Department of Built Environment

Environments for Healthy and Active Ageing

Tiina E. Laatikainen

Aalto University

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Environments for Healthy and Active Ageing

Tiina E. Laatikainen

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Aalto University
School of Engineering
Department of Built Environment
Spatial Planning and Transportation Engineering

Supervising professor
Professor Marketta Kyttä, Aalto University, Finland

Thesis advisor
Professor Marketta Kyttä, Aalto University, Finland

Preliminary examiners
Dr. Erja Portegijs, University of Jyväskylä, Finland
Dr. Sarah Foster, RMIT University, Australia

Opponent
Dr. Erja Portegijs, University of Jyväskylä, Finland

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Abstract

Our populations are ageing at fast and at the same time our globe is confronting significant health challenges including increases in physical inactivity, obesity, and other non-communicable diseases. Maintaining mobility and physical activity are fundamental factors in healthy ageing, and the physical environment has been linked to various individual health outcomes. Understanding what kinds of environments can support older adults' everyday mobility can help researchers, planners and decision makers find ways to facilitate and motivate older adults to move outdoors and in planning healthy communities.

Ecological models propose that multiple levels of factors influence health behavior, often including the physical, sociocultural, and policy environments as well as individuals' personal psychological and sociodemographic backgrounds. In this thesis, address the gap in health promotion research, which have had methodological challenges in capturing the complex interactions of individual and physical environmental characteristics in certain spatial settings. Thus, the possibilities and challenges of online participatory mapping method in health promotion research and among older adults are studied. I also study different physical environmental contexts and how they are associated with the health and physical activity of older adults, namely adults aged 55 to 75, in the Helsinki Metropolitan Area, Finland.

My findings show that participatory mapping methods are well suited for health promotion research and offer ways to overcome the challenges previous studies have had in capturing the spatiality of human health behavior. The online participatory mapping method was found suitable for older adults but there are some cognitive, sensory, and motor challenges that need to be considered. Additionally, the findings show that the built environment is direclty linked to older adults' walking, and that green and blue spaces close to home describe older adults' perceptions of a quality environment, and thus could motivate older adults getting outdoors. Moreover, the findings show that the physical environment is associated with the perceived health of older adults, but the way the environment is studied and measured should be carefully considered. I conclude that the physical environment can play a core role in supporting older adults' health behavior despite their personal interests and background. Furthermore, I present a revised ecological model of physical activity where the context is given its place.

In the future, studies in the field of health promotion should investigate simultaneously the personal, sociocultural, and psychological as well as the physical and policy environment features with spatially bounded context-specific methods. Emphasis should be given to longitudinal studies to more comprehensively examine causal relations. Moreover, I would recommend future research to place focus not only on what is inside one's head but more on what one's head is inside of.

Keywords Older Adults, Everyday Physical Activity, Physical Environment, Health, Participatory Mapping, PPGIS, Ecological Models

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Tiivistelmä

Väestömme ikääntyy vauhdilla. Samanaikaisesti fyysinen inaktiivisuus, ylipaino sekä monet elintapasairaudet yleistyvät joka puolella maailmaa. Arkiliikkuminen on yksi keskeinen ikääntyvän väestön terveyttä ja toimintakykyä ylläpitävä tekijä. Lisäksi, fyysisen ympäristön—niin rakennetun kuin luonnonympäristön—on osoitettu olevan yhteydessä väestön terveyteen. Tarvitaankin tietoa siitä, millainen ympäristö tukee ikääntyvien aktiivista arkiliikkumista.

Ekologisten mallien mukaan yksilön terveyskäyttäytymiseen vaikuttavat niin fyysinen, sosiokulttuurinen kuin poliittinen ympäristö sekä monet yksilön fyysiset, psyykkiset ja sosio-ekonomiset tekijät. Väitöstutkimukseni keskittyy tarkastelemaan kontekstuaalisuuteen, tilaan ja paikkaan, liittyviä metodisia haasteita joita aiemmissa terveyden edistämiseen keskittyvissä tutkimuksissa on kohdattu. Lähestyn näitä haasteita paikkaan kytkeytyvän internet-pohjaisen osallistavan paikkatietomenetelmän, PehmoGIS:n, kautta. Työssäni selvitän osallistavan paikkatietomenetelmän soveltuvuutta ympäristöterveystieteelliseen tutkimukseen ja ikääntyville. Lisäksi, tarkastelen ikääntyvien pääkaupunkiseudulla asuvien 55-75-vuotiaiden arkielämän käytäntöjä ja liikkumista lähiympäristössä. Selvitän, mitkä fyysisen ympäristön piirteet tukevat ikääntyvien terveyttä ja arkiliikkumista. Työssä tarkastelen ekologisten mallien mukaisesti monien eri tekijöiden vaikutusta ikääntyvien arkielämän käytäntöihin ja liikkumiseen.

Tulosten perusteella voidaan todeta, että osallistavat paikkatietomenetelmät sopivat hyvin ympäristöterveystieteelliseen tutkimukseen ja tarjoavat ratkaisun aiemmin kohdattuihin kontekstuaalisiin haasteisiin. Internet-pohjainen osallistava paikkatietomenetelmä soveltuu käytettäväksi myös ikääntyvien parissa, mutta tiettyjä kognitiivisia, motorisia ja sensorisia haasteita voi esiintyä. Lisäksi, tulokseni osoittavat, että fyysinen ympäristö on yhteydessä ikääntyvien fyysisesti aktiiviseen arkiliikkumiseen huolimatta yksilön henkilökohtaisista tekijöistä. Tulokset osoittavat myös, että viher- ja vesiympäristöt lähellä kotia ovat merkityksellisiä ympäristön laatutekijöitä ikääntyville. Fyysinen ympäristö näyttää olevan yhteydessä myös ikääntyvien koettuun terveyteen. Tulosten perusteella vaikuttaa siltä, että fyysinen ympäristö voi tukea paatuneenkin sohvaperunan fyysisesti aktiivista arkiliikkumista, mikäli ympäristö suunnitellaan ikäystävällisin ja terveyttä edistävin kriteerein. Esitän väitöstyön tulosten pohjalta myös muokatun version ekologisesta mallista, jossa kontekstin eli fyysisen ympäristön rooli tuodaan keskeisemmäksi osaksi mallia.

Tutkittaessa ihmisten terveyskäyttäytymistä huomiota pitäisi kiinnittää enenemässä määrin arkiliikkumiseen. Tulevaisuudessa ympäristöterveystieteen kentälle tarvitaan erityisesti monimenetelmällisiä sekä –tieteellisiä kontekstin huomioivia pitkittäistutkimuksia tarkastelemaan eri tekijöiden syy-yhteyksiä arkiliikkumiseen. Tulevaisuudessa, tutkimuksen tulisi keskittää huomio yksilön sijaan kontekstiin jossa yksilö kulloinkin on.

Avainsanat Ikääntyminen, fyysinen aktiivisuus, arkiliikkuminen, fyysinen ympäristö, terveys, osallistava paikkatieto, PPGIS, ekologiset mallit

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Käpylä, Helsinki 10.4.2019
Tiina E. Laatikainen

“Ask Not What’s Inside Your Head, but What Your Head’s Inside of”

William M. Mace

Contents

List of Abbreviations and Symbols

AT	active travel
EEP	everyday errand point
GIS	geographic information system
GPS	global positioning system
HMA	Helsinki Metropolitan Area
HR	home range
IREM	individualized residential exposure model
MAUP	Modifiable Areal Unit Problem
PA	physical activity
PM	participatory mapping
PPGIS	Public Participation Geographic Information System
WHO	World Health Organization

List of Tables and Figures

List of Publications

This thesis is based on the four peer-reviewed articles listed below. The articles are referred to by their Roman numerals in the text. The articles are reprinted here with the kind permission of the respective publishers.

Article I Gottwald, S., Laatikainen, T. E., & Kyttä, M. (2016). Exploring the usability of PPGIS among older adults: Challenges and opportunities. *International Journal of Geographical Information Science*, 30(12), 2321–2338, doi: 10.1080/13658816.2016.1170837

Article II Laatikainen, T. E., Broberg, A., & Kyttä, M. (2017). The physical environment of positive places: Exploring differences between age groups. *Preventive Medicine*, 95, S85–S91, doi: 10.1016/j.ypmed.2016.11.015

Article III Laatikainen, T. E., Hasanzadeh, K., & Kyttä, M. (2018). Capturing exposure in environmental health research: Challenges and opportunities of different activity space models. *International Journal of Health Geographics*, 17(1), 29, doi: 10.1186/s12942-018-0149-5

Article IV Laatikainen, T. E., Haybatollahi, M., & Kyttä, M. (2019). Environmental, individual and personal goal influences on older adults' walking in the Helsinki Metropolitan Area. *International Journal of Environmental Research and Public Health*, 2019, 16(1), doi: 10.3390/ijerph16010058

Author's Contribution

Publication 1: Exploring the usability of PPGIS among older adults: Challenges and opportunities.

The author was responsible for collecting the data and performing the analyses with S. Gottwald. The author was responsible for co-writing the paper. S. Gottwald was responsible for collecting the data and performing the analyses with the author of this thesis and the main contributor in writing the paper. M. Kyttä was responsible for co-writing the paper.

Publication 2: The physical environment of positive places: Exploring differences between age groups

The author was responsible for writing the main parts of the paper and performing the statistical and geospatial analyses. A. Broberg and M. Kyttä were responsible for co-writing the paper.

Publication 3: Capturing exposure in environmental health research: Challenges and opportunities of different activity space models

The author was responsible for data collection and preparatory analyses of the data. The author was the main contributor in writing the paper. K. Hasanzadeh was responsible for the statistical and geospatial analyses and co-writing the paper. M. Kyttä was responsible for co-writing the paper.

Publication 4: Environmental, individual and personal goal influences on older adults' walking in the Helsinki Metropolitan Area

The author was responsible for data collection, was the main contributor in writing the paper, and performed the geospatial analysis. The author was responsible for the statistical analysis with M. Haybatollahi. M. Haybatollahi was the main contributor in the statistical analysis and participated in writing the manuscript. M. Kyttä was responsible for co-writing the paper.

1. Introduction

The human population is confronting significant health challenges during the 21st century, including increases in physical inactivity, unhealthy diets, obesity, and other non-communicable diseases (Giles-Corti et al., 2016). It is estimated that physical inactivity alone causes 6%–10% of the major non-communicable diseases, such as cardiovascular diseases, cancers, and diabetes, worldwide (Lee et al., 2012). In addition to various health challenges, physical inactivity is responsible for substantial economic burdens around the world (Ding et al., 2016). Alongside the pandemic of physical inactivity, our globe is confronting considerable population ageing. According to the World Health Organization (WHO) (2010, p. 10), "global health is being influenced by three trends: population ageing, rapid unplanned urbanization, and globalization, all of which result in unhealthy environments and behaviors."

In Europe, 25% of the population is already aged 60 years or older, and by 2050, all regions of the world excluding Africa will have almost one-quarter or more of their populations over 60 years old (United Nations Department of Economic and Social Affairs, 2017). "Old age dependency ratio" is an indicator that aims to quantify the ratio between 65+-year-old adults and working-age adults in our societies. According to the Official Statistics of Finland (2018), this ratio will be 37 in 2020 and is projected to rise to 43 by year 2030. The statistics describe blunt facts about ageing societies, but these often negatively toned viewpoints could be altered if older adults were not seen merely as dependent and a burden on our societies. Instead, if older adults can maintain their health and live in such contexts that allow their ongoing productive engagement in society, they could perhaps be seen more as a disregarded societal resource (Beard & Petitot, 2010).

It is evident that ageing is associated with physiological changes that result in structural and functional decline, which in turn impact older adults' daily activities and preservation of independent living, even in the absence of discernible diseases (Chodzko-Zajko et al., 2009). However, there is also an abundance of evidence that physical activity (PA) mitigates age-related biological changes and their associated health effects, reduces the risk for chronic diseases, and can preserve functional capacity of older adults (Chodzko-Zajko et al., 2009; King & King, 2010). Maintaining mobility—one's ability to move around and take care of everyday activities—has been recognized as one fundamental factor in healthy ageing (Rejeski & al., 2011).

The impacts of PA on older adults' health have been widely studied in the fields of health promotion, public health, gerontology, and sport and medical sciences (Cavanagh et al., 1998; Cerin, Nathan, van Cauwenberg, Barnett, & Barnett, 2017; Hirvensalo, Rantanen, & Heikkinen, 2000; Kerr, Rosenberg, & Frank, 2012; Nelson et al., 2007; Rantakokko, Iwarsson, Hirvensalo, et al., 2010; Stokols, 1996; Winters et al., 2015). Previous research has recognized walking as one of the most common forms of PA among older adults (Chodzko-Zajko et al., 2009; Owen, Humpel, Leslie, Bauman, & Sallis, 2004). In their study, Kramer and colleagues (1999) found that older adults who received aerobic training simply in terms of walking showed substantial improvements in performance on tasks requiring executive control compared to anaerobically trained subjects. Studies have also found that walking is associated with substantial reductions in the risk of cardiovascular events in older adults (Hakim et al., 1998; Manson et al., 2002). In a U.S. study, regular PA, including walking, was found to be associated with better cognitive function and less cognitive decline in women aged 70–81 years (Weuve et al., 2004). Furthermore, PA along with a rich social life and mental activities are the main protective factors for dementia in later life (Fratiglioni, Paillard-Borg, & Winblad, 2004). Manson and colleagues (2002) have concluded that even a moderate-intensity exercise, such as walking, generates substantial health benefits for older adults, whereas prolonged sitting time predicts increased risk of cardiovascular events. In light of the current research results, it is evident that PA has notable health benefits for older adults, yet older Finns are one of the least active segments in our population (Karvinen, Kalmari, & Koivumäki, 2012).

As people get older, the role of the neighborhood becomes central in older adults' daily lives (Rantakokko et al., 2010; Yen, Michael, & Perdue, 2009). According to Fang and colleagues (2016), one core determinant of health in later life is how and where one lives. Decreases in physical and cognitive functioning that follow the ageing process can lead to greater dependence on the immediate home and neighborhood environment (Yen et al., 2009). Understanding what kinds of environments can support older adults' mobility and PA can help researchers and planning practitioners find ways to facilitate and motivate older adults to move outdoors and in planning healthy communities (Eronen, von Bonsdorff, Rantakokko, & Rantanen, 2013).

According to the ecological models of health behavior (Giles-Corti, Timperio, Bull, & Pikora, 2005; Richard, Gauvin, & Raine, 2011; Sallis et al., 2006; Sallis & Owen, 2015), multiple levels of factors influence human health behavior, often including the physical, sociocultural, and policy environments as well as individuals' personal psychological and sociodemographic backgrounds. These factors work together and influence interactions across different levels meaning that older adults who prefer functional exercise might appreciate and start immediately using new pedestrian routes implemented in their neighborhood. However, those who have physical limitations or are not very interested in active ageing living in the same area could neglect such investments without further encouragement, instructions, or social support (Portegijs et al., 2017).

Previous research has found a host of individual characteristics associated with older adults' PA behavior (Notthoff, Reisch, & Gerstorf, 2017). Demographic variables, such as gender and education, subjective health, and psychological factors (e.g., motivation, self-efficacy) have all been found associated with older adults' PA. Studies across the globe have found gender differences in PA (Hirvensalo et al., 1998; Yasunaga et al., 2007; Zhao et al., 2011), but at the same time, other studies report not finding differences between gender and PA (Ferreira et al., 2010; Stephan et al., 2011). In addition, results regarding the associations between other individual demographic variables, such as education or marital status, and PA remain relatively inconsistent (Notthoff et al., 2017). Thus, it seems that selected demographic, psychological, and psychosocial factors have an impact on older adults' PA, but research results remain contradictory and varied.

In addition, numerous studies show results between the physical environment and individuals' physical, social, and mental health (Sallis et al., 2016; (Sallis et al., 2016; Van Cauwenberg et al., 2011; Yen et al., 2009). A wide range of research has shown that environmental factors such as street connectivity, accessibility, residential density, quality of traffic environment, green spaces, and mixed land uses are associated with older adults' PA behavior (Giles-Corti et al., 2016; Kerr, Rosenberg, & Frank, 2012; Sallis et al., 2016). Already a decade ago, Saelens and colleagues (2008) concluded that evidence on physical environmental correlates of walking appears sufficient to support policy changes to increase the viability of walking. Yet, still to date the results regarding the association between various physical environment characteristics and older adults' PA remain inconsistent. Studies have found green spaces and parks associated with older adults' PA (Eronen et al., 2013, Sallis et al., 2016; Thornton et al., 2016), yet others report negative association between the presence of neighbourhood parks and older adults' PA (Borst et al., 2009; Chaudhury, Campo, Michael, & Mahmood, 2016). Land-use mix has often been reported being positively associated with walking (Christiansen et al., 2016; Frank, Kerr, Rosenberg, & King, 2010; Saelens et al., 2008), but in a recent international comparison study mixed land-use was not found associated with adults PA (Sallis et al. 2016).

Several studies have concluded that the inconsistencies in the results are potentially related to methodological, contextual and measurement challenges (Kwan, 2012; Saelens et al., 2008; Van Cauwenberg et al., 2011). Limited geographical scale of studies focusing simply to residential neighbourhood settings and issues related to residential self-selection have been acknowledged as potential measurement challenges (Saelens and Handy, 2008; Van Cauwenberg et al.,2011; Barnett et al., 2017). Previous studies have mainly focused on analyzing the environmental features around individuals' residences or neighborhoods, presuming that people simply move around in these areas. Thus, these approaches account only for the environmental features around individuals' residences and neglect the spatial and temporal realities of where, when and how long, individuals are actually moving around (Howell, Farber, Widener & Booth, 2017). The importance of differentiation of PA by domains has also been dis-

cussed as a potential solution to overcome the discrepancies in the results (Notthoff et al., 2017; Saelens & Handy, 2008; Van Cauwenberg et al., 2011). Additionally, previous studies suggest following the ecological principles and inclusion of the moderating effects of age, gender, socio-economic status and psychosocial and policy factors to improve the quality of research designs (Chaudhury et al., 2016; Van Cauwenberg et al., 2011).

Besides the associations found between PA and the physical environment, the perceived quality of the built environment has been linked to wellbeing in the general population (Kyttä, Broberg, Haybatollahi, & Schmidt-Thomé, 2015). Studies have also shown that social engagement between people enhances health and that environmental features, such as well-maintained local parks and aesthetics, can promote vivid social interaction among residents of certain areas and even minimize the impact of fear of crime on recreational walking in the neighborhood (Kaźmierczak, 2013; Foster, Giles-Corti, & Knuiman, 2014; Sullivan, Kuo, & Depooter, 2004). Moreover, natural environments have been strongly linked to restorative and stress-relieving effects (Korpela, Ylén, Tyrväinen, & Silvennoinen, 2008; Tyrväinen et al., 2014).

