoor reproduction of outdoors sounds. Standardized setting | Running. Standardized activity | PA in an outdoor NE was associated with an external focus of attention, greater likability, improved mood and lower production of stress hormones as compared with PA indoors. |
| Hartig et al. (1991) [42] | 102 adults | Two studies: Quasi-experimental with pre-test measurements on three groups (one control). Experimental trial with pre-test measurements and between-subjects design (two treatments and a control). Randomized allocation (method not described) | Experiences in wilderness environment and a natural reserve. Spontaneously chosen environment and standardized setting | Vacation experiences and walking. Self-reported and standardized activity | Experiences in NEs were associated with greater restorative effects, overall happiness and improved cognitive performances as compared to the other experiences. Some effects on positive affect were also found. No effects were found on physiological indicators of stress (blood pressure and heart rate) |
| Hartig et al. (2003) [43] | 112 students | Experimental trial with between-subjects design (two treatments). Random allocation stratified by gender (method not described). | Natural reserve adjacent to a forest. Standardized setting | Passive contemplation and walking. Standardized activity | As compared to PA in a urban setting, PA in a NE elicited a reduction of the blood pressure, an improvement of attention and cognitive performance, and greater positive psychological responses (positive affect and reduced anger). |
| Hillsdon et al. (2006) [98] | 4,950 middle-aged adults | Cross-sectional study. Recruitment through approach by general practitioner. | Availability of urban green-spaces. Objective measure | General PA. Self-reported | No statistical evidence of a relationship between availability of NEs and PA was found. |
| Hoehner et al. (2010) [64] | 7 parks implementing interventions targeting different audiences (general park visitors, tourists, employees from nearby businesses and youths) | Synthesis of findings from seven quasi-experimental cases, each of which used pre- measurements. | National and urban parks. Standardized settings | Park-based activities, such as walking, hiking, biking on trails and kayaking. Self-reported, onsite observation and existing interventions | The interventions showed some effects on awareness of PA benefits on health and in encouraging 'active' use of NEs. Parks offer important sources of PA, and relatively simple and low-cost interventions can efficiently promote PA. |
| Hug et al. (2009) [59] | 319 members of fitness centres | Onsite survey (subjects approached for interview) | Outdoor NE with features for PA and exercise. Standardized setting | Gym-based PA. Self-reported | The NE was reported to provide greater potential for restoration than the indoor-exercise setting. Different restorative qualities predicted exercise frequencies in the different environments, with <i>compatibility</i> predicting frequency of PA in the NE. The use the NE was influenced by season and weather. |
| Kaczynski & Mowen (2011) [99] | 585 adults | Cross-sectional study using random sampling design (respondents selected from a property list). | Availability of urban parks. Objective measure (method not described) | Park based PA. Self-reported | Access to NEs was positively associated with PA. The association appear to not be determined by a self-selection phenomenon. E.g. people giving greater importance to NEs did not necessarily reside in areas with greater access to it. |

Table 1 Summary of papers included that report original research (Continued)

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|----------------------------------|------------------|--|---|--|--|
| Kaczynski et al. (2008) [85] | 380 adults | Cross-sectional study. Sampling through systematic selection of household in four neighbourhoods. | Availability and quality of urban parks. Objective measure | Park-based PA. Self-reported | Number of features and, to a lesser extent, size and residential proximity were significantly associated with use of a NE for PA purposes. Paved trails, unpaved trails and wooded areas were the stronger predictors of PA. Natural parks interconnected by trails may be effective for PA promotion. |
| Kaczynski et al. (2009) [79] | 384 adults | Cross-sectional study. Sampling through systematic selection of household in four neighbourhoods. | Availability of urban parks within the neighbourhood. Objective measure | Moderate to vigorous PA (general, neighbourhood- and park-based). Self-reported | Availability of NEs predicted the residents meeting minimum recommended PA levels, both general and park-based. Women, younger and older individuals were more likely to meet minimum recommended PA when NEs were available around home. |
| Karusisi et al. (2012) [63] | 7,290 adults | Cross-sectional study. Recruitment during health check-up (without <i>a priori</i> sampling). | Availability of urban green and open spaces within the neighbourhood. Objective measure | Jogging. Self-reported | Availability of NEs predicted PA behaviour (frequency and location), with neighbourhood experiences and attitudes towards health being only a modest mediator. Other factors predicting PA behaviour were socio-economic status, perceived neighbourhood's social cohesion, neighbourhood-related stress and having friends. |
| Kerr et al. (2006) [41] | 44 young adults | Two experimental trials with counterbalanced cross-over design (two treatments). Random allocation not specified. | Garden of a University Campus. Standardized setting | Running. Standardized activity | PA in a NE vs. PA indoors showed different effects on mood, with different patterns for competitive or recreational runners. The former reported greater rating of tension and effort, while the latter yield greater 'pride'. |
| King et al. (2012) [100] | 2305 adults | Multi-level cross-sectional study. Cluster and stratified random sampling design was used. | Availability of urban parks both referring to smaller and larger parks (type of park not assessed). Objective measure | Walking. Self-reported | Total NE area and proximity to NEs were respectively not associated and negatively associated with PA. |
| Kouthouris & Spontis (2005) [32] | 329 young adults | Observational and intervention (invitation to participate in an outdoor program). Convenience sample with recruitment through announcements. | Different setting for outdoors recreations. Standardized setting | Outdoor recreation program, including lake canoe/kayak, orienteering, and archery. Existing intervention | Theory of planned behaviour well predicted PA behaviour in the NE. PA was predicted by intention, which was in turn predicted by attitudes and perceived behavioural control. Subjective norm did not weight in the applied model, while an effect was observed for the added variable 'role identity'. |

Table 1 Summary of papers included that report original research (Continued)

