REORIENTING BEHAVIORAL INTERVENTIONS: INTEGRATING SPATIOTEMPORAL METHODS AND BEHAVIORAL ECONOMIC PRINCIPLES TO STRENGTHEN CONTEXT SPECIFIC INTERVENTIONS

by

Brittany Barber

Submitted in partial fulfilment of the requirements
for the degree of Doctor of Philosophy

at

Dalhousie University
Halifax, Nova Scotia
November 2022

Dalhousie University is located in Mi'kma'ki, the
ancestral and unceded territory of the Mi'kmaq.
We are all treaty people.

Table of Contents

LIST OF TABLES

LIST OF FIGURES

ABSTRACT

Cardiovascular diseases (CVD) are a leading cause of death worldwide yet are largely preventable through lifestyle modification targeting risk factors such as physical inactivity, unhealthy diets, obesity, high blood pressure, smoking, high cholesterol, and harmful use of alcohol. Behavioral interventions have proven effective at managing CVD risk factors and preventing repeat cardiac events; however, the effectiveness of behavioral interventions is challenged by limited maintenance of behavior change, lack of spatiotemporal contexts influencing day-to-day activities, and limited understanding of decisions patients make as part of their daily routines. The aim of this study is to investigate how theoretical and methodological principles of health geography and behavioral economics can be used to strengthen interventions. This study used a two-phased, mixed-methods research design guided by adapted geo-ethnography techniques and in-depth interviews. In phase one, adapted geo-ethnography techniques were used with a customized digital mapping tool to gather detailed descriptions about the timing and location of patient day-to-day routines. In phase two, qualitative methods were used to gather in-depth descriptions about facilitators and barriers to increasing physical activity (PA) and what context specific behavioral economic strategies could be used to influence decisions about engaging in PA. Data were gathered from one cardiac intervention program from June to September 2021. A total of 29 individuals (19 men and 10 women) between the ages of 45 to 81 referred to the program after a cardiac event participated. Patients exceeded minimum guidelines for daily PA by walking in their neighborhood but were sedentary for long periods of time watching television at home. Patients had capability and were motivated for PA but were challenged to identify opportunities to adapt sedentary routines and increase PA. Behavioral economic principles including disrupting default routines, increasing commitments, changing the messenger, and introducing incentives were identified as potentially useful strategies to improve decisions for increasing PA. This thesis makes several contributions including the coupling of spatiotemporal contexts and behavioral economic principles to conceptualize a new understanding of data collection tools to measure and report contexts of patient behaviors and strategies for tailoring interventions to improve decisions for modifying behaviors.

LIST OF ABBREVIATIONS USED

APEASE	Implementation Framework for Behavior Change Techniques: Affordability, Practicality, Effectiveness and Cost-effectiveness, Acceptability, Side-effects/ Safety, Equity
BCW	Behavior Change Wheel
COM-B	Capability, Opportunity, and Motivation of Behavior Change
CVD	Cardiovascular Disease
EMA	Ecological Momentary Assessment
GIS	Geographic Information Systems
GPS	Global Positioning System
MET Scores	Metabolic Equivalents
MINDSPACE	Behavioral Economic Principles Framework: Messenger, Incentives, Norms, Defaults, Salience, Priming, Affect, Commitments, Ego
MVPA	Moderate to Vigorous Physical Activity
PA	Physical Activity
RCT	Randomized Controlled Trial
SDH	Social Determinants of Health
TDF	Theoretical Domains Framework
UK	The United Kingdom
3D	Three Dimensional

ACKNOWLEDGEMENTS

I am forever grateful for the experiences that have led me to this point and several important people that have contributed to my growth, both personally and professionally.

I will always remember the advice a mentor shared when I first began this PhD journey. *"Focus on building life experiences and not just your resume."* This advice encouraged me to seek opportunities like teaching yoga, spin, and learning how to sail. I feel so incredibly grateful for some of the risks I took over the past five years that have shaped important life lessons.

Thank you to many thought-provoking professors and mentors at Western University and Dalhousie University that have instilled a passion for lifelong learning. It has been a privilege to learn and apply this knowledge within my dissertation.

To my co-supervisors, Drs. Daniel Rainham and George Kephart – You have supported my learning and helped to shape me into a confident and independent health scientist. Daniel and Tarah – thank you for welcoming me into your home and extending an open invitation for coffee and dinner, which I always took you up on. George – thank you for random check-in phone calls, they were more meaningful than you realize. Thank you for welcoming me into your home with Monique, hosting many fantastic house concerts.

To my committee members Drs. Michael Vallis and Ruth Martin-Misener – thank you for enthusiasm in every meeting, challenging my thinking, and supporting me to the end.

Much of my success has been influenced by strong female mentors. Lori Weeks, you have supported me from the start of my masters and offered many learning opportunities. You are the kindest person I have had the pleasure of working with. Natalie St. Jacques, you provided many essential learning opportunities in epidemiology and have shown me what research is outside academia. Christine Cassidy and Janet Curran – you have created an incredible research program and swept me under your wing in the transition to a post-doc. I feel so grateful to start the next chapter working with you both.

To my family, having three older sisters in academia has not always been easy but your success is always something I've looked up to. To Lisa and Shaun – thank you for being important mentors, hosting Sunday dinners, and celebrating every success during graduate school. And my parents, Vicky and Greg – My love for learning and work ethic come from you. Even if you didn't know what every milestone meant, you were there to celebrate me and encourage me to continue going.

To my friends that are my chosen family, I would not be where I am without all the coffee walks, dinners, wine nights, adventures, and sanity check-ins. You are all so brilliant and successful and mean so much to me.

Lastly, to my pups Hugo and Navi for diligently taking me on daily walks through Point Pleasant Park where a lot of ideas and mental breakthroughs occurred.

CHAPTER 1

INTRODUCTION

1.1 Statement of the Problem

"Despite the importance of treating chronic disease, only prevention has sustainable public health potential." - North Karelia Project
(Puska & Jaini, 2020).

Canada continues to face significant public health challenges in preventing chronic diseases, where 1 in 5 adults can expect to experience cardiovascular disease, cancer, chronic respiratory diseases, or diabetes (Public Health Agency of Canada, 2018). Cardiovascular disease (CVD) is the leading cause of death, years of healthy life lost, and morbidity globally (Roth et al., 2018; Wang et al., 2016). CVD a leading cause of death in Canada and the United States (World Health Organization, 2021) and a significant burden on the sustainability of Canada's healthcare system as the most expensive disease to treat, totaling over 21 billion in direct (medical) and indirect (lost earnings) costs (Public Health Agency of Canada, 2016).

CVD includes a group of disorders of the heart and blood vessels (i.e., coronary artery disease, heart valve disease, pericardial disease, heart arrhythmias, congenital health disease, cardiomyopathy, and health failure) that mainly lead to an acute health event such as a heart attack (i.e., myocardial infarction) or stroke due to a blockage preventing blood from flowing to the heart or brain (World Health Organization, 2020). The most common reason for the blockage is a build-up of fatty deposits on the inner walls of the blood vessels that supply the heart or brain (World Health Organization, 2020). CVD is largely caused by lifestyle behaviors and could be avoided by modifying behavioral risk factors including smoking, physical inactivity, obesity, poor nutrition, high blood pressure, high cholesterol, and harmful use of alcohol (Roth et al., 2018; World Health Organization, 2015). Behavioral interventions and pharmaceutical therapies are critical for managing risk factors and preventing a future cardiac event.

However, the sustainability and effectiveness of behavioral interventions is limited by challenges associated with maintenance of behaviors (Graham et al., 2020) and intervention strategies that are not tailored to the contexts influencing patients' day-to-day health activities (McQuoid, Jowsey & Talaulikar, 2017).

1.2 Behavioral Interventions for Cardiovascular Disease

Behavioral interventions for CVD have been implemented across three levels including individual, community, and policy levels. Individual interventions delivered within clinic-based settings most often use education and counselling strategies to target CVD behavioral risk factors including smoking, nutrition, physical activity (PA), and medication adherence (Cutler, 2004). For example, an innovative multiple risk factor intervention trial (MRFIT) for CVD provided behavioral counselling to 12,000 men targeting behavioral risk factors like smoking, blood pressure and cholesterol (Gotto, 1997). The MRFIT intervention was found to reduce lifestyle risk factors like smoking (59% at baseline to 32% 6-years post intervention) and blood pressure (reduction of 10.5 mm Hg from baseline to 6-years post intervention) but did not significantly reduce mortality outcomes at 10-years post intervention (p>0.10) (Kjelsberg, Cutler & Dolecek, Gotto, 1997). Interventions have since been integrated within community-based settings to account for the influence of environments in which behaviors occur.

Community interventions for CVD most often involve multi-sector partnerships (e.g., government departments, organizations) and occur within public sector settings (e.g., schools, recreation centers) (Castillo et al., 2019; Farquhar et al., 1985; Ndejjo et al., 2021). A well-known community intervention, the Stanford Five-City Project, investigated the influence of community-wide education for reducing the prevalence,

morbidity, and mortality of CVD for individuals between the ages of 25 to 74 (Farquhar et al., 1985). The Five-City Project found that after 30 to 64 months of education (delivered through television and radio, newspaper, mass-distributed print media, and direct education counselling), community education interventions were effective, in comparison to communities without education programs, at significantly reducing population level CVD total risk mortality (15%, $p<0.005$) and CVD risk (16%, $p=0.09$), including reduction from baseline in smoking rate (13%, $p<0.01$), systolic blood pressure mm Hg (4%, $p<0.001$), resting heart rate beats per minute (3%, $p<0.001$), and plasma cholesterol mmol/L (2%, $p<0.01$) (Farquhar et al., 1990). Furthermore, another multi-level community CVD intervention within 2 Chinese cities targeted smoking, PA, and diet behaviors within neighborhood, school, workplace, and community health settings (Lv et al., 2014). This study found community interventions were effective at significantly reducing smoking (from 25% at baseline to 18% post 2-year intervention) and increasing metabolic equivalent of PA (from 1204 at baseline to 1386 post 2-year intervention) (Lv et al., 2014). However, there were nonsignificant changes to diet (increase in frequency of fruit and vegetable consumption score of 24 mean/weekly at baseline to 25 mean/weekly post 2-year intervention) between the intervention versus comparison city ($p>0.10$) (Lv et al., 2014).

Strategies aimed at reducing CVD risk across populations have been implemented through policy level interventions targeting behavioral risk factors like diets high in sugar, sodium and fat, smoking, and physical inactivity (Pearson, 2011). The North Karelia project, a leading policy level intervention in Finland aimed to reduce CVD morbidity and mortality by targeting changes in lifestyle and environment to reduce high

serum cholesterol, blood pressure and smoking (Puska & Jaini, 2020; Vartiainen, 2018). Population strategies included a Hypertension Register for all hypertensive patients along with hypertension clinics in each local health center to follow-up with frequent health examinations for monitoring pharmaceutical treatment and blood pressure readings (Vartiainen, 2018). The North Karelia project also developed policies to improve population-wide nutritional education and dietary behaviors through a Salt Project intervention targeting reduced salt consumption in packaged foods (Tuomilehto et al., 1981; Vartiainen, 2018). Health education (newspaper articles and nutritional counselling) and policy interventions improved public awareness of salt reduction in diets and encouraged industries to reduce salt in packaged foods, resulting in a significant population reduction in salt consumption (13 grams at baseline to 9.5 grams for men and 10 grams to 7.4 grams for women) and reduced mean systolic blood pressure (149 mmHg to 134 mmHg for men, and 153 mmHg to 129 mmHg for women) from 1972 to 2012 (Laatikainen et al., 2016; Puska & Jaini, 2020). Furthermore, policy interventions within the United Kingdom targeting a tax increase on sugary soft drinks has led to manufacturers reformulating products to significantly reduce sugar content (from 4.4g/100ml in 2015 to 2.9g/100ml in 2018) and the sale (30% decrease) of sugary soft drinks between 2015 to 2018 (Bandy et al., 2020). Interventions targeting behavior change within each of the three levels have a critical role for reducing CVD and shifting health system culture towards early intervention and awareness of lifestyle behaviors that could be adapted to reduce risk of disease over the life course. This thesis focuses on individual behavioral interventions within clinic-based settings and explores how CVD

interventions could be improved by tailoring strategies to the contexts influencing patients' day-to-day health activities.

Improvements to the design of behavioral interventions that reduce risk of CVD, or a repeat event have been made by integration of a theoretical framework, use of technologies to monitor and provide feedback, and strategies to deliver individualized counselling. First, interventions using a theoretical framework show improved outcomes for PA (Mohebbi, Sabouri & Tol, 2021; Room et al., 2017), weight loss, smoking cessation (Winter, Sheats & King, 2016), and knowledge of self-management of hypertension, lipids, and blood glucose (Hong et al., 2021). Most frequently cited theories within CVD interventions include the Social Cognitive Theory, the Transtheoretical Model, and the Theory of Planned Behavior/ Reasoned Action (Seguin et al., 2020; Winter, Sheats & King, 2016). Second, CVD interventions using technologies to monitor and provide feedback on patient behaviors show improved outcomes for medication adherence, arrhythmias, blood pressure monitoring, and increased PA (Santo & Redfern, 2020; Wongvibulsin et al., 2019). Technologies adopted within interventions most commonly include smartphone applications, wearable devices, and text-messaging programmes (Gold et al., 2021; Santo & Redfern, 2020). Third, individualized counselling through email prompts, telephone calls, and text messages show improved outcomes for blood pressure, total cholesterol, weight, glucose (Yousuf et al., 2019), quality of life, self-management strategies, and reduced hospital re-admission rates (Inglis et al., 2010). Even with improvements to the design of interventions, the effectiveness and sustainability of CVD interventions is challenged by strategies that do not adequately consider contexts outside clinic-based settings that influence where, when,

and how health activities occur, and strategies are not tailored to patients' existing routines to support maintenance of behavior change (Gold et al., 2021; Graham et al., 2020).

1.3 Aim of the Thesis

This thesis aims to explore how theory and principles from two disciplines, health geography and behavioral economics, can be applied to address some of the challenges facing behavioral interventions. The rest of this chapter will introduce health geography and behavioral economics as two theoretical and methodological pillars of this thesis and operationalize how these disciplines provide insight of spatiotemporal contexts and decision-making processes that influence day-to-day patient behaviors.