Thus, there is an abundance of evidence that the different physical and sociocultural environments and individual personal psychological and sociodemographic backgrounds are associated with older adults' PA. However, most of the research to date has concentrated mainly on studying either the personal or the environmental factors associated with PA or on defining which objective or subjective measures of the physical environment have an effect on older adults' PA and health. According to Sallis and colleagues (2006), the usage of traditional individual focused theories and models, such as the Theory of Planned Behavior (Ajzen, 1991) or the Social Cognitive Theory (Bandura, 1989), has led to almost an exclusive focus on interventions and studies that simply target individuals or small groups. Yet, as the ecological models suggest, studying single-level influences is not optimal and the focus should be more on multiple-level influences. There are some studies that have simultaneously examined factors at multiple levels following the principles of the ecological models (Carlson et al., 2012; Giles-Corti et al., 2005; Mertens et al., 2018; Sawyer, Ucci, Jones, Smith, & Fisher, 2017; Thornton et al., 2016; Van Holle et al., 2015). Yet, not much reseach that focuses on the multiple-level influences on older adults health behaviors exist.

Ecological models direct attention from a mere focus on one-level influences on health behavior toward a focus on multiple-level influences. Sallis and Owen (2015) present five principles of ecological perspectives that can be applied to many different health behaviors: 1) Multiple levels of factors influence health behavior, 2) Environmental contexts are significant determinants of health behavior, 3) Influences on behaviors interact across levels, 4) Ecological models should be behavior-specific, and 5) Multiple-level interventions should be most effective in changing behaviors. However, it should be noted that ecological models do not aim to displace other health behavior theories but aim to create a broader context for studying human health behavior and applying multiple

theories in the same study or health intervention setting (Sallis & Owen, 2015, p. 45).

The ecological approach has become a distinctive feature and widely applied in the field of health promotion during the past few decades, but the models have a long history in multiple disciplines, which have developed the models in slightly different directions (Richard et al., 2011). The models are described with multiple, interchangeable labels, such as ecological perspective, social-ecological model, social-ecological approaches, ecological model(s), and multiple-level models (Boulton, Horne, & Todd, 2018; Richard et al., 2011; Sallis et al., 2006). In this thesis, I will use the concept of ecological models when referring to this approach where human health behavior is seen as being influenced by a combination of individual-, sociocultural-, environmental-, nature-, information-, and policy-level factors (Sallis & Owen, 2015).

Ecological models fit particularly well to health promotion and PA research because of the spatial nature of physical activities (Sallis & Owen, 2015; Stokols 1992). PA is always done in specific places, thus it is a priority to study the characteristics of places that support or hinder PA (Sallis et al., 2006). However, ecological models emphasize that all levels of influence are important, and studies that account for multiple-level correlates or determinants should explain health behavior better than studies that focus on single-level (Sallis & Owen, 2015). Hence, the spatial extent of PA should be complemented with other factors of potential influence on PA, and it is widely accepted that ecological models should be domain- and context-specific (Ding et al., 2012).

Sallis and colleagues (2006, p. 301) have developed an ecological model of PA that focuses on four domains of active living: *active recreation, household activities, occupational activities,* and *active transport* (Figure 1). In the model, all of the factors that are thought to influence the four different domains of active living are presented as different levels and more detailed features within each level are listed. In the model, the PA behavioral level is central and highlighted because it is the outcome of interest (Sallis et al., 2006, p 301). In the center of the model, there is the intrapersonal level (including demographic, biological, pshychological factors), which Sallis and colleagues (2006) suggest approaching with psychosocial theories. The next level in the model is the perceived environment and around the perceived environment is the layer of behavior settings. The perceived environment level is distinguished from the objective level of the environment (behavior settings), but both are emphasized as being important in influencing active living domains. In the model, the physical environment level is referred to as behavior settings, places where the PA may occur (Sallis et al., 2006, p. 302). For each of the four domains of active living, the key behavior settings are listed with detailed characteristics that can also have an influence on other domains of active living. Sallis and colleagues (2006) further explain the detailed characteristics with an example about neighborhood walkability, which can have an effect on both active recreation and active transport, but perhaps different characteristics influence recreational and transport walking. Natural environment variables are presented separately from the behavior settings because, according to Sallis and colleagues (2006, p.

302), their influences are not confined to any specific setting. In addition, the model presents the role of sociocultural environments as cutting across all levels. The model also includes the information environment that is according to Sallis and colleagues (2006, 2015) present in virtually every behavior setting because it can include multiple variables, such as news, healthcare counseling, and advertising. The outermost level illustrated in the model represents the policy environment that is seen as influencing different domains of active living through different mechanisms. According to Sallis and colleagues (2006) the policy realms of the built environment, such as land-use and development policies and transportation regulations, can play a significant role in many different active living domains. Additionally, policy incentives and programs, for example, to promote public health through managing public recreation facilities could have a huge impact on some domains of active living.

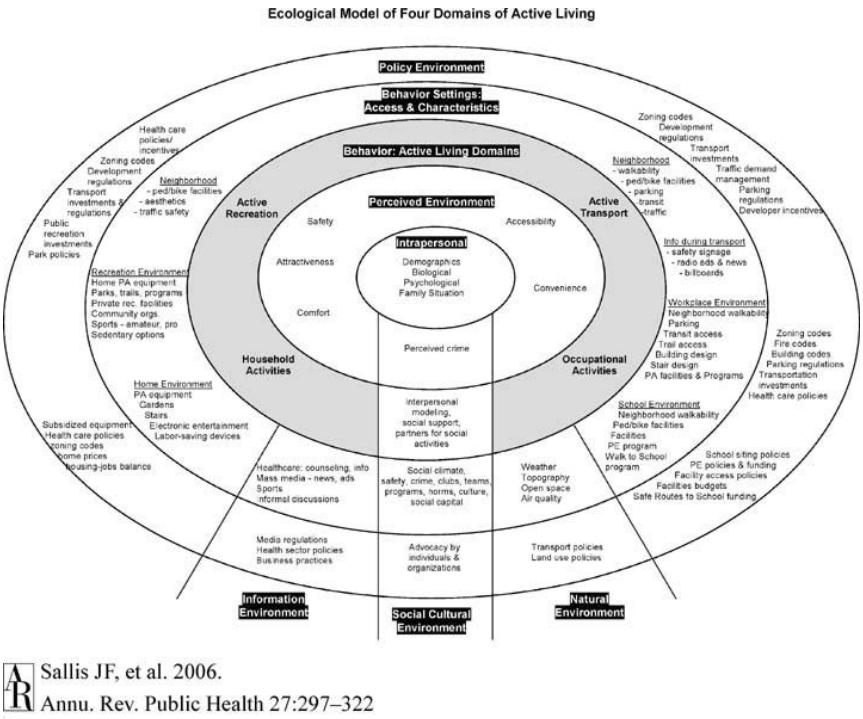

Figure 1. The ecological model of four domains of active living by Sallis et al. (2006). Reprinted, with permission, from the Annual Review of Public Health, Volume 27, ©2006 by Annual Reviews (www.annualreviews.org).

According to Sallis and Owen (2015), ecological models do not specify suitable theories nor applicable variables or study processes but provide a framework for creating a comprehensive approach to study the multiple-level influences of human health behavior. Furthermore, Sallis and Owen (2015, p. 45) summarize that the challenge in using ecological models is finding the most appropriate and influential theories and models for the purpose of the study or health intervention in question. While ecological models direct research toward examining

the multiple levels of influence on health behaviors, they tell very little about how different levels and variables interact or which variables interact when studying, for example, different PA behaviors (Sallis et al., 2006). In addition, developing and collecting measures of influences at multiple levels and attaching them to specific places is far more demanding than conducting a study that focuses on single-level influences (Sallis & Owen, 2015).

As briefly discussed earlier, studies adopting the principles of ecological models have had some considerable methodological challenges developing and collecting measures of influence at multiple levels and capturing the complex interactions of individual and physical environmental characteristics (Sallis et al., 2006). In addition, capturing the context (referred to as the behavior settings in the model) where the health behavior actually takes place is not straightforward, and previous studies have mainly focused on general-level residential neighborhood environments, overlooking people's true mobility behavior (Hasanzadeh et al., 2018; Perchoux, Chaix, Cummins, & Kestens, 2013). The discrepancies between the previous results can potentially be explained by methodoligcal and analytical challenges in capturing the context where the health behaviour actually takes place (Kwan, 2012; Hasanzadeh et al., 2018; Zhao, Kwan, & Zhou, 2018). Most of the previous research interested in the environmental effects on human health and PA has simply focused analyzing either the perceived environment characteristics, or alternatively the objective environment characteristics around individuals' residences or neighborhoods that have been delineated through administrative units or residential buffers. Some studies have found stronger associations between the perceived environment and PA compared to objectively assessed environment and PA and conclude that this might be due to that the perceived measures are closely aligned with the individual and their own definition of 'neighbourhood' (Barnett et al., 2017). However, studying PA behaviour out of the context, disconnected from the physical space, is not optimal, as PA is always done in specific places (Sallis and Owen, 2015). Additionally, due to the static nature of administrative units and buffers as analytical units, studies applying them tend to assume that individuals are exposed solely to the environment around their residence and, thus, manage to capture only a hypothetical individual exposure. Analysing people' PA behavior solely around their residence or based on an administrative borders can easily lead to flawed interpretations about the health impacts of the physical environmental factors (Hasanzadeh et al. 2018; Holliday, Howard, Emch, Rodriguez, & Evenson, 2017; Kwan, 2018; Zhao et al., 2018). Thus, instead of relying solely on individuals perceptions of the physical environment charateristics or simply on residential neighborhoods, health promotion research should take a step towards more dynamic and person-based methods and units of analysis. This would allow researchers to define the spatiotemporal extents of individuals' neighborhoods and spatial exposure (Hasanzadeh et al., 2018; Kestens, Thierry, Shareck, Steinmetz-Wood, & Chaix, 2018; Perchoux, Chaix, Brondeel & Kestens, 2016).

In this thesis, my main objective is to use spatially explicit methods to examine multiple factors that support older adults toward healthier everyday lives following the principles of ecological models (Sallis et al., 2006; Sallis & Owen,

2015). While acknowledging that the health and ageing challenges of the 21st century require broad transdisciplinary examination and various-level decisions and policymaking, it can be stated that supporting older adults' healthy and active ageing necessitates better understanding of the roles that both the physical environment and individual factors play. In this thesis, I am mainly interested in older adults' everyday practices and thus focus on studying older adults' recreational and walking behavior as presented in the ecological model of PA (Sallis et al., 2006, p. 302). From PA behavior, I have chosen to focus mainly on walking, as it has been recognized as one of the most common forms of PA among older adults (Chodzko-Zajko et al., 2009; Owen, Humpel, Leslie, Bauman, & Sallis, 2004). Additionally, I also touch upon older adults' perceived health and perceived quality of the environment, following the principles of the ecological models (Sallis & Owen, 2015).

Previous studies have shown that older adults' physical health and functioning as well as perceived and objectively measured health is connected to the physical environment (Cummins et al., 2005; Kerr et al., 2012; Tyrväinen et al., 2014). As my main interest lies in understanding the concurrent relationship of the individual and physical environmental factors influencing older adults' healthy and active ageing, this thesis focuses mostly on studying the intrapersonal (including demographic and pshychological factors), perceptual, and physical environmental levels of the ecological model of PA. Thus, not all levels of influences presented in the ecological model are covered in this thesis (Sallis et al., 2006, p. 301). While previous studies have shown that social environmental factors, such as crime and safety, are strong correlates of older adults PA (Barnett et al., 2017), these factors were not included in this study. A review that focused on older adults AT instead of PA, found no evidence of associations with AT and neighbourhood traffic and crime-related safety (Cerin et al., 2017). According to a recent study conducted in Helsinki, the residents perceive their neighbourhoods and the city centre safe (Kvartti, 2019). In addition, Finland along with other Nordic countries score high in International World Values Survey especially in interpersonal trust (Medrano, 2013). Moreover, international comparison study found Finland being the most child-friendly country in the world, which can also be seen as an indicator of the safetiness of the environment (Shaw et al., 2015). Thus, crime and safety were not considered causing major issues in the HMA residents' daily lives. Furthermore, focusing concurrently to the individual and the physical environmental characteristics can already be seen as a step towards unravelling the nexus between different levels of the ecological model. In this thesis, I take incremental steps towards more comprehensive understanding of the multi-level influences to older adults' health behaviour.

In this thesis, my aim is to address the gap in previous health promotion studies, which have had considerable methodological challenges developing and collecting measures of influences at multiple levels and capturing the complex interactions of individual and physical environmental characteristics in certain spatial settings. In addition, I aim to address the gap in research that focuses on

the multiple-level influences of health behaviors by examining how multiple levels of factors can support healthy and active ageing. Thus, in this thesis I have two main objectives. Firstly, I focus on studying the **possibilities and challenges of online participatory mapping (PM) methods in health promotion research and in applying ecological models among older adults**. Here I focus on exploring PM methods and their potential in closing the gap in health promotion research where there have been challenges in developing and collecting measures of influences at multiple levels and capturing the spatial context of health behavior. This objective is mainly methodological in its aim to understand:

1) Are online PM methods suitable for older adults?

2) Can online PM methods fit into health promotion research and in using ecological models of health behavior?

The second objective of this thesis is to **study different physical environmental contexts and how they are associated with the health and PA of older adults**, namely adults aged 55 to 75, in the Helsinki Metropolitan Area (HMA), Finland. My main focus is on studying how multiple levels of factors influence older adults' active and healthy everyday lives by applying the main principles of the ecological model of PA (Sallis et al., 2006). Under this objective, I am particularly interested in understanding:

3) Which features of the built environment do older adults' perceive as a quality environment and, thus, could encourage them getting outdoors?

4) How can the physical environment support the health of older adults?

5) How do multiple intrapersonal and physical environmental factors influence older adults' walking?

The four articles that constitute this thesis address the aforementioned research objectives and questions. More specifically, these articles explore the following themes.

Article I explores the challenges and opportunities of online PM methods among older adults. **I aim to answer Research Question 1 by studying Article I**. Because a very limited amount of previous research has been conducted on older adults' usage of online PM methods, the article addresses this research gap. The article explores the challenges and opportunities that older adults face when using an online PM tool and the usability requirements in the production of an online map survey. The article showcases how an online mapping survey tool can be developed to better respond to the needs of older adults and studies how older adults' performance in mapping tasks differ between modified and non-modified online PM surveys.

Article II aims to understand which features of the built environment people of different ages perceive as appealing. Thus, I **aim to answer Research Question 3 by studying article II**. In the article, the online PM methodology is also applied and discussed. Thus, it also **touches upon Research Question 2**. The article widens our understanding about the types of environments that are perceived as being good quality across different age groups. The article compares how older, working-age, and young adults, adolescents, and children perceive the built environment.

Article III combines both of the objectives of this thesis. The aim of the article is to explore whether the associations between the built environment and older adults' perceived health differ when individuals' environmental exposure is assessed with several different spatial units of analysis. In the article, four different spatial units of analysis are compared. It compares the administrative unit, 500-meter residential buffer, home range model, and individualized residential exposure model (IREM) and studies how the built environment impacts the perceived health of older adults when measured with these four different models. The article discusses the relationship of the physical environment and the perceived health of older adults as well as the novel ways of modeling the human-environment interactions using PM methods. Thus, **I aim to answer Research Questions 2 and 4 by studying Article III**.

Article IV explores the multiple levels of factors that influence older adults' walking. **I aim to answer Research Question 5 by studying Article IV.** The article examines the individual, personal psychological, and physical environmental features that direct older adults' walking within their everyday environments, including the environment outside their immediate home vicinity. The article focuses also on the methodological-level objective of this thesis by using an online PM method and using the collected data to model the individual home ranges of the study participants. Thus, it also **touches upon Research Question 2**. The article combines both of the objectives of this thesis by using an online PM method and a novel modeling of individual activity spaces to study simultaneously and context-sensitively the associations between both the individual and the environmental features and older adults' walking behavior in the environments where the respondents actually report themselves moving around.

The concepts of health, wellbeing, health promotion, and healthy and active ageing are central to this thesis. Thus, before moving forward, it is essential to define and clarify what is meant by these concepts. According to WHO (2004, p. 28), health is a state of complete physical, mental, and social wellbeing and not merely the absence of disease or infirmity. Health has various dimensions and is at large culturally defined (WHO, 2004). As for wellbeing, WHO (2004, p. 56) defines it as a dynamic state of physical, mental, and social wellness; a way of life that equips the individual to realize the full potential of his/her capabilities and to overcome and compensate for weaknesses; and a lifestyle that recognizes the importance of nutrition, physical fitness, stress reduction, and self-responsibility. Furthermore, according to WHO (2004, p. 56), wellbeing is a result of four key factors to which an individual can affect at varying degrees:

human biology, social and physical environment, healthcare system, and lifestyle. Health promotion is the process of enabling people to increase control over, and to improve, their health. According to WHO (2004, p. 30), health promotion is any combination of health education and related organizational, polital and economic interventions designed to facilitate behavioral and environmental adaptations that will improve or protect health. In this thesis, I refer to the concept of health according to the definition made by WHO. Thus, in this thesis, health is understood as an umbrella concept that covers the aspects of physical, mental, and social wellbeing. I will also touch upon the concept of health promotion and define it as any organizational, polictical, practical or societal aim to improve or protect health. Healthy and active ageing are widely used concepts in this thesis. I have chosen these concepts to oppose framing old age merely in terms of losses and to emphasize the ageing population's actual physical, social and cognitive capabilities (Boudiny, 2013). Healthy and active ageing are in many parts of this thesis understood in terms of the everyday activities of an active and healthy lifestyle.

In the following sections of this thesis, I introduce the foundations of my research in more depth. This is followed by a short overview of the main methodology, online PM, which is used throughout the research. I will then provide a summary of the data collection procedures and data sources. Finally, I present the main findings together with a discussion and conclusions.

2. Theoretical foundations

2.1 Ageing population and older adults' health—global and local challenges

Demographics are changing all around the world, and current population projections forecast continuing growth in the share of older adults in each continent (United Nations Department of Economic and Social Affairs, 2017). Finland has one of the oldest populations in Europe (European Comission, 2018). The share of Finnish people over 65 years old is currently 21.4% and is estimated to be 26.4% of the population by 2030 and 28.7% by 2050 (Official Statistics of Finland, 2018). Populations in other parts of the world are also projected to age significantly over the next few decades (United Nations Department of Economic and Social Affairs, 2017). The "old age dependency ratio" will be 36.8% in 2020 and is projected to rise to 43% by year 2030 in Finland (Official Statistics of Finland, 2018). This means that in 2030 there might be only two working-age adults per one adult aged 65 years and older. The Finnish Ministry of Social Affairs and Health (2011) has listed the ageing of the population as one of the nation's core challenges for the 2010s, but the challenges seem to continue in the coming decades, too. Thus, the population ageing needs to be seriously considered in several fields of policymaking both locally and globally.