| | | | | | |
|--------------------------------|---|---|--|--|---|
| Lackey & Kaczynski (2009) [69] | 574 adults | Cross-sectional study using random sampling design (respondents selected from a property list. | Availability of urban parks. Objective and perceived measure | Park- and neighbourhood-based PA. Self-reported | A poor match was found between perceived and objective distance to NEs. Some associations between proximity to NEs and PA were found. The match between perceived and objective proximity to parks was a predictor of park-based PA, with self-efficacy not being a predictor of the match. |
| Lee & Moudon (2008) [101] | 608 adults | Cross-sectional study using spatial randomized sampling design. | Presence of nature elements and views within the neighbourhood (urban area). Objective measure | Walking, cycling, moderate and vigorous PA. Self-reported | Presence of NEs was more commonly reported by sufficiently active individuals. Factors such as poor lighting, distance to destinations, hilly terrain, traffic and dangerous crossing conditions were barriers to PA. |
| Li (2010) [22] | 49 adults overall | Monographic review of a series of studies. The individual studies were experimental trials with non-counterbalanced cross-over design (two treatments). | Experiences of <i>Shinrin-yoku</i> (forest bathing trips). | Walking in forest environment. | As compared with trips in urban settings, <i>Shinrin-yoku</i> was associated with reduced stress hormones and improved immune resources, possibly via reduced allostatic load. Improvements in mood were also reported. |
| Li et al. (2011) [61] | 16 male adults | Experimental trial with pre-test measurements and non-counterbalanced cross-over design (two treatments). | Forest environments. Standardized setting | Walking (day trip). Standardized activity | PA in the NE, as compared to walking in urban environment, and reduced blood pressure, stress hormones and improve the profile of metabolic parameters. |
| Librett et al. (2006) [102] | 4,345 adults | Cross sectional using a stratified random sampling design. | Use of trails. Self-reported | General moderate to vigorous PA and trails visitation. Standardized activity | Trail-users were more likely to achieve minimum recommended levels of PA. Presence of NEs was reported to be important for choosing a place where to live. |
| Maas et al. (2008) [103] | 4,899 representing the overall population | Cross-sectional study using random sampling. | Availability of green-spaces within the neighbourhood (urban) Objective measure | Walking, cycling, sport activities and gardening Self-reported | In general, there was no significant association between availability of NEs and overall PA, e.g. meeting minimum recommendations. A negative relationship was found for cycling, while only gardening was positively associated with availability of NEs. Age-related differences were observed. |
| Mao et al., 2012 [55] | 20 young males | Experimental trial with between-subjects design and pre-test measurements. Random allocation. | <i>Shinrin-yoku</i> (forest bathing trips) | Walking. Standardized activity | As compared with PA in an urban setting, PA in the NE was associated with improved mood and profile of physiological indicators of stress (cortisol and immune parameters). |

Table 1 Summary of papers included that report original research (Continued)

| | | | | | |
|----------------------------------|--------------------------|--|---|--|---|
| Mason, Kearns & Bond (2011) [68] | 5,657 adults | Cross sectional study using random stratified sampling design. | Availability of urban parks and open spaces within the neighbourhood. Self-reported | Walking. Self-reported | Use and quality of NEs, along with general shops, were associated with more PA. Physical (perceived safety) and social aspects were the strongest predictors of PA. |
| Mayer et al., 2009 [53] | 232 young adults overall | Multiple experimental study using between-groups design with pre-test measurements. Random allocation not specified. | Experience of PA in natural settings and exposure to 'virtual reality. | Walking. Standardized activity | As compared with urban settings, walking in a NE was associated with improved connectedness to nature and positive emotions, with connectedness to nature mediating the effects on positive emotions. Experiences of real nature led to greater effects than experiences of virtual nature did. |
| McGinn et al. (2007) [104] | 1,659 adults | Cross-sectional study. Random digit dialled phone survey. | Perception of urban neighbourhood physical characteristics including natural elements as barriers to PA. Objective and self-reported measures | Leisure and transportation PA. Self-reported | There was little agreement between objective and perceived measurements of the environment. Perception of environmental barriers to PA (e.g. presence/lack of trees) was associated with different outcomes of PA. |
| Michael et al. (2010) [80] | 513 older men | Prospective cohort study. Recruitment through clinical sites and stratified sampling. | Availability of urban parks and trials within the neighbourhood. Objective measure | Walking. Self-reported | Older men living closer to a NE had increased probability to maintain or increase amounts of PA as compare to men living farther from NEs. Though, socio gradient was observed. |
| Michimi & Wimberly (2012) [105] | 931,116 adults overall | Two cross-sectional studies. Random digit dialled phone survey. | Proximity to outdoor recreational opportunities and availability of natural amenities in non-metropolitan areas. Objective measure | General PA. Self-reported | There was a positive association between availability of NE and PA, which was also associated with lower risk for obesity. |
| Mitchell (2012) [57] | 3,750 adults | Cross-sectional study. Sampling design not described. | Experiences of PA in different NEs (forest, woodland, open space, or park). Self-reported | General PA. Self-reported | PA in quality NEs as compared to PA in other environments was associated with a lower risk for poor mental health. |
| Morita et al., 2007 [51] | 498 adults | Experimental/Quasi-experimental trial using a mixed design with repeated measurements. Probable self-selection. Random allocation not specified. | <i>Shinrin-yoku</i> (forest bathing trips) | Walking. Non-standardized activity | As compared to a non-NE location, walking in a NE was associated with improvements of mood and anxiety. |
| Mowen et al. (2007) [74] | 1,515 older adults | Cross-sectional study with recruitment of subjects on different sites. | Availability of urban parks. Objective measure | PA 'status' (i.e. sedentary/active). Self-reported | Proximity to NEs was associated with more frequent visits to NEs and PA. The duration of visits which was longer in subjects living farther away, was not associated with PA. |

Table 1 Summary of papers included that report original research (Continued)

| | | | | | |
|---------------------------------|---|---|---|---|--|
| Mytton et al. (2012) [106] | 54,296 adults | Cross-sectional study. Cluster sampling with selection of respondents to be representative of national population. | Availability of nature elements and green-spaces within the neighbourhood. Objective measure | General PA and specific outdoor PA. Self-reported | Residing in neighbourhood with greater availability of NEs was a predictor of meeting recommended levels of PA, although this association was not explained by type of PA typically taking place in NE. |
| Nelson & Woods (2010) [81] | 2,159 adolescents | Cross-sectional study. Sampling technique not described. | Presence of natural elements along the way to/from school. Self-reported | Active commuting to school. Self-reported | Among other characteristics of the physical environment, there were some associations NEs and PA, although mixed results were found. Different patterns were observed across genders. |
| Ortega-Smith et al. (2004) [58] | 100 older adult users of the district parks | Cross-sectional study. Onsite recruitment. | Use of urban parks. Self-reported | Park based PA 'status' (sedentary/active). Self-reported | An indirect effect, although weak, of NE-based leisure on stress and health was observed. The relationship between NE-use, PA and stress was not clear. |
| Park et al. (2010) [47] | 280 young males overall | Multiple experimental trials, with pre-test measurements and counterbalanced cross-over design. Random allocation (method not described). | Forest environment. Standardized setting | Walking. Self-reported | As compared to urban environments, being in a NE was associated with an improvement of mood and physiological indicators of stress such as heart rate, blood pressure, salivary cortisol and indicators of cardiac autonomic control |
| Pate et al. (2008) [82] | 1,506 girls | Cross-sectional study. Subjects recruited in schools (all students invited), which were chosen with the goal of providing balanced sample. | Availability of parks within the neighbourhood. Objective measure | Moderate and vigorous PA. Self-reported | Along with other PA/recreational facilities, availability of NEs was positively associated with girls' participation in PA, although social-gradients (based on ethnicity) were observed. |
| Pretty et al. (2005) [45] | 100 adults | Experimental trial, with pre-test measurements and between-subjects design (four treatments and a control). Random allocation (method not described). | Exposure to images of NEs on a screen. Standardized setting | Light-intensity treadmill exercise. Self-reported | PA whilst viewing images of pleasant NEs was associated with reduced blood pressure, and improvements in self-esteem and mood profile, as compared with PA whilst viewing scenes of built environment. Images of unpleasant NEs had the most dramatic effect on psychological responses to PA. |
| Pretty et al. (2007) [46] | 263 adults | Quasi-experimental, with pre-test measurements. Cluster sampling design used to select random sample of cases. | Different setting for 'green-exercise'/ outdoor recreations activities in the countryside. Standardized setting | Different 'green-exercise' (PA in natural environment) e.g. walking in NE, horse-riding, and fishing, canal boating and conservation activities. Existing interventions | Experiences of green exercises were associated with improved mood and self-esteem. |