1.4 Health Geography

Social and physical environments play an important role in promoting or inhibiting health behaviors (Macintyre, Ellaway & Cummins, 2002), including the way individuals interact with the broader environment and factors influencing the timing and location of day-to-day activities. Health geography, the first pillar of this thesis, makes connections between environments and health including multi-level factors influencing health behaviors and health-related phenomena. Health geography methodologies have been applied to explore spatial and temporal distributions of disease, patterns of health and health inequities across physical, social, and political environments, and organization of communities like the location and accessibility of services across environments (Dummer, 2008). For example, health geography research has examined spatial distributions and environmental contexts of clusters of breast cancer mortality (Kulldorff et al., 1997), physical and social access to healthy supermarkets versus fast food outlets

by car, bus, and foot (Burns & Inglis, 2007), and attributes of social and physical environments influencing obesity including supermarkets, high measures of neighborhood disorder (i.e., policing levels, physical dereliction, violent crime), and access to local facilities (i.e., financial services, health-related stores, supermarkets) (Stafford et al., 2007). A renewed interest in health and place research, including Canada's recent national research priority for healthy cities, calls upon health scientists to consider the spatiality and temporal characteristics of health challenges and improve population health by maximizing health-promoting features within the built environment through community design (Canadian Institutes of Health Research, 2019). Spatiotemporal methods are critical for investigating environmental factors associated with individual activities; such as the effect of urban planning and infrastructure like sidewalks has for promoting or inhibiting PA (Shashank & Schuurman, 2019), or the association between locations and density of fast food restaurants and childhood obesity (Laxer & Janssen, 2014). Spatiotemporal methods strengthen an understanding of complex health issues connecting people, time, and place including contexts of where day-to-day behaviors occur, when and for how long, and connections to place that influence why and with whom activities occur (Kwan & Ren, 2008).

1.4.1 Methods to Assess Spatiotemporal Contexts

Methods to assess unique spatiotemporal contexts surrounding the timing and location of health activities include quantitative approaches like time-use techniques, map-based questionnaires, and wearable devices like accelerometers and global positioning systems (GPS). Time-use measurements, including time-diaries and time-use surveys, provide important information on temporal dimensions of day-to-day activities

(Bauman, Bittman & Gershuny, 2019). For example, population time-use surveys are used in Canada (Statistics Canada, 2022) and the United States (Tudor-Locke, Johnson & Katzmarzyk, 2010) to monitor changes in time use, particularly around employment, unpaid caregiving, transportation, and leisure. Map-based questionnaires provide context by collecting locational coordinates of activities using mapping software and survey questions about individual behaviors (Hinrichs et al., 2020; Rantanen & Kahila, 2009). For example, map-based questionnaires provided important public health insight of environments where men in Sri Lanka were engaged in high-risk behaviors, indicating men were smoking and drinking excessive alcohol at schools, places of worship, and factory locations (Silva et al., 2016). A combination of wearable devices like accelerometers and GPS have been used to contextualize features of the built environment in which PA occurs. For example, accelerometers and GPS technologies show that individuals are more likely to engage in moderate to vigorous PA within environments with high greenness index scores (odds ratio = 1.15, 95% CI=1.03, 1.30) in comparison to environments with high street density and walkability scores (odds ratio = 0.69, 95% CI=0.67, 0.71) (Tamura et al., 2019). The quantitative methods described are some examples of methods to assess spatiotemporal contexts of the location and timing of health activities; however, they do not adequately gather information about why behaviors occur, including contexts influencing individual perceptions, experiences, and social interactions.

Mixed-method approaches that combine geographic information system (GIS) with interview or survey techniques have been developed to account for the spatiotemporal contexts of individual perceptions, experiences, behaviors and social

contacts influencing day-to-day health activities (Baur et al., 2014). Ecological momentary assessment (EMA) mixed methods gather real-time information on participants' behaviors, perceptions, and emotions, when they occur in natural environments with repeated occurrence and observations of events over time (Dunton, 2017; Stone & Shiffman, 1994). EMA involves use of an electronic device to notify participants at fixed or random times throughout the day to respond to survey questions and report their behaviors (Degroote et al., 2020). For example, EMA has been used to explore contextual factors about where and with whom children's leisure-time physical activity occurs (Dunton et al., 2012). Randomly timed EMA surveys show children reported they spent the largest proportion of time physically active with family members and friends (39%), outdoors away from home (42%), at a park or trail (37%), and felt very safe (78%) (Dunton et al., 2012).

Advancements to EMA include use of location-tracking devices like global positioning systems (GPS) so the timing of geographic ecological momentary assessment (GEMA) notifications are linked to participants' location where specific events occur. For example, GEMA has been used to capture the effects of noise exposure on real-time perceptions of annoyance in different activity contexts in Guangzhou, China (Zhang et al., 2020). Portable noise and air sensors (capable of recording real-time air quality $PM_{2.5}$, temperature, and humidity) with GPS-equipped mobile phones were used to measure environmental noise and notify participants at specific time intervals to respond to GEMA questions about their perception of current noise and annoyance at different activity places (Zhang et al., 2020). Findings indicate participants were more likely to report feeling annoyed from noise near their residence ($OR=1.44$, $p>0.01$) however,

participants exposed to higher levels of noise during the day were less likely to report feeling annoyed due to noise (OR=0.74, $p<0.05$) (Zhang et al., 2020).

Mixed-method approaches combining GIS with qualitative interviews are useful for gathering rich details of participants' experiences including in-depth descriptions of contexts influencing health behaviors. Three well-known research studies have applied mixed-method GIS approaches to create novel research techniques including geo-ethnography, grounded visualization, and geo-narrative. First, geo-ethnography methods have been used to combine locational coordinates of activities with contextual information of participants' experiences through interviews (Matthews et al., 2005; Milton et al., 2015). Matthews et al., 2005 lead the first geo-ethnography study by exploring how GIS methods could be coupled with ethnographic techniques to contextualize day-to-day activities for low-income families in different neighborhood environments. This study provided visualizations of unique differences in spatiotemporal patterns of activities with in-depth descriptions of social, economic, and physical constraints influencing decisions about day-to-day health activities (Matthews et al., 2005). Geo-ethnography methods have since been applied to explore how older adults interact with and define their neighborhood (Milton et al., 2015), as well as how food insecurity influences where, when, and how women living in urban and rural communities make decisions about shopping for food (MacNell, 2018). Second, grounded visualization methods have been used to represent community-planning, housing, demographic, and neighbourhood boundaries in the context of how individuals form attachments to place (Knigge & Cope, 2006). For example, grounded visualization has been applied to explore how a community garden influenced perceptions of ethnic,

social identities and social structures within a neighborhood with high crime and housing vacancies (Knigge & Cope, 2006). Third, geo-narrative methods have been used to explore daily activities through quantitative 3D life paths with contextual experiences linked to activities through participants' daily activity diaries (Kwan & Ding, 2008). For example, geo-narrative methods have been used to explore the experiences of Muslim women in Ohio after the 9/11 terrorist attacks. This study used daily activity diary surveys to generate 3D life paths of day-to-day activities for Muslim women and linked contextual factors of how transportation, access and use of public space, and perceptions of safety and risk within their community environment influenced their activities (Kwan & Ding, 2008). These mixed-method examples provide valuable insights about the importance of understanding spatiotemporal patterns of activities within the contexts influencing day-to-day health behaviors.

However, applying spatiotemporal mixed method techniques within different settings, like behavioral interventions, is challenging as spatiotemporal techniques are time intensive and require expertise to analyze quantitative locational data with qualitative accounts of contextual factors influencing health activities. Understanding how behavioral interventions can adapt spatiotemporal mixed method techniques is critical for collecting spatiotemporal information from patients about their day-to-day health activities and tailoring context specific strategies that target the most opportune time and place to disrupt routine behaviors. Health geography spatiotemporal mixed-methodology is the first pillar of this thesis and provides insight into contexts outside clinic-based settings that influence when and where health activities occur and

opportunities for tailoring intervention strategies and modifying behaviors within existing routines.

1.5 Behavioral Economic Principles

In addition to spatiotemporal contexts in which health activities occur, we know many routine health activities are influenced by automatic decisions about day-to-day activities under constraints of limited time and resources (Betsch, Fiedler & Brinkmann, 1998; Marteau, Hollands & Fletcher, 2012). Behavioral economic principles, the second pillar of this thesis, provide insight into factors influencing individual behaviors including cognitive biases and unconscious habits that commonly lead to automatic versus reflective decision-making processes (Thaler & Sunstein, 2003). Behavioral economics is an evolving field, rooted in psychology and economics, and explains how individual thought processes and decisions are often impulsive, habitual, and biased in predictable ways (Kahneman & Tversky, 1984). A foundation of behavioral economic principles is questioning how individuals deviate from objective decision-making processes including slow and deliberate thinking processes that optimize utility (Tversky & Kahneman, 1974). Instead, behavioral economic theory hypothesizes that individual behaviors and decision-making processes are heavily influenced by external factors including environmental stimuli that compromise individual strength of executive functions associated with frontal lobe cognitive processes (Friedman & Miyake, 2017; Marteau, Hollands & Fletcher, 2012). For example, an experiment in a buffet dining area found that environmental stimuli like providing default options through pre-portioned salads significantly increased vegetable consumption (increase of 45 grams between intervention and control, p=0.016), and priming through visual cues of green plants,

green serving bowls and the smell of herbs significantly reduced consumption of meat (reduction of 116 grams between intervention and control, $p<0.01$) (Friis et al., 2017). Furthermore, external factors like cognitive load and fatigue have been shown to deplete executive functioning required for slow thinking and diminish task-switching inhibitory control required for making decisions that are consistent with goal-directed behaviors (Dohle et al., 2018). For example, an investigation of opioid prescribing behaviors shows that physicians experience prescription decision fatigue after each working hour throughout the day and are 1.5 times more likely to prescribe opioids after 9 hours of work (Hughes et al., 2020). Behavioral economic principles are critical for understanding contexts influencing decision-making processes and identifying what strategies could disrupt routines so that decisions about engaging in health promoting activities become easier and automatic.

1.5.1 Application of Behavioral Economic Principles

Interventions targeting individual, community, and policy levels have increased effectiveness by adopting behavioral economic principles that encourage health promoting activities and improved decision-making (Halpern, Ubel & Asch, 2007). Interventions at the individual level have commonly targeted hygiene practices through environmental primes including visuals of staring eyes, reminder posters, and the smell of citrus cleaning products (Elia et al., 2022; King et al., 2016; Vande Welde, Overgaard & Bastien, 2021). For example, hand hygiene compliance of healthcare professionals within a hospital setting found the smell of citrus cleaning products significantly improved hygiene practice (47% intervention vs. 15% control, $p=<0.01$) followed by use of male staring eyes above washing station (33% intervention vs. 15% control, $p=0.038$) (King et

al., 2016). Interventions within community settings have been critical during COVID-19 to improve mask wearing behaviors. Behavioral economic strategies including social norms, messenger, and affect that were applied through social media campaigns and local news briefings with community leaders show improved mask wearing compliance in public settings (Krawiec et al., 2021; Prevent Epidemics, 2021). For example, villages in Bangladesh using social norm strategies found that providing colored masks with mask-wearing promotional media messages significantly increased mask wearing behaviors by 28 percent in comparison to villages without an intervention (41% compliance in intervention villages vs. 13% compliance in control villages) (Abaluck et al., 2021). Interventions within community health settings have also applied behavioral economic strategies through use of messenger and priming to reduce health system costs related to missed medical appointments (Hallsworth et al., 2016). In the United Kingdom missed hospital appointments were reduced from 11 percent to 8 percent ($p<0.01$, totalling 5,800 fewer missed appointments per year) by sending patients a text reminder about their appointment with information about how much the appointment costs the health system (Hallsworth et al., 2015). Interventions at the policy level have integrated behavioral economic strategies to increase awareness of nutritional content that poses a significant health risk including high consumption of sugar, sodium, and fat. For example, policy interventions aimed at reducing salt consumption have used strategies such as priming through front-of-pack labeling, changing default salt with low-sodium substitutes, and incentives for food manufacturers to reformulate product ingredients with reduced sodium (Santos et al., 2021). Policies that incentivize food manufacturers to reformulate existing products are effective for reducing individual sodium intake by approximately

1.5g/day (Hyseni et al., 2017) and household consumption of sugar from soft drinks by 30g/week (Pell et al., 2021). For example, in the United Kingdom a sugar tax was implemented to incentivize manufacturers to reduce sugar within soft drinks to <5g sugar/100ml, through a two-tiered tax levy charging £0.18/L on drinks that have between ≥5g to <8g of sugar and £0.24/L for drinks with ≥8g sugar/100ml (Government of United Kingdom, 2018; Pell et al., 2021). One year after this tax policy was implemented consumption of drinks with high sugar (≥8g sugar/100ml) was reduced by 44 percent, equivalent to 155mL per household per week (Pell et al., 2021). Despite little change in purchasing behaviors of drinks with low sugar (<5g sugar/100ml), manufacturers reduced sugar by 10 percent in products, equivalent to reduction of 30g/week per household (Pell et al., 2021). These examples of behavioral economic interventions provide insight into external contexts like environmental stimuli that make decisions to engage in health promoting activities easier and automatic.

In the context of clinical interventions, incentives are the most widely adopted behavioral economic principle for increasing PA behaviors among patients (Hare et al., 2021; Waddell et al., 2020). A meta-analysis of PA interventions shows that modest financial incentives ($1.40 US/day) were associated with positive intervention effects and increased mean daily step counts during an intervention period (pooled mean difference 607 daily step count) and at follow-up assessment (pooled mean difference 513 daily step count) (Mitchell et al., 2020). Although incentives significantly increased patient PA, how incentives are delivered has been shown to influence the effectiveness of PA interventions (Hare et al., 2021). For example, when comparing differences between immediate versus delayed incentives, findings indicate immediate incentives are

associated with greater PA outcomes from baseline in comparison to delayed incentives (2762 vs. 2016 steps/day increase, difference = 746 steps/day, p=0.009) (Adams et al., 2017).