Older adults should not be looked at only through the numbers of dependency ratios and seen as a mere burden to our society. If older adults can maintain their health until the last years of their lives and live in such contexts that support their needs and productive engagement in society, they could instead be seen as a potential societal resource (Beard & Petitot, 2010). While functional and structural decline and changes in bodily conditions are inevitable with advancing age (Chodzko-Zajko et al., 2009), older adults should not be declared simply as fragile and a constricted population segment. Regular PA has shown increasing life expectancy through its direct influence on chronic disease prevention and preservation of functional capacity (Simonsick, Guralnik, Volpato, Balfour, & Fried, 2005). PA has proven to be an essential factor in the prevention and treatment of a range of health conditions, such as obesity, type 2 diabetes, cardiovascular disease, and osteoporosis (Chodzko-Zajko et al., 2009; Nelson et al., 2007; Rantakokko, Iwarsson, Hirvensalo, et al., 2010). Research has also shown that active travel (AT), namely walking and cycling, has health benefits across the population even after adjustment for all other forms of PA

(Kelly et al., 2014). Maintaining mobility in old age has been shown to be a central factor in healthy ageing (Rejeski & al., 2011).

Walking is one of the most important forms of outdoor recreation for older adults—to run errands, to participate in community activities, and to have an active social life (Karvinen et al., 2012; Owen et al., 2004). Thus, studying older adults' PA behavior and especially the multiple factors that influence their everyday outdoor mobility choices and walking behavior is a central part of supporting healthy and active ageing. In addition, understanding which factors mostly influence older adults toward healthy lifestyles and PA and their motivations to get outdoors is essential to planning healthy communities. An ecological model of PA (Sallis et al., 2006; Sallis & Owen, 2015) is a well-suited framework for studying older adults' everyday behaviors. However, as stated by Sallis and Owen (2015, p. 45), the model of PA provides merely a meta-model that helps to organize other theories and models into a coherent whole. The challenge in using ecological models lies in the identification of the most suitable theories that fit the purpose, behavior, and population of interest (Sallis & Owen, 2015). Thus, in the following section, I introduce and discuss suggested theoretical and methodological approaches that are suitable for applying ecological models to study context-sensitively the various factors associated with older adults' everyday health behaviors.

2.2 Transactional research approach capturing the multiple levels of factors of ecological models

Ecology is a field of the biological sciences that studies the interrelations between organisms and their environments. From its early roots in biology, the concept evolved to the fields of geography and sociology in the beginning of the 1900s when researchers began to apply ecological principles in their analyses of human communities (Stokols, 2018). According to Stokols (2018), the term *human ecology* was first introduced by Robert Park and Ernest Burgess in 1921 who launched a study at the University of Chicago about the spatial distribution of health and behavioral disorders. The ecological paradigm has evolved since around the late 1960s in several disciplines to provide a general framework for understanding and studying the nature of people-environment interactions (Stokols, 1996).

Ecological models of health behavior evolve from the behavioral and public health sciences and place focus on the transactional relationship between people and their physical and sociocultural environments (Sallis & Owen, 2015). As for the concept of transactional relationships of people and their environments, it is strongly embedded in the transactional worldview where the person-environment relationship is seen as a holistic system where there are no separate elements or sets of discrete relationships (Altman & Rogoff, 1987). Instead, the person-environment relationship is seen as a context-specific, dynamic, and interactive system. The transactional worldview has been mostly applied in the fields of environmental psychology and social ecology (Altman & Rogoff, 1987).

According to the core principles of environmental psychology and social ecology, environments and their inhabitants are dynamic systems where the actions of individuals as well as groups change the environment and, in turn, the environment changes their behavior, experiences, and wellbeing (Gifford, Steg, & Reser, 2011; Stokols, 2018). In the transactional worldview, neither one of the components, environment or human, hold a deterministic role but more of a probabilistic one (Kyttä, 2004). Thus, the transactional approach assumes that the *aspects* instead of different *elements* of a system—that is, the person and context—coexist and jointly define one another and contribute to the meaning and nature of a holistic event (Altman & Rogoff, 1987, p. 24). To put this another way, it is not separate independently functioning *elements,* such as the human and the physical environment, whose patterns of relationships constitute the whole. Instead, in the transactional worldview, there are no separate elements or actors in an event, but there are acting relationships. For example, the actions of one person can only be described and understood in relation to the actions of other persons in the given spatio-temporal context (Altman & Rogoff, 1987).

While the ecological models of health behavior (Bauman et al., 2012; Giles-Corti et al., 2005; Sallis et al., 2006; Sallis & Owen, 2015) place focus on the nature of human transactions in relation to the physical and sociocultural environments, only a few theoretical mentions to the transactional worldview have been made. Sallis and Owen (2015) mention the works of Kurt Lewin (1951) and Roger Barker (1965; 1968), who both represent the transactional worldview in many aspects. Lewin's work has considered the psychological processes to be embedded in the physical and social situations that form a life space and emphasized holistic units of analysis (Altman & Rogoff, 1987, p. 28). The life space, according to Lewin (1951), is a dynamic field that is made up of continually changing person-environment relationships. Roger Barker's (1968) ecological psychology and the concept of behavior settings is another example of research aiming to understand the dynamic quality of the human-environment interaction. As early as in the 1960s, Barker (1965) stated that research has failed to see that the behavior and the environment are mutually causally related. Behavior setting is a central concept in Barker's and his associates' work that, according to Altman and Rogoff (1987, p. 29), can be seen as a confluence of actions in relation to places and things, and these actions are organized in systematic temporal sequences and patterns. In other words, human behavior is inseparable from the physical and social environment, and behavior setting is a good concept to understand the dynamic quality of person-environment interaction (Altman & Rogoff, 1987, p. 29). According to Barker's (1968) view, human behaviors can be predicted more accurately from the situations people are in than from people's individual characteristics. The ecological model of PA (2006; 2015) refers to the concept of behavior setting in describing the physical environmental level. However, the model does not specify in more detail what is meant by the concept or if it represents Barker's idea of behavior setting. In the ecological model of PA, behavior setting is simply described as "places where physical activity may occur" (Sallis et al., 2006, p. 302).

In addition to the seminal works of Lewin and Barker, Sallis and Owen (2015) mention the research and theorizing of social ecology by Daniel Stokols (1992, 1996, 2018). Stokols's work represents well the transactional worldview. Stokols (1992) has developed ecological analysis of health behavior and focused particularly on the conceptualization of health-promotive environments. In his work, Stokols (1992, 1996) has brought the contextually oriented view of human health and wellbeing to the field of health promotion. According to Altman and Rogoff (1987, p. 32), Stokols and other transactionally oriented researchers aim to understand and describe the holistic networks of person-environment configurations in terms of a formal causation perspective. The work of Stokols has had a strong contribution in embedding the social-ecological approach to the field of health promotion research and in particular to the contemporary ecological models in public health (Sallis & Owen, 2015). Stokols (2018) has described social ecology as a transdisciplinary, overarching perspective for framing scientific and societal problems in relation to alternative spatial, temporal, sociocultural, and virtual contexts.

Besides the aforementioned works, which lay ground to ecological models, there are some examples of theoretical works that capture the principles of transactional research that have not been mentioned alongside the ecological models. I will briefly introduce a few examples that have guided my theoretical thinking in applying the ecological models and in understanding the human-environment relationship. These theories are not directly applied or discussed in this thesis but are worth mentioning because they created ground for transactional worldview, and I believe they could serve as suitable theoretical approaches and frameworks for future research applying the ecological models.

The seminal work of J. J. Gibson on ecological perceptual psychology and the concept of affordances is one of the core examples of transactional thinking. According to Altman and Rogoff (1987, p. 27), Gibson's theoretical approach rejects the separateness of contexts and psychological processes and treats them as aspects of a holistic unit. Theoretically, this means that one cannot discuss what happens to the perceiver but rather is always required to ask what happens in the ecological totality of which the perceiver is a part. According to Kyttä (2004), Gibson's ecological perceptual psychology is based on the assumption that the person-environment relationship is immediate and based on practical activity rather than on being analytical.

In his work, Gibson (1986) brought about the concept of affordances, which refers to the perceived opportunities and restrictions concerning a person's actions in a given environment. In other words, people do not perceive benches and a bridge merely in physical terms but in a functional and utilitarian way; they perceive them as places to sit and a way to cross a river. Affordances are unique for each individual but can be shared within a group of people (Altman & Rogoff, 1987). For an older person, a bench next to a walkway can afford a place to rest while walking to get groceries, but for a teenager, the same bench can afford an opportunity for parkour tricks. Affordances can elicit activities, drawing people into perhaps unplanned behavior because the environment

makes doing so easy and enjoyable (Ward Thompson, 2013) but can be expanded to include the emotional, social, and sociocultural opportunities and restrictions that an environment offers (Kyttä, 2004). In Figure 2, I aim to illustrate how the same physical setting can be perceived by different individuals—a teenager perceives opportunities for socializing with peers near a school yard, a young adult perceives affordances for commuting by bike, and an elderly person perceives the recreational potential of the green spaces.

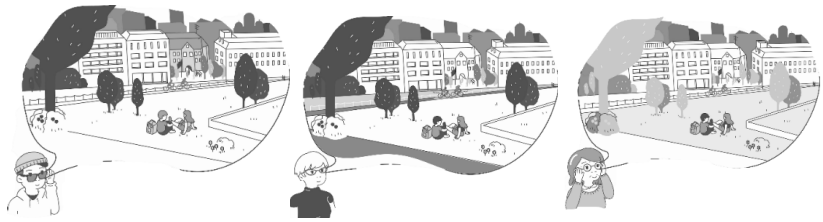

Figure 2. An illustration of J. J. Gibson's (1986) idea of how individuals perceive varying opportunities and restrictions for different actions in a given environment. Illustrations by Ada Peiretti.

Additionally, humanistic and relational geographical approaches in understanding the concepts of place and space can be seen as transactional in many aspects (Altman & Rogoff, 1987). Yi-Fu Tuan's (1974) understanding of the intimate connection of people and places brought a new holistic perspective to the field of geography and positivist spatial sciences in the 1970s. According to Altman and Rogoff (1987, p. 31), Tuan's phenomenological approach and descriptions of homes, buildings, cities, and regions as inseparable confluences of environmental and psychological experiences can be seen as examples of transactional worldview. In his work, Tuan focused on the relationship between humans and their environment and exploring the ways in which humans are, or become, "Beings-in-the-World" (Hubbard & Kitchin, 2010, p. 429). Moreover, the relational thinking of space and place by geographer Doreen Massey (2005) can be considered transactional in its aim to recognize space as the product of interrelations—as something deeply social and constructed in time. For Tuan, space as a concept is more abstract whereas place is something familiar and concrete. For Massey (2005), the concepts of space and place are not as separate. Massey rejects the thought of place as a mere state of nostalgia and inertia to which human identities and emotions simply just attach (Hubbard & Kitchin, 2010, p. 301). Instead, Massey proposes that place should be understood as "porous networks of social relations." According to Massey (2005), space is socially constructed and social is spatially constructed. Acknowledging that the concepts of space and place are multifold and could be discussed a lot further, they are not the central tenet of this thesis. However, due to the spatial nature of this thesis, I find it important to define my understanding of these concepts. I have chosen to mainly refer to the concept of place as a localized space, without considering space to be more abstract than place. In this thesis, place as a concept is understood to include abstract, concrete, emotional, individual, cultural, and social aspects that can be defined by geographic coordinates.

The nature of this thesis is essentially transactional in its approach to trying to understand older adults' everyday encounters with their environment and to study human health behavior context sensitively. Thus, applying an ecological model of PA (Sallis et al., 2006) fits well to my study purposes. However, using the ecological model requires theories that account for transactional understanding of the human-environment relationship, and thus, the theoretical foundations of this thesis rest upon the transactional worldview (Altman & Rogoff, 1987). The work of Daniel Stokols on ecological analysis of health behavior and his conceptualization of health-promotive environments guides my theoretical thinking. In addition, while the concept of behavioral settings is not used in the articles that comprise this thesis, Roger Barkers' (1968) thinking about human behaviors and how they can be predicted more accurately from the situations people are in than from people's individual characteristics is central. Moreover, the humanistic relational geographical thinking of the concept of place and space is embedded in this thesis. Finally, I want to underline that Gibson's understanding of humans and the environment forms the theoretical backbone here: one cannot discuss simply what happens in the perceiver but rather is always required to ask what happens in the ecological totality of which the perceiver is a part.

While the identification of the most suitable theories that fit the purpose, behavior, and population of interest in this thesis is central, there are still additional aspects that require attention in using the ecological models of health behavior. According to Sallis and Owen (2015), ecological models suit well for studying PA because of the spatial nature of PA. Thus, the spatial aspect is in the core of studying PA and in applying the ecological models. However, capturing the context where the health behavior in question takes place is not straightforward when aiming to study the multiple-level influences of human health behavior. Finding methods that can account simultaneously for such intrapersonal and physical environmental factors is not straightforward. Thus, in the next section I will briefly discuss the challenges and possibilities in applying ecological models from a methodological perspective.

2.3 Applying context to the ecological models of health behavior

While the past few decades have seen a growing body of research interested in studying the PA behavior in relation to the physical environmental contexts, not many studies have focused on the human-environment relationship following the principles of the transactional worldview using the ecological model framework. Sallis and colleagues (2006; 2015) have outlined that the usage of ecological models has had some considerable methodological challenges that might have had an effect on applying the models more widely. Capturing the context—the spatial reality of human behavior—is not straightforward, especially when studies or potential health interventions aim at focusing on both the human and physical environment simultaneously.

While previous, generous research has shown that individual as well as environmental features are associated with PA among older adults, these features have not been thoroughly studied concurrently and context-sensitively according to the principals of ecological models (Sallis & Owen, 2015). It is widely accepted that the environmental context can shape or constrain individual determinants of PA, but few studies have focused on examining simultaneously the multifaceted influences of the environment and the individual on older adults' PA. Studies that have examined the associations between the neighborhood built and natural environments and the health of older adults have found a host of environmental characteristics associated with older adults' health behaviors (Kerr et al., 2012; Sallis et al., 2016). However, most of these studies tend to assume that the physical environment (the behavior setting as described in the PA model) that influences health behavior is merely the immediate home environment or a neighborhood determined by administrative boundaries. This is a rather ill-fitting assumption because human behavior is very unlikely bound to administrative boundaries or static buffered areas defined around individuals' homes.

PM methods, such as the Public Participation Geographic Information System (PPGIS), have been convenient tools for previous studies investigating the active two-way human-environment relationship (Brown & Kyttä, 2018; Kyttä, Broberg, & Kahila, 2012; Kyttä, Broberg, Tzoulas, & Snabb, 2013; Raymond, Brown, & Weber, 2010). Localization of human behavioral patterns and experiences by advanced PM tools attach them to a specific physical environmental context (Brown & Kyttä, 2014; Kyttä et al., 2013). Thus, the human behavior, perceptions, opinions, and experiences get geographic coordinates, which allow simultaneous geographic information system (GIS)-based analysis of human behavior in relation to the physical environment (Brown & Kyttä, 2014). These kinds of spatially bounded studies have proven effective, and the usage of PM tools have provided a way to overcome the identified contextual challenges and improved our understanding about the mechanisms that connect place to health (Kyttä et al., 2015, 2013). However, in the health promotion field, the context of human health behavior is often still defined based on static neighborhood boundaries. While there are some examples of global positioning system (GPS) tracking used in defining the context of PA behavior, PPGIS methods have not been applied (Chaix et al., 2013; Hirsch, Winters, Ashe, Clarke, & McKay, 2016). PPGIS methods have proven comparable to GPS in capturing the context, but the research and recruiting requirements in using PPGIS are substantially lower (Hasanzadeh et al., 2018; Kestens et al., 2018).

Previous studies interested in the relationship between the environment and human health have mainly used static spatial units of analysis to capture the physical environment. Leal and Chaix (2011) found that 90% of the studies examining the associations between the built environment and cardiometabolic risk factors focused solely on residential environments. Administrative boundaries, postal code areas, and census tracts are examples of static and simple spatial units of analysis to study the environmental context. More developed spatial

units of analysis are buffers, spherical or network, that are created around individual home locations of study participants. In other words, research has focused on studying human health behavior in relation to the environment within administrative or residential buffer boundaries. These units have been a popular way of defining the spatial extent of individuals' exposure to different environmental features, mostly due to their availability and ease of use (Hasanzadeh, Broberg, & Kyttä, 2017; Holliday et al., 2017). However, such approaches are embedded with a presumption that individual health behavior is bound to static administrative boundaries or certain buffered distances around individuals' homes. Thus, these approaches have been criticized for being too static and not accounting for actual individual differences in mobility exterior to the place of residence because they tend to ignore individuals' true spatio-temporal behaviors (Hasanzadeh et al., 2017; Kwan, 2018; Perchoux et al., 2013). According to Kwan (2012), this kind of "uncertain geographic context problem" can be one of the major reasons for the inconsistency in the research findings regarding the effects of the built environment on health. Thus, in this thesis, in addition to studying how the physical environment can support healthy and active ageing, the objective is to study the possibilities of online PM methods in environmental health research among older adults as well as the novel ways of modeling the human-environment interactions using data collected through online PM methods.

2.4 Summary

In this thesis, I follow the main principles of the ecological model of PA where multiple-level and interacting factors are considered to affect older adults' PA behavior (Sallis et al., 2006; Sallis & Owen, 2015). The transactional worldview comprises the theoretical foundations of this thesis where the human and the environment are not seen as separate *elements* but more as *aspects* of a system—that is, person and context (Altman & Rogoff, 1987, p. 24). The theoretical works of J.J Gibson (1986) and Daniel Stokols (1992, 1996) direct my understanding of human-environment interaction in this thesis. Thus, the person-environment relationship is seen and understood as immediate and based on practical activity rather than on being analytical. Gibson's (1986) way of understanding perceptions as a functionally active process is embedded in the theoretical grounds of this thesis. Stokols' (1992, 1996) contextually oriented view of human health and wellbeing supplements the theoretical framework of this thesis. The theoretical framework is employed with varying consistency because the thesis also has a strong methodological approach. This thesis focuses also examining the possibilities of PPGIS methods in health promotion research among older adults and the novel ways of modeling the human-environment interactions using PM data.