Table 1 Summary of papers included that report original research (Continued)

| | | | | | |
|--------------------------------|---|---|--|---|--|
| Prince et al. (2011) [70] | 3,883 adults | Cross sectional study. Random digit dialled phone survey, applying standard survey weights. | Availability of urban green-spaces and parks within the neighbourhood. Objective measure | General PA. Self-reported | No associations or even some negative ones were found between availability of NE and PA. Association between PA and food environment, social cohesion, socio-economic status of the neighbourhood and were observed. Different patterns across genders were observed. |
| Prince et al. (2012) [71] | 4,727 adults | Cross sectional study. Random digit dialled phone survey, applying standard survey weights. | Availability of urban green-spaces and parks within the neighbourhood. Objective measure | Leisure time PA. Self-reported | There was some association between availability of NEs and PA. Associations were observed also for food environment, crime and season with different patterns across genders. |
| Rhodes et al. (2006) [31] | 315 adults | Cross sectional study using random sampling. | Availability of attractive natural sight within the neighbourhood. Self-reported | Walking. Self-reported | Theory of planned behaviour [28] efficiently predicted the environment-walking relationship, with NEs and land-use-mix predicting PA via affective and instrumental attitudes and, to a lesser extent by subjective norms. Perceived behavioural control did not relevantly weighted in the model. |
| Richardson et al. (2013) [107] | 12,488 youth and adults | Cross-sectional study. Sampling design not described. | Availability of vegetation and green-spaces within the neighbourhood. Objective measure (national databases) | Moderate to vigorous PA. Self-reported | Availability of NEs was associated with probability to meet recommended PA levels, and reduced risk for poor mental health and cardiovascular diseases. |
| Ries et al. (2009) [66] | 329 adolescents (predominantly Afro-American) | Cross-sectional study. Non-randomized recruitment among two schools. | Availability of urban parks within the neighbourhood. Objective and self-reported measures | General PA and park-based PA. Self-reported and measured by accelerometry | Associations between the availability of NEs and PA were observed. Use of NEs by peers, age, gender and ethnicity/race also influenced the NE-PA relationship. |
| Rodriguez et al. (2012) [108] | 293 adolescent girls | Prospective cohort study. Recruitment among from a previous study. | Availability of urban parks within the neighbourhood. Objective measure | Moderate to vigorous PA. Accelerometry and GPS | NE, along with presence of schools and population density, was positively associated with PA. Road length and number of food outlets was negatively associated with PA. |
| Ryan et al. (2010) [49] | 66 young adults (study 2) | Experimental trial, with pre-test measurements and between-subjects design. Random allocation (method not described). | Experience of PA in a NE. Standardized setting | Walking. Standardized activity | Walking in a NE had greater impacts on subjective vitality than walking in an interesting and varied indoor setting. |
| Scott & Jackson (1996) [67] | 1,054 adults | Cross-sectional. Random digit dialled phone survey. | Use of different types of public parks. Self-reported | Park visitation. Self-reported | 'Lack of time' was the most commonly reported reason for not visiting NEs. Older women were less likely to visit parks because of fear of crime, lack of companionship and poor health. Improvement of programming and information would encourage more visits to NEs. |

Table 1 Summary of papers included that report original research (Continued)

| | | | | | |
|--------------------------------|------------------|---|---|---|--|
| Sharpe et al. (2004) [3] | 1,936 adults | Cross-sectional. Random digit dialled phone survey. | Availability and use of parks and other outdoor recreations facilities (e.g. trails and routes for walking and cycling). Self-reported | Moderate to vigorous PA. Self-reported | Among other environmental and policy factors, use of NEs was associated with PA. However, knowledge and quality of the infrastructure were important factors in determining the use of NEs for PA purposes. |
| Shores & West (2009) [88] | 139 young adults | Observational study using convenience sample (students recruited during classes). | Perception of public parks as a source of 'leisure' ("activity enjoyable for its own sake"). Self-reported | Leisure time PA. Self-reported | Most of PA perceived as 'leisure' was carried out in private fitness centres and dance clubs. NEs were only a small source of the leisure-time PA. Companionship and sociality appear to be important factors for engaging in leisure PA. |
| Shores et al. (2008) [72] | 454 older adults | Cross-sectional study using stratified random sampling design. | Availability of parks in rural areas. Self-reported | PA status (active or inactive). Self-reported | Proximity to NEs was positively associated with PA. Other important variables predicting PA were access to social support, safety and reported ability to walk to a local park. |
| Stigsdotter et al. (2010) [87] | 11,238 adults | Cross-sectional study using stratified random sampling design. | Proximity to green-spaces and motives to visit them. Self-reported | Various PA and outdoor recreations. Self-reported | PA was reported as the most important reason for visiting NEs from less stressed individuals; those who are more stressed visit NEs to relax, seek for quiet places and engage in social activities. Proximity to NEs was associated with more frequent visits to NEs, better quality of life and less stress. |
| Sugiyama et al. (2008) [24] | 1,895 adults | Cross-sectional study using cluster random sampling design. | Perception of availability of nature and green-spaces within the neighbourhood (urban). Self-reported | Leisure and transport walking. Self-reported | The NE was a predictor of PA and social factors. PA explained the link between the NE and physical health. The relationship between NE and mental health was only partly accounted for by PA and social coherence. |
| Thompson et al. (2012) [27] | 25 adults | Observational exploratory study, using convenience sampling design. | Availability of green-space within the neighbourhood (urban). Self-reported | General PA. Self-reported | Availability of NEs was associated with less perceived stress and, along with PA, with better cortisol profiles. A direct association between availability of NEs and PA was not found. |
| Toftager et al. (2011) [109] | 21,832 adults | Cross-sectional study using stratified random sampling design. | Proximity to green spaces (beach, seaside, lake, park, urban green space, forest or other open green spaces excluding agricultural fields). Self-reported | Leisure time moderate to vigorous PA. Self-reported | Proximity to NEs was associated with more PA. People living closer to NEs had increased chances in using it for PA purposes. |