Although behavioral economic principles have been applied within population-level interventions, behavioral economic strategies are not commonly tailored to spatiotemporal contexts that influence the timing and location of individual health activities. It is not evident how behavioral economic principles are tailored to when and where patients' routine activities occur, so that existing CVD interventions can adapt context specific behavioral economic strategies to disrupt patients' day-to-day routines and improve decisions for adapting health activities. Understanding what behavioral economic principles could be applied to improve CVD interventions and when and where they can be tailored is critical for identifying the most opportune time and place to disrupt routines and improve automatic decisions for modifying behaviors. The significance of this thesis is to advance knowledge about how theoretical and methodological approaches of health geography and behavioral economics can strengthen CVD interventions by gathering information about the social and environmental contexts outside of clinic-based settings that influence when, where and how decisions about health activities occur.

1.6 Research Purpose and Objectives

The purpose of this research is to explore how behavioral interventions could solicit information from patients about the spatiotemporal contexts in which their health behaviors occur and how this information could be used to identify opportunities for incorporating context specific behavioral economic principles to overcome challenges within clinical interventions. To achieve this overarching purpose, the following research

objectives are explored:

1. Investigate how theoretical and methodological principles of health geography and behavioral economics can inform improvements to clinical interventions
2. Develop an approach for collecting spatiotemporal information about patients' day-to-day health activities, and how interventions can use spatiotemporal information within clinical interventions
3. Identify contexts influencing patients' capability, opportunity, and motivation for increasing PA, and what context specific behavioral economic principles could be used to tailor interventions

The primary research question under investigation is how can spatiotemporal contexts of patient health activities and context specific behavioral economic intervention strategies be used to adapt behavioral interventions and overcome challenges to behavior change?

In exploring these research objectives, this thesis addresses several challenges that compromise the sustainability and effectiveness of behavioral interventions. First, the operationalization of theory and methods from interdisciplinary fields of health geography and behavioral economics provide a new way of thinking about spatiotemporal patterns of health behaviors such as when and where activities occur and cognitive biases influencing day-to-day decisions about engaging in different health activities. Second, the geo-ethnography mixed-methods approach that was employed in this thesis develops and implements a data collection and communication tool that could be used to collect and visually display spatiotemporal information about the time-location sequences of patient health behaviors within clinical interventions. Third, building upon results of patients' spatiotemporal patterns, the application of behavioral economic

principles provides a novel approach for identifying opportunities to disrupt routines and make decisions for engaging in PA easier and more automatic. By identifying when and where patients default to automatic decision-making processes, the context specific behavioral economic strategies that could be applied to support patients with adapting day-to-day routines are explored. These research objectives provide a strong foundation for improving behavior interventions by using information about the timing and location of existing routines so that interventions are tailored to support patients with automatic decisions about adapting health activities and increasing PA.

1.7 Conceptual Framework and Justification

Two theoretical and methodological pillars of health geography and behavioral economics inform this thesis and contribute innovative ways of conceptualizing external social and environmental contexts influencing health behaviors. Information of when, where, and how patients make decisions about their day-to-day health activities is critical for tailoring interventions, yet theoretical and methodological techniques from health geography and behavioral economics are not commonly adopted to improve the design of CVD interventions. Figure 1 represents the conceptual framework of this thesis by expanding upon contexts influencing behaviors that are not adequately captured within approaches like population health, social determinants of health and health psychology. This section will discuss relevant literature and provide a justification for this thesis by identifying how spatiotemporal contexts and decision-making processes expand current approaches for behavior change. A more detailed discussion of how health geography and behavioral economics can be applied within behavioral interventions is found in Chapter 2.

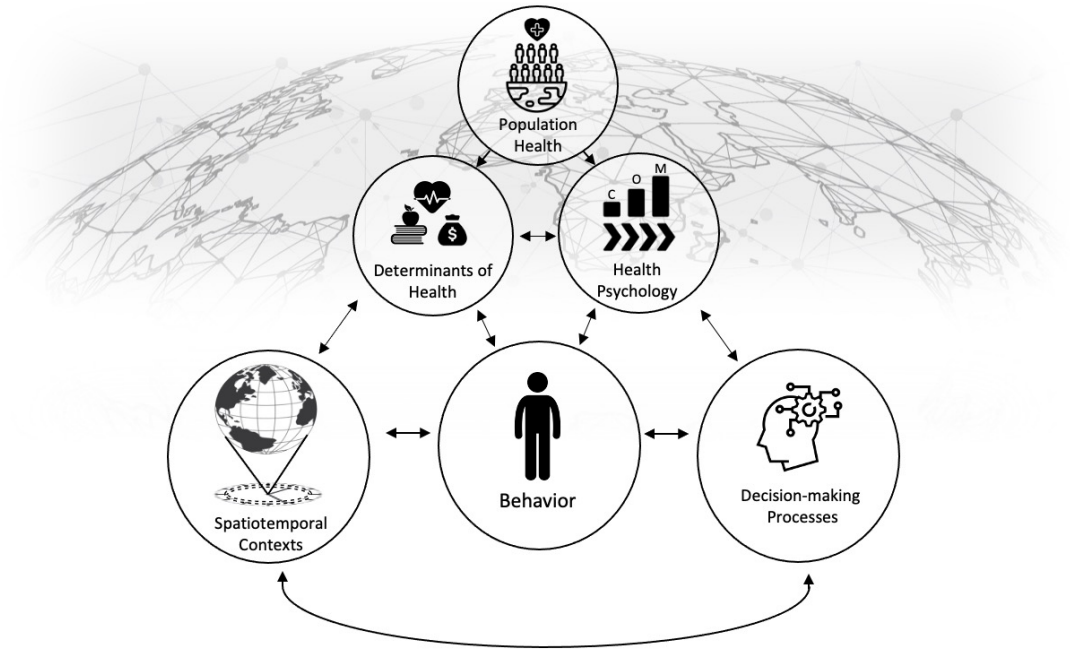


Figure 1. Conceptual Framework of Contextual Pillars Health Geography and Behavioral Economics

1.7.1 Contextual Pillars of Health Geography and Behavioral Economics

Understanding why some populations are healthier than others has been a central question guiding the conceptualization of a population health approach. When significant investments to healthcare systems and public health were made, they were predominately focused on "sickness care systems" with few resources devoted to understanding upstream determinants of health (Evans & Stoddart, 1990). A shift in thinking about the collective health of populations and upstream influences on disease outcomes incited a new conceptual framework to represent the wide range of determinants connecting individual health (i.e., behaviors and biology) and well-being to broader social and physical environments in which they occur (Evans & Stoddart, 1990; Friedman & Starfield, 2003). A population health approach refers to interrelated conditions that

influence the health of populations over the life course, such as how the health and behaviors of individuals are influenced by interactions within social, economic, and physical environments (Dunn & Hayes, 1999; Kindig & Stoddart, 2003). To explain population health outcomes different measures have been applied to understand health status (e.g., health surveys and diagnostic tools), predict risks (e.g., screening tests or indicators of risk), explain determinants (e.g., exposures, genetic factors), and evaluate outcome measures (e.g., monitoring impact of programs and policies) (McDowell, Spasoff & Kristjansson, 2004). Measures and assessments of population health, whether systematic or comprehensive, influence how populations manage health risks including health policies for modifying social (i.e., cultural) and environmental (i.e., physical) settings that inhibit or promote health behaviors (Edwards, 1999; Krewski et al., 2007).

A population health approach accounts for the interactions individuals have within social and physical environments. However, population health approaches have not adequately accounted for the spatiality of social and physical environments influencing when, where, and how individuals make decisions about routine health activities. For example, spatiotemporal contexts and decision-making processes about day-to-day health activities is critical for contextualizing differences in health behaviors between individuals living in the same physical environment with similar social and economic conditions. Within the conceptual framework (Figure 1) for this thesis, population health approaches provide a broad understanding of interconnections between social, economic, and physical environments. Individual social determinants of health (SDH) and health psychology contextualize how individual level factors influence the spatiality of health behaviors and decisions individuals make about health activities day-

to-day. A contribution of this thesis is to expand social and psychological theories by operationalizing how behaviors are not merely influenced by interconnections between social and physical environments but the contexts influencing the timing, location, and decisions to engage in day-to-day health activities.

In a population health approach, differences in health outcomes across populations are largely attributed to SDH, including the conditions in which individuals are born, grow, live, and age; and the broader social and physical environments influencing daily life (Wilkinson & Marmot, 2003). SDH include economic and social conditions including, but not exclusively, income stability, housing, employment and working conditions, education and literacy, access to health care, and social and community contexts (Public Health Agency of Canada, 2001). A broad range of quantitative and qualitative methods are used to assess SDH (Elias, Jutte & Moore, 2019); however, SDH approaches do not adequately consider contexts connecting multiple SDH in time and space. A primary contribution of this thesis is expanding population health approaches like SDH by demonstrating the importance of spatiotemporal contexts influencing the timing and location of individual health activities and health outcomes over time.

Theoretical and methodological techniques from health geography contribute important insight for understanding complex health behaviors connecting individuals, time, and place (Curtis & Jones, 1998; Hagerstrand, 1970). Health geography provides a different way of thinking about contexts influencing health behaviors of individuals living in the same environment with similar SDH. For example, time poverty has recently been recognized as a health inequity affecting SDH (Strazdins et al., 2016). Time poverty

recognizes that health inequities are influenced by an individual's ability to adapt to time constraints based on capability, opportunity, and resources (i.e., access to transportation, flexible work schedule) to adapt space-time activity paths (Bissonnette et al., 2012; Comber et al., 2011). Spatiotemporal contexts are critical for operationalizing social and physical environments influencing day-to-day activities and individual factors influencing capability, opportunity, and motivation for behaviors and changes in health over time.

Theories of health psychology have helped to examine individual differences in health behaviors, including lifestyle activities and factors influencing why individuals behave the way they do. Theoretical frameworks focusing on psychological determinants of behavior conceptualize how individual attitudes, perceptions, and experiences influence decisions for engaging in activities that increase or reduce risk of disease (Becker et al., 1977; Janz & Becker, 1984). For example, the Health Belief Model is a key theory explaining health behaviors depend upon two variables: 1) the value individuals attribute towards a particular goal such as avoiding illness and, 2) an individual's belief or perception that action will achieve an expected goal such as preventing illness (Rosenstock et al., 1988). Most psychological theories explain behavior change as cognitive-behavioral processes influenced by underlying motivation, beliefs, and emotions. For example, the COM-B model is a widely adopted approach explaining determinants of behaviors are driven by individual capability, opportunity, and motivation (Michie, van Stralen & West, 2011; Willmott, Pang & Rundle-Thiele, 2021). Yet, we know behaviors are not solely driven by intrinsic and deliberate thought

processes and individuals commonly default to automatic decisions influenced by environmental stimuli and unconscious habits (Marteau, Hollands & Fletcher, 2012).

A primary contribution of this thesis is expanding theoretical approaches like health psychology by demonstrating the importance of contexts like cognitive biases and environmental stimuli, influencing automatic decisions towards day-to-day activities (Tversky & Kahneman, 1974). Behavioral economics provides important insights into psycho-social contexts by demonstrating how individual decisions are commonly not slow and deliberate. They are often impulsive, habitual, and biased in predictable ways (Kahneman & Tversky, 1984). There are important individual differences in strength of executive functioning associated with cognitive processes (Friedman & Miyake, 2017), and external factors like fatigue or cognitive load that deplete self-regulating decision-making processes and task-switching inhibitory control (Dohle et al., 2018). Behavioral economic principles provide a new way of thinking about barriers to behavior change, cognitive executive functioning, contexts reinforcing automatic day-to-day habits, and opportunities for disrupting automatic decision-making processes.

1.8 Significance in the Context of COVID-19

The significance of theoretical and methodological contributions of this thesis are heightened by COVID-19. Disruptions to daily routines and health activities were experienced globally and adaptations to social and physical environments influenced how individuals interacted in time and space, including virtual space. Within Canada various acute care health services were rapidly transitioned to online eHealth and telemedicine platforms, individuals began working virtually at home, and community restrictions limited individual autonomy to move freely in time and space. Individuals were acutely

aware of barriers and facilitators influencing adaptations to day-to-day routines including contexts of neighborhoods and housing, flexible employment, and social support networks. This thesis signifies the importance of conceptualizing spatiotemporal contexts of patients' day-to-day routines, a critical factor for encouraging individuals to adapt day-to-day health activities during COVID-19. The timing and location of health activities is also critical for identifying what intervention strategies can be tailored across different settings to improve decisions for reducing COVID-19 risk, including vaccinations and masks in public spaces. Spatiotemporal contexts and behavioral economic strategies provide critical insights of contexts influencing behaviors and strategies to modify interventions across diverse settings, a valuable contribution for improving effectiveness of public health interventions for infectious diseases and sustainability of interventions for chronic diseases.

1.9 Organization of the Thesis

This thesis contains five chapters, including a series of three manuscript-based papers formatted for publication comprising Chapters 2, 3, and 4. The following chapter consists of a conceptual framework to operationalize how theoretical and methodological techniques from health geography and behavioral economics can be applied to improve behavioral interventions. This framework discusses how spatiotemporal information is critical for assessing social, physical, and environmental contexts influencing the timing and location of day-to-day activities, and how spatiotemporal contexts strengthen our understanding of behaviors and intersect with existing behavior change theories. The importance of tailoring interventions using context specific behavioral economic strategies to disrupt routines by making decisions to modify behaviors easier and

automatic is also discussed. These theoretical and methodological pillars are critical for operationalizing the type of information behavioral interventions need to solicit from patients to strengthen the design of interventions, so they are tailored to the contexts in which health activities occur.

The second paper, in Chapter 3, explores techniques to solicit spatiotemporal information about patient day-to-day routines and health activities within a clinic-based intervention. A mixed method approach was employed to develop an adapted geo-ethnography approach for collecting detailed descriptions of the contexts influencing the timing and location of patient activities. This chapter contributes an innovative tool for displaying patient time-use patterns, allowing healthcare professionals to gain quick insight of patterns in the timing and location of health behaviors across patient groups. It also contributes insight into how interventions can use spatiotemporal information about patients' day-to-day health activities by identifying when and where opportunities exist for disrupting routine behaviors and increasing PA.