3. Research methods, approach, and process

The broad aim of my research that is presented in this thesis is to understand how the physical environment in concurrence with individual factors can support healthy and active ageing. To examine and understand the multifaceted influences that the environment has on human health behavior, special context-sensitive methodologies are needed. Thus, PM methods have had a central role in the studies of this thesis.

An internet-based SoftGIS method, an advanced example of PPGIS, was used in all of the studies in this thesis. The SoftGIS method was originally developed at Aalto University for collecting online spatial experiential knowledge and engaging non-experts in participatory urban planning and decision-making processes (Brown & Kyttä, 2014; Kyttä & Kahila, 2011). The benefits of SoftGIS methods for transactional human-environment research are multiple. With the online SoftGIS surveys, researchers are able to study various aspects of human behavior in relation to the physical environment. PPGIS methods, such as the SoftGIS, offer ways to study the human experiences and behavioral patterns in relation to the physical environment. In previous studies, the SoftGIS method has been used for studying the perceptions about residential environmental quality (Kyttä et al., 2013), children's independent mobility and AT behavior (Broberg, Kyttä, & Fagerholm, 2013; Broberg, Salminen, & Kyttä, 2013; Sarjala, Broberg, & Hynynen, 2015), environmental justice and accessibility (Laatikainen, Tenkanen, Kyttä, & Toivonen, 2015), children's behavior settings, and perceived health (Kytta et al., 2012; Kyttä et al., 2018) and social sustainability of urban settings (Kyttä et al., 2015). Previous research has also studied SoftGIS methodology and PPGIS as tools to be used in urban and environmental planning, community development, and decision-making contexts (Kahila-Tani, 2015; Kahila-Tani, Broberg, Kyttä, & Tyger, 2016; Schmidt-Thomé, Wallin, Laatikainen, Kangasoja, & Kyttä, 2014).

The most evident benefit of using the SoftGIS method in person-environment research is the spatial dimension of the surveys. All of the surveyed behavioral aspects get geographic coordinates and thus can be analyzed simultaneously with more conventional register-based GIS data depicting the various aspects of the physical world. For this thesis, the SoftGIS method enabled creating a study setting that could follow the multilayered ecological model of PA (Sallis et al., 2006) where various aspects associated with PA were taken into account. Localizing human experiences, perceptions, and behavioral patterns to a map gives

them geographic coordinates and thus attaches them to certain physical settings. Article **I** created grounds for using the SoftGIS method in studies with an older population, and the SoftGIS method allowed for a context-sensitive study setting in articles **II**, **III**, and **IV**.

The material and data sets used in the articles of this thesis have been collected in three different research projects (Table 1). The ActiveAGE research project (2014–2018) was funded by the Finnish Culture and Education Ministry, and two work packages of the project were essential in regards to this thesis. In the first work package of the ActiveAGE project, the objective was to explore the usability of PPGIS among older adults and to develop a usable online PPGIS method for a place-based study of older adults' person-environment relationships. The data and materials collected in the first phase of the project were used in creating article **I**.

The second work package of the ActiveAGE study consisted of online SoftGIS data collection. A random sample of 5,000 residents of the HMA aged between 55 and 75 years was acquired from Finland's Population Register Center in the fall of 2015. In total, 1,139 full or partial responses were received. In the "Me and my everyday environment" survey, the participants used an online tool, the Maptionnaire®, to mark on a map their home and everyday errand points (EEP) (Figure 3). EEP's consisted of shopping, leisure and recreational, office, bureaus and businesess, and outdoor and sport facility places. For the EEPs, the respondents also described how often they visit the places and by which mode of transport they access those places. In addition, the respondents were asked to mark on the map the places of their everyday environment where they feel happy. Respondents also answered questions related to their sociodemographic background, perceived health, and personal psychological features, namely their personal life goals. Articles **III** and **IV** are based on particular parts of the collected "Me and my everyday environment" data set (Table 1).

The materials and data sets from article **II** were obtained from the Kids Out! research project and Urban Happiness research project. In article **II**, the data sets of these two projects are combined. In both the Kids Out! and Urban Happiness projects, the respondents were asked to mark positive locations of their living environment on a map. The Kids Out! data set was collected from 16 comprehensive schools in HMA (the cities of Espoo, Helsinki, and Vantaa) in 2011. The data set from the Urban Happiness research project was collected in 2009. For the project, 10,000 invitations were sent to a random sample of the adult population (15–65 years old) from 11 residential areas of the HMA (including only the cities of Espoo and Helsinki). Survey responses from 2,027 residents of Helsinki and 1,092 of Espoo were received. The tools that were used to collect the Kids Out! and Urban Happiness data set were early versions of the SoftGIS methodology that were at that time upheld by the Aalto University.

Table 1. The data sets used in different articles.

	Article I	Article II	Article III	Article I
Project where the data was collected	ActivAGE	Urban Happiness / Kids Out!	ActivAGE	ActivAGE
Year the data was collected	2015	2009 / 2011	2015	2015
Geographical context	Helsinki Metropolitan Area	Helsinki Metropolitan Area	Helsinki Metropolitan Area	Helsinki Metropolitan Area
Participant recruitment	Sequential sampling method for older adult visitors of Kamppi Service Center, Helsinki	10,000 randomly sampled residents from 11 residential areas of Espoo and Helsinki / 16 comprehensive schools in HMA participated with 5th and 8th grade students	5000 randomly sampled HMA residents, 55 to 75 years old	5000 randomly sampled HMA residents, 55 to 75 years old
Response rate	The researchers tried to find as many relevant cases as possible until a saturation point was reached	31 %	23 %	23 %
n of the final study participants	20	3119 / 896	844	844
Collected measures used in the study	Records of computer screens and participants' voices, researchers' field notes	6381 positive place markings, age of the respondent / 1799 positive place markings, age of the respondent	EEP's + travel mode and visitation frequency, home points, sociodemographic background, perceived health; (1) overall health situation, (2) ability to function, (3) quality of life, and (4) state of happiness, GPS tracks (n=29)	EEP's + travel mode; walking, and visitation frequency, home points, personal goals, sociodemographic background, perceived health; (1) overall health situation, (2) ability to function, (3) quality of life, and (4) state of happiness
Address of the survey	app.maptionnaire.com/825	softgis.fi/helsinki / softgis.fi/children	app.maptionnaire.com/825	app.maptionnaire.com/825
Funding	Finnish Ministry of Education and Culture	National Technology Agency of Finland / Finnish Ministry of Education and Culture through Finnish Academy's Research Programme on the health and welfare of children and young people	Finnish Ministry of Education and Culture	Finnish Ministry of Education and Culture
Partners	City of Helsinki Department of Social Services and Health Care and Culture and Leisure unit	Tampere University of Technology, UKK Institute, LaTrobe University (AU), City of Bendigo (AU), University of Tokyo (JPN)	Cities of Espoo, Helsinki, and Vantaa	City of Helsinki Culture and Leisure unit

Figure 3. The interfaces of the different surveys used to collect the data sets for this study. Right: "Me and my everyday environment" survey from 2015; Left: Kids Out! –survey from 2011.

3.1 The spatial models used in the study

There are different spatial units of analysis that have been used in different articles in this thesis. Therefore, I will briefly introduce them. In article **II**, a 50-meter spherical buffer was used to capture the physical environment around the positive places mapped by the participants (Figure 4, a). In this article, there was interest in the immediate physical environment around the positive places mapped by the participants and, thus, it was decided that a simple spherical buffer was a suitable spatial unit of analysis for that particular study. In article **III**, four different spatial units of analysis were compared. An administrative unit, 500-meter residential buffer, home range model (HR), and IREM were used to assess the associations between the built environment and perceived health of the respondents (Figure 4, a, b, c, d). In article **III**, the authors were particularly interested in what kind of results different spatial units of analysis return in studying the environmental influences on older adults' perceived health. The first model, administrative boundary, is a commonly used spatial unit of analysis in the broad field of environmental health promotion. The administrative unit was based on the postal areas and determined for each individual based on their place of domicile. The second model used was a 500-meter circular buffer around each individual's home, another commonly used spatial unit of analysis in studies focusing on the associations between a neighborhood's built environment and human health. The third model used was the HR model, which is an individual-specific versatile boundary method that considers the individual-specific variations of HRs. The model uses customized minimum convex polygons to capture individuals' true experienced neighborhoods instead of static administrative boundaries or plain spherical buffers around individuals' homes (Hasanzadeh et al., 2017). The HR model uses PPGIS data to delineate individual HRs. To delineate an HR, one needs spatial locational data about an individual's residence and/or places the individual visits. An HR model returns a vector-based polygon representing individuals' HRs. The HR model was also used as a spatial unit of analysis for studying the multiple-level correlates of older adults' AT in article **IV**. The fourth model used in article **III** is IREM. Somewhat similarly to the HR model, IREM uses PPGIS data about places visited by respondents to delineate the model. However, in IREM, the

exposure is expressed by assigning weights for places visited in terms of reported visits per month with the highest frequency of visits assigned to the home location (Hasanzadeh et al., 2018). IREM returns a raster model in which each cell represents the degree of the individual's exposure. In addition, IREM estimates the level of exposure by considering the travel behavior of each individual. Following the IREM criteria, the level of place exposure was estimated for each respondent throughout individual activity spaces by using information on home location, visited places, frequency of visits, travel paths, and use of travel modes (article **III**).

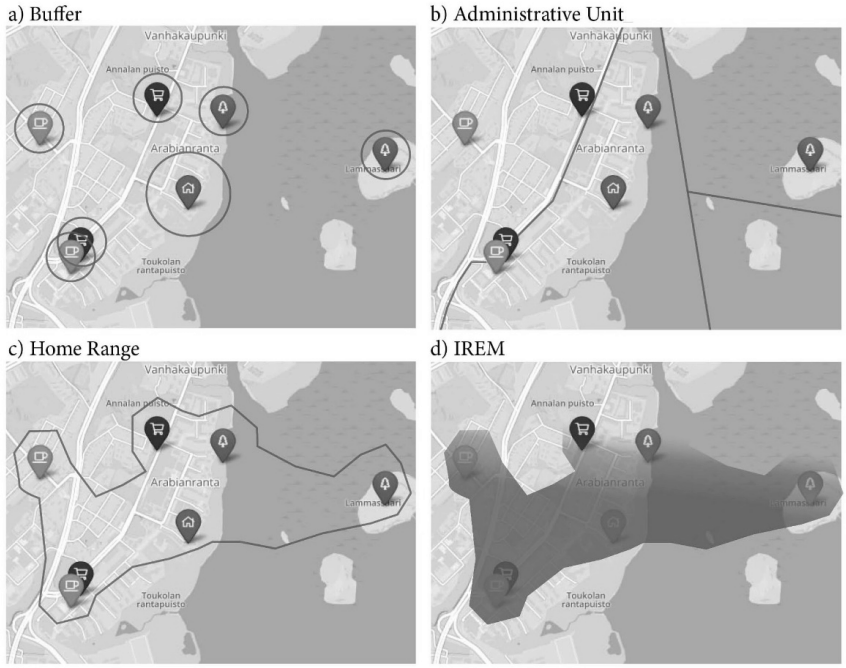

Figure 4. Illustrations of different spatial units of analysis used in articles **II**, **III**, and **IV**.

4. Results and Discussion

In this section, I will present and discuss the findings according to the objectives and research questions of this thesis. Firstly, the objective of this thesis has been to study possibilities and challenges of online participatory mapping methods in health promotion research and in applying ecological models among older adults and, secondly, to study different physical environmental contexts and how they are associated with PA and health of older adults following the principles of the ecological models. I will present and discuss the results per the five research questions that were presented in the introduction.

4.1 Online participatory mapping methods in research about older adults

A key methodological objective of this thesis has been to explore the usability of PPGIS among older adults. The results of article I suggest that online PM methods are suitable for older adults but that there are some considerable challenges that need to be considered. It was concluded that older adults face certain cognitive, sensory, and motor challenges when using online PM tools, most of them very similar to challenges they encounter when using the internet and computers in general. Thus, no major challenges related to PPGIS tools in particular were found among older adults. However, it should be noted that the study took place in Finland where residents of all ages are rather active users of computers and the internet (Taipale, 2013). According to the results, in the future, researchers and practitioners aiming at engaging participants of all ages through PPGIS tools should consider a few particular aspects related to challenges that older adults face when using computers, the internet, and online tools. The cognitive challenges that older adults faced were mostly related to general usage of computers, such as difficulties using the mouse wheel and zooming buttons on the maps, whereas the motoric challenges were related to a certain PM exercise that was route drawing. As cognitive and motoric challenges are known to increase alongside ageing (Chodzko-Zajko et al., 2009), participation through online PPGIS by the oldest population should be very carefully considered. Sensory challenges were related mostly to the relatively small text, icons, and elements in the tool. Thus, modifiability of the size of the text and other elements seems particularly important in making any online tool more

usable for the older adult population. A recent study about the usability of internet mapping platforms in participatory spatial planning concluded that there is great potential in reaching a wide audience and in engaging people with web-mapping interfaces (Rzeszewski & Kotus, 2019). Rzeszewski and Kotus (2019) found that the quality and quantity of produced PPGIS data were similar between younger and older adults. Similar to article I, Rzeszewski and Kotus (2019) concluded that age does not seem to be a barrier in PPGIS when the interface is properly designed. In article I, the online PPGIS tool Maptionnaire® interface was modified together with the service provider according to the first-phase results of the study. Later, the modified version of the tool was used to collect data about older adults' everyday practices and environments in the ActivAGE research project. Afterwards, the data collected in the ActivAGE project were compared to another data set that was collected in an earlier version of Maptionnaire® in an Everyday Urbanity research project. The results showed that older adults had used mapping elements significantly more in the ActivAGE study ($M = 5.8$, $SD = 4.68$) compared to the Everyday Urbanity study ($M = 5.0$, $SD = 3.57$), $t(1373) = 3.43$, $p = .001$. Furthermore, it was concluded that designing PM tools for marginal groups, such as older adults, could ensure the usability of the tools across all user profiles. In addition, it was concluded that both the functional and content design of online surveys and mapping tools are essential for greater usability that in turn provide better possibilities for large-scale public engagement.

4.2 Participatory mapping methods in health promotion research

Other methodological objective of this dissertation has been to study the possibilities and challenges of online PM methods in health promotion research and in applying ecological models. The data for articles II, III, and IV were collected with an online PPGIS tool and thus comprise the results and discussion of this section. All of the results concluded the relevance of including a place-based perspective and PPGIS type of spatially referenced data to studies on health promotion and human-environment interactions. The results summarize that localization of human experiences and behavioral patterns by PM tools attach them to a specific physical environmental context, and thus, the human behavior and experiences get geographic coordinates, which allows simultaneous GIS-based analysis of actual human (health) behavior in relation to the physical environment.

Article II includes analysis of the physical environment around positive place markings that respondents of different age groups had mapped using an online PPGIS tool. This article summarized that the place-based approach provided intriguing insights about which kinds of outdoor environments individuals of different age groups perceive as being positive and where they choose to go to and spend their time. The data and analysis of mapped positive places offered a possibility for identifying whether different age groups favor different types of

physical environments. Using the PPGIS method, the perceptions of respondents were localized to actual physical space, and the kind of physical environmental characteristics that depict such positive places were analyzed. Respondents' perceptions received geographical coordinates, which in turn made a versatile GIS analysis of the physical settings possible.

Article III compared two common residential units of analysis and two novel activity space models that use PPGIS data to delineate individual activity spaces and studied how different kinds of spatial analytical units can effect the results of the association between older adults' perceived health and the physical environment. It was concluded that by using the novel activity space models delineated from PPGIS data, future research could better capture the various health-promotive aspects of the physical environment. An additional notable methodological result from article III is that the activity spaces generated from PPGIS data showed general consistency with the GPS activity spaces. When a 4-km cutoff distance to the GPS activity space was applied, the home range model covered almost 80% and IREM 65% of the GPS activity space. The administrative unit covered 59 % of the GPS activity space and the buffer showed the lowest match rate with an average overlap of around 55%. Kestens et al. (2018) found similar results in their study comparing activity spaces delineated from public PM data to activity spaces delineated from GPS data. Some studies in the field of health promotion and public health have used GPS data to capture the notions of activity spaces and environmental exposure (Chaix et al., 2013; Hirsch et al., 2016; Kestens et al., 2018). According to the results of article III, studying environmental exposure through PM methods and with PPGIS-type data seems accurate and precise compared to GPS but is considerably less demanding, costly, and time consuming.

In article IV, PPGIS data enabled a spatial and context-sensitive approach to study older adults' AT patterns by the principles of ecological models (Sallis & Owen, 2015). The results suggest that future studies, including interventions, on health behavior and PA should investigate simultaneously the individual demographic and psychological as well as the built environment factors with spatially bounded context-specific methods. It was concluded that the usage of PPGIS data offered a possibility to study the exact geographical areas where the respondents live in and move around instead of using plain administrative areas or residential buffers. According to the results, novel exposure modeling approaches, such as the individual HR model, enable researchers to study the characteristics of the environment within those exact geographical areas where people live in and report moving around.

Ecological models emphasize that multiple levels of factors influence health behavior and that environmental contexts are significant determinants of human health behavior (Sallis & Owen, 2015). Thus, it should be of prime importance for researchers in the field of health promotion to aim to capture the actual contexts where the health behavior takes place. Using PPGIS tools could help overcome previously indentified contextual challenges. Altogether, the results suggest that PPGIS approaches add value to health promotion research. The context-sensitivity and spatiality of PPGIS approaches introduce novel

ways to capture the multidimensional aspects related to human health behavior. Future research adopting the principles of ecological models of health behavior (Sallis & Owen 2015) should sincerely consider implementing PPGIS methodologies in their study settings in order to capture the multidimensional nature of everyday PA behavior.

4.3 Green and blue spaces close to home describe older adults' perceptions of a quality environment

According to the ecological models (Sallis & Owen, 2015), perceived environment is one of the factors influencing active living. While the perceived quality of the physical environment has been studied previously (Bonaiuto, Fornara, & Bonnes, 2003; Fornara, Bonaiuto, & Bonnes, 2009), few studies have focused on the perceptions of a quality environment of different age groups. Article II attempts to understand what qualities of the physical environment older adults appreciate and thus might motivate them to move outdoors and if these qualities are different from other age groups. Findings from article II show that there are differences in the perceptions of the physical environment quality across age groups. Individuals of different ages favor different kinds of physical environments. When analyzing places that different age groups perceive as positive and good quality, it was found that older adults' and two other adult age groups' positive places were mostly located in green and blue spaces. Article II reported that median percentage of green and blue land uses within a 50-meter buffer of positive places was 12% for children, 16% for adolescents, 27% for young adults, 31% for working age adults and finally 32% for older adults. Adolecents' and young children's positive places were mostly characterized by sports-related, institutional, and commercial spaces. Article II reported median percentage of sports-related land uses being 30% for children, 39% for adolescents, 18.5% for young adults and 24% for both working age and older adults.