Table 1 Summary of papers included that report original research (Continued)

| | | | | | |
|-------------------------------------|--|---|---|--|--|
| Van den Berg & Custers, (2011) [54] | 30 middle-aged adults | Experimental trial with between-subjects design and pre-test measurements. Random allocation. | Experience of gardening activity. | Gardening. Standardized activity | After an induced stress, both reading and gardening were associated with an improvement in stress parameters (mood and salivary cortisol), with greater improvements observed after gardening. The difference between the 'stress recovery' interventions was somewhat weak. |
| Ward Thompson et al. (2012) [110] | 96/61 older adults | Cross-sectional and longitudinal cohort / quasi-experimental study, with pre- and post-intervention measurements. | Availability of urban parks and other natural environments. Self-reported / perceived | General PA & any outdoor activity. Self-reported and measured by accelerometry | Availability of clean and quite NEs with attractive, barrier-free routes to it was positively associated with more PA. No significant change of PA ratings was found after the neighbourhood improvement intervention. |
| Wen & Zang (2009) [111] | 3,530/907 adults | Multilevel cross sectional study. Random digit dialled phone survey. | Availability of urban parks within the neighbourhood. Objective measure | Exercise behaviour. Self-reported | Access to NEs was not associated with PA. Predictors of PA were social capital and access to restaurants/bars. |
| Wen et al. (2007) [73] | 41,545 adults | Cross-sectional study. Random digit dialled phone survey. | Availability of parks/open-spaces within the neighbourhood. Self-reported | Leisure and transport walking. Self-reported | Availability of NEs along with neighbourhood social cohesion was positively associated with PA. Individual socio-demographic and safety did not have significant effects on PA, while differences for race/ethnicity were observed. |
| West et al. (2012) [112] | Adult respondents within 67 metropolitan statistical areas | Cross-sectional study using random sampling design. | Availability of urban parks within the neighbourhood. Objective measure | Moderate and vigorous PA. Self-reported | Availability of NEs was positively associated with probability of meeting PA recommendations, and negatively associated with risk of being overweight/obese. |
| Wilson et al. (2011) [86] | 10,286 middle-age adults | Cross sectional study using a stratified two-stage cluster design. | Availability of different NEs. Objective and self-reported measure | Walking. Self-reported | Different NEs had different effects on PA. E.g. proximity to rivers and coasts was positively associated, while tree coverage was negatively associated and proximity to parks was not associated. Other environmental factors also predicted PA. |
| Witten et al. (2008) [113] | 12,529 youths and adults | Cross-sectional study. Sampling design not reported. | Availability to different NEs. Objective measures | Brisk walking, moderate and vigorous PA. Self-reported | Different NEs had different effects on PA and BMI. E.g. parks were not associated with PA, while some associations were found for beaches/coasts. |
| Yamaguchi et al. (2006) [62] | 15 young males | Experimental trial, with counterbalanced cross-over design (two treatments and a control). | Low threshold exercise in NE. | Walking. Standardized activity | As compared to urban environment, PA in NE was associated with an improved profile of indicators of sympathetic nervous activity (salivary amylase). |

Table 2 Summary of papers included that report theoretical studies and literature reviews

| AUTHORS | NUMBER OF INCLUDED PAPERS | STUDY DESIGN | EXPERIENCE OF THE NATURAL ENVIRONMENT | TYPE OF PHYSICAL ACTIVITY (PA) | SUMMARY OF FINDINGS |
|----------------------------------|---------------------------|--|---|---|--|
| Bedimo-Rung et al. (2005) [5] | Not reported | Theoretical paper based on existing literature. | Availability and perception of urban parks and other NEs | Park-based activities | A conceptual model based on an analysis of literature depicts how park features, condition, access, aesthetic, safety and policy might enhance or undermine physical activity levels and public health. |
| Bowler et al. (2010) [10] | 24 papers | Systematic review of literature with meta-analysis. Assessment of quality not reported | Experiences in various NEs, including laboratory and outdoor settings | Various, including laboratory-based experimental trials | Exposure to the NE whilst engaging in PA is associated with greater health benefits than PA alone, especially for what concerns psychological outputs (e.g. positive emotions and indicators of mental health). Benefits of PA in contact with nature on indicators of physical health, such as blood pressure and cortisol production, remain somehow inconclusive. |
| Gelter (2000) [12] | Not reported | Theoretical paper based on existing literature. | Experiences in the wilderness. | <i>Friluftsliv</i> (traditional Scandinavian outdoor recreations) | Friluftsliv is analysed in relationship with its socio-historical background and underlying physiological mechanisms. Implications for environmental and PA education are discussed. |
| Gladwell et al. (2013) [14] | Not reported | Theoretical paper based on existing literature. | Contribution of the NE to PA and health. | General PA, active living. | The impact of the NE for human health, including possible motivational mechanisms that may encourage PA, is discussed. |
| Kaczynski & Henderson (2007) [8] | 50 papers | Systematic review of literature. Assessment of quality not reported | Availability of parks. | General PA, including neighbourhood-based PA and active transport, among others | Availability of NEs was generally associated with more PA and health within the community. Parks, trails, and other open spaces had some of the most consistent relationships with PA, when compared with indoor recreation facilities and sport centres. |
| Lee & Maheswaran (2011) [9] | 35 papers | Systematic review of literature. Assessment of quality was performed and reported. | Availability of NEs, prevalently urban green spaces | General PA, including neighbourhood-based PA and active transport, among others | There are evidences of a positive association between availability of NEs and health via PA. Anyway, the relationship between access to NEs, PA and health is likely to be complex, and yet remain controversial. Methodological challenges and quality of the available studies in this field are discussed. |
| Thompson Coon et al. (2011) [11] | 11 papers | Systematic review of Literature. Assessment of quality performed and reported. | PA experiences in various settings, including laboratory and outdoor settings | Various, including laboratory-based experimental trials. | Compared with PA indoors, PA in NE had greater effects on indicators of mental health and well-being. Methodological challenges and quality of the available studies in this field are discussed. |