Chapter 4 builds upon results of spatiotemporal patterns in the previous chapter by identifying what context specific behavioral economic strategies could potentially be useful for influencing automatic decisions to increase PA. This third paper gathers contextual factors influencing patients' decision-making processes to increase PA and identifies important facilitators and barriers to behavior change based on capability, opportunity, and motivation to increase PA. Specific behavioral economic strategies were identified as potential techniques for tailoring interventions based on the contexts of when, where, and how patients make decisions about day-to-day activities.

The fifth chapter provides an integrated discussion of findings from the three manuscripts, summarizes contributions to the fields of behavior change and behavior interventions, and discusses future directions for research. Relevant appendices and a comprehensive list of references for chapters 1 and 5 follows.

Chapter 1 (this introduction) and chapter 5 (integrated discussion) was written by Brittany Barber (BB) with editorial assistance from Daniel Rainham (DR), George Kephart (GK), Ruth Martin-Misener (RM), and Michael Vallis (MV).

Chapter 2 is based on conceptual work conducted by BB with assistance from DR and GK. BB conceived the paper, wrote the manuscript, and all authors provided revisions and approved the final version of the manuscript submitted for publication.

Chapter 3 is based on work conducted by BB. This study was conceived by BB with assistance from DR and GK. BB was responsible for data collection, analysis, and interpretation with supervision by DR and GK. BB wrote the manuscript and all authors provided editorial assistance and revisions.

Chapter 4 is based on work conducted by BB. This study was conceived by BB with assistance from DR and GK. BB was responsible for data collection, analysis, and interpretation with supervision by DR and GK. BB wrote the manuscript and all authors provided editorial assistance and revisions.

References

Abaluck, J., Kwong, L. H., Styczynski, A., Haque, A., Kabir, Md. A., Bates-Jefferys, E., … & Mobarak, A. M. (2022). Impact of community masking on COVID-19: A cluster-randomized trial in Bangladesh. *Science*, *375*(6577), eabi9069. https://doi.org/10.1126/science.abi9069

Adams, M. A., Hurley, J. C., Todd, M., Bhuiyan, N., Jarrett, C. L., Tucker, W. J., Hollingshead, K. E., & Angadi, S. S. (2017). Adaptive goal setting and financial incentives: A 2 × 2 factorial randomized controlled trial to increase adults' physical activity. *BMC Public Health*, *17*, 286. https://doi.org/10.1186/s12889-017-4197-8

Ball, K., Hunter, R. F., Maple, J.-L., Moodie, M., Salmon, J., Ong, K.-L., Stephens, L. D.,… & Crawford, D. (2017). Can an incentive-based intervention increase physical activity and reduce sitting among adults? The ACHIEVE (Active Choices IncEntiVE) feasibility study. *International Journal of Behavioral Nutrition and Physical Activity*, *14*(1), 35. https://doi.org/10.1186/s12966-017-0490-2

Bandy, L. K., Scarborough, P., Harrington, R., Rayner, M., & Jebb, S. (2020). Reductions in sugar sales from soft drinks in the UK from 2015 to 2018. *BMC Med*, *18*(20). https://doi.org/10.1186/s12916-019-1477-4

Bauman, A., Bittman, M., & Gershuny, J. (2019). A short history of time use research; implications for public health. *BMC Public Health*, *19*(S2), 607. https://doi.org/10.1186/s12889-019-6760-y

Baur, N., Hering, L., Raschke, A. L., & Thierbach, C. (2014). Theory and Methods in Spatial Analysis. Towards Integrating Qualitative, Quantitative and Cartographic Approaches in the Social Sciences and Humanities. *Historical Social Research, 39*(2), https://doi.org/10.12759/hsr.39.2014.2.7-50

Becker, M., Kirscht, J., Haefner, D., & Drachman, R. (1977). The health belief model and prediction of dietary compliance: A field experiment. *Journal of Health and Social Behavior*, *4*(18), 348–366. https://doi.org/10.2307/2955344

Betsch, T., Fiedler, K., & Brinkmann, J. (1998). Behavioral routines in decision making: The effects of novelty in task presentation and time pressure on routine maintenance and deviation. *European Journal of Social Psychology*, *28*(6), 861–878. https://doi.org/10.1002/(SICI)1099-0992(1998110)28:6<861::AID-EJSP899>3.0.CO;2-D

Bissonnette, L., Wilson, K., Bell, S., & Shah, T. I. (2012). Neighbourhoods and potential access to health care: The role of spatial and aspatial factors. *Health & Place*, *18*(4), 841–853. https://doi.org/10.1016/j.healthplace.2012.03.007

BMJ. (2021). *Consumption of sugar from soft drinks falls within a year of UK sugar tax | BMJ*. https://www.bmj.com/company/newsroom/consumption-of-sugar-from-soft-drinks-falls-within-a-year-of-uk-sugar-tax/

Boruchowicz, C., Lopez Boo, F., Pfeifer, F., Russo, G., & Pacheco, T. (2020). *Are Behaviorally Informed Text Messages Effective in Promoting Compliance with COVID-19 Preventive Measures?: Evidence from an RCT in the City of São Paulo*. Retrieved from https://publications.iadb.org/publications/english/document/Are-Behaviorally-Informed-Text-Messages-Effective-in-Promoting-Compliance-with-COVID-19-Preventive-Measures-Evidence-from-an-RCT-in-the-City-of-Sao-Paulo.pdf

Burns, C. M., & Inglis, A. D. (2007). Measuring food access in Melbourne: Access to healthy and fast foods by car, bus and foot in an urban municipality in Melbourne. *Health & Place*, *13*(4), 877–885. https://doi.org/10.1016/j.healthplace.2007.02.005

Canadian Institutes of Health Research. (2019). *Healthy Cities Research Initiative—CIHR*. Retrieved from https://cihr-irsc.gc.ca/e/51570.html

Castillo, E. G., Ijadi-Maghsoodi, R., Shadravan, S., Moore, E., Mensah, M. O., Docherty, M., Aguilera Nunez, M. G.,… & Wells, K. B. (2019). Community Interventions to Promote Mental Health and Social Equity. *Current Psychiatry Reports*, *21*(5), 35. https://doi.org/10.1007/s11920-019-1017-0

Comber, A. J., Brunsdon, C., & Radburn, R. (2011). A spatial analysis of variations in health access: Linking geography, socio-economic status and access perceptions. *International Journal of Health Geographics*, *10*(1), 44. https://doi.org/10.1186/1476-072X-10-44

Curtis, S., & Jones, I. R. (1998). Is There a Place for Geography in the Analysis of Health Inequality? *Sociology of Health & Illness*, *20*(5), 645–672. https://doi.org/10.1111/1467-9566.00123

Cutler, D. (2004). Behavioral Health Interventions: What Works and Why? In *Critical Perspectives in Racial and Ethnic Differences in Health and Late Life* (Anderson NB, Bulatao RA, Cohen B (Editors)). National Academies Press (US). https://www.ncbi.nlm.nih.gov/books/NBK25527/

Degroote, L., DeSmet, A., De Bourdeaudhuij, I., Van Dyck, D., & Crombez, G. (2020). Content validity and methodological considerations in ecological momentary assessment studies on physical activity and sedentary behaviour: A systematic review. *International Journal of Behavioral Nutrition and Physical Activity*, *17*(1), 35. https://doi.org/10.1186/s12966-020-00932-9

Dohle, S., Diel, K., & Hofmann, W. (2018). Executive functions and the self-regulation of eating behavior: A review. *Appetite*, *124*, 4–9. https://doi.org/10.1016/j.appet.2017.05.041

Dummer, T. J. B. (2008). Health geography: Supporting public health policy and planning. *Canadian Medical Association Journal*, *178*(9), 1177–1180. https://doi.org/10.1503/cmaj.071783

Dunn, J. R., & Hayes, M. V. (1999). Toward a Lexicon of Population Health. *Canadian Journal of Public Health, 90*(1), S7–S10. https://doi.org/10.1007/BF03403570

Dunton, G. F., Kawabata, K., Intille, S., Wolch, J., & Pentz, M. A. (2012). Assessing the Social and Physical Contexts of Children's Leisure-Time Physical Activity: An Ecological Momentary Assessment Study. *American Journal of Health Promotion*, *26*(3), 135–142. https://doi.org/10.4278/ajhp.100211-QUAN-43

Dunton, G. F. (2017). Ecological Momentary Assessment in Physical Activity Research. *Exercise and Sport Sciences Reviews*, *45*(1), 48-54. https://doi.org/10.1249/JES.0000000000000092

Edwards, N. (1999). Population Health: Determinants and Interventions. *Canadian Journal of Public Health*, *90*(1), 10–12. https://doi.org/10.1007/BF03404090

Elia, F., Calzavarini, F., Bianco, P., Vecchietti, R. G., Macor, A. F., D'Orazio, A., Dragonetti, A., D'Alfonso, A., Belletrutti, L., Floris, M., Bert, F., Crupi, V., & Aprà, F. (2022). A nudge intervention to improve hand hygiene compliance in the hospital. *Internal and Emergency Medicine*. https://doi.org/10.1007/s11739-022-03024-7

Elias, R. R., Jutte, D. P., & Moore, A. (2019). Exploring consensus across sectors for measuring the social determinants of health. *SSM - Population Health*, *7*, 100395. https://doi.org/10.1016/j.ssmph.2019.100395

Emrich, T., Qi, Y., Lou, W., & L'Abbe, M. (2017). Traffic-light labels could reduce population intakes of calories, total fat, saturated fat, and sodium. *PLOS One*, *12*(2), e0171188. https://doi.org/doi:10.1371/journal.pone.0171188

Evans, R., & Stoddart, G. (1990). Producing Health, Consuming Health Care. *Social Science & Medicine*, *31*(12), 1347–1363. https://doi.org/10.1016/0277-9536(90)90074-3

Farquhar, J., Fortmann, S., Maccoby, N., Haskell, W., Williams, P., Flora, J., Taylor, B., … & Hulley, S. (1985). The Stanford Five-City Project: Design and Methods. *American Journal of Epidemiology*, *122*(2), 323–334. https://doi.org/10.1093/oxfordjournals.aje.a114104

Farquhar, J. W., Fortmann, S., Flora, J., Taylor, B., Haskell, W., Willams, P., Maccoby, N., & Wood, P. (1990). Effects of communitywide education on cardiovascular disease risk factors. The Stanford Five-City Project. *JAMA: The Journal of the American Medical Association*, *264*(3), 359–365. https://doi.org/10.1001/jama.264.3.359

Friedman, D. J., & Starfield, B. (2003). Models of Population Health: Their Value for US Public Health Practice, Policy, and Research. *American Journal of Public Health*, *93*(3), 366–369.

Friedman, N. P., & Miyake, A. (2017). Unity and Diversity of Executive Functions: Individual Differences as a Window on Cognitive Structure. *Cortex*, *86*, 186–204. https://doi.org/10.1016/j.cortex.2016.04.023

Friis, R., Skov, L. R., Olsen, A., Appleton, K. M., Saulais, L., Dinnella, C., Hartwell, H., Depezay, L., Monteleone, E., Giboreau, A., & Perez-Cueto, F. J. A. (2017). Comparison of three nudge interventions (priming, default option, and perceived variety) to promote vegetable consumption in a self-service buffet setting. *PLOS ONE*, *12*(5), e0176028. https://doi.org/10.1371/journal.pone.0176028

Gao, Z., & Lee, J. E. (2019). Emerging Technology in Promoting Physical Activity and Health: Challenges and Opportunities. *Journal of Clinical Medicine*, *8*(11), 1830. https://doi.org/10.3390/jcm8111830

Gold, N., Yau, A., Rigby, B., Dyke, C., Remfry, E. A., & Chadborn, T. (2021). Effectiveness of Digital Interventions for Reducing Behavioral Risks of Cardiovascular Disease in Nonclinical Adult Populations: Systematic Review of Reviews. *Journal of Medical Internet Research*, *23*(5), e19688. https://doi.org/10.2196/19688

Gotto, A. M., Jr. (1997). The Multiple Risk Factor Intervention Trial (MRFIT): A Return to a Landmark Trial. *JAMA*, *277*(7), 595–597. https://doi.org/10.1001/jama.1997.03540310093041

Government of United Kingdom. (2018). *Sugar tax revenue helps tackle childhood obesity*. Government of United Kingdom. Retrieved from https://www.gov.uk/government/news/sugar-tax-revenue-helps-tackle-childhood-obesity

Graham, H., Prue-Owens, K., Kirby, J., & Ramesh, M. (2020). Systematic Review of Interventions Designed to Maintain or Increase Physical Activity Post-Cardiac Rehabilitation Phase II. *Rehabilitation Process and Outcome*, *9*, 1179572720941833. https://doi.org/10.1177/1179572720941833

Hagerstrand, T. (1970). *What about people in regional science? 24*(1), 7–24.

Hallsworth, M., Berry, D., Sanders, M., Sallis, A., King, D., Vlaev, I., & Darzi, A. (2015). Stating Appointment Costs in SMS Reminders Reduces Missed Hospital Appointments: Findings from Two Randomised Controlled Trials. *PLOS ONE*, *10*(9), e0137306. https://doi.org/10.1371/journal.pone.0137306

Hallsworth, M., Snijders, V., Burd, H., Prestt, J., Judah, G., Huf, S., & Halpern, D. (2016). *Applying Behavioral Insights: Simple ways to improve health outcomes* (pp. 1–48) [World Innovation Summit for Health]. https://www.bi.team/wp-content/uploads/2016/11/WISH-2016_Behavioral_Insights_Report.pdf

Halpern, S. D., Ubel, P. A., & Asch, D. A. (2007). Harnessing the Power of Default Options to Improve Health Care. *New England Journal of Medicine*, *357*(13), 1340–1344. https://doi.org/10.1056/NEJMsb071595

Hare, A. J., Patel, M. S., Volpp, K., & Adusumalli, S. (2021). The Role of Behavioral Economics in Improving Cardiovascular Health Behaviors and Outcomes. *Current Cardiology Reports*, *23*(11), 153. https://doi.org/10.1007/s11886-021-01584-2

Hinrichs, T., Zanda, A., Fillekes, M. P., Bereuter, P., Portegijs, E., Rantanen, T., Schmidt-Trucksäss, A., Zeller, A. W., & Weibel, R. (2020). Map-based assessment of older adults' life space: Validity and reliability. *European Review of Aging and Physical Activity*, *17*(1), 21. https://doi.org/10.1186/s11556-020-00253-7

Hong, P., Chen, K., Chang, Y., Cheng, S., & Chiang, H. (2021). Effectiveness of Theory-Based Health Information Technology Interventions on Coronary Artery Disease Self-Management Behavior: A Clinical Randomized Waitlist-Controlled Trial. *Journal of Nursing Scholarship*, *53*(4), 418–427. https://doi.org/10.1111/jnu.12661

Hughes, J., Lysikowski, J., Acharya, R., Phelps, E., & Kandil, E. (2020). A Multi-year Analysis of Decision Fatigue in Opioid Prescribing. *Journal of General Internal Medicine*, *35*(4), 1337–1339. https://doi.org/10.1007/s11606-019-05217-x

Hyseni, L., Elliot-Green, A., Lloyd-Williams, F., Kypridemos, C., O'Flaherty, M., McGill, R., Orton, L., … & Capewell, S. (2017). Systematic review of dietary salt reduction policies: Evidence for an effectiveness hierarchy? *PLoS ONE*, *12*(5), e0177535. https://doi.org/10.1371/journal.pone.0177535

Inglis, S. C., Clark, R. A., McAlister, F. A., Ball, J., Lewinter, C., Cullington, D., Stewart, S., & Cleland, J. G. (2010). Structured telephone support or telemonitoring programmes for patients with chronic heart failure. *Cochrane Database of Systematic Reviews*, *CD007228*(8). https://doi.org/doi:10.1002/14651858.CD007228.pub2.