The results regarding the importance of green and blue spaces is in line with previous research where the green, blue, and natural areas have been shown to be important for the adult population and particularly for older adults (Ottoni, Sims-Gould, Winters, Heijnen, & McKay, 2016; Takano et al., 2002; Ward Thompson & Aspinall, 2011). According to these results, it seems evident that the provision of green, blue, and natural spaces is one central factor in supporting healthy and active ageing. However, it should be noted that overemphasizing the importance of green spaces in urban planning and in health promotion research literature could have its pitfalls because the overall results indicated that for adolescents and younger children the green spaces were underrepresented in their positive places compared to other land uses. Thus, perhaps combining green and blue spaces with sporting areas and playgrounds as well as commercial-related land-use elements could serve as a potential solution for creating intergenerational environments for promoting people of all ages to get outdoors.

The median distance to the positive places was found to be shortest for older adults (406 meters) among all studied age groups (435 m for children, 1165 m for adolescents, 522 m for young adults, 465 m for working age adults). This is a particularly interesting finding given that children are often seen as the primary group constrained to neighborhood environments. Thus, the questions of territorial range, a well-studied concept among children (Carver, Veitch, Sahlqvist, Crawford, & Hume, 2014; Kyttä et al., 2012), should be carefully considered among older adults, especially during and after a transition to retirement and alongside the ageing process. In summary, the results suggest that positive places of older adults are in close proximity to home and strongly characterized by green and blue elements of the physical environment. The provision of green and blue spaces and other important destinations that older adults visit in rather close proximity to their residence or providing housing for older adults in close proximity to green and blue spaces are potential strategies for urban planning and land-use management to create environments that support the wellbeing and PA of older adults.

4.4 The physical environment is associated with the perceived health of older adults, but the way the physical environment is studied and measured should be carefully considered

Prior research has reported highly heterogeneous results about the contextual effects on health and PA. Thus, in article III the authors compared whether the association between the physical environment characteristics and older adults' perceived health outcomes differ when measuring the environmental characteristics with different spatial units of analysis. According to the results, the use of different spatial units seems to influence the associations between the physical environment characteristics and older adults' perceived health. In article III, it was found that the amount of green space was positively associated with respondents' perceived health when respondents' actual exposure to the physical environmental characteristics was assessed with IREM (overall health $r=0.01$, $p<0.05$; functional capability $r=0.09$, $p<0.05$; quality of life $r=0.09$, $p<0.05$). IREM, a spatial unit of analysis that accounts for the true individual exposure and activities undertaken in a certain place, uses PPGIS data to delineate respondents' activity spaces. Green space was associated positively with older adults' perceived health when the actual places that older adults reported visiting and spending their time were studied. In contrast, when analyzing the association between green space and perceived health using an administrative neighborhood boundary, the amount of green space was found negatively associated with respondents' perceived health (overall health $r=-0.25$, $p<0.01$; functional capability $r=-0.03$, $p<0.01$; quality of life $r=-0.17$, $p<0.01$; happiness $r=-0.10$, $p<0.05$). Thus, higher green area proportions around the residency decreased the respondents' perceived health. Furthermore, the results indicate that true exposure to green spaces instead of availability of green spaces are associated with older adults' health. In a Danish study, researchers found somewhat similarly that respondents who did not report having stress were more likely to actually visit a green space than adults who reported stress (Stigsdotter

et al., 2010). Furthermore, a UK study concluded that it is a combination of a sufficient amount of activity and enjoyable outdoor experiences that fosters health in older adults (Sugiyama & Ward Thompson, 2007). These results point toward conclusions that good accessibility, perceived quality, and desirability instead of quantity and plain availability of green spaces are focal aspects in planning healthy communities and cities. This conclusion is further supported by findings from a study conducted in Tokyo, where they found that green areas that were accessible from home and easy to walk in positively influenced the longevity of urban senior citizens (Takano, Nakamura, & Watanabe, 2002).

In addition, the walkable environment was found to be positively correlated with older adults' perceived health measures when studied with the HR model (overall health $r=0.10$, $p<0.05$; quality of life $r=0.12$, $p<0.01$; happiness $r=0.10$, $p<0.05$) but not when IREM was used as a unit of analysis. Briefly, the main difference between the HR model and IREM is that the former captures the boundaries of individual activity spaces and creates a kind of versatile activity polygon of respondents' everyday activities whereas the latter creates an exposure grid that captures areas of higher and lower exposure to the environment. Both of these models use PPGIS data, such as everyday activity points marked on a map by respondents. What is intriguing is that these models return different results when different environmental characteristics are being analyzed. Green space associated positively with older adults' health when individuals' true exposure to green spaces was analyzed using IREM but not when the availability of green spaces was analyzed with administrative units, residential buffers, or the HR model. On the other hand, walkability of the environment was positively associated with older adults' health when the availability of walkable environment characteristics was analyzed with the HR model but not when analyzed with IREM. Based on these results, it was concluded that true exposure to green spaces is a key for health, but this is not the case with walkability of the environment. Moreover, being exposed to a walkable environment does not necessarily associate with health, but it is the availability and supply of highly walkable environments that associates with older adults' health. Previous research has shown that being truly exposed to a natural environment has immediate health effects (Tyrväinen et al., 2014), and it is well known that AT habits have health benefits across the population (Kelly et al., 2014). Thus, the provision of walkable environments could motivate older adults toward walking habits, which in turn enhances their health, and creating accessible natural areas where older adults can expose themselves to the health-promotive aspects of green spaces would be an optimal solution for creating supportive environments for healthy and active ageing.

Finally, article III discusses the uncertain geographic context problem, which has been strongly linked to the conventional spatial units of analysis used in health promotion research (Kwan, 2012; Zhao et al., 2018). The findings suggest that using rather simplistic and static units of analysis, such as administrative neighborhood boundaries or home buffers, are not very suitable approaches for measuring the activities of individuals or capturing individual environmental exposure. It is evident that researchers in the field of health promotion should

more carefully consider the usage of different spatial units and evaluate their implications for the research outcomes in order to better assess the contextual effects of human health. Assuming that individuals move around and are exposed simply to the immediate residential neighborhood is overly simplistic and might return false results about the human-environment interaction.

4.5 Multiple factors influence older adults' walking behaviour —the physical environment plays one of the core roles

Finally, the results of article IV show that multiple levels of factors influence older adults' walking habits. The results of five separate OLS regression models showed that residential (β=0.720, $p < 0.001$) and walkway (β=0.278, $p < 0.001$) density, the density of public transit stops (β=0.532, $p < 0.001$) and intersections (β=0.092, $p < 0.05$), and the density of recreational sport places (β=0.135, $p < 0.01$) all have significant direct effects on older adults' walking. Residential and public transit stop densities were shown to have the largest direct effect on older adults' walking. While a vast amount of previous research has shown that the physical environment is associated with PA (Saelens & Handy, 2008; Sallis et al., 2016), only a few studies have actually accounted for multiple levels of individual and environmental factors simultaneously (Mertens et al., 2018; Carlson et al., 2012). In article IV, it was found that personal features do not have a mediating role in the relationship between the physical environment and walking by older adults in the HMA. Thus, according to the findings, the physical environment has an independent effect on older adults' walking behavior, regardless of individual demographic or psychological features. This is a very intriguing result given that previous research in health promotion has lacked in its capability to account for residential self-selection (Cao, Mokhtarian, & Handy, 2009). Previous studies have not been able to distinguish whether it is the physical environment characteristics, such as walkability, that solely support everyday PA of residents of certain neighborhoods or if it is simply that certain types of people who appreciate PA lifestyles tend to settle and live in highly walkable neighborhoods. Moreover, these results add to the previous evidence by showing that the associations between the physical environment and older adults' walking behaviors exist, even after controlling the motivational features behind people's actions. Thus, according to the results, the physical environment can play a core role in supporting, or in the worst case discouraging, older adults' walking behaviors despite their personal interests and background.

These results are interesting given that for long studies in the field of health promotion have accounted mainly for individual behaviors (Glanz, Rimer, & Viswanath, 2015). Recently, one of the most popular theories applied in health behavior research, the Theory of Planned Behavior, has been strongly criticized for placing too much emphasis on the role of conscious factors in predicting behavior and also for not explaining sufficient variability in behavior (Sheeran, Gollwitzer, & Bargh, 2013; Sniehotta, Presseau, & Araújo-Soares, 2014). While the Theory of Planned Behavior has arguably many great strengths in its capability of predicting individuals' behavior (Conner, 2015), perhaps especially in

health promotion studies that focus on PA behavior, its applicability should be reviewed through ecological models and at least be complemented with other theories that emphasize the role of the environement. This way, the environment, which arguably plays a significant role in influencing PA behavior, could be better recognized and focus would not be too strongly placed on the individual.

While the environment was found to play an important role in older adults' walking behavior, it was also found that older adults' personal goals related to PA and sports have a direct positive effect on walking, meaning that the higher the importance that PA- and sports-related goals are for an older adult, the more they walk for transport. The direct effect of PA and sports goal factor was significant and varied between β=0.124 and β=0.175 in the five different models. These findings further strengthen the findings of previous studies where older adults' personal goals related to PA and cultural functions were found associated with high exercise activity (Milla Saajanaho et al., 2014). In addition, these results support the principle of the ecological perspective where multiple levels of factors are thought to influence health behavior. According to the results, a walkable, well-connected, and destination-rich environment may encourage the walking behavior of even those older adults who are not very interested in PA, and psychological factors are associated with everyday PA in older adults. These results support health interventions targeting both individuals and the environments being most effective in getting older adults to move actively in their everyday lives compared to interventions that focus solely on the individual or the environment (Sallis & Owen, 2015).

5. Conclusions

This section draws conclusions from all four articles that comprise this thesis. In this section, I conclude both the scientific and practical implications of the four studies but also discuss briefly about environmental health promotion in Finland, especially from the viewpoint of the everyday PA behavior of older adults. In this section, I also discuss the main recognized limitations of this study and finally draw together some future research recommendations.

The interdisciplinary approach of this thesis and the study setting combining both theoretical and empirical objectives contribute to the ecological models of health behavior. The empirical and methodological findings of this thesis strengthen the notions of ecological models of health behavior—multiple levels of factors influence health behavior and environmental contexts play a significant role in determining health behavior (Sallis & Owen, 2015). This thesis illustrates the potential of a transactional research approach for the studies applying the ecological models of health behavior. A transactional research approach emphasizes the two-way relationship between the human and the environment and thus supports the very principles of the ecological models. While ecological models have been central to health promotion practices for decades, still to date there has been a need to refine the concepts and methods used in research and practice (Sallis & Owen, 2015). While ecological models broaden perspectives about the multiple-level factors that affect human health behavior, they do not identify specific constructs or how the models should be used in research and practice. This might in turn have an effect on the recognized theoretical and methodological challenges of applying the models more widely (Sallis et al., 2006; Sallis & Owen, 2015). This thesis has illustrated, through incremental steps taken in articles I–IV, how transactional theories in general and a methodology that strongly rests upon the transactional worldview in particular can contribute to applying the ecological models of health behavior. According to Sallis and Owen (2015), ecological models offer a framework for integrating other theories and models for creating a comprehensive study design.

In my conclusions, there is great potential to apply the theoretical grounds of transactional worldview and public PM methodologies more closely to the field of health promotion and studies applying the ecological models. According to Sallis and Owen (2015, p. 45), the challenge that depicts the usage of ecological models of health behavior is to identify the appropriate theories and models for the purpose, behavior, and population of interest. Thus, research applying ecological models could benefit from a profound theoretical and methodological

scrutiny to create more comprehensive study settings where the mentioned multiple-level factors could be considered.

Articles I–IV of this thesis highlight that localization of human experiences and behavioral patterns by PM methods attach them to a specific physical environmental context. Hence, the human behavior and experiences receive geographic coordinates, which allow for simultaneous GIS-based analysis of human health behavior in relation to the physical environment. The central tenet of the ecological model of PA is that the intrapersonal, sociocultural, perceptual, physical environmental, and policy factors all can influence health behavior with varying degrees depending on the behavior and population of interest (Sallis et al., 2006). PM methodologies that are based on the theoretical grounds of transactional worldview, complemented with other methods, theories, and analyses, can touch upon several different layers of these factors simultaneously. In this thesis, article II focused on studying both perceptual and physical environmental factors simultaneously. Article III studied older adults' perceived health in relation to the physical environment, and finally, article IV studied various intrapersonal and environmental factors in relation to older adults' everyday AT. The possibilities of studying the multiple levels of human-environment interaction through PPGIS methodologies can be seen as an advantage compared to other methods applied in the field of health promotion research (Glanz et al., 2015).

This thesis contributes to still understudied possibilities of context-sensitive PM methods in health promotion research. The research approach described in this thesis is novel in its methodological contributions. Studying the usability and later using the online PM methods among older adults, has been seminal and offers fresh openings to various fields of health promotion research. The findings of article I and the whole thesis more broadly offer practical implications for those already working with online PM methods and older adults and computer interfaces. The online PM methods offer potential ways to collect research data but also for engaging citizens for participatory planning practices (Kahila-Tani et al., 2016; Pocewicz, Nielsen-Pincus, Brown, & Schnitzer, 2012). Rzeszewski and Kotus (2019) focused in their study only on PM in urban planning and argued its relevance due to the findings of one study (Ståhle & Balfors, 2017), where the rate of practical implementations in the PPGIS area outpaced the academic inquiry. I disagree with this argument and suggest that, despite the low level of academic inquiry to date, PM methods have great potential in various fields of research, environmental health promotion being one great example. Articles I–IV demonstrate the various possibilities that PM methods offer for future environmental health research and especially in applying the ecological models more broadly. While GPS studies have recently gained grounds in the field of environmental health promotion (Hirsch et al., 2016; Wheeler, Cooper, Page, & Jago, 2010), the usage of GPS is highly demanding, especially in terms of participant recruitment and participation as well as data collection. As this thesis and other studies have shown, PPGIS offers practical alternatives for GPS in capturing the context of human health behavior (Chaix et al., 2013; Kestens et al., 2018). Also, the usage of HR and IREM models to capture the

true individual activity space and environmental exposure is still to date rather rare, especially in the field of environmental health research where the questions of Modifiable Areal Unit Problem (MAUP) and Uncertain Geographical Context Problem (Kwan, 2012; Zhao et al., 2018) are rather understudied.

In article IV, the effect of the physical environment to older adults walking was studied with PM method and by using the HR model. HR captures the boundaries of individual activity spaces and creates a kind of versatile activity polygon of respondents' everyday activities. Studying environments where the respondent's acutally move around was possible by using the HR model, which has not been done much in previous studies on older adult's AT. Most of the previous studies on PA and AT have used static spatial models or individuals' perceptions to capture the physical environment, which in turn could be a potential cause in the discrepancies in the results between different studies (Kwan, 2012, 2018). Previous studies report varying environmental features being associated with older adults' PA or AT in particular. In their review, Cerin and colleagues (2017) found land use mix and access to destinations as more consistent correlates of older adults' AT than residential density and street connectivity, wheres in article IV residential and public transit stop densities were shown to have the largest direct effect on older adults' AT. The spatial units of analysis used in the studies might explain these differences. In the review by Cerin and colleagues (2017), the spatial units of analysis of different studies was not assessed or used as a criteria, but they conclude that neighbourhood environmental attributes were more frequently gauged via self-reports than objective measures. A review by Barnett and colleagues (2017), where older adults PA and total walking was assessed, concluded that effects were generally stronger for associations between the perceived environment and PA than between objective environment and PA. However, the spatial modelling of the objective environment was neither assessed in the Barnett and colleagues (2017) review. The HR model used in article IV captured the actual objective environment where the respondets reported walking and returned strong associations for all individual components of walkability – namely residential, public transit stop and destination density and connectivity. Perhaps, the stonger associations between the perceived environmental characteristics and AT found in previous studies is related to perceptions capturing better the actual activity spaces of individuals, similarly to the HR model, compared to residential buffers and other static models focusing simply on residential environments. However, relying simply to perceived environment attributes when studyin the physical environment is not perhaps optimal without attaching the perceptions to spatial settings as the planning and design of the environements is always a context sensitive effort. In this thesis, I have tried to advance research to a direction where human behavior and the environment is seen as a whole. In my view, human-environment interaction should be treated by the principles of transactional worldview instead of looking at a single health behavior out of context and treating the environment as a separate unit from human behavior.

According to the results of articles II-IV there are some small modifications and potential amendments that could be implemented to the ecological model

of PA, especially when studying older adults PA. Firstly, the four domains of PA, as represented in the model (Sallis et al., 2006; Sallis & Owen, 2015), are not equally important in the case of older adults. Occupational activities might not even exist for the retired and thus need no special attention. On the other hand, household activities (not studied here) might be more important in enhancing PA among older adults compared to younger adult population, especially for the oldest part of the ageing population whose daily lives might be mostly constrained to home and immediate home-surrounding environments (Saajanaho et al., 2015). The domains of active recreation and especially active travel are particularly important forms of PA among older adults and should be emphasized when the ageing population is of particular interest.

Besides the need for modifying the domains of active living when studying or conducting interventions among older adults, the ecological model of health behavior could benefit from reviewing the model and especially the behavior setting layer. According to Roger Barker (1968), a behavior setting occurs naturally as a function of collective actions of a group of individuals and has a specific geographical location and temporal boundaries. Barker (1965) has described behavior settings as preperceptual units that exists independently of anyone's perception of them, and they can be exactly identified, reliably described, and correctly enumerated. According to Altman and Rogoff (1987) a behavior setting as described by Barker can be seen as "a confluence of actions in relation to places and things, and these actions are organized in systematic temporal sequences and patterns". Furthermore, according to Heft (2001, p. 254) individuals and objects (the milieu) are interjacent components of a behavior setting, meaning that the relation situated between individuals and objects generates and maintains the behavior setting. Moreover, a behavior setting has been described as a physical and social system in which action of group of people at a given time takes place according to norms, rules, and practices (Kyttä et al., 2018). Given these definitions, the usage of the concept of behavior setting in the current ecological models of health behavior (Sallis et al., 2006; Sallis & Owen, 2015) seems rather fallacious.