Table 3 Analysis of studies included based on constructs of the theory of planned behaviour

| Type of physical activity output | Overall positive effects | Partially or moderately positive effects ^a | Mixed or no effects ^b | Overall negative effects | Study of underlying mechanism ^c |
|---|--|---|----------------------------------|--------------------------|---|
| Behavioural beliefs | | | | | |
| Psychological states ^d | [10,11,21,31,40,43,45-49, 51-55,57] | [92,107] | [41,44,50] | | [21,31,48] |
| Stress relief (psychological) ^e | [23,31,44,59,87] | [10,27] | [58] | | [60] |
| Stress relief (physiological) ^f | [25,27,43,47,61,62] [42,43,55] | [10,40,45,58] [54] | [42,44] | | [25] |
| Instrumental beliefs | [65,91] | [64] | | | [31,63,89,91] |
| Feelings about/interest in nature | [53,91] | | | | [53,59,67,91] |
| Normative and control beliefs | | | | | |
| Perceived behavioural control/ self-efficacy | | | | | [31,32,56,69,88] |
| Social support | [23,24,87,91] | | | [59] | [24,63,66,68,70-73,88,111] |
| Personal barriers | | | | | [9,59,67,70-72,75-82,88] |
| Environmental barriers | | | | | [3,9,23,24,31,50,58,63,64, 66-75,77,78,80,81,83-87, 90,93,96,97,100,101,103, 104,106,109,110,113] |
| Behavioural intention | | | | | |
| Intention to visit NEs or engage in PA | [31] | [67,102] | | | [31,32] |
| Motives for visiting NEs | [109] | | | | [67,87,91] |
| Likeability/Preference | [40,44,50] | | | | [5,12,14] |
| PA behaviours | | | | | |
| General PA | [23,24,31,56,63,65,72,73, 75,78,79,83,84,87,92,94, 95,101,102,105-110,112] | [3,8,9,64,66,68,69,71,77, 80,82,88,93,113] | [27,70,81,86,96-98, 103,111] | [100] | [31,104] |
| NE-based PA | [63,65,76,79,85,99,109] | [64,66,69] | [58,74,103,106] | | [5,12,14,32,59,99] |

Theoretical and literature studies are highlighted in bold.

^(a)Significance was of moderate extent (e.g. other factors were more relevant), or achieved for only part of PA outputs or population subgroup.

^(b)The analysis returned no effects or mixed effects, i.e. some positive and some negative, in relation to different study variables or population subgroups.

^(c)The study describes mechanisms underlying the effects of NE on the specific variable.

^(d)Mood, self-esteem, vitalization, positive affect, happiness, and mental health parameters.

^(e)Perceived environment for restoration, self-reported stress.

^(f)Stress hormones, blood pressure, other indicators of allostatic load (e.g. salivary amylase and heart rate variability, and brain-wave activity).

[31,63-65] and feelings about nature [53], were used either as dependent or independent variables, or included in mediation models. Furthermore, we identified a number of normative beliefs [31,32,63,66-68] and control beliefs [23,24,31,32,56,59,63,66-86], which were also widely used as controlling/moderating variables.

Under the *intention* construct, we classified outcomes that included intention to walk [31] or engage in outdoor recreations [32] and 'likeability/preference' (i.e. whether the participants preferred to engage in PA at either an NE or a control environment) [40,44,50]. Motives/reasons for visiting NEs [67,87-91] were also considered in relation to intention. For *PA behaviour* we classified outcomes referring to PA measurements as a dependent variable in relation to NEs, studied only in observational studies [3,23,27,31,32,56,59,63-66,68-88,90,92-113],

whereas in experimental studies PA was set as an intervention. In several studies the behavioural outcome concerned general levels of PA, leisure-time PA or moderate-to-vigorous PA. A number of studies measured specific types of PA that take place in NEs, such as walking, cycling, gardening and NE-based PA [24,31, 32,59,63-66,68,69,74-80,85,90,93,97,99-101,103,104,106, 109,110]. Most of the studies used self-reported measurements of PA, whereas only a few studies used objective measurements such as actigraphy [66,108,110] or direct observation [76,85].

In the reviewed studies, various NEs were examined, including forests and national parks, and urban green spaces or the presence of elements of nature within the neighbourhood. NEs consisted mainly of vegetation (e.g. trees, gardens or parks), although several studies also

included water (e.g. lakes, beaches and sea views). Four experimental studies used 'virtual' NEs, displaying images of them [21,45,53,60]. Most of the studies used objective assessments of the NE. However, some studies used self-reported or perceptions of NEs [3,24,31,68,72,73,75,77,102,104,109,110], and others a combination of perceived and objective measurements [63,66,74,85]. In several studies, NEs were defined as 'parks' without explicit reference to the amount or type of nature contained within it [3,65,66,71-74,76,78-80,82,84,93,99,100,108,111,112]. Therefore, it may be assumed that in these studies NEs were mixed with different types of built environments such as playgrounds and sports fields. In two experimental studies, NEs referred to outdoor space surrounding a college campus [40,41].

With regard to the specific types of PA (including studies in which PA was not the dependent variable), of the studies reviewed, general PA levels and walking were the types most represented [22,24,25,31,42,43,47,49,51-53,55,60-62,64,68,73,75,77,78,80,86,89,90,93,100,101,103,104,113]. Other PA types included running/jogging [40,41,44,50,63], NE-based PA [23,59,64-66,69,76,79,85] and outdoor recreation [32,46,67,87,91,106,110]. In two studies, gardening was also used as a dependent variable [103] or intervention [50].

Underlying TPB beliefs

Behavioural beliefs

Positive psychological states In line with existing reviews [10,11], we found that PA in touch with nature was quite consistently associated with greater benefits in terms of positive emotions and psychological states, compared with PA in the indoor and/or urban setting. Improvements in mood and positive affect were shown in case studies [42,46], as well as in controlled trials, in which experiences in NEs were compared with those in urban settings [43,47,51-53,55,61] or indoors [40,42,49,53,60], and also in laboratory studies where participants exercised on a treadmill while images of NEs or built environments were displayed on a screen [21,45]. Positive effects were also found on participants' self-esteem [45,46,48], happiness [42] and indicators of mental health [57], again with positive effects shown for experiences in a NE. Furthermore, it was found that affective beliefs such as enjoyment [31,56] influenced the relationship between perceived availability of NEs and number of people engaging in leisure PA. In particular, positive effects on psychological states were found when participants were engaged in 'light' PA such as walking [42,43,45,47,49,51-53,55,60].

Whether the intensity of the PA can impact the positive psychological states associated with exposure to nature appears to be somewhat controversial. In a meta-analysis investigating the dose-response of psychological responses

to PA in NEs, it was found that improvements in self-esteem decrease with growing PA intensity, whereas effects on mood were depicted better as a 'U'-shaped dose-response curve, with greater improvements for light or moderate-to-vigorous PA intensity [48]. A dose-response was observed for the duration of exposure to PA in NEs, with shorter exposure (5 minutes) showing the greatest effects [48]. Some studies on running [41,44,50] did not find positive effects for NEs on participant mood. However, it was observed that a perception of lack of safety may have influenced the mood when running in NEs [50], and some limitations were the result of small sample size [44]. On the other hand, one study on running [40], and studies using other types of outdoor recreation [46] that are more intensive or complex than walking, showed positive effects on psychological states.