Janz, N. K., & Becker, M. H. (1984). The Health Belief Model: A Decade Later. *Health Education Quarterly*, *11*(1), 1–47. https://doi.org/10.1177/109019818401100101

Kahneman, D., & Tversky, A. (1984). Choices, values, and frames. *American Psychologist*, *39*(4), 341–350.

Kindig, D., & Stoddart, G. (2003). What Is Population Health? *American Journal of Public Health*, *93*(3), 380–383.

King, D., Vlaev, I., Everett-Thomas, R., Fitzpatrick, M., Darzi, A., & Birnbach, D. J. (2016). "Priming" hand hygiene compliance in clinical environments. *Health Psychology*, *35*(1), 96–101. https://doi.org/10.1037/hea0000239

Kjelsberg, M., Cutler, J., & Dolecek, T. (1997). Brief description of the multiple risk factor intervention trial. *American Journal of Clinical Nutrition*, *65*(1), 191–195. https://doi.1093/ajcn/65.1.191S

Knigge, L., & Cope, M. (2006). Grounded Visualization: Integrating the Analysis of Qualitative and Quantitative Data through Grounded Theory and Visualization. *Environment and Planning A: Economy and Space*, *38*(11), 2021–2037. https://doi.org/10.1068/a37327

Krawiec, J. M., Piaskowska, O. M., Piesiewicz, P. F., & Białaszek, W. (2021). Tools for public health policy: Nudges and boosts as active support of the law in special situations such as the COVID-19 pandemic. *Globalization and Health*, *17*(1), 132. https://doi.org/10.1186/s12992-021-00782-5

Krewski, D., Hogan, V., Turner, M. C., Zeman, P. L., McDowell, I., Edwards, N., & Losos, J. (2007). An Integrated Framework for Risk Management and Population Health. *Human and Ecological Risk Assessment: An International Journal*, *13*(6), 1288–1312. https://doi.org/10.1080/10807030701655798

Kulldorff, M., Feuer, E. J., Miller, B. A., & Freedma, L. S. (1997). Breast Cancer Clusters in the Northeast United States: A Geographic Analysis. *American Journal of Epidemiology*, *146*(2), 161–170. https://doi.org/10.1093/oxfordjournals.aje.a009247

Kwan, M., & Ren, F. (2008). Analysis of human space-time behavior: Geovisualization and geocomputational approaches. In *Understanding Dynamics of Geographic Domains* (In Hornsby, K.S., Yuan, M. (Eds.), pp. 93–113). CRC Press.

Laatikainen, T., Nissinen, A., Kastarinen, M., Jula, A., & Tuomilehto, J. (2016). Blood Pressure, Sodium Intake, and Hypertension Control: Lessons from the North Karelia Project. *Global Heart*, *11*(2), 191–199. https://doi.org/10.1016/j.gheart.2016.04.011

Laxer, R. E., & Janssen, I. (2014). The proportion of excessive fast-food consumption attributable to the neighbourhood food environment among youth living within 1 km of their school. *Applied Physiology, Nutrition, and Metabolism*, *39*(4), 480–486. https://doi.org/10.1139/apnm-2013-0208

Luong, M.-L. N., Hall, M., Bennell, K. L., Kasza, J., Harris, A., & Hinman, R. S. (2021). The Impact of Financial Incentives on Physical Activity: A Systematic Review and Meta-Analysis. *American Journal of Health Promotion: AJHP*, *35*(2), 236–249. https://doi.org/10.1177/0890117120940133

Lv, J., Liu, Q.-M., Ren, Y.-J., He, P.-P., Wang, S.-F., Gao, F., Li, L.-M., & on behalf of the Community Interventions for Health (CIH) collaboration. (2014). A community-based multilevel intervention for smoking, physical activity and diet: Short-term findings from the Community Interventions for Health programme in Hangzhou, China. *Journal of Epidemiology and Community Health*, *68*(4), 333–339. https://doi.org/10.1136/jech-2013-203356

Macintyre, S., Ellaway, A., & Cummins, S. (2002). Place effects on health: How can we conceptualise, operationalise and measure them? *Social Science & Medicine*, *55*(1), 125–139. https://doi.org/10.1016/S0277-9536(01)00214-3

MacNell, L. (2018). A geo-ethnographic analysis of low-income rural and urban women's food shopping behaviors. *Appetite*, *128*, 311–320. https://doi.org/10.1016/j.appet.2018.05.147

Marteau, T. M., Hollands, G. J., & Fletcher, P. C. (2012). Changing Human Behavior to Prevent Disease: The Importance of Targeting Automatic Processes. *Science*, *337*(6101), 1492–1495. https://doi.org/10.1126/science.1226918

Matthews, S. A., Detwiler, J. E., & Burton, L. M. (2005). Geo-ethnography: Coupling Geographic Information Analysis Techniques with Ethnographic Methods in Urban Research. *Cartographica: The International Journal for Geographic Information and Geovisualization*, *40*(4), 75–90. https://doi.org/10.3138/2288-1450-W061-R664

McDowell, I., Spasoff, R. A., & Kristjansson, B. (2004). On the Classification of Population Health Measurements. *American Journal of Public Health*, *94*(3), 388–393.

McQuoid, J., Jowsey, T., & Talaulikar, G. (2017). Contextualising renal patient routines: Everyday space-time contexts, health service access, and wellbeing. *Social Science & Medicine*, *183*, 142–150. https://doi.org/10.1016/j.socscimed.2017.04.043

Michie, S., van Stralen, M. M., & West, R. (2011). The behaviour change wheel: A new method for characterising and designing behaviour change interventions. *Implementation Science*, *6*(42), 1–11. https://doi.org/10.1186/1748-5908-6-42

Milton, S., Pliakas, T., Hawkesworth, S., Nanchahal, K., Grundy, C., Amuzu, A., Casas, J.P., & Lock, K. (2015). A qualitative geographical information systems approach to explore how older people over 70 years interact with and define their neighbourhood environment. *Health & Place*, *36*, 127–133. https://doi.org/10.1016/j.healthplace.2015.10.002

Mitchell, M. S., Orstad, S. L., Biswas, A., Oh, P. I., Jay, M., Pakosh, M. T., & Faulkner, G. (2020). Financial incentives for physical activity in adults: Systematic review and meta-analysis. *British Journal of Sports Medicine*, *54*(21), 1259–1268. https://doi.org/10.1136/bjsports-2019-100633

Mohebbi, B., Sabouri, M., & Tol, A. (2021). Application of health education and promotion theory-based interventions on patients with cardiovascular disease: A systematic review. *Journal of Education and Health Promotion*, *10*(236), 14. https://doi.10.4103/jehp.jehp_173_21

Ndejjo, R., Hassen, H. Y., Wanyenze, R. K., Musoke, D., Nuwaha, F., Abrams, S., Bastiaens, H., & Musinguzi, G. (2021). Community-Based Interventions for Cardiovascular Disease Prevention in Low-and Middle-Income Countries: A Systematic Review. *Public Health Reviews*, *42*, 1604018. https://doi.org/10.3389/phrs.2021.1604018

Patel, M. S., Small, D. S., Harrison, J. D., Fortunato, M. P., Oon, A. L., Rareshide, C. A. L., Reh, G., Szwartz, G., Guszcza, J., Steier, D., Kalra, P., & Hilbert, V. (2019). Effectiveness of Behaviorally Designed Gamification Interventions With Social Incentives for Increasing Physical Activity Among Overweight and Obese Adults Across the United States. *JAMA Internal Medicine*, *179*(12), 1624–1632. https://doi.org/10.1001/jamainternmed.2019.3505

Patel, M. S., Volpp, K. G., Rosin, R., Bellamy, S. L., Small, D. S., Fletcher, M. A., Osman-Koss, R., Brady, J. L., Haff, N., Lee, S. M., Wesby, L., Hoffer, K., Shuttleworth, D., Taylor, D. H., Hilbert, V., Zhu, J., Yang, L., Wang, X., & Asch, D. A. (2016). A Randomized Trial of Social Comparison Feedback and Financial Incentives to Increase Physical Activity. *American Journal of Health Promotion : AJHP*, *30*(6), 416–424. https://doi.org/10.1177/0890117116658195

Pearson, T. A. (2011). Public Policy Approaches to the Prevention of Heart Disease and Stroke. *Circulation*, *124*(23), 2560–2571. https://doi.org/10.1161/CIRCULATIONAHA.110.968743

Pell, D., Mytton, O., Penney, T. L., Briggs, A., Cummins, S., Penn-Jones, C., Rayner, M., Rutter, H., Scarborough, P., Sharp, S. J., Smith, R. D., White, M., & Adams, J. (2021). Changes in soft drinks purchased by British households associated with the UK soft drinks industry levy: Controlled interrupted time series analysis. *BMJ*, *372*, n254. https://doi.org/10.1136/bmj.n254

Prevent Epidemics. (2021). *Promoting mask-wearing during the COVID-19 pandemic: A policymaker's guide* (pp. 1–18). https://preventepidemics.org/wp-content/uploads/2020/08/Promoting-Mask-Wearing-During-COVID-19.pdf

Public Health Agency of Canada. (2001). *Social determinants of health and health inequalities* [Policies]. https://www.canada.ca/en/public-health/services/health-promotion/population-health/what-determines-health.html

Puska, P., & Jaini, P. (2020). The North Karelia Project: Prevention of Cardiovascular Disease in Finland Through Population-Based Lifestyle Interventions. *American Journal of Lifestyle Medicine*, *14*(5), 495–499. https://doi.org/10.1177/1559827620910981

Rantanen, H., & Kahila, M. (2009). The SoftGIS approach to local knowledge. *Journal of Environmental Management*, *90*(6), 1981–1990. https://doi.org/10.1016/j.jenvman.2007.08.025

Rosenstock, I. M., Strecher, V. J., & Becker, M. H. (1988). Social Learning Theory and the Health Belief Model. *Health Education Quarterly*, *15*(2), 175–183. https://doi.org/10.1177/109019818801500203

Room, J., Hannink, E., Dawes, H., & Barker, K. (2017). What interventions are used to improve exercise adherence in older people and what behavioural techniques are they based on? A systematic review. *BMJ Open*, *7*(12), e019221. https://doi.org/10.1136/bmjopen-2017-019221

Roth, G. A., Mensah, G. A., Johnson, C. O., Addolorato, G., Ammirati, E., Baddour, L. M., Barengo, N. C., … & Fuster, V. (2020). Global Burden of Cardiovascular Diseases and Risk Factors, 1990–2019. *Journal of the American College of Cardiology*, *76*(25), 2982–3021. https://doi.org/10.1016/j.jacc.2020.11.010

Santo, K., & Redfern, J. (2020). Digital Health Innovations to Improve Cardiovascular Disease Care. *Current Atherosclerosis Reports*, *22*(12), 71. https://doi.org/10.1007/s11883-020-00889-x

Santos, J. A., Tekle, D., Rosewarne, E., Flexner, N., Cobb, L., Al-Jawaldeh, A., Kim, W. J., Breda, J., Whiting, S., Campbell, N., Neal, B., Webster, J., & Trieu, K. (2021). A Systematic Review of Salt Reduction Initiatives Around the World: A Midterm Evaluation of Progress Towards the 2025 Global Non-Communicable Diseases Salt Reduction Target. *Advances in Nutrition*, *12*(5), 1768–1780. https://doi.org/10.1093/advances/nmab008

Satcher, D. (2010). Include a Social Determinants of Health Approach to Reduce Health Inequities. *Public Health Reports*, *125*(Suppl 4), 6–7.