Sallis and colleagues (2006, p. 302; 2015, p. 52) have described behavior settings as "places where physical activity may occur", and in the ecological model of health behavior they emphasize the importance of considering both access to these settings and their specific characteristics. In the model (Sallis et al., 2006, p. 301), behavior setting is represented as one of the layers that influence the four domains of active living. Moreover, Sallis and colleagues (2006, p. 302; 2015, p. 52) present "key behavior settings with illustrative components or characteristics" in the model, such as the neighborhood and its walkability. According to Barker (1968), a behavior setting has specific geographical location and temporal boundaries, and thus could be seen as representing physical settings where (physical) activity may occur. However, one should keep in mind that key characteristics of behavior settings are the functions of collective actions of a group of individuals, and the transactional nature. Thus, the social element is embedded in the concept of behavior setting. Furthermore, behavior setting is a relational concept where individuals and the physical settings cannot be taken

apart. Thus, representing behavior setting as a separate layer in the ecological model is not optimal.

Looking into the transactional worldview can provide a potential solution. As according to the transactional worldview, environments and their inhabitants are dynamic systems, where the actions of individuals as well as groups of individuals, change the environment and in turn, the environment changes their behavior, experiences and wellbeing (Altman & Rogoff, 1987; Kyttä, 2004). The transactional worldview assumes that the person and the context coexist and jointly define one another, and contribute to the meaning and nature of a holistic event (Altman & Rogoff, 1987, p. 24). In his work Barker (1968), has emphasized that the human behavior is inseparable from the physical and social environment. However, the spatial context—the physical environment—, is not clearly represented in the current ecological model of PA. Instead, the model simply merges the physical environment and the behavior setting and treats them as a unified single layer in the model. I propose that the ecological model of PA could benefit from revising and re-conceptualizing some parts of the model. Especially, the layer that depicts the physical environment, which has been for more than a decade referred somewhat incorrectly as a behavior setting-layer needs revision. Instead of labeling one of the layers as a behavior setting, it should be labeled as the physical environment (the spatial context). The ecological model of PA would benefit from a revised model where the physical environment is one of the layers instead of behavior settings. In Figure 5 I present a revised ecological model of PA where the context—the physical environment—is given its place. The revised layer depicts the physical environment, both built and natural, and the characteristics and accessibility of the physical environment. Then, by combining the intrapersonal, perceived, socio-cultural and physical and policy environment layers and examining their influences on PA with place-based methods such as PPGIS or GPS, one could conduct a study of behavior settings. However, researchers should keep in mind that behavior settings are by definition functions of collective actions of a group of individuals (Barker, 1968).

While Barker's (1968) concept of a behavior setting is arguably very suitable for studying the multifaceted nature of PA, it has some limitations. Behavior settings are places with functions of collective actions of a group of individuals (Barker, 1968; Heft, 2001). While PA can often be social, there are arguably many forms of PA that do not have social elements but still they happen in place with a specific geographical location and temporal boundaries. One might take a walk in a forest all alone and in a Finnish context perhaps to escape the crowds and to just be alone. Thus, behavior setting as a concept does not suit all purposes when studying PA. According to Heft (2001), even Barker himself sometimes described some settings as behavior setting even when they did not include any features of a collective activity. To overcome and avoid confusion, Heft has suggested that individual's functionally significant milieu features could be viewed as affordances rather than behavior settings (Heft, 2001, p. 298). Heft (2001) has suggested that the concept of affordances could be useful for studying and understanding places affording certain possibilities for an individual.

Based on the results of this thesis and the discussion presented above, I promote Heft's idea of using the concept of affordances when studying the features of individual's functionally significant milieus.

Moreover, the ecological model of PA should neglect the usage of the term neighborhood in the model. The physical environmental characteristics can expand geographically to a much wider extent than to a mere neighborhood. While the neighborhood can be in some cases seen being equivalent to the physical environment, the model and future studies would benefit from looking also outside the residential neighborhoods. It could be that the conceptualization of various physical environment characteristics as simply as neighborhood characteristics has led previous studies focusing mostly to residential neighborhood settings instead of looking at the actual PA behavior . Perhaps future studies would benefit from a simple reconceptualization of the concept and start directing their focus also outside the residential neighborhoods. In addition, departing from the ecological model of PA (Sallis et al., 2006, p. 301) I have extended the information environment layer to cut across all levels that are thought to influence PA. This is because the information flow through i.e. news, advertisements and social media can be seen influencing health behaviors across levels, including policy, physical environment, perceptions and intrapersonal and socio-cultural levels, not only the policy and behavior settings (Sallis et al., 2006, p. 301).

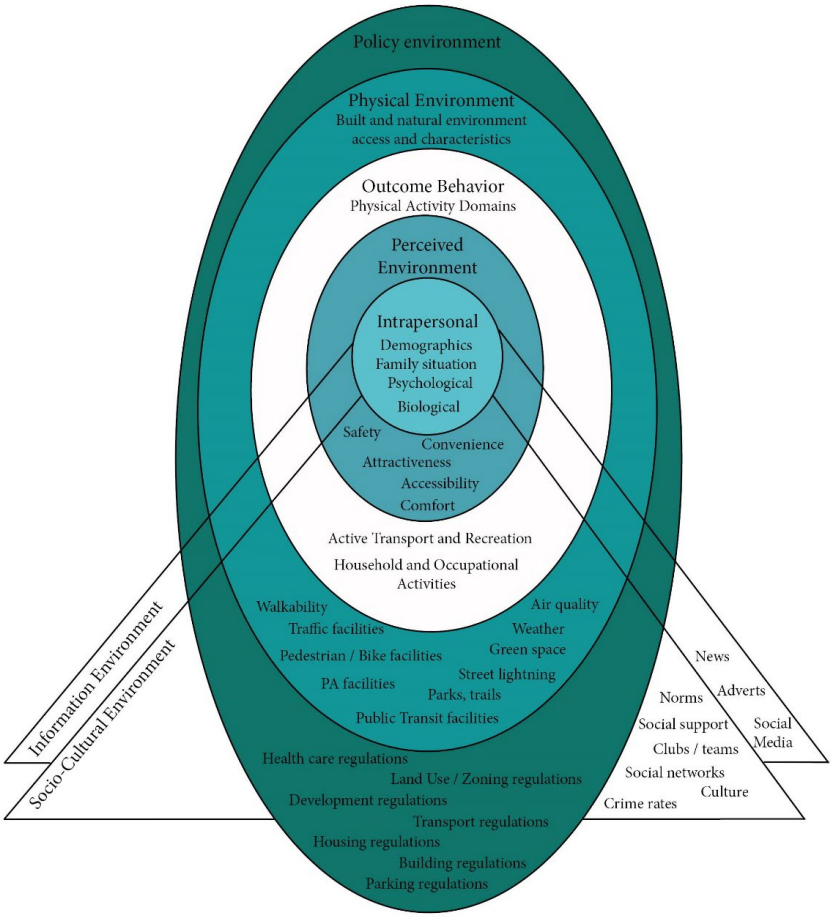

Figure 5. The revised ecological model of PA. In this model, the outcome behavior of interest are the four different domains of PA. The model illustrates some key characteristics and variables of each layer, but is not comprehensive in many respects.

The empirical findings of this thesis do not only broaden the research knowledge of health promotion but also contribute to urban planning and urban, environmental, and health management practices in various levels. Firstly, it offers intriguing insights about the perceptions and everyday practices of older adults living in the HMA. The broad findings of articles II, III, and IV offer place-based knowledge for the practitioners of the HMA but also for international scholars and practitioners interested in environmental health promotion and questions about healthy and active ageing.

It has been shown that accessing the outdoor environment can play a significant role in maintaining the health of older adults (Takano et al., 2002). The findings of articles II–IV demonstrate that various characteristics of the physical environment depict older adults' perceptions of a quality environment and support healthy and active ageing. The results of articles II–IV show that the

characteristics of the physical environment can play an important role in supporting healthy and active ageing, regardless of individuals' personal interests and sociodemographic background. Thus, according to the findings of this thesis, certain types of physical environments can support walking behavior even in the least active segments of older adult populations who are not particularly interested in PA. These are intriguing and important findings considering the burning societal questions related to older adults' inactivity around Finland and globally (Ding et al., 2016; Karvinen et al., 2012; Kolu, 2018). Also, this is an important finding given that ageing populations are particularly prone to the characteristics of their immediate home-surrounding environments (Rantakokko, Iwarsson, Kauppinen, et al., 2010). The neighborhood and near-home physical environment can at their best support healthy and active ageing and at their worst pose barriers for older adults to get outdoors and be physically active in their everyday lives.

As of late, the concept of ageing in place has become more focal in policymaking and research. The concept is based on an assumption that enabling ageing populations to live within the community instead of relying solely on institutionalized housing will not only benefit older adults themselves but also be a cost-effective solution for society (Sixsmith & Sixsmith, 2008). Regardless of the pious aims, ageing in place policies can become negative experiences and might not be desired by all when housing and community do not meet the needs of older adults (Fang et al., 2016; Sixsmith & Sixsmith, 2008). Thus, developing age-friendly environments and communities should be a central target for planners and policymakers, especially if the ageing in place policies are central in national policymaking. Should the role of the physical environment in supporting ageing populations' healthy everyday lives be neglected, the ageing in place policies can at their worst lead to a society that shuts its older population inside their homes. A British study found that older adults living in a neighborhood that they felt was supportive were three times more likely to be in good health compared to those living in a neighborhood that was unsupportive (Aspinall et al., 2010). Moreover, Takano and colleagues (2002) found that the quality of the physical environments near a residence showed a positive association with the longevity of older residents in Tokyo.

The findings of article II show that older adults' perceptions of a quality environment are green and blue spaces and that the places that are good quality are located close to home. In contrary, according to the results of article III, higher green area proportions around older adults' residencies decrease their perceived health. However, when older adults' true exposure to green spaces was analyzed using a novel exposure model of IREM, it was found that green spaces were positively associated with respondents' perceived health. In article II, the quality environments were studied by buffering the positive place markings with a 50-meter buffer. Thus, article II focused only on the immediate physical environment around the positive places marked by the respondents but did not look into the home surroundings or exposure outside the positive places. Both of these results further suggest that true exposure to green spaces, instead of plain availability of green spaces around the home, are important to older adults.

Based on the results presented in this thesis, I conclude that the accessibility, quality, and desirability, instead of quantity and plain availability of green spaces, are focal aspects in planning healthy and PA-promotive cities for older adults. The findings of article IV in turn suggest that in urban milieus that offer dense residential settings with multiple walkways, public transit stops, intersections, and destinations, the older adults walk for transport even if they are not particularly interested in PA and active lifestyle. Thus, creating environments that support active and healthy ageing requires that planning policies and practices highlight the importance of creating walkable environments where residents, old and young, can easily walk in their everyday lives.

A true challenge that lies ahead for urban planning and management practitioners and policymakers, according to the results of this thesis and other previous studies, is the reconciliation of the natural and urban milieus. Natural environments, such as various kinds of green and blue spaces, have undoubtedly a great impact on human health, but at the same time, dense, well-connected, and walkable urban milieus seem to support older adults' PA behavior. In urban contexts, such as the HMA, a constant competition over different usages of space and land uses occurs, and consolidation of different uses is not straightforward. However, creating cities where both the natural environment and densely built urban environment can coexist should be the target of city planning as both of these elements have been shown to support healthy and active ageing and also the health of the general population (Cerin et al., 2017; Giles-Corti et al., 2016; Mitchell & Popham, 2007; Sallis et al., 2016).

Helsinki, the capital of Finland, is 719 km² in size, of which 70% is sea and 30% land areas. Green spaces, urban parks, fields, urban forests, and nature conservation areas cover together 36% of the land area in Helsinki (Jaakola, Vass, Saarto, Haglund, & Sundström-Alk, 2018). In addition, 35% of all journeys done in Helsinki in 2017 were by walking, 34% by public transit, 31% by private car, and 9% by cycling (Jaakola et al., 2018). These numbers indicate that Helsinki could be seen as a potential example of a city that manages to uphold an urban context where dense and well-connected urban settings and various nature settings complement each other. However, as demonstrated in several parts of this thesis and also in other studies, mere availability of services or modification of the environment per se does not guarantee its usage and popularity, but it is the accessibility, usability, and desirability that counts (Golicnik & Ward Thompson, 2010; Laatikainen et al., 2015). Globally thinking, perhaps the City of Helsinki could emphasize its role more as the world's urban nature capital in the future, and locally thinking, the City of Helsinki should make sure that such areas are accessible and usable by all of its residents.

As the ageing phenomena as well as inactivity are both evident in Finnish society, strategical actions to promote everyday PA and active ageing are critical for health promotion. The wellbeing of ageing populations and costs of inactivity are burning societal questions all around Finland—not only in the HMA (Karvinen et al., 2012; Kolu, 2018). The direct costs of inactivity to the health care system in Finland have been estimated at EUR 600 million yearly (Kolu, 2018). The first-ever national physical exercise policy report was published in

Finland in October 2018 (Valtioneuvosto, 2018). The report outlines that the physical exercise policies in Finland during the next decade need to target considerable increases in PA across the whole population as well as on supporting construction of spaces for exercise and creating diverse and equal PA possibilities for all (Valtioneuvosto, 2018). The physical exercise research report (Itkonen, Lehtonen, & Aarresola, 2018) that was put together to form a basis for the national policy report outlines that planning and land-use policies that account for and support PA can actively affect the possibilities for increasing exercise activity across the whole population. In the research report, planning and land-use policy of the everyday environments are seen as potentially affecting the PA behavior of the Finnish population. However, the final policy document (Valtioneuvosto, 2018) focuses merely on the construction of exercise spaces, neglecting the role of planning the everyday environments to support PA, even though the report states that after sports halls, natural environments, walkways, and trails are the most important spaces to exercise. The policy document only briefly mentions the role of the physical environment and planning for supporting PA and exercise but does not offer potential plans of action for this part. This could be due to the fact that land-use planning as well as transportation planning are municipal- and city-level tasks in Finland, and national-level policies cannot really touch upon them. However, most likely, the national physical exercise policy report leaves the role of land-use planning for supporting PA so impalpable due to the fact that its potential has not been truly understood and recognized in the national policymaking level. Should this be the case, it is alarming given that it is well known that the physical environment plays crucial role in supporting PA.

In contrast to the national report, the City of Helsinki has shown exemplary actions in understanding that the everyday PA behavior, such as walking and cycling, takes place mostly in the physical environment that residents use on a daily basis and emphasizes the role of planning and urban management. The City of Helsinki has included an Exercise and Mobility Scheme Project as one of the core projects in the Helsinki City Strategy for 2017–2021 (City of Helsinki, 2018). The project emphasizes that "Both the urban environment and the provision of sports and cultural activities are developed on an equal basis in different parts of town so as to encourage residents to exercise" and that "The city is planned and built in a way that addresses different kinds of people's needs" (City of Helsinki, 2018, p. 10). In this thesis, I have tried to advance to a direction of understanding the everyday physical environment as an inseparable part of older adults' healthy everyday lives and the potential the everyday environment has in supporting healthy and active ageing. Land-use policies and urban planning and management that emphasize the role of the dense residential settings, walkways, green spaces, and accessibility of services by walking or cycling can, according to the results discussed in this thesis, play a central role in supporting PA behavior across the whole population.

5.1 Limitations

Articles I–IV all acknowledge and discuss detailed limitations. Such limitations are mostly related to the potential technology divide, the vulnerability of the measures related to the bias of self-reporting, and the cross-sectional nature of the studies. I acknowledge all of the aforementioned limitations, but in this part, I will mostly focus on the potential general-level shortcomings of the research presented in this thesis and limitations related to the PPGIS methodology.

While the PPGIS tools have evident advantages, there are some aspects of the methodology that could have caused limitations to this thesis and need further discussion. The PPGIS methodology could be seen as causing limitations for the studied population group, even when there are studies showing its applicability to both older adults and a wider audience. Those older adults with very poor computer literacy or no access to the internet could be excluded from the studies. The lower income groups were underrepresented in the ActivAGE data collection, which could be a result of the method used. However, Finns are technologically well-oriented, and age does not play a significant role in their use of public e-services (Taipale, 2013). In addition, low participation rates of lower income groups is not limited only to online studies (Lancee & Van de Werfhorst, 2012). PPGIS methods have been applied more widely in recent years both in research and in practice, in particular in participatory planning practices (Brown & Kyttä, 2018; Ives et al., 2017; Kahila-Tani, 2015). The need for the map itself in certain cases for communicating spatial knowledge has been questioned very recently because mapping is seen as a cognitively demanding task that is burdened with uncertainties such as the accuracy and precision of mapping (Rzeszewski & Kotus, 2019). Accuracy, precision, and map literacy should be considered as also causing potential limitations to this study. The computer and map literacy and the questions of accuracy are concrete challenges that should be accounted for, but at the same time, they are not challenges that root for rejection of PPGIS as an effective tool in participatory planning practices or in research.

While in this thesis I have aimed to depict the multiple levels of factors influencing human health behavior, the policy, sociocultural, information, and natural environment contexts are the ones that I have not covered. It has been shown that the sociocultural environment plays a great role in older adults' health and PA (Barnett et al., 2017; Chaudhury et al., 2016; Kaźmierczak, 2013; Sullivan et al., 2004), and the exclusion of such measures need to be carefully considered when interpreting the results of this thesis. The shortage of the policy, information, and natural-level factors in the studies of this thesis need to be acknowledged when further discussing the results. Furthermore, no micro level environmental features, such as presence of benches, associated with older adults' positive places or everyday habits were not studied here, which could have added valuable input to the study (Ottoni et al., 2015) .

It should be noted that all of the studies included in this thesis are cross-sectional. Thus, the studies cannot provide definite information about cause-and-

effect relationships, but more show links and associations between certain variables. While the path analysis conducetd in article IV could evaluate causal hypotheses, it could not establish the direction of causality.

Additionally, this study has concentrated on a single metropolitan region, the HMA; thus, the generalizability of the results should be carefully considered when taking the discussion forward. The study has mainly focused on older adults that do not represent the oldest, as the age of the respondents of the ActiveAGE study was between 55 and 75 years old. Thus, the limitations of the age group involved might need to be acknowledged when further discussing the results of this thesis. A considerable limitation, related to the spatial units of analysis used in articles II–IV, is related to the question of, what is context-sensitive enough for what purpose? More details often lead to more complexity, which could be seen as a potential challenge and a limitation. Using complex models to capture the human-environment interactions offers researchers ways to study the exact environments where individuals move around and spend their time, and the detailed information about the exposure and human mobility behavior is no doubt crucial in understanding the human-environment interactions. More detail and complexity can be a challenge in applying research findings to practice. For an urban planner, using advanced models is most likely impossible but also very challenging for a researcher without background and skills in geoinformatics. This is central especially in the fields of health promotion where the planning and land-use policies play a big role in enabling and putting findings into practice. Additionally, for an urban planner, neighborhoods that border plain administrative units are the units they work with—an urban planner does not plan and design the physical environment of individuals but the physical environment of certain neighborhoods or municipalities or even cities. Thus, the questions are how to draw policies and plans if not to certain neighborhoods or cities and how to study and draw conclusions about the physical environment influencing human health behavior if not by studying the environments where people actually move around.