Stress relief

Individuals who had higher stress ratings, reported visiting NEs to 'relax', 'seek quiet places' and 'get away from the usual demands of life' [87,91]; they tended to stay longer when they visited the NE [58]. The NE is perceived as providing greater potential for restoration, compared with indoor exercise facilities and urban settings [42-44,59,60], and apparently engaging in vigorous PA does not reduce such a perception of the environment. In fact, NEs were assigned greater potential for restoration than other environments, irrespective of whether the participants were walking at a comfortable pace [22,25,42,43,45,47,49,62], running [40,44] or engaging in other forms of PA and recreation [23,27,59]. In a recent study using a mobile EEG, while participants walked in NEs after an induced stressor, researchers were able to show that brain wave activity indicated stress-relief effects in accordance with the Kaplans' ART [25]. Moreover, access to NEs and PA was associated with reduced self-reported stress and biological indicators of stress [23,27,58,87], although the interrelationships of NE, PA and stress were not fully explained. It has been suggested that PA may play an intermediate role, indirectly eliciting stress relief through social support [23,58,87]. However, in an exploratory study, a direct effect of PA on stress was observed, parallel to but independent of the NE [27]. In addition, several experimental studies showed positive effects on different indicators of psychosomatic stress when PA was in an NE compared with PA in other environments (i.e. indoor or urban settings) [40,47,54,55,62], although systematic synthesis indicated that, overall, the effects of PA in NEs on stress hormones remain somewhat inconclusive [10,11]. Mixed results have been reported with regard to blood pressure, because some studies reported positive effects after experiences of PA in NEs [43,45,47,61] whereas others found no effects [42], or even

negative effects when PA was associated with unpleasant images of NEs [45].

Instrumental beliefs

Instrumental beliefs, such as expected health benefits of PA, are likely to influence participation in PA, irrespective of the environmental conditions. Instrumental beliefs were found to mediate the environment-walking relationship [31]. Having health goals, along with using environments that support walking, were found to sustain walking routines [89]. However, attitudes towards health seem to have a small effect on mediating the relationship between the availability of NEs and neighbourhood-based PA behaviour [63]. On the other hand, some studies suggest that NEs may impact people's attitudes toward PA via instrumental beliefs. For instance, there was a strong agreement among people living near to parks that availability of neighbourhood NEs is a benefit, and such a belief was associated with higher general and NE-based PA [65]. 'Mental and physical health' was found to be an important benefit reported by visitors to NEs [91], and proximity to green spaces was positively associated with visiting NEs for 'exercise and keep in shape' [109]. Moreover, NE-based interventions have been reported to have some positive impacts on enhancing awareness of the benefits of PA for health [64].

Feelings about nature

Some traditional/philosophical approaches to outdoor activities refer to the feelings of 'commitment to nature', which are associated with the perceived need to be in touch with nature and the wilderness [12]. Increases in connectedness to nature (a measure of individuals' trait levels of feeling emotionally connected to the natural world) were found to mediate the positive psychological states in response to experiences in nature [53]. Compatibility (the perceived restorative quality described in Kaplans' ART that quantifies to what extent an environment is compatible with the individual's inclinations or preferences) predicted the frequency of exercising in the NE [59]. Accordingly, 'enjoy nature' was an important benefit reported by visitors to NEs [91], whereas the lack of interest in engaging in NE-based recreation (e.g. 'pursue recreation in other areas' and 'don't like to participate in nature or outdoor recreation') was reported as a recurrent reason by people who do not visit NEs [67]. Although we identified few studies taking into account how an individual's feelings about nature impact the relationship between PA behaviours and positive psychological responses to experiences in nature [53,59], overall the findings indicate that individuals with stronger feelings about nature may be more predisposed to visit available NEs. Feelings about nature can represent a motivational factor for engaging in outdoor recreations,

which then allow a person to be in close touch with nature. On the other hand, in activities such as neighbourhood walking or jogging, the individual-NE relationship is more 'superficial', with the NE providing a quiet and aesthetically pleasing environment for the individual [31,63]. Here instrumental beliefs such as health and aesthetic goals may play an important role. Interestingly, some studies reported that experiences in nature can increase people's connectedness to nature [53]. Unfortunately, implications for this effect on PA behaviour, i.e. whether interventions aiming to increase people's feelings about nature increase their predisposition to use available NEs for PA purposes, have not been explored.

Normative beliefs

To what extent normative beliefs influence PA behaviours in NEs have revealed mixed results. For instance, subjective norm was found to mediate the association between perceived availability of NEs in the neighbourhood and walking [31], whereas no effect predicted participation in outdoor recreation [32]. PA is an opportunity to meet friends and spend time with them, so an individual's choice to engage in PA, as well as its location, can be subjected to influences by friends' perceived expectations [88]. Companionship or having friends to engage in PA with has been identified as a factor influencing participation in leisure PA, as well as the use of NEs for PA purposes [66-68]. For example, people who choose to use a NE as an arena for PA report less expected social benefits, while their choice is weighted more by the individual's environmental compatibility (see 'Feelings about nature' above) [59]. It was found that college students spent most of their leisure PA in fitness centres and dance clubs, which are meeting points for school mates and friends, whereas NE-based PA was less endorsed [88]. Similarly, individuals who envisage companionship as a motivational strategy engaged in less neighbour-based PA such as walking, although they engaged more in other forms of PA [89].

Control beliefs

Perceived behavioural control and self-efficacy (conceptually similar to perceived behavioural control [28]) are known to influence participation in PA, irrespective of the environmental conditions. However, they have not been found to significantly mediate the relationship between availability of NEs in the neighbourhood and PA [31,56,69]. It has been suggested that the environment might have a more 'direct' effect on behaviours through unknown mechanisms that strengthen the conversion of intention to behaviour [56]. For instance, the intention to engage in moderate PA, such as walking, may be influenced more by attitude than perceived behavioural control [31]. Although the stronger effect of attitude was

evidenced only on neighbourhood-based PA (such as walking or jogging), perceived behavioural control had a stronger effect in predicting participation in outdoor recreation in activities such as lake canoeing/kayaking, orienteering and archery [32]. Perceived ability to walk to local NEs was also found to be a predictor of PA among older adults living in rural areas [88].

Although perceived behavioural control may not mediate the relationship between availability of NEs and certain types of PA [31,56], actual behavioural control, as an expression of individual or environmental barriers, could possibly have a direct impact on the relationship. In fact, as previously outlined [5,9], several studies concluded that the characteristics of the individual or environment impact the relationship between NEs and PA. In particular, individual characteristics such as gender, age and family status are likely to influence perceived behavioural control or reflect subjective norms. For instance, some girls and women perceive walking or running alone in NEs as dangerous and/or not socially convenient [50,77,81].