Seguin, M. L., Rangnekar, A., Renedo, A., Palafox, B., McKee, M., & Balabanova, D. (2020). Systematic review of frameworks used to conceptualise health pathways of individuals diagnosed with cardiovascular diseases. *BMJ Global Health*, *5*(9), e002464. https://doi.org/10.1136/bmjgh-2020-002464

Shashank, A., & Schuurman, N. (2019). Unpacking walkability indices and their inherent assumptions. *Health & Place*, *55*, 145–154. https://doi.org/10.1016/j.healthplace.2018.12.005

Silva, J. P., Gunathunga, M. W., & Jayasinghe, S. (2016). Mapping Unhealthy Behavior Among Economically Active Men Using GIS in Suburban and Rural Areas of Sri Lanka. *Asia-Pacific Journal of Public Health / Asia-Pacific Academic Consortium for Public Health*, *28*(1 Suppl), 10S-16S. https://doi.org/10.1177/1010539515611723

Solaki, A., Berto, F., & Smets, S. (2021). The Logic of Fast and Slow Thinking. *Erkenntnis*, *86*(3), 733–762. https://doi.org/10.1007/s10670-019-00128-z

Sonnenberg, L., Gelsomin, E., Levy, D. E., Riis, J., Barraclough, S., & Thorndike, A. N. (2013). A traffic light food labeling intervention increases consumer awareness of health and healthy choices at the point-of-purchase. *Preventive Medicine*, *57*(4), 253–257. https://doi.org/10.1016/j.ypmed.2013.07.001

Stafford, M., Cummins, S., Ellaway, A., Sacker, A., Wiggins, R. D., & Macintyre, S. (2007). Pathways to obesity: Identifying local, modifiable determinants of physical activity and diet. *Social Science & Medicine*, *65*(9), 1882–1897. https://doi.org/10.1016/j.socscimed.2007.05.042

Stanovich, K. E. (2012). Environments for fast and slow thinking. *Trends in Cognitive Sciences*, *16*(4), 198–199. https://doi.org/10.1016/j.tics.2012.01.009

Statistics Canada. (2022). *Time Use Survey*. Retrieved from https://www23.statcan.gc.ca/imdb/p2SV.pl?Function=getSurvey&SDDS=4503

Strazdins, L., Welsh, J., Korda, R., Broom, D., & Paolucci, F. (2016). Not all hours are equal: Could time be a social determinant of health? *Sociology of Health & Illness*, *38*(1), 21–42. https://doi.org/10.1111/1467-9566.12300

Stone, A. A., & Shiffman, S. (1994). Ecological Momentary Assessment (EMA) in Behavioral Medicine. *Annals of Behavioral Medicine*, *16*(3), 199–202. https://doi.org/10.1093/abm/16.3.199

Tamura, K., Wilson, J. S., Goldfeld, K., Puett, R. C., Klenosky, D. B., Harper, W. A., & Troped, P. J. (2019). Accelerometer and GPS Data to Analyze Built Environments and Physical Activity. *Research Quarterly for Exercise and Sport*, *90*(3), 395–402. https://doi.org/10.1080/02701367.2019.1609649

Thaler, R. H., & Sunstein, C. R. (2003). Libertarian Paternalism. *The American Economic Review*, *93*(2), 175–179. https://www.jstor.org/stable/3132220

Tudor-Locke, C., Johnson, W. D., & Katzmarzyk, P. T. (2010). Frequently Reported Activities by Intensity for U.S. Adults: The American Time Use Survey. *American Journal of Preventive Medicine*, *39*(4), e13–e20. https://doi.org/10.1016/j.amepre.2010.05.017

Tuomilehto, J., Puska, P., Tanskanen, A., Karppanen, H., Pietinen, P., Nissinen, A., Enlund, H., & Ruotsalainen, P. (1981). A community-based intervention study on the feasibility and effects of the reduction of salt intake in North Karelia, Finland. *Acta Cardiologica*, *36*(2), 83–104.

Tversky, A., & Kahneman, D. (1974). Judgment under uncertainty: Heuristics and biases. *Science*, *185*(4157), 1124–1131.

Vande Velde, F., Overgaard, H., & Bastien, S. (2021). Nudge strategies for behavior-based prevention and control of neglected tropical diseases: A scoping review and ethical assessment. *PLOS Neglected Tropical Diseases*, *15*(11), 27. https://doi.org/10.1371/journal.pntd.0009239

Vartiainen, E. (2018). The North Karelia Project: Cardiovascular disease prevention in Finland. *Global Cardiology Science & Practice*, *2*(13), 1–9. https://doi.org/10.21542/gcsp.2018.13

Waddell, K. J., Shah, P. D., Adusumalli, S., & Patel, M. S. (2020). Using Behavioral Economics and Technology to Improve Outcomes in Cardio-Oncology. *JACC: CardioOncology*, *2*(1), 84–96. https://doi.org/10.1016/j.jaccao.2020.02.006

Wang, H., Naghavi, M., Allen, C., Barber, R. M., Bhutta, Z. A., Carter, A., Casey, D. C., … & Murray, C. J. L. (2016). Global, regional, and national life expectancy, all-cause mortality, and cause-specific mortality for 249 causes of death, 1980–2015: A systematic analysis for the Global Burden of Disease Study 2015. *The Lancet*, *388*(10053), 1459–1544. https://doi.org/10.1016/S0140-6736(16)31012-1

Wilkinson, R. G., & Marmot, M. G. (2003). *Social determinants of health: The solid facts (pp. 1–33).* World Health Organization. Retrieved from https://www.euro.who.int/__data/assets/pdf_file/0005/98438/e81384.pdf

Willmott, T. J., Pang, B., & Rundle-Thiele, S. (2021). Capability, opportunity, and motivation: An across contexts empirical examination of the COM-B model. *BMC Public Health*, *21*(1), 1014. https://doi.org/10.1186/s12889-021-11019-w

Winter, S. J., Sheats, J. L., & King, A. C. (2016). The Use of Behavior Change Techniques and Theory in Technologies for Cardiovascular Disease Prevention and Treatment in Adults: A Comprehensive Review. *Progress in Cardiovascular Diseases*, *58*(6), 605–612. https://doi.org/10.1016/j.pcad.2016.02.005

Wongvibulsin, S., Martin, S. S., Steinhubl, S. R., & Muse, E. D. (2019). Connected Health Technology for Cardiovascular Disease Prevention and Management. *Current Treatment Options in Cardiovascular Medicine*, *21*(6), 29. https://doi.org/10.1007/s11936-019-0729-0

World Health Organization. (2015). *Cardiovascular diseases: Avoiding heart attacks and strokes*. https://www.who.int/news-room/questions-and-answers/item/cardiovascular-diseases-avoiding-heart-attacks-and-strokes

World Health Organization. (2020). *The top 10 causes of death*. WHO Newsroom Report. https://www.who.int/news-room/fact-sheets/detail/the-top-10-causes-of-death#:~:text=The%20world's%20biggest%20killer%20is,8.9%20million%20deaths%20in%202019.

World Health Organization. (2021). *Cardiovascular diseases (CVDs)*. https://www.who.int/news-room/fact-sheets/detail/cardiovascular-diseases-(cvds)

Yousuf, H., Reintjens, R., Slipszenko, E., Blok, S., Somsen, G. A., Tulevski, I. I., & Hofstra, L. (2019). Effectiveness of web-based personalised e-Coaching lifestyle interventions. *Netherlands Heart Journal*, *27*(1), 24–29. https://doi.org/10.1007/s12471-018-1200-7

Zhang, X., Zhou, S., Kwan, M.-P., Su, L., & Lu, J. (2020). Geographic Ecological Momentary Assessment (GEMA) of environmental noise annoyance: The influence of activity context and the daily acoustic environment. *International Journal of Health Geographics*, *19*(1), 50. https://doi.org/10.1186/s12942-020-00246-w

CHAPTER 2

REORIENTING INTERVENTIONS TOWARDS UPSTREAM PREVENTION OF CHRONIC DISEASE

The work in Chapter 2 has been submitted for publication and is currently under review. Barber, Brittany., Kephart, George., Martin-Misener, Ruth., Vallis, Michael., & Rainham, Daniel. Reorinting Interventions Towards Upstream Prevention of Chronic Disease. *Journal of Prevention and Health Promotion.* Revisions Requested November 26th, 2022.

- Behavioral interventions are challenged by lack of information about the contexts influencing where, when, and how health activities occur and common automatic decisions patients make as part of their daily routine
- Health geography and behavioral economics provide insights for strengthening interventions
- Context specific intervention strategies require information about four dimensions of health behaviors including space, place, time, and ecological contexts

2.0 Abstract

The long-term economic viability of modern health care systems is uncertain, in part due to costs of health care at the end of life and increasing health care utilization associated with an increasing population prevalence of multiple chronic diseases. Control of health care spending and sustaining delivery of health care services will require strategic investments in prevention to reduce risk of disease and its complications over an individual's life course. Evidence indicates the majority of chronic disease burden could be prevented through early intervention and behavior change targeting high-risk factors such as physical inactivity, unhealthy diets, obesity, high blood pressure, smoking, high cholesterol, and harmful use of alcohol. Behavioral interventions are one approach that have proven effective at reducing risk and preventing chronic disease; however, large-scale efforts to reduce population level chronic disease are challenging and have not been very successful at reducing the burden of chronic diseases. A new approach is required to identify how, when, and where to intervene to disrupt patterns of behavior associated with high-risk factors using context specific intervention strategies that can be scaled.

This paper introduces the need to integrate the theoretical and methodological principles of health geography and behavioral economics as opportunities to advance interventions for prevention of chronic disease. It discusses how behavioral interventions for chronic disease can be strengthened by characterizing environments where patterns of health behavior occur and contexts that influence how day-to-day decisions are made.

2.1 Introduction

The doctor will see you now. An anecdotal example of a typical health care appointment could involve Patient A, who is 53 years old and diagnosed with hypertension. Since their diagnosis, Patient A has had regular appointments to monitor blood pressure, medication, and is continually reminded that lifestyle changes are equally important for treatment, self-management, and prevention of disease progression. The provider has made recommendations for Patient A to exercise regularly, maintain a healthier body weight, and eat foods low in sodium, fat, and sugar. Patient A does not fully understand how much they have to change their lifestyle and has expressed they struggle with changing their daily routine to fit in time for regular exercise and cut back on the amount of fast food they eat. The provider is aware Patient A is a single parent and works fulltime but does not have enough time during the appointment to gather more information for providing behavioral counselling. At the end of the appointment the provider recommends the patient keep track of their blood pressure so they can review the information during their next appointment.

This generalized observation of a typical patient and provider interaction is an example of how health care services traditionally operate. Often there is little opportunity to assess the social, physical, and environmental factors influencing patients' day-to-day activities, many of which contribute to health outcomes such as chronic disease. How would this typical health care interaction change if providers were to integrate critical details of where a patient lives and how they spend their time, including what they do for a living, activities they frequently engage in, and factors influencing day-to-day decisions about engaging in different health activities? By visualizing key spatiotemporal contexts about a patient's day-to-day routine, insight can be gained about a patient's activity space, use of time, and factors influencing how they make decisions about their activities that can impact health outcomes. Knowing that Patient A does not have stable means of transportation and limited access to fresh food options close to home is critical for understanding patterns in the day-to-day decisions they make, the resources they have and constraints they experience. Having information about activity space, use of time, and factors influencing decision-making is critical for both patients and providers. Patients may not fully understand how to adjust their routine behaviors that have become automatic over time, and providers may not be unaware of how to adjust delivery of care to encourage appropriate behavior change strategies based on patient capability and opportunity. The aim of this paper is to examine the potential for improving the efficacy of behavioral interventions for prevention of chronic disease and population-wide compression of morbidity. We make the case there are key questions that should be asked of patients to gather critical information about day-to-day routine activities for the purpose of tailoring strategies to improve behavioral interventions.

A person's day-to-day routine is a major determinant of patterns in health behaviors that influence health outcomes over time. Forming stable everyday routines is important for structuring daily tasks and responsibilities, achieving activities for physical functioning like eating and sleeping, and maintaining habits for health and wellbeing like exercising or taking medication (McQuoid, Jowsey & Talaulikar, 2017; Wagner & Ryan, 2004; Zisberg et al., 2007). A stable routine can be supportive for maintaining habits that improve health status (e.g., daily exercise, healthy diet), and detrimental when trying to break from a routine with well-established habits that pose a risk for disease (e.g., smoking, excessive alcohol) (Ersche et al., 2017). Although habits that form everyday routines often become automatic (Nilsen et al., 2012), there are important contextual factors influencing how and why patterns of behavior develop (Von Korff et al., 1992), such as the characteristics of where people live, work, and play.

2.1.1 Health Geography

Regardless of stage in life, a person's social, physical, and cultural experiences will occur in specific contexts (or places) that are associated with health and health-related behaviors. Spatiotemporal contexts include day-to-day behaviors across space, temporal patterns in behaviors, and connections to place that influence where, why, and with who activities occur (Kwan & Ren, 2008). These unique contexts are described as an individual's "activity space" or their totality of activities and interactions with people and places over time (McQuoid, Jowsey & Talaulikar, 2017). Visualizing activity space is important for identifying barriers and facilitators that influence how well an individual can manage their health and adapt day-to-day routines (McQuoid, Jowsey & Talaulikar, 2017). Identifying a patient's activity space within their day-to-day routine is also critical

for providing direct feedback to patients about why certain habits have formed either knowingly or not, while also equipping care providers and patients with information to identify when and where to effectively disrupt their routine to encourage health improving activities.

2.1.2 Prevention of Chronic Disease

Prioritizing strategies for prevention is important given chronic diseases remain a leading cause of death, years of healthy life lost (Nyberg et al., 2020), and challenges the sustainability of health care systems internationally (World Health Organization, 2021). Approximately 1 in 2 adults can expect to experience cardiovascular disease, cancer, chronic respiratory diseases, or type 2 diabetes in their lifetime (World Health Organization, 2021). Evidence indicates a majority of chronic diseases are largely preventable through early intervention and upstream prevention targeting behavior change of high-risk factors like physical inactivity, sedentary behavior, smoking, excess alcohol consumption, and obesity (Public Health Agency of Canada, 2015; World Health Organization, 2021). Upstream prevention refers to targeting underlying causes of health problems (Rose, 1992) by modifying behaviors linked to development of risk factors and enhance health promoting behaviors that reduce likelihood of illness onset (Homer, Hirsch, & Milstein, 2007). Modest behavior change has proven effective at reducing risk factors and preventing chronic diseases; yet large-scale efforts to reduce population level chronic disease are challenging (Kaplan, 2009) and have not been very successful at reducing the burden of chronic diseases over time (Kelly & Barker, 2016; World Health Organization, 2020a). Behavioral interventions continue to be challenged with shifting the curve of population health by isolating individual level behaviors rather than

integrating the contexts in which behaviors occur so that interventions can be scaled to influence population wide change (Hagger & Weed, 2019). A new approach is required to strengthen behavioral interventions by integrating information about environmental contexts where routine health behaviors occur with strategies that can be scaled across populations to influence how individuals make decisions about improving their health behaviors.