5.2 Future research recommendations

There are some future research directions and recommendations that I can draw based on the studies of this thesis. Future research applying the principles of ecological models of health behavior (Sallis & Owen, 2015) should aim at including the policy and the sociocultural, information, and natural environment levels to the studies. Including the policy level to modeling and analysis might not be straightforward and easily applied, but results and potential implications of studies should be discussed simultaneously with the policies relevant to the study setting. In the future, the sociocultural factors need to be more carefully considered when studying any health behavior of older adults. Social interactions most likely play a very crucial part in motivating older adults to get outdoors and move, as social contacts have been shown to be important factors in

supporting health (House, Landis, & Umberson, 1988). In future studies focusing on older adults' health and PA, sociocultural factors should be well embedded in the research setting alongside the intrapersonal, perceptual, and physical environmental factors. Furthermore, future studies should pay attention to differentiation of PA by domains to overcome the discrepancies in the results. It is very different to study the total PA compared to walking for transport and the physical environmental effects. It is very possible that the physical environment has very little to do with older adults' total PA that is gained through household activities compared to their walking.

Additionally, future studies should aim for longitudinal study settings to more comprehensively examine causal relations of PA and the use of advanced statistical and spatial data modeling among the studied variables, as also suggested elsewhere (Bauman et al., 2012). Based on the results and discussion presented in this thesis, I suggest that future studies on PA and health across all ages should investigate simultaneously the personal, sociocultural, and psychological as well as the physical and policy environment features with spatially bounded context-specific methods to capture the exposure. Methods, such as SoftGIS, that are based on sound theoretical foundations of the transactional research approach offer ways to overcome the shortcomings and limitations of earlier research applying the ecological models of health behavior. I acknowledge that GPS devices with built-in accelerometers also offer potential for detailed-level PA studies capturing the exposure, but their usage can add a lot of complexity to the study settings and analysis. Especially if the aim of the research is to create understanding about the relationship between the built environment and human behavior or evaluate potential plans from the health perspective, future studies should carefully think about the methods and study settings applied so that the results are easily translated to planning practice.

To conclude, if I was to give one piece of advice based on the results and discussion of this thesis, I would recommend future research in the field of environmental health promotion to place focus not only on what is inside one's head but more on what one's head is inside of.

References

Ajzen, I. (1991). The theory of planned behavior. *Organizational Behavior and Human Decision Processes*, *50*(2), 179–211.

Altman, I., & Rogoff, B. (1987). World views in psychology: Trait, interactional, organismic, and transactional perspectives. *Handbook of Environmental Psychology*, *1*, 7–40.

Aspinall, P. A., Thompson, C. W., Alves, S., Sugiyama, T., Brice, R., & Vickers, A. (2010). Preference and relative importance for environmental attributes of neighbourhood open space in older people. *Environment and Planning B: Planning and Design*, *37*(6), 1022–1039.

Bandura, A. (1989). Human agency in social cognitive theory. *American Psychologist*, *44*(9), 1175.

Barker, R. G. (1965). Explorations in ecological psychology. *American Psychologist*, *20*(1), 1.

Barker, R. G. (1968). Ecological psychology; concepts and methods for studying the environment of human behavior. 242 p. Stanford University Press, California.

Barnett, D. W., Barnett, A., Nathan, A., Van Cauwenberg, J., & Cerin, E. (2017). Built environmental correlates of older adults' total physical activity and walking: a systematic review and meta-analysis. *International Journal of Behavioral Nutrition and Physical Activity*, *14*(1), 103.

Bauman, A. E., Reis, R. S., Sallis, J. F., Wells, J. C., Loos, R. J. F., & Martin, B. W. (2012). Correlates of physical activity: Why are some people physically active and others not? *The Lancet*, *380*(9838). https://doi.org/10.1016/S0140-6736(12)60735-1

Beard, J. R., & Petitot, C. (2010). Ageing and urbanization: Can cities be designed to foster active ageing? *Public Health Reviews*, *32*(2), 427–450.

Bonaiuto, M., Fornara, F., & Bonnes, M. (2003). Indexes of perceived residential environment quality and neighbourhood attachment in urban environments: A confirmation study on the city of Rome. *Landscape and Urban Planning*, *65*(1–2), 41–52.

Borst, H. C., de Vries, S. I., Graham, J. M., van Dongen, J. E., Bakker, I., & Miedema, H. M. (2009). Influence of environmental street characteristics on walking route choice of elderly people. *Journal of Environmental Psychology*, *29*(4), 477-484

Boudiny, K. (2013). 'Active ageing': from empty rhetoric to effective policy tool. *Ageing & Society*, *33*(6), 1077–1098.

Boulton, E. R., Horne, M., & Todd, C. (2018). Multiple influences on participating in physical activity in older age: Developing a social ecological approach. *Health Expectations*, *21*(1), 239–248.

Broberg, A., Kyttä, M., & Fagerholm, N. (2013). Child-friendly urban structures: Bullerby revisited. *Journal of Environmental Psychology*, *35*, 110–120. https://doi.org/10.1016/j.jenvp.2013.06.001

Broberg, A., Salminen, S., & Kyttä, M. (2013). Physical environmental characteristics promoting independent and active transport to children's meaningful places. *Applied Geography*, *38*(1), 43–52. https://doi.org/10.1016/j.apgeog.2012.11.014

Brown, G., & Kyttä, M. (2014). Key issues and research priorities for public participation GIS (PPGIS): A synthesis based on empirical research. *Applied Geography*, *46*, 122–136. https://doi.org/10.1016/j.apgeog.2013.11.004

Brown, G., & Kyttä, M. (2018). Key issues and priorities in participatory mapping: Toward integration or increased specialization? *Applied Geography*, *95*, 1–8.

Cao, X., Mokhtarian, P. L., & Handy, S. L. (2009). Examining the Impacts of Residential Self-Selection on Travel Behaviour: A Focus on Empirical Findings. *Transport Reviews*, *29*(3), 359–395. https://doi.org/10.1080/01441640802539195

Carlson, J. A., Sallis, J. F., Conway, T. L., Saelens, B. E., Frank, L. D., Kerr, J., … King, A. C. (2012). Interactions between psychosocial and built environment factors in explaining older adults' physical activity. *Preventive Medicine*, *54*(1), 68–73. https://doi.org/10.1016/j.ypmed.2011.10.004

Carver, A., Veitch, J., Sahlqvist, S., Crawford, D., & Hume, C. (2014). Active transport, independent mobility and territorial range among children residing in disadvantaged areas. *Journal of Transport & Health*, *1*(4), 267–273. https://doi.org/10.1016/j.jth.2014.01.004

Cavanagh, P., Evans, J., Fiatarone, M., Hagberg, J., McAuley, E., & Startzell, J. (1998). Exercise and physical activity for older adults. *Med Sci Sports Exerc*, *30*, 1–29.

Cerin, E., Nathan, A., van Cauwenberg, J., Barnett, D. W., & Barnett, A. (2017). The neighbourhood physical environment and active travel in older adults: a systematic review and meta-analysis. *International Journal of Behavioral Nutrition and Physical Activity*, *14*(1), 15. https://doi.org/10.1186/s12966-017-0471-5

Chaix, B., Meline, J., Duncan, S., Merrien, C., Karusisi, N., Perchoux, C., … Kestens, Y. (2013). GPS tracking in neighborhood and health studies: a step forward for environmental exposure assessment, a step backward for causal inference? *Health & Place*, *21*, 46–51.

Chaudhury, H., Campo, M., Michael, Y., & Mahmood, A. (2016). Neighbourhood environment and physical activity in older adults. *Social Science & Medicine*, *149*, 104–113. https://doi.org/10.1016/J.SOCSCIMED.2015.12.011

Chodzko-Zajko, W. J., Proctor, D. N., Fiatarone Singh, M. A., Minson, C. T., Nigg, C. R., Salem, G. J., & Skinner, J. S. (2009). Exercise and physical activity for older adults. *Medicine and Science in Sports and Exercise*, *41*(7). https://doi.org/10.1249/MSS.0b013e3181a0c95c

Christiansen, L. B., Cerin, E., Badland, H., Kerr, J., Davey, R., Troelsen, J., … & Salvo, D. (2016). International comparisons of the associations between objective measures of the built environment and transport-related walking and cycling: IPEN adult study. *Journal of transport & health*, *3*(4), 467-478.

City of Helsinki. (2018). *The most functional city in the world - Helsinki City Strategy 2017-2021*. Retrieved from https://www.hel.fi/static/helsinki/kaupunkistrategia/strategia-en-2017-2021.pdf

Conner, M. (2015). Extending not retiring the theory of planned behaviour: a commentary on Sniehotta, Presseau and Araújo-Soares. *Health Psychology Review*, *9*(2), 141–145.

Cummins, S., Stafford, M., Macintyre, S., Marmot, M., & Ellaway, A. (2005). Neighbourhood environment and its association with self rated health: evidence from Scotland and England. *Journal of Epidemiology & Community Health*, *59*(3), 207-213.

Ding, D., Lawson, K. D., Kolbe-Alexander, T. L., Finkelstein, E. A., Katzmarzyk, P. T., van Mechelen, W., & Pratt, M. (2016). The economic burden of physical inactivity: a global analysis of major non-communicable diseases. *The Lancet*, *388*(10051), 1311–1324. https://doi.org/10.1016/S0140-6736(16)30383-X

Ding, D., Sallis, J. F., Conway, T. L., Saelens, B. E., Frank, L. D., Cain, K. L., & Slymen, D. J. (2012). Interactive effects of built environment and psychosocial attributes on physical activity: a test of ecological models. *Annals of Behavioral Medicine*, *44*(3), 365–374.

Eronen, J., von Bonsdorff, M., Rantakokko, M., & Rantanen, T. (2013). Environmental facilitators for outdoor walking and development of walking difficulty in community-dwelling older adults. *European Journal of Ageing*, 1–9.

European Comission. (2018). *Eurostat regional yearbook 2018*. https://doi.org/10.2785/23197

Fang, M. L., Woolrych, R., Sixsmith, J., Canham, S., Battersby, L., & Sixsmith, A. (2016). Place-making with older persons: Establishing sense-of-place through participatory community mapping workshops. *Social Science & Medicine*, *168*, 223–229. https://doi.org/10.1016/J.SOCSCIMED.2016.07.007

Ferreira, M. T., Matsudo, S. M. M., Ribeiro, M. C. S. A., & Ramos, L. R. (2010). Health-related factors correlate with behavior trends in physical activity level in old age: longitudinal results from a population in São Paulo, Brazil. *BMC Public Health*, *10*(1), 690.

Fornara, F., Bonaiuto, M., & Bonnes, M. (2009). Cross-Validation of Abbreviated Perceived Residential Environment Quality (PREQ) and Neighborhood Attachment (NA) Indicators. *Environment and Behavior*, *42*(2), 171–196. https://doi.org/10.1177/0013916508330998

Foster, S., Giles-Corti, B., & Knuiman, M. (2014). Does Fear of Crime Discourage Walkers? A Social-Ecological Exploration of Fear As a Deterrent to Walking. *Environment and Behavior, 46(6)*, 698–717. https://doi.org/10.1177/0013916512465176

Frank, L., Kerr, J., Rosenberg, D., & King, A. (2010). Healthy aging and where you live: community design relationships with physical activity and body weight in older Americans. *Journal of Physical Activity and Health*, *7*(s1), S82-S90.

Fratiglioni, L., Paillard-Borg, S., & Winblad, B. (2004). An active and socially integrated lifestyle in late life might protect against dementia. *The Lancet Neurology*, *3*(6), 343–353. https://doi.org/10.1016/S1474-4422(04)00767-7

Gibson, J. J. (1986). *The ecological approach to visual perception*. Routledge.

Gifford, R., Steg, L., & Reser, J. P. (2011). Environmental Psychology. In F. M. Cheung, M. C. Knowles, M. Kyrios, L. Littlefield, B. Overmier, & J. M. Prietro (Eds.), *IAAP Handbook of Applied Psychology* (First Edit). Blackwell Publishing.

Giles-Corti, B., Timperio, A., Bull, F., & Pikora, T. (2005). Understanding physical activity environmental correlates: Increased specificity for ecological models. *Exercise and Sport Sciences Reviews*, *33*(4). https://doi.org/10.1097/00003677-200510000-00005

Giles-Corti, B., Vernez-Moudon, A., Reis, R., Turrell, G., Dannenberg, A. L., Badland, H., … Owen, N. (2016). City planning and population health: a global challenge. *The Lancet*. https://doi.org/10.1016/S0140-6736(16)30066-6

Glanz, K., Rimer, B., & Viswanath, K. (2015). *Health behavior and health education: theory, research, and practice*. John Wiley & Sons.

Golicnik, B., & Ward Thompson, C. (2010). Emerging relationships between design and use of urban park spaces. *Landscape and Urban Planning*, *94*(1), 38–53.

Hakim, A. A., Petrovitch, H., Burchfiel, C. M., Ross, G. W., Rodriguez, B. L., White, L. R., … Abbott, R. D. (1998). Effects of walking on mortality among nonsmoking retired men. *New England Journal of Medicine*, *338*(2), 94–99.

Hasanzadeh, K., Broberg, A., & Kyttä, M. (2017). Where is my neighborhood? A dynamic individual-based definition of home ranges and implementation of multiple evaluation criteria. *Applied Geography*, *84*. https://doi.org/10.1016/j.apgeog.2017.04.006

Hasanzadeh, K., Laatikainen, T., & Kyttä, M. (2018). A place-based model of local activity spaces: individual place exposure and characteristics. *Journal of Geographical Systems*. https://doi.org/10.1007/s10109-017-0264-z

Heft, H. (2001). *Ecological psychology in context: James Gibson, Roger Barker, and the legacy of William James's radical empiricism*. L. Erlbaum Mahwah, NJ.

Hirsch, J. A., Winters, M., Ashe, M. C., Clarke, P., & McKay, H. (2016). Destinations That Older Adults Experience Within Their GPS Activity Spaces Relation to Objectively Measured Physical Activity. *Environment and Behavior*, *48*(1), 55–77. https://doi.org/10.1177/0013916515607312

Hirvensalo, M., Rantanen, T., & Heikkinen, E. (2000). Mobility difficulties and physical activity as predictors of mortality and loss of independence in the community-living older population. *Journal of the American Geriatrics Society*, *48*(5). https://doi.org/10.1111/j.1532-5415.2000.tb04994.x

Hirvensalo, M., Lampinen, P., & Rantanen, T. (1998). Physical exercise in old age: An eight-year follow-up study on involvement, motives, and obstacles among persons age 65-84. *Journal of Aging and Physical Activity*, 6(2), 157–168.

Holliday, K. M., Howard, A. G., Emch, M., Rodriguez, D. A., & Evenson, K. R. (2017). Are buffers around home representative of physical activity spaces among adults? *Health & Place*, *45*, 181–188.

House, J. S., Landis, K. R., & Umberson, D. (1988). Social relationships and health. *Science*, *241*(4865), 540–545.

Howell, N. A., Farber, S., Widener, M. J., & Booth, G. L. (2017). Residential or activity space walkability: What drives transportation physical activity?. *Journal of Transport & Health*, *7*, 160-171.

Hubbard, P., & Kitchin, R. (2010). *Key thinkers on space and place*. Sage.

Itkonen, H., Lehtonen, K., & Aarresola, O. (2018). *Tutkimuskatsaus liikuntapoliittisen selonteon tausta-aineistoksi*.

Ives, C. D., Oke, C., Hehir, A., Gordon, A., Wang, Y., & Bekessy, S. A. (2017). Capturing residents' values for urban green space: Mapping, analysis and guidance for practice. *Landscape and Urban Planning*, *161*, 32–43. https://doi.org/10.1016/J.LANDURBPLAN.2016.12.010

Jaakola, Vass, Saarto, Haglund, & Sundström-Alk. (2018). *Helsinki facts and figures 2018*. Helsinki. Retrieved from https://www.hel.fi/hel2/tietokeskus/julkaisut/pdf/18_12_11_tasku18_en_net.pdf

Kahila-Tani, M. (2015). Reshaping the planning process using local experiences: Utilising PPGIS in participatory urban planning. Aalto University, Espoo.

Kahila-Tani, M., Broberg, A., Kyttä, M., & Tyger, T. (2016). Let the Citizens Map—Public Participation GIS as a Planning Support System in the Helsinki Master Plan Process. *Planning Practice & Research*, *31*(2), 195–214.

Karvinen, E., Kalmari, P., & Koivumäki, K. (2012). The National Policy Programme for Older People's Physical Activity; Health and well-being from physical activit, *17*, 22.

Kaźmierczak, A. (2013). The contribution of local parks to neighbourhood social ties. *Landscape and Urban Planning*, *109*(1), 31–44.

Kelly, P., Kahlmeier, S., Götschi, T., Orsini, N., Richards, J., Roberts, N., ... Foster, C. (2014). Systematic review and meta-analysis of reduction in all-cause mortality from walking and cycling and shape of dose response relationship. *International Journal of Behavioral Nutrition and Physical Activity*, *11*(1), 132. https://doi.org/10.1186/s12966-014-0132-x

Kerr, J., Rosenberg, D., & Frank, L. (2012). The Role of the Built Environment in Healthy Aging: Community Design, Physical Activity, and Health among Older Adults. *Journal of Planning Literature*, *27*(1), 43–60.

Kestens, Y., Thierry, B., Shareck, M., Steinmetz-Wood, M., & Chaix, B. (2018). Integrating activity spaces in health research: Comparing the VERITAS activity space questionnaire with 7-day GPS tracking and prompted recall. *Spatial and Spatio-Temporal Epidemiology*, *25*, 1–9. https://doi.org/10.1016/J.SSTE.2017.12.003

King, A. C., Sallis, J. F., Frank, L. D., Saelens, B. E., Cain, K., Conway, T. L., ... & Kerr, J. (2011). Aging in neighborhoods differing in walkability and income: associations with physical activity and obesity in older adults. *Social science & medicine*, *73*(10), 1525-1533.

King, A. C., & King, D. K. (2010). Physical activity for an aging population. *Public Health Reviews*, *32*(2), 401–426.

Kolu, P. (2018). Liikkumattomuus käy kalliiksi. *Liikunta Ja Tiede*, *55*(5), 38–40.

Korpela, K. M., Ylén, M., Tyrväinen, L., & Silvennoinen, H. (2008). Determinants of restorative experiences in everyday favorite places. *Health & Place*, *14*(4), 636–652.

Kramer, A. F., Hahn, S., Cohen, N. J., Banich, M. T., McAuley, E., Harrison, C. R., ... Boileau, R. A. (1999). Ageing, fitness and neurocognitive function. *Nature*, *400*(6743), 418.