Individual barriers

The most commonly reported reason *not* to visit NEs was 'lack of time' followed by personal barriers (e.g. poor health) [67]. However, different studies found that age [48,67,79,103] and gender [48,66,67,70,71,76,77,79,81,83,92] also affected the way NEs impact on PA behaviours, although mixed results were reported. For example, some studies suggest that NEs may encourage PA, especially among girls and women [70,71,79,83], whereas others reported that women perceive more barriers in NEs than men do, especially in relation to perceived safety [50,67,76,81]. Greater effects by the presence of NE on psychological states [48] and PA behaviour [79] were found in younger and older individuals, as compared to middle age groups. However, these findings were not always confirmed, possibly due to other factors such as perceived safety [67]. Differences across age-groups were also associated with the type of PA [103]. The effects of socioeconomic status and race/ethnicity on the way NEs promote PA appear to be more consistent, with lower socioeconomic status and being a member of an ethnic minority seen as barriers to the use of NEs for PA purposes [63,66,68,70,80,82]. Perceived safety is also consistently found to be an important factor influencing PA and visits to NEs [66-68,72,75,77,78,81,90], although not in *all* studies [73,97].

Environmental barriers

Environmental barriers such as traffic [78,97,101], gradient of the pavement [78,84,101,104], poor lighting [86,101], lack of safety [66-68,71,72,75,77,81,100] and noise/air pollution [75,110] were found to have negative

influences on PA behaviours and possibly to hinder visits to NEs. On the contrary, street connectivity [78,86], land-use mix [31,81] and destinations available within walking distance [68,73,101] are environmental characteristics that promoted PA, irrespective of the presence/absence of NEs. The social environment (e.g. social cohesion within the neighbourhood) was also consistently found to influence PA behaviour [63,66,67,70,72,90,111], possibly to a greater extent than the availability of NEs [72,111]. On the other hand, findings suggest that NEs can also play a reverse role, providing individuals with social benefits and opportunities to engage in social activities [23,24,58,66,74,87,91]. Differences between rural and urban environments have been identified, with the NE-PA relationship being stronger for people living in urban rather than rural areas [63,96,103,106], probably due to differences in land-use mix and connectivity.

The *subjective perceptions* of environment also operate as barriers and appear to be a stronger predictor of PA [65,104]. For example, distance to NEs from people's residences was a barrier to visits to NEs and their use for PA purposes [69,72,74,77,80,85-87,93,109,113]. Though, *perceived* and *objective* walking distances from NEs correlated poorly with each other, and self-efficacy did not explain the mismatch [69]. An 'incorrect' perception of the distance to NEs might be due to lack of information; in fact 'lack of information/knowledge' was found to be an important reason for not visiting NEs [3], whereas improved information was self-reported as a strategy that would encourage people to visit NEs and engage in PA [64,67].

Although there is overwhelming agreement about environmental barriers hampering the use of NEs for PA purposes [5,9], to date little has been said about the specific characteristics of NEs that promote active living [5]. Some studies suggest that those that provide a greater variation between nature and built elements have greater effects on PA promotion [78,83,85]. For example, extensive tree coverage discouraged individuals from engaging in PA [86]. On the contrary, naturalistic urban parks furnished with paved paths and features supporting PA were found to be a strong predictor of park visits and PA [85]. Neighbourhoods with well-maintained pavements that offer attractive views of nature appeared to be an important element in encouraging neighbourhood-based PA such as walking [31]. In particular, views of parks/gardens [31,63,69,81,90,101,110] and the seaside [81,90], as well as the presence of trees [75,81,90,101,104], were consistently found to encourage PA, even for a practical reason such as providing shelter from the sun [104].

Intention

The 'presence of attractive nature views' in the neighbourhood was found to predict walking via subjective

norm, attitudes and intention, with affective beliefs ('feeling good' and 'stress relief') providing stronger prediction than instrumental beliefs (e.g. health-related benefits) [31]. Intention was also found to predict participation in outdoor recreations such as canoeing/kayaking, orienteering and archery [32].

Unfortunately we found only two studies investigating whether intention predicts PA behaviour in NE, whereas other studies investigated the explicit reasons and motives for visiting NEs and how these motives supported PA. 'Enjoying nature/getting fresh air' and 'reducing stress' were reported as the most common reasons for visiting NEs, especially among individuals who reported higher stress levels [87,91]. 'Exercise and staying in shape' was also reported as an important reason for visiting NEs [87,109], especially among people living closer to them [109]. Experimental studies found that NEs were perceived as more 'likeable/preferable' by runners compared with indoor or urban settings [40,44], and 'neighbour nature' was reported as an important environmental factor helping people sustain walking routines [89,90]. Furthermore, respondents have reported that they would visit NEs if available near their homes [67,102].

Physical activity behaviour

In an attempt to answer the question of whether NEs can encourage active living, a large number of cross-sectional studies tried to define the relationship between access to green areas and PA rates. Most of the studies indicate that availability of NEs within the living environment is generally associated with more PA [23,31,63,65,72-76,79,83-85,87,92,94,95,99,101,105,107-110,112], although some yield partial associations or small effect sizes [3,66,68,71,77,80,82,93,106,113]. There are, however, studies that showed no association between NEs and PA [27,96-98,111] or even a negative association [100]. Other studies found mixed effects, with differences relating to the type of NE [81,86], type of PA [103] and participants' gender [70,71,81]. However, many studies have not accounted for whether respondents with more accessibility to NEs actually engaged in more PA in them, while measuring total PA levels as a dependent variable. In the attempt to have better disclosure of the NE-PA relationship, some studies have specifically investigated possible associations between availability of NEs and NE-based PA, and most of these studies did find positive associations [63-66,69,76,79,85,99,109]. Yet some studies reported unclear [58,74] or mixed results [103,106], especially with respect to the specific type of PA studied.

A question was raised about the possibility of a self-selection phenomenon: Do individuals who are already physically active choose to live in areas where more PA opportunities exist? Only two studies addressed this

question and excluded the effect of self-selection, concluding that NEs can actually encourage people to embrace active lifestyles [56,99]. As availability of NEs within a living environment appears to promote neighbourhood-based PA, another question was raised: Do visits to NEs such as parks and green spaces make a relevant contribution to overall PA levels? Although visits to NEs do not necessarily imply engagement in PA [5], visits to NEs even for 'sedentary' purposes can lead to increased PA, because people who visited NEs more often were more likely to meet the minimum recommended levels of PA [3,76,102].

Integration

According to the reviewed studies and in light of the TPB, evidence supported the theory that availability of NEs can increase motivation to engage in PA via intention and affective beliefs such as positive emotions and stress relief. Positive PA experiences can enhance attitudes toward PA and perceived behavioural control, leading to firmer intentions to engage in PA. Individual and environmental barriers, as expressions of one's *actual* behavioural control and social support, influence the process via perceived behavioural control and subjective norm. Instrumental beliefs such as expected health benefits and the desire to enjoy nature also impact the process via behavioural attitudes. The conceptual model that emerged (Figure 2) is depicted as a double circular one in order to portray the two different roles that NEs have as PA arenas.