2.1.3 Behavior Change

Several behavior science theories explain why individuals engage or refrain from certain behaviors. Foundational models like the Health Belief Model explain that behaviors are the desire to avoid illness and the belief that taking action can prevent illness (Becker et al., 1977). Further, subsequent theories like the Social Cognitive theory explain that factors within social environments shape thought processes, motivation, and behavioral outcomes (Bandura, 1999). To account for multi-level contextual (i.e., social and environmental) and individual determinants of behavior, a comprehensive framework known as the Behavior Change Wheel (BCW) was developed to aid in understanding behaviors and improve intervention strategies (Michie, van Stralen & West, 2011). Foundational frameworks like the BCW (Michie, van Stralen & West, 2011) and Theoretical Domains Framework (TDF) (Atkins et al., 2017) recognize health behaviors are complex and include numerous internal and external influencing factors, and targets for implementing interventions (Michie, Atkins & West, 2014). Behavior change frameworks are widely applied in the context of health to inform clinical practice guidelines and enhance risk reduction for prevention of chronic disease, including interventions targeting physical activity (PA) (Orrow et al., 2012; Zelko et al., 2018),

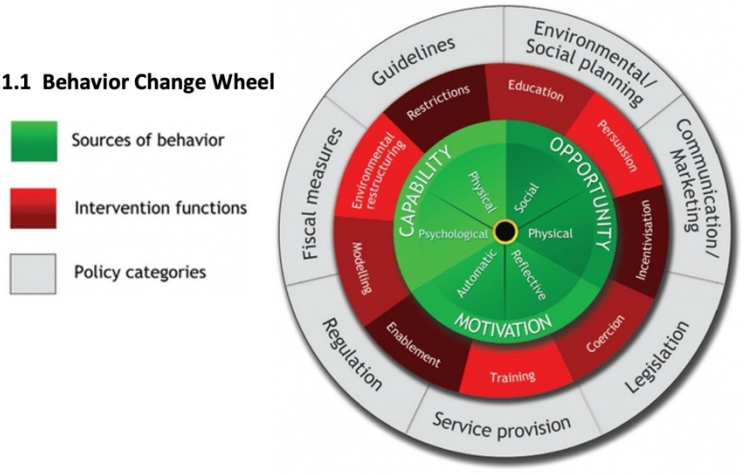
eating behaviors (Abbate et al., 2020), and smoking cessation (Odorico et al., 2019). Frameworks like the BCW are predominately applied to emphasize individual motivation, capability, and cognitive restraint for behavior change (Jacob et al., 2018; Room et al., 2017; Winter, Sheats & King, 2016), yet we know individuals commonly default to fast thinking processes when making routine day-to-day decisions about their activities (Betsch, Fiedler & Brinkmann, 1998; Marteau, Hollands & Fletcher, 2012). Tailoring interventions to the contexts of when and where individuals commonly default to automatic decision-making processes is critical for disrupting routine behaviors and improving the effectiveness of behavioral interventions.

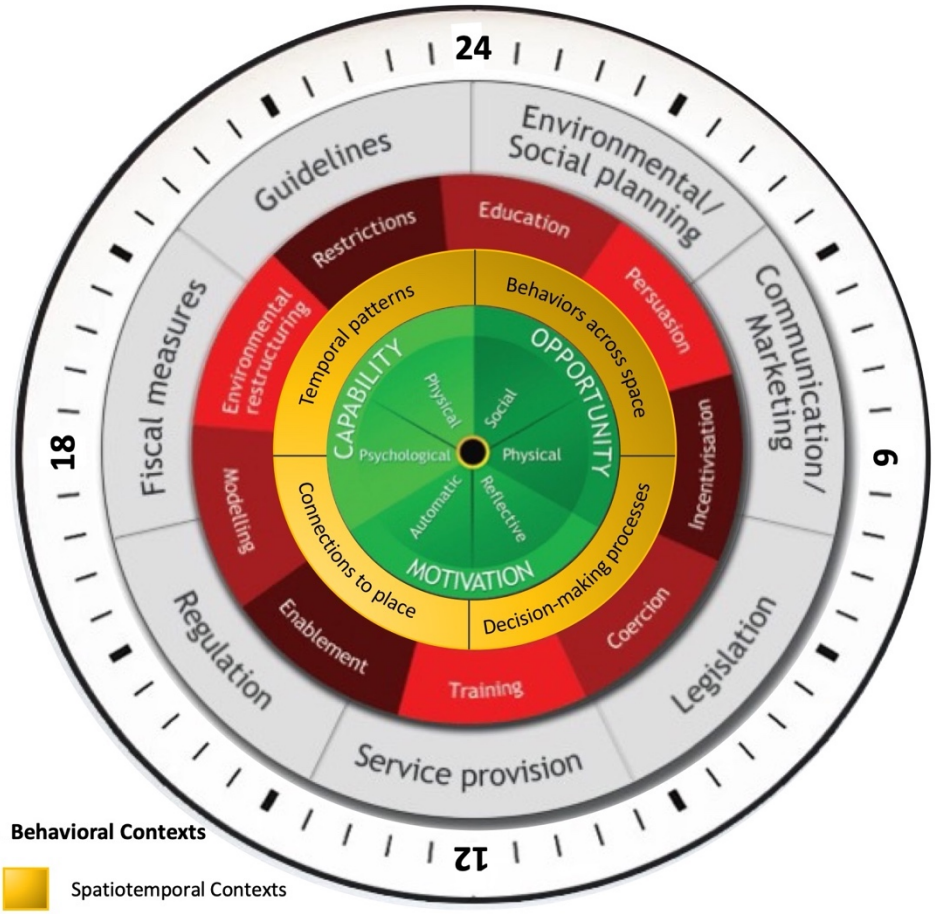
Combining ideas from health geography and behavioral economics, there lies an opportunity to collect and investigate patient health information to strengthen the design of behavioral interventions for prevention of chronic disease. Evidence on the effectiveness of behavioral interventions indicates the most significant shift towards prevention is made through supporting self-management and individual behavior change (Reynolds et al., 2018; Wagner, 1998). Instilling behaviors that promote health and prevent disease (or reduce risk of disease) requires tailored intervention strategies that disrupt unhealthy patterns in behavior and encourage decisions about engaging in health promoting activities that are easier and automatic. Ideally these health interventions would be upstream to reduce risk factors at an early point in time across an individual's lifecourse so that health resources contribute towards maximizing healthy lifespans and postponing the onset of chronic disease (Fries, Bruce & Chakravarty, 2011).

2.2 Tailoring Behavioral Interventions with Information on People, Time, and Place

To improve behavioral interventions for prevention of chronic diseases there needs to be a better understanding of behaviors, specifically the way individuals interact within the broader environment, as well as factors influencing daily activities and behaviors associated with their health. Principles and theory from health geography and behavioral economics can strengthen our understanding of behaviors, and how to change them. We have developed a framework that intersects with the BCW to explain the types of factors influencing an individual's spatiotemporal context, use of time, and decisions about routine activities (See Figure 2.1).

2.1.1 Behavior Change Wheel





2.1.2 Behavioral Contexts

Spatiotemporal Contexts

Use of time

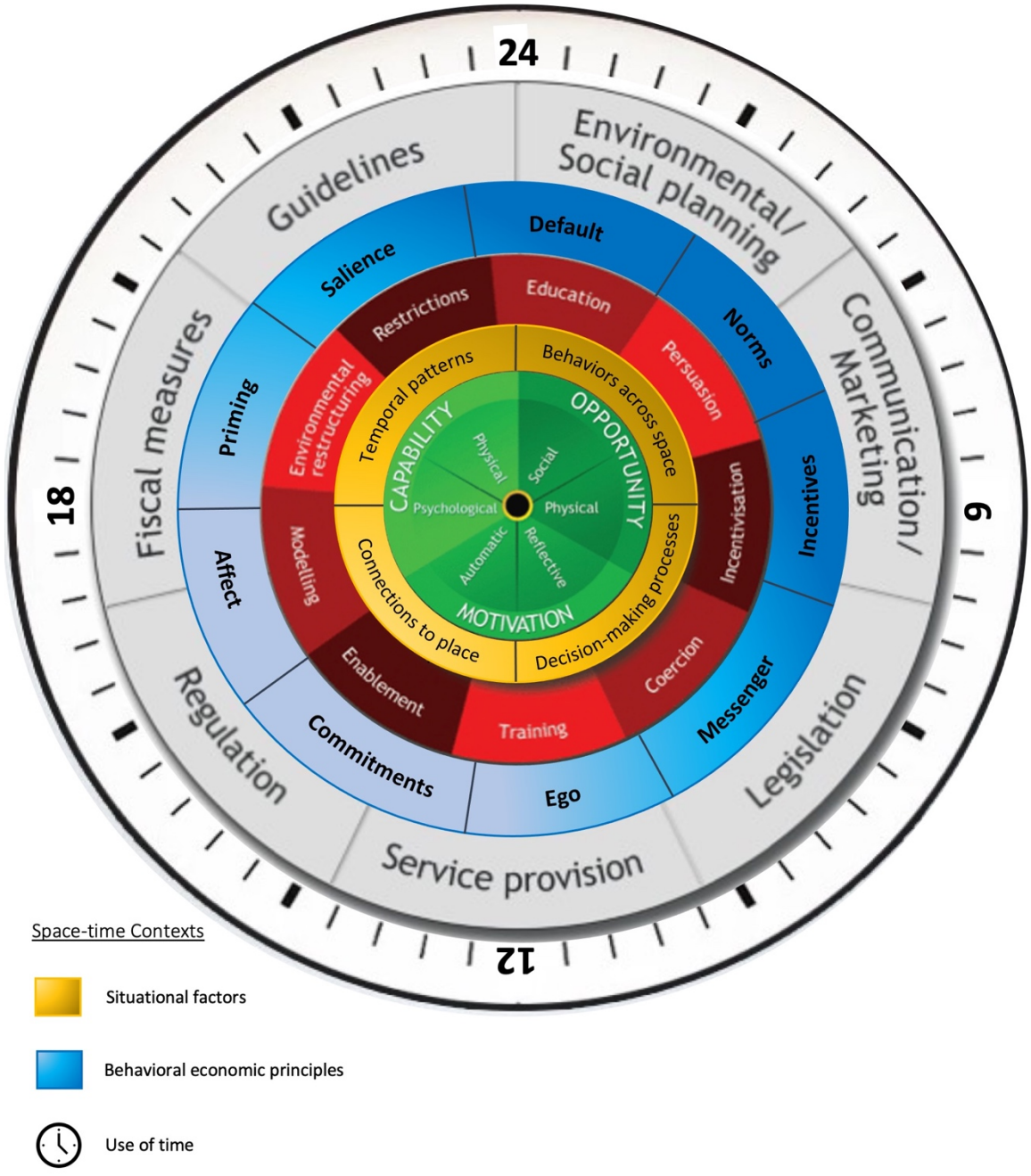


Figure 2.1 A Continuum of Behavioral Interventions

2.3 A Continuum of Behavioral Interventions

The foundation of this adapted framework is the BCW (Figure 2.1.1), which includes three layers describing individual level sources of behavior (green), potential intervention functions (red), and categories for types of policies to deliver intervention functions (white) (Michie, van Stralen & West, 2011). While the BCW encourages intervention designers to consider multiple sources of individual and system level factors, this adapted framework builds on existing evidence by suggesting an additional layer (yellow) within Figure 2.1.2 to conceptualize spatiotemporal contexts that influence how individuals form day-to-day routines. By integrating ecological theory (Curtis & Jones, 1998) it encourages behavior change interventions to explore the relationships individuals have with their environment, how individuals interact with one another across built environments, how relationships with space and place change over time, and how complex health issues connect people, time, and place (Tunstall, Shaw, & Dorling, 2004). The additional yellow layer of spatiotemporal contexts recognizes there are intricate external factors, including connections to place and fluctuating health behaviors across different environments that influence an individual's intrinsic capability, opportunity, and motivation for behavior change.

2.3.1 Time Geography

The outer layer of this adapted BCW (Figure 2.1.3) incorporates a 24-hour clock to signify the importance of how individuals spend their time, indicating there are opportunities and constraints that exist within everyday routines that influence intervention strategies for encouraging behavior change. The construct of time represented by the 24-hour clock incorporates important theoretical contributions from

time-geography, emphasizing that daily activities exist on a continuous and sequential continuum within a three-dimensional spatial-temporal frame (Hägerstrand 1970, 1985; Lenntorp, 1999; Sui, 2012). Theory from time-geography provides insight for improving behavioral interventions by understanding that health behaviors and health outcomes are often influenced by an individual's ability to adapt their routine activity space under time constraints (Bissonnette et al., 2012; Comber et al., 2011). Figure 2.1.3 reinforces the idea that time is socially distributed based on an individual's resources (i.e., access to transportation, restrictive employment schedules, proximity to health services, childcare) and can influence their capabilities, constraints, and opportunities for adapting day-to-day activities like increasing health improving activities (Strazdins et al., 2016).

Understanding social patterns of time and how individuals spend their time can support efforts to tailor intervention strategies, such as encouraging individuals to adapt existing routines based on information of where, when, and how they spend their time. Time-diaries are one example of techniques for documenting how individuals spend their time (Chatzitheochari et al., 2018), and bring awareness to where and why individuals experience challenges with adapting their day-to-day activities. For example, understanding that an individual experiences chronic time deficits and typically eats fast food along their commute to work is important for identifying strategies to encourage small incremental changes like choosing healthier menu options at the fast-food places frequently visited, drinking coffee or tea without added sugar, or swapping sugary soda beverages for water. Intervention strategies that require increased time spent on health improving activities like PA are less likely to be effective for individuals that struggle with chronic time deficits. Evidence indicates individuals that experience chronic time

deficits, known as time poverty, and spend over 80 hours a week on employment and caregiving responsibilities are more likely to experience barriers to PA, sleep deprivation and high stress leading to negative mental health outcomes (Strazdins et al., 2016).

A discussion of spatiotemporal contexts raises an important question; at what point in time would strategies be most effective to disrupt routine decision-making processes and encourage behavior change? Principles from behavioral economics provides critical insight of cognitive biases, such as emotional responses or availability of information that influence how individuals make automatic decisions about their routine activities. Theory from behavioral economics provides insight about biases in human judgement and flawed decision-making processes that cause individuals to rely on automatic versus reflective thought processes (Kahneman & Tversky, 1984). Factors influencing an individual's automatic decision-making process are critical for identifying patterns in their everyday routines and habitual decisions that make it difficult to change routines that stem from unconscious habits (Nilsen et al., 2012).