Kvartti (2019). *Kvartti Neljännesvuosijulkaisu 01/2019*. City of Helsinki, Executive Office, Urban Research and Statistics. Libris Helsinki, p. 138.

Kwan, M.-P. (2012). The uncertain geographic context problem. *Annals of the Association of American Geographers*, *102*(5), 958–968.

Kwan, M.-P. (2018). The Neighborhood Effect Averaging Problem (NEAP): An Elusive Confounder of the Neighborhood Effect. *International Journal of Environmental Research and Public Health*, *15*(9), 1841. https://doi.org/10.3390/ijerph15091841

Kyttä, M. (2004). *Children in Outdoor Contexts. Affordances and Independent Mobility in the Assessment of Environmental Child Friendliness*. Helsinki University of Technology.

Kyttä, M., Broberg, A., Haybatollahi, M., & Schmidt-Thomé, K. (2015). Urban happiness: context-sensitive study of the social sustainability of urban settings. *Environment and Planning B: Planning and Design*, 0265813515600121.

Kyttä, M., Broberg, A., Tzoulas, T., & Snabb, K. (2013). Towards contextually sensitive urban densification: Location-based softGIS knowledge revealing perceived residential environmental quality. *Landscape and Urban Planning*, *113*, 30–46.

Kyttä, M., Broberg, A. K., & Kahila, M. H. (2012). Urban environment and children's active lifestyle: Softgis revealing children's behavioral patterns and meaningful places. *American Journal of Health Promotion*, *26*(5), e137–e148.

Kyttä, M., & Kahila, M. (2011). Softgis methodology. *GIM International*, *25*(3).

Kyttä, M., Oliver, M., Ikeda, E., Ahmadi, E., Omiya, I., & Laatikainen, T. (2018). Children as urbanites: mapping the affordances and behavior settings of urban environments for Finnish and Japanese children. *Children's Geographies, 16:3,* 319-332, DOI:10.1080/14733285.2018.1453923

Laatikainen, T., Tenkanen, H., Kyttä, M., & Toivonen, T. (2015). Comparing conventional and PPGIS approaches in measuring equality of access to urban aquatic environments. *Landscape and Urban Planning*, *144*. https://doi.org/10.1016/j.landurbplan.2015.08.004

Lancee, B., & Van de Werfhorst, H. G. (2012). Income inequality and participation: A comparison of 24 European countries. *Social Science Research*, *41*(5), 1166–1178.

Leal, C., & Chaix, B. (2011). The influence of geographic life environments on cardiometabolic risk factors: a systematic review, a methodological assessment and a research agenda. *Obesity Reviews*, *12*(3), 217–230.

Lee, I.-M., Shiroma, E. J., Lobelo, F., Puska, P., Blair, S. N., & Katzmarzyk, P. T. (2012). Effect of physical inactivity on major non-communicable diseases worldwide: an analysis of burden of disease and life expectancy. *The Lancet*, *380*(9838), 219–229. https://doi.org/10.1016/S0140-6736(12)61031-9

Lewin, K. (1975). *Field Theory in Social Science: Selected Theoretical Papers*, by Kurt Lewin, Ed. by Dorwin Cartwright. Greenwood Press.

Manson, J. E., Greenland, P., LaCroix, A. Z., Stefanick, M. L., Mouton, C. P., Oberman, A., … Siscovick, D. S. (2002). Walking compared with vigorous exercise for the prevention of cardiovascular events in women. *New England Journal of Medicine*, *347*(10), 716–725.

Massey, D. (2005). *For Space*. London: Sage.

Medrano, J.D., 2013. World Map of Interpersonal Trust. <http://www.jdsurvey.net/jds/jdsurveyMaps.jsp?Idioma=I&SeccionTexto=0404&NOID=104> (visited 6.4.2019).

Mertens, L., Van Dyck, D., Deforche, B., De Bourdeaudhuij, I., Brondeel, R., & Van Cauwenberg, J. (2018). Individual, social, and physical environmental factors related to changes in walking and cycling for transport among older adults: A longitudinal study. *Health and Place* 55, 120–127.

Ministry of social affairs and health. (2011). *Socially Suistanable Finland*. Retrieved from http://urn.fi/URN:ISBN:978-952-00-3136-7

Mitchell, R., & Popham, F. (2007). Greenspace, urbanity and health: Relationships in England. *Journal of Epidemiology and Community Health*, *61*(8), 681–683.

Nelson, M. E., Rejeski, W. J., Blair, S. N., Duncan, P. W., Judge, J. O., King, A. C., … Castaneda-Sceppa, C. (2007). Physical activity and public health in older adults: Recommendation from the American College of Sports Medicine and the American Heart Association. *Medicine and Science in Sports and Exercise*, *39*(8), 1435–1445.

Notthoff, N., Reisch, P., & Gerstorf, D. (2017). Individual Characteristics and Physical Activity in Older Adults: A Systematic Review. *Gerontology*, *63*(5). https://doi.org/10.1159/000475558

Official Statistics of Finland. (2018). *Population projection [e-publication] ISSN=1798-5153*. Helsinki. Retrieved from http://www.stat.fi/til/vaenn/index_en.html

Organization, W. H. (2010). *Global Recommendations on Physical Activity for Health*. Switzerland: World Health Organization.

Ottoni, C. A., Sims-Gould, J., Winters, M., Heijnen, M., & McKay, H. A. (2016). "Benches become like porches": Built and social environment influences on older adults' experiences of mobility and well-being. *Social Science & Medicine*, *169*, 33–41. https://doi.org/10.1016/J.SOCSCIMED.2016.08.044

Owen, N., Humpel, N., Leslie, E., Bauman, A., & Sallis, J. F. (2004). Understanding environmental influences on walking: Review and research agenda. *American Journal of Preventive Medicine*, *27*(1), 67–76.

Pennock, M., & Ura, K. (2011). Gross national happiness as a framework for health impact assessment. *Environmental Impact Assessment Review*, *31*(1), 61-65.

Perchoux, C., Chaix, B., Brondeel, R., & Kestens, Y. (2016). Residential buffer, perceived neighborhood, and individual activity space: New refinements in the definition of exposure areas–The RECORD Cohort Study. *Health & place*, *40*, 116-122.

Perchoux, C., Chaix, B., Cummins, S., & Kestens, Y. (2013). Conceptualization and measurement of environmental exposure in epidemiology: accounting for activity space related to daily mobility. *Health & Place*, *21*, 86–93.

Pocewicz, A., Nielsen-Pincus, M., Brown, G., & Schnitzer, R. (2012). An Evaluation of Internet Versus Paper-based Methods for Public Participation Geographic Information Systems (PPGIS). *Transactions in GIS*, *16*(1), 39–53.

Portegijs, E., Keskinen, K., Tsai, L. T., Rantanen, T., & Rantakokko, M. (2017). Physical limitations, walkability, perceived environmental facilitators and physical activity of older adults in Finland. *International journal of environmental research and public health*, *14*(3), 333.

Rantakokko, M., Iwarsson, S., Hirvensalo, M., Leinonen, R., Heikkinen, E., & Rantanen, T. (2010). Unmet physical activity need in old age. *Journal of the American Geriatrics Society*, *58*(4), 707–712.

Rantakokko, M., Iwarsson, S., Kauppinen, M., Leinonen, R., Heikkinen, E., & Rantanen, T. (2010). Quality of life and barriers in the urban outdoor environment in old age. *Journal of the American Geriatrics Society*, *58*(11), 2154–2159.

Raymond, C. M., Brown, G., & Weber, D. (2010). The measurement of place attachment: Personal, community, and environmental connections. *Journal of Environmental Psychology*, *30*(4), 422–434. https://doi.org/10.1016/j.jenvp.2010.08.002

Rejeski, W., PH, B., DC, G., Jr, & al, et. (2011). Translating weight loss and physical activity programs into the community to preserve mobility in older, obese adults in poor cardiovascular health. *Archives of Internal Medicine*, *171*(10), 880–886.

Richard, L., Gauvin, L., & Raine, K. (2011). Ecological Models Revisited: Their Uses and Evolution in Health Promotion Over Two Decades. *Annual Review of Public Health*, *32*(1), 307–326. https://doi.org/10.1146/annurev-publhealth-031210-101141

Rzeszewski, M., & Kotus, J. (2019). Usability and usefulness of internet mapping platforms in participatory spatial planning. *Applied Geography*, *103*, 56–69. https://doi.org/10.1016/J.APGEOG.2019.01.001

Saajanaho, M., Rantakokko, M., Portegijs, E., Törmäkangas, T., Eronen, J., Tsai, L.-T., … Rantanen, T. (2015). Personal goals and changes in life-space mobility among older people. *Preventive Medicine*, *81*. https://doi.org/10.1016/j.ypmed.2015.08.015

Saajanaho, M., Viljanen, A., Read, S., Rantakokko, M., Tsai, L.-T., Kaprio, J., … Rantanen, T. (2014). Older women's personal goals and exercise activity: an 8-year follow-up. *Journal of Aging and Physical Activity*, *22*(3), 386–392.

Saelens, B. E., & Handy, S. L. (2008). Built environment correlates of walking: a review. *Medicine and Science in Sports and Exercise*, *40*(7 Suppl), S550-66. https://doi.org/10.1249/MSS.0b013e31817c67a4

Sallis, J., Cervero, R. B., Ascher, W., Henderson, K. A., Kraft, M. K., & Kerr, J. (2006). *An ecological approach to creating active living communities*. *Annual Review*

of Public Health (Vol. 27). https://doi.org/10.1146/annurev.publhealth.27.021405.102100

Sallis, J. F., Cerin, E., Conway, T. L., Adams, M. A., Frank, L. D., Pratt, M., … Owen, N. (2016). Physical activity in relation to urban environments in 14 cities worldwide: a cross-sectional study. *The Lancet*, *387*(10034), 2207–2217. https://doi.org/10.1016/S0140-6736(15)01284-2

Sallis, J., & Owen, N. (2015). Ecological models of health behavior. In K. Glanz, B. K. Rimer, & K. Viswanath (Eds.), *Health behavior: theory, research, and practice*. (5th ed.s, pp. 43–64). San Francisco: Jossey-Bas.

Sarjala, S.-M., Broberg, A., & Hynynen, A. (2015). Children and youth transport in different urban morphological types. *Journal of Transport and Land Use*. https://doi.org/10.5198/jtlu.2015.803

Sawyer, A., Ucci, M., Jones, R., Smith, L., & Fisher, A. (2017). Simultaneous evaluation of physical and social environmental correlates of physical activity in adults: A systematic review. *SSM - Population Health*, *3*. https://doi.org/10.1016/j.ssmph.2017.05.008

Schmidt-Thome, K., Wallin, S., Laatikainen, T., Kangasoja, J., & Kyttä, M. (2014). Exploring the use of PPGIS in self-organizing urban development: Case softGIS in Pacific Beach. *The Journal of Community Informatics*, *10*(3).

Shaw, B., Bicket, M., Elliott, B., Fagan-Watson, B., Mocca, E., Hillman, M., 2015. Children's independent mobility. An International Comparison and Recommendations for Action. Policy Studies Institute, London.

Sheeran, P., Gollwitzer, P. M., & Bargh, J. A. (2013). Nonconscious processes and health. *Health Psychology*, *32*(5), 460.

Simonsick, E. M., Guralnik, J. M., Volpato, S., Balfour, J., & Fried, L. P. (2005). Just get out the door! Importance of walking outside the home for maintaining mobility: Findings from the Women's Health and Aging Study. *Journal of the American Geriatrics Society*, *53*(2), 198–203.

Sixsmith, A., & Sixsmith, J. (2008). Ageing in place in the United Kingdom. *Ageing International*, *32*(3), 219–235.

Sniehotta, F. F., Presseau, J., & Araújo-Soares, V. (2014). Time to retire the theory of planned behaviour. Taylor & Francis.

Stephan, Y., Boiche, J., Trouilloud, D., Deroche, T., & Sarrazin, P. (2011). The relation between risk perceptions and physical activity among older adults: a prospective study. *Psychology & Health*, *26*(7), 887–897.

Stigsdotter, U. K., Ekholm, O., Schipperijn, J., Toftager, M., Kamper-Jørgensen, F., & Randrup, T. B. (2010). Health promoting outdoor environments-Associations between green space, and health, health-related quality of life and stress based on a Danish national representative survey. *Scandinavian Journal of Public Health*, *38*(4), 411–417.

Stokols, D. (1992). Establishing and maintaining healthy environments: toward a social ecology of health promotion. *American Psychologist*, *47*(1), 6.

Stokols, D. (1996). Translating social ecological theory into guidelines for community health promotion. *American Journal of Health Promotion*, *10*(4), 282–298.

Stokols, D. (2018). *Social ecology in the Digital Age: Solving complex problems in a globalized world*. Academic Press.

Ståhle, A., & Balfors, B. (2017). Toward Cyborg PPGIS: exploring socio-technical requirements for the use of web-based PPGIS in two municipal planning cases, Stockholm region, Sweden AU - Babelon, Ian. *Journal of Environmental Planning and Management*, *60*(8), 1366–1390. https://doi.org/10.1080/09640568.2016.1221798

Sugiyama, T., & Ward Thompson, C. (2007). Older people's health, outdoor activity and supportiveness of neighbourhood environments. *Landscape and Urban Planning*, *83*(2–3), 168–175.

Sullivan, W. C., Kuo, F. E., & Depooter, S. F. (2004). The fruit of urban nature: Vital neighborhood spaces. *Environment and Behavior*, *36*(5), 678–700.

Taipale, S. (2013). The use of e-government services and the Internet: The role of socio-demographic, economic and geographical predictors. *Telecommunications Policy*, *37*(4–5), 413–422.

Takano, T., Nakamura, K., & Watanabe, M. (2002). Urban residential environments and senior citizens' longevity in megacity areas: the importance of walkable green spaces. *Journal of Epidemiology & Community Health*, *56*(12), 913–918.

Thornton, C. M., Kerr, J., Conway, T. L., Saelens, B. E., Sallis, J. F., Ahn, D. K., … King, A. C. (2016). Physical activity in older adults: An ecological approach. *Annals of Behavioral Medicine*, *51*(2), 159–169.

Tuan, Y.-F. (1974). *Topophilia: A Study of Enviromental Perception, Attitude, and Values*. Prentice Hall.

Tyrväinen, L., Ojala, A., Korpela, K., Lanki, T., Tsunetsugu, Y., & Kagawa, T. (2014). The influence of urban green environments on stress relief measures: A field experiment. *Journal of Environmental Psychology*, *38*, 1–9.

United Nations Department of Economic and Social Affairs, P. D. (2017). *World Population Prospects: The 2017 Revision, Key Findings and Advance Tables*.

Valtioneuvosto. (2018). *Valtioneuvoston selonteko liikuntapolitiikasta*.

Van Cauwenberg, J., De Bourdeaudhuij, I., De Meester, F., Van Dyck, D., Salmon, J., Clarys, P., & Deforche, B. (2011). Relationship between the physical environment and physical activity in older adults: A systematic review. *Health and Place*, *17*(2), 458–469.

Van Holle, V., Van Cauwenberg, J., Deforche, B., Van de Weghe, N., De Bourdeaudhuij, I., & Van Dyck, D. (2015). Do psychosocial factors moderate the association between objective neighborhood walkability and older adults' physical activity?. *Health & place*, *34*, 118-125.

Wang, Y., Chau, C. K., Ng, W. Y., & Leung, T. M. (2016). A review on the effects of physical built environment attributes on enhancing walking and cycling activity levels within residential neighborhoods. *Cities*, *50*, 1-15.

Ward Thompson, C. (2013). Activity, exercise and the planning and design of outdoor spaces. *Journal of Environmental Psychology*, *34*, 79–96.

Ward Thompson, C., & Aspinall, P. A. (2011). Natural environments and their impact on activity, health, and quality of life. *Applied Psychology: Health and Well-Being*, *3*(3), 230–260.

Weuve, J., Kang, J. H., Manson, J. E., Breteler, M. M. B., Ware, J. H., & Grodstein, F. (2004). Physical activity, including walking, and cognitive function in older women. *Jama*, *292*(12), 1454–1461.

Wheeler, B. W., Cooper, A. R., Page, A. S., & Jago, R. (2010). Greenspace and children's physical activity: a GPS/GIS analysis of the PEACH project. *Preventive Medicine*, *51*(2), 148–152. https://doi.org/10.1016/j.ypmed.2010.06.001

WHO. (2004). *A glossary of terms for community health care and services for older persons*. WHO.

Winters, M., Voss, C., Ashe, M. C., Gutteridge, K., McKay, H., & Sims-Gould, J. (2015). Where do they go and how do they get there? Older adults' travel behaviour in a highly walkable environment. *Social Science & Medicine (1982)*, *133*, 304–312. https://doi.org/10.1016/j.socscimed.2014.07.006

Yasunaga, A., Park, H., Watanabe, E., Togo, F., Park, S., Shephard, R. J., & Aoyagi, Y. (2007). Development and evaluation of the physical activity questionnaire for elderly Japanese: the Nakanojo study. *Journal of Aging and Physical Activity*, *15*(4), 398–411.

Yen, I. H., Michael, Y. L., & Perdue, L. (2009). Neighborhood Environment in Studies of Health of Older Adults. A Systematic Review. *American Journal of Preventive Medicine*, *37*(5), 455–463.

Zhao, G., Ford, E., Li, C., & Balluz, L. (2011). Physical Activity in U.S. Older Adults with Diabetes Mellitus: Prevalence and Correlates of Meeting Physical Activity Recommendations. *Journal of the American Geriatrics Society*, *59*(1), 132–137. https://doi.org/10.1111/j.1532-5415.2010.03236.x

Zhao, P., Kwan, M.-P., & Zhou, S. (2018). The Uncertain Geographic Context Problem in the Analysis of the Relationships between Obesity and the Built Environment in Guangzhou. *International Journal of Environmental Research and Public Health* . https://doi.org/10.3390/ijerph15020308

Being physically active has notable health benefits for older adults and the quality of everyday environment is in link with people's health. Thus, understanding what kinds of environments support older adults' everyday physical activity can help researchers, planning practitioners and decision makers find ways to facilitate and motivate older adults to move outdoors and in planning healthy communities. According to the findings of this dissertation, the built environment is directly linked to older adults' everyday physical activity regrdless of their personal interests. In addittion, green and blue spaces close to home describe older adults' perceptions of a quality environment, and thus could motivate older adults getting outdoors. Moreover, the findings show that the built environment is associated with the perceived health of older adults. Finally, this dissertation argues that participatory mapping methods are well suited for health promotion research and offer ways to overcome the challenges previous studies have had in capturing the spatiality of human health behavior.

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