On the one hand, elements of nature integrated within people's living environments, such as attractive natural views in the neighbourhood, can encourage active living through mode of transport and leisure PA such as walking, cycling or jogging. On the other hand, NEs are arenas for outdoor recreations that imply a closer relationship between the individual and the NE itself, such as hiking, gardening, fishing, etc. In both cases, experiences in NEs influence individual attitudes toward PA, and strengthen motivation to embrace an active lifestyle, whereas personal and environmental factors either positively or negatively influence the process. In both circles, visits to NEs and their use for PA purposes are mediated by intention. The two circles differ not only in the type of PA and PA-NE relationship involved, but also in the way that other factors influence one's intention to use NEs for PA purposes. For example, attitudes towards outdoor recreation are likely to be influenced by feeling about nature, and the intention to participate in outdoor recreation is impacted more by perceived behavioural control. However, attitudes towards neighbourhood-based PA such as walking or jogging appear to be influenced more by instrumental beliefs such as expected health and aesthetic benefits, and the intention to engage in such

activities is subjected less to perceived behavioural control, while it appears to be more attitude-driven.

Discussion

The natural environment is a resource promoting health and wellbeing through reduction of stress and risk for poor mental health [10,11,26,57], and its relevance in land-use planning has been advocated [6,7]. Some evidence indicates also that visits to NEs can reduce the risk of chronic diseases such as cancer [22] and cardiovascular diseases [114]. Furthermore, availability of NEs within the living environment can play a significant role in promoting PA, both providing the opportunity to engage in PA and sustaining active living [5,14,31,89,90]. Active lifestyles, characterized by more low-threshold PA in everyday life routines and less sedentary behaviour (e.g. watching TV), have been shown to have the potential to impact greatly on health, even when not engaging in a purposeful exercise programme [115,116]. Therefore, interventions that encourage active living among the population, through both mode of transport and leisure activities, can have a great impact on promoting health. Walking and cycling are an important source of aerobic PA for many. However, the WHO also recommends that: 'Muscle-strengthening activities should be done involving major muscle groups on two or more days a week' [1]. It is therefore important that interventions pay attention to promote a variety of PA that offers greater potential for muscle conditioning through whole-body involvement. Different outdoor recreations, including gardening and use of fitness trails, can provide such physical conditioning. However, promotion of such types of PA can be challenging because of greater personal barriers (i.e. self-efficacy or perceived behavioural control). Interventions must therefore act at a multilevel scale, targeting individuals as well as the living environment to induce behavioural changes in the population [2]. Such a multilevel approach includes both infrastructural intervention and social campaigns. The identification of environmental preferences and belief-based targets for the promotion of PA are an important stage for effective interventions. Throughout this integrative study, it has been shown how NEs can support motivation to embrace and sustain an active lifestyle, and underlying beliefs, possible barriers to PA and preferred environmental characteristics were identified. The environmentally and belief-based targets identified in this paper should be used in land-use planning as well as in social campaigns promoting active living through messages to the community.

Strengths and limitations of the study

To date, this study is the most extensive review of literature about the health effects of PA in NEs, presenting a

novel and extensive analysis of motivational processes underlying the relationship between experiences of nature and PA behaviours. We used systematic methodologies to identify and analyse relevant papers and the TPB to guide this synthesis. The TPB was chosen because it has been previously used to explain behaviour with regard to PA and NEs [31,32], and it has been proposed as a valuable model to explain the links between environmental cognitions and PA [4]. These elements make this study a robust one compared with other reviews of literature attempting to explain how NEs can improve motivation to engage in PA [12,14]. Nevertheless, limitations should be taken into account.

One of these is the inferences regarding the causal interrelationship of behavioural, normative and control beliefs, intention and behaviours, when only a few studies directly investigated the role of attitudes, subjective norms and perceived behavioural control in mediating the effects of NEs that promote PA. The link of beliefs, intention and behaviour is therefore partially deductive in this review. Another limitation concerns the possibility of not being able to include all the available literature. Only peer-reviewed journal articles were included, which, on one the hand, guarantees a minimum quality standard for the reviewed publications, but, on the other, may have excluded a number of other studies (i.e. grey literature). Finally, due to the large variety of study designs, it was not possible to conduct a proper assessment of quality through a standardized instrument.

Implications for health-promotion interventions

On consideration of the application of our findings and the proposed theoretical model, a number of recommendations for future PA-promoting interventions are formulated:

- *Social campaigns* promoting visits to NEs and active living should focus on individual targeted beliefs that sustain people's intention to engage in PA. Health benefits and stress-relieving effects of being in touch with nature, as well as the advantages of using NEs as a strategy to sustain PA for fitness and aesthetic purposes, must be used in messages to the community. Such communication can consist of both public campaigns and individual messages via family doctors. The latter might be particularly relevant in impacting on people's subjective norms.
- *Programming* of activities that aim to promote social interactions and positive experiences in NEs, such as organizing walking groups or other group activities, may encourage people to visit NEs and engage in PA.
- *Information* about the health benefits of being in touch with nature, provided by family doctors, as well as school-based 'outdoor education', may

positively impact on individual subjective norms as well as attitudes towards outdoor recreation via feelings about nature.

- *The quality of an NE*, especially with respect to safety, aesthetics and *accessibility*, plays a central role in determining its use for PA purposes. It is therefore of paramount importance to guarantee availability of quality NEs to promote active living through urban/infrastructural interventions. However, as the presence of infrastructures facilitating PA alone does not automatically mean that people will use NEs, accessibility, good maintenance and information must be involved too.

Recommendation for future research

The conceptual model explaining motivation for PA in NEs presented here provides us with an alternative way to approach personal (i.e. salient beliefs that have room for improvement in a TPB prediction equation) and environmental factors in which we may intervene. Future studies, especially those using an experimental design, should explore the relationship between availability of NEs within the living environment and PA. It is not clear to what extent and how an individual's feelings about nature can influence the NE-PA relationship and the psychological states associated with experiences in NEs, so researchers should also consider these variables in future studies.

Conclusions

Natural environments such as green or open spaces, but also attractive views of nature integrated within the urban landscape, are important environmental factors sustaining PA in the population. Individual characteristics and environmental barriers may, however, impact the relationship between availability of NEs and PA behaviours. PA-promoting interventions should aim to guarantee access and good maintenance of NEs. Information and programming of social activities may also encourage more use of NEs. Social campaigns via media and health institutions should advertise how nature can help motivate maintenance of a PA routine, reduce stress, and achieve aesthetic and health goals.

Abbreviations

ART: Attention-restoration theory; NE: Natural environment; PA: Physical activity; TPB: Theory of planned behaviour; WHO: World Health Organization.

Competing interests

The authors declare that they have no competing interests.

Authors' contributions

GC was responsible for the conception of the work, carried out the literature search and integration of the framework, and drafted the manuscript. SC provided substantial contributions to revision of the intellectual content and final development and write up of the manuscript. Both authors approved the final manuscript.

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Author details

¹Department of Dental Care and Public Health, Hedmark University College, Elverum, Norway. ²Department of Sports and Physical Education, Hedmark University College, Elverum, Norway.

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