2.3.2 Behavioral Economics

Behavioral economic principles known as nudges have only recently been used within health interventions, but have proven to be valuable techniques for influencing an individual's daily behaviors, and have the potential to be scaled across population level behaviors (Goodchild et al., 2016; Vlaev et al., 2016). A nudge is a behavioral economic technique that uses subtle prompts, while maintaining freedom of choice, to disrupt automatic decision-making processes (Thaler & Sunstein, 2008). Nudges are implemented using heuristic principles such as priming of information, use of defaults, incentives or loss aversion, social norms, and affect through emotional associations

(O'Donoghue & Rabin, 2000; Rolls et al., 2004; Sunstein & Thaler, 2003). The most common behavioral economic principles used to nudge are defined and described in the MINDSPACE framework (See Table 2.1) (The Behavioral Insights Team, 2015; Vlaev & Makki, 2018).

Table 2.1 MINDSPACE Framework Definitions of 9 Constructs

Construct	Definition
1. Messenger	We are heavily influenced by who communicates information. We are affected by the perceived *authority* of the messenger (whether formal or informal). Demographic and behavioral *similarities* between the expert and the recipient can improve the effectiveness of the intervention. We are also affected by the *feelings* we have for the messenger. We also use more rational and cognitive means to assess how convincing a messenger is.
2. Incentives	Our responses to incentives are shaped by predictable mental shortcuts such as *strongly* avoiding losses (we dislike losses more than we like gains), referencing points (the value of something depends on where we see it from), *overweighting* small probabilities (hence why lotteries may act as a powerful motivation), *mental* budgets (allocating money to discrete bundles), *present bias* (we prefer more immediate payoffs).
3. Norms	We are strongly influenced by what others do. Social and cultural norms are the behavioral expectations, or rules, within a society or group. Norms can be explicitly stated or implicit in observed behavior. People often take their understanding of social norms from the behavior of others. Relate the norm to your target audience as much as possible and consider social networks.
4. Defaults	We "go with the flow" of pre-set options. Many decisions we take every day have a default option, whether we recognise it or not. Defaults are the options that are pre-selected if an individual does not make an active choice. Defaults exert influence as individuals regularly accept whatever the default setting is, even if it has significant consequences.
5. Salience	Our attention is drawn to what is novel and seems relevant to us. Our behavior is greatly influenced by what our attention is drawn to. People are more likely to register stimuli that are *novel* (messages in flashing lights), *accessible* (items on sale next to checkouts), *simple* (a snappy slogan), and *relevant* (easier to grab attention at moments when people enter a new situation or life-stage such as moving house, going to university, pregnancy etc.). We also look for a prominent *anchor* (such as unusual or extreme experiences, price, and advice) on which to base our decisions.
6. Priming	Our acts are often subconsciously influenced by cues in the environment. People's subsequent behavior may be altered if they are first exposed to certain sights, words or sensations, which activate associated concepts in memory. In other words, people behave differently if they have been 'primed' by certain cues beforehand.
7. Affect	Our emotional associations can powerfully shape our actions. Emotional responses to words, images, and events can be very rapid and automatic. Moods, rather than deliberate decisions, can therefore influence judgements. People in good moods make unrealistically optimistic judgements, whilst those in bad moods make unrealistically pessimistic judgements.

Construct	Definition
8. Commitments	We seek to be consistent with our public promises and reciprocate acts. We use commitments devices to achieve long-term goals. It has been shown that commitments usually become more effective as the costs for failure increase. One common method for increasing such costs is to make commitments public, since breaking the commitment will lead to significant reputational damage. Even the very act of writing a commitment is our strong instinct for reciprocity, which is linked to a desire for fairness.
9. Ego	We act in ways that make us feel better about ourselves. We tend to behave in a way that supports the impression of a positive and consistent self-image. We think the same way for groups that we identify with. We also like to think of ourselves as self-consistent. So, what happens when our behavior and our self-beliefs are in conflict? Interestingly, often it is our beliefs that get adjusted, rather than our behavior.

1. Vlaev I, Makki F. Applying behavioral insights in health: Tackling key non communicable diseases. *Report of the WISH Policy Briefing on Behavioral Insights,* 2018.
2. Institute for Government. MINDSPACE: Influencing behavior through public policy. 2015. Accessed January 5, 2021. https://www.bi.team/wp-content/uploads/2015/07/MINDSPACE.pdf

A range of behavioral economic nudges have been used within the design of public health interventions. For example, nudges like priming of information have been effectively used to encourage a significant number of commuters along subway pedways to use the stairs instead of the elevator by posting visual cues of words that represent an active lifestyle like “fit”, “lean”, “active”, and “athletic” (Wryobeck & Chen, 2003). Emotional affect has shown to significantly improve interventions for smoking cessation through the use of narratives, images, and videos showing participants’ loved ones suffering from a heart attack (May et al., 2010). Within 1 week, 54 percent of subjects quit or decreased consumption and remained abstinent at 6 months (May et al., 2010). Nudges serve an important purpose for improving existing behavioral interventions for prevention of chronic disease (Mollenkamp et al., 2019) and have the potential to influence population health outcomes through early intervention and incremental changes that target high-risk behaviors. To visualize how behavioral economic techniques could be implemented within behavioral interventions, a proposed framework is presented

within Figure 2.1.3 to suggest the types of principles that could be used to strengthen behavioral interventions.

In the context of behavioral interventions, the timing and location of a nudge can be just as important as the technique employed for shifting decision-making processes. Understanding an individual's routine and spatiotemporal contexts could enhance the delivery of a nudge by identifying the most opportune moment in time and place to influence decisions. For instance, priming with words and pictures of healthy foods right before grocery shopping, or salience through flashy text notifications of healthy menu options at nearby restaurants as an individual is deciding where to eat. Intersecting spatiotemporal contexts and behavioral economic techniques within Figure 2.1.3 could also be helpful when testing and re-testing the effectiveness of a nudge technique over time.

Nudges may be successful at one moment in time, yet it is unclear whether the effectiveness of certain nudges decreases as they are repeated, and individuals become accustomed to the same technique (Beshears & Kosowsky, 2020). For example, within Norway two exercise facilities used a picture of "observing eyes" on sanitizing spray bottles to nudge members' hygienic behavior of wiping down equipment after each use (Mobekk et al., 2020). This intervention found the presence of observing eyes significantly increased use of sanitizing spray during a 9-week period, however, during a follow-up period the effect of the nudge decreased and there were no real significant differences in members' behaviors over time (Mobekk et al., 2020). Within the context of health interventions, nudges are not a silver bullet, and they continually require adjustments to maintain effectiveness based on the target population and contexts in

which they are applied (Halpern & Sanders, 2016). When evaluating the implementation and outcomes of nudges over time, spatiotemporal contexts could provide important insights to identify when and where nudge techniques need to be adjusted to maintain or improve effectiveness after repeated exposures.

2.3.3 Interventions for Prevention of Chronic Disease

Behavioral economic principles also align with the BCW outer layer (white) of policy strategies and provide additional techniques for scaling behavioral interventions, such as integrating nudges within regulations, guidelines, communication/marketing, and legislation. A common misconception of population wide interventions is that they are costly and require large-scale changes to alter environments and social structures (Milat et al., 2014). Behavioral economic theories add value to behavioral interventions by reinforcing the idea that nudges are low-cost techniques that can initiate small incremental changes to individual behaviors with the potential to be scaled for high levels of exposure and huge effect across populations (Frank, 2004; Vlaev et al., 2016).

Although nudges are directed at individual-level behaviors, integrating nudges within regulatory or policy strategies provides a more effective way of establishing population wide standards of behavior that become engrained as social norms, such as attitudes towards day-to-day health decisions. For instance, interventions aiming to reduce the purchase of processed foods high in sugar, sodium, and fat found that targeting individual eating behaviors at grocery stores with traffic-light labels are effective priming cues for influencing better decisions and significantly reduced consumption of overall calories, fat, and sodium (Emrich et al., 2017; Roberto et al., 2012). Categorizing food items on a grocery shelf with nutritional warnings that signify red (to avoid), orange

(moderate), or green (within nutritional guidelines) allowed consumers to identify healthier options and made decisions easier (Emrich et al., 2017). Although nutritional labels are available on food items, deciphering which foods are high above recommended nutritional guidelines can be time consuming and complicated. This intervention implements nutritional guidelines and breaks down a complicated decision so that individuals can use fast thinking processes through the use of a simple visual prime (Roberto et al., 2012).

Further, increasing the scale of this intervention through legislation and regulation, the United Kingdom (UK) introduced an industry level sugar tax to gradually reduce the amount of sugar that is produced within soft drinks (Government of United Kingdom, 2018). This governmental nudge aimed at accelerating social norms for healthy eating and reducing childhood obesity within the UK generated population wide impacts by incentivizing corporate producers of soft drinks to reformulate their existing products with low-calorie sweeteners to avoid paying a sugar tax (Behavioral Insights Team, 2018). From this legislative nudge there was an 11 percent reduction of sugar in soft drinks, which is the equivalent to removing 10,000 tonnes of sugar from UK shelves (Behavioral Insights Team, 2018). By scaling the behavioral economic principle of loss aversion to industry this nudge generated corporate industry changes and population wide behavior change, illustrating how the majority of people can benefit from nudges that make decision-making processes easier and encourage healthier behaviors, such as reducing sugar consumption without restricting the purchasing decisions or quality of products for consumers (Sunstein & Thaler, 2003).

2.4 What Types of Questions Do We Need to Ask Within Health Care Settings?

Although evidence signifies the importance of understanding how features of an individual's context, such as characteristics of the built environment, influence health behaviors that contribute to disease outcomes, behavior change interventions rarely integrate information about the timing and location of an individual's activities (schedules) that are useful for tailoring intervention strategies. Theory from health geography provides insight to conceptualize how spatiotemporal contexts influence activities and decision-making processes based on constraints that compel individuals to prioritize between a number of potential activities and require individuals to adapt their routine activities under spatiotemporal restrictions (Anstiss, 2009; Hägerstrand, 1970).

What types of questions are required to gather the most critical information about an individual's spatiotemporal contexts and everyday routine? An answer could involve a conversation between a patient and provider that starts with, *"What does a typical day look like for you? Can you tell me how you spend your time every day, beginning with what time you wake up in the morning and what you do until it ends when you go to bed."* By following up with subtle prompts about where, with whom, and for how long activities last, a health provider can learn why a patient engages in specific daily behaviors. It is commonly understood that people are creatures of habit and life is largely patterned with routines, such as the time you wake up, what you eat for breakfast, the commute you take to work, and how you spend your time in the evenings until you go to bed. Although seasonal changes may shift the activities individuals engage in, there are temporal patterns in behaviors across space, their connections to place, and how people make decisions about their day-to-day routine. This information is critical to understand

where, when, and how behavioral intervention strategies would be most beneficial to encourage a change in routine activities. The shift towards team-based care models provides opportunities to gather information about patients' routine activities and to embed health professionals with behavioral counselling skills as part of care teams. Team-based care models, in comparison to solo-provider models, can support the integration of behavioral counselling and behavior change programs for early intervention, prevention, and self-management of chronic disease as part of patient-centered care (Mitchell et al., 2019; Wagner et al., 2017).

By sparking conversation about how individuals spend their time, health providers can initiate a meaningful conversation about spatiotemporal contexts that influence how individuals make decisions about their routine use of time, barriers to managing their health or achieving their desired health goals, and where opportunities exist to disrupt routine patterns of behaviors to increase health improving activities. Asking an individual to describe their day-to-day routine and explain why they make certain decisions about their behaviors also encourages individuals to reflect on why habits have formed either knowingly or not in everyday life. Bringing awareness to the choices individuals have when making decisions about their activities, versus circumstances beyond their control, can be empowering and instill a sense of responsibility and optimism that risk of chronic disease can be mitigated by small incremental changes in their day-to-day routine like adding a brisk 30-minute walk or eating a minimum of 5 fruits and vegetables.

Equipping health providers and patients with information about spatiotemporal contexts and use of time is critical for shifting health system's culture towards early

intervention for prevention of chronic disease. The proposed framework suggests that shifting a predominately reactive health care culture towards upstream prevention requires additional information about patterns in health behaviors to understand an individual's risk on a continuum, versus the dichotomy of low risk or high risk when disease is diagnosed. A predominant approach for prevention and management of chronic disease continues to rely on pharmaceutical treatments and clinical interventions for high-risk patients (Grady & Gough, 2014). This may be effective on a per patient basis but can only treat small proportions of populations and is not cost-effective or sustainable at preventing chronic disease across populations (Fagan et al., 2019). A more cost-effective intervention is required that can be delivered to higher proportions of patients. This framework suggests integrating behavior change programs that are tailored to the contexts of community environments and patient routine activities can be delivered to higher proportions of patients through team-based care models. While there has been limited success of behavioral interventions within clinical settings to prevent chronic disease (Edlind et al., 2018), innovative techniques from behavioral economics have increased effectiveness of behavioral interventions (Hagger & Weed, 2019; Mollenkamp, Zeppernick & Schreyogg, 2019). By identifying the contexts of community environments and patient routine activities, behavioral interventions can identify the conditions necessary to scale behavioral interventions across populations with cost-effective strategies that nudge individuals to make better decisions about their routine day-to-day behaviors.

2.5 What Type of Information is Required to Strengthen Behavioral Interventions?

Health interventions are more likely to be effective when they are designed around the way societies are organized and relevant to individual behaviors across different environments (Rose, 1992); then what type of information is required to improve behavioral interventions? A critical challenge for improving behavioral interventions continues to be integrating knowledge of individual level geographic patterns of health behaviors, so that strategies can be tailored and scaled across populations to improve prevention of chronic disease. Part of this challenge is in the way health care services traditionally operate with little information to assess the social, physical, and environmental factors influencing patient day-to-day activities and patterns in health behaviors over time. As illustrated within the anecdotal example of Patient A, patients and providers are often unaware of the opportunities to adapt day-to-day activities to reduce high blood pressure and manage risk for progression of chronic disease. Although the provider can make generic recommendations for Patient A to exercise regularly and eat foods low in sodium, fat, and sugar, tailored recommendations for how Patient A could adapt existing routines with healthier choices would be more useful. To illustrate the type of information required to strengthen health interactions and improve behavioral interventions for prevention of chronic disease, we provide a visualization of how insights from health geography and behavioral economic principles can generate awareness of multiple dimensions of health (see Figure 2.2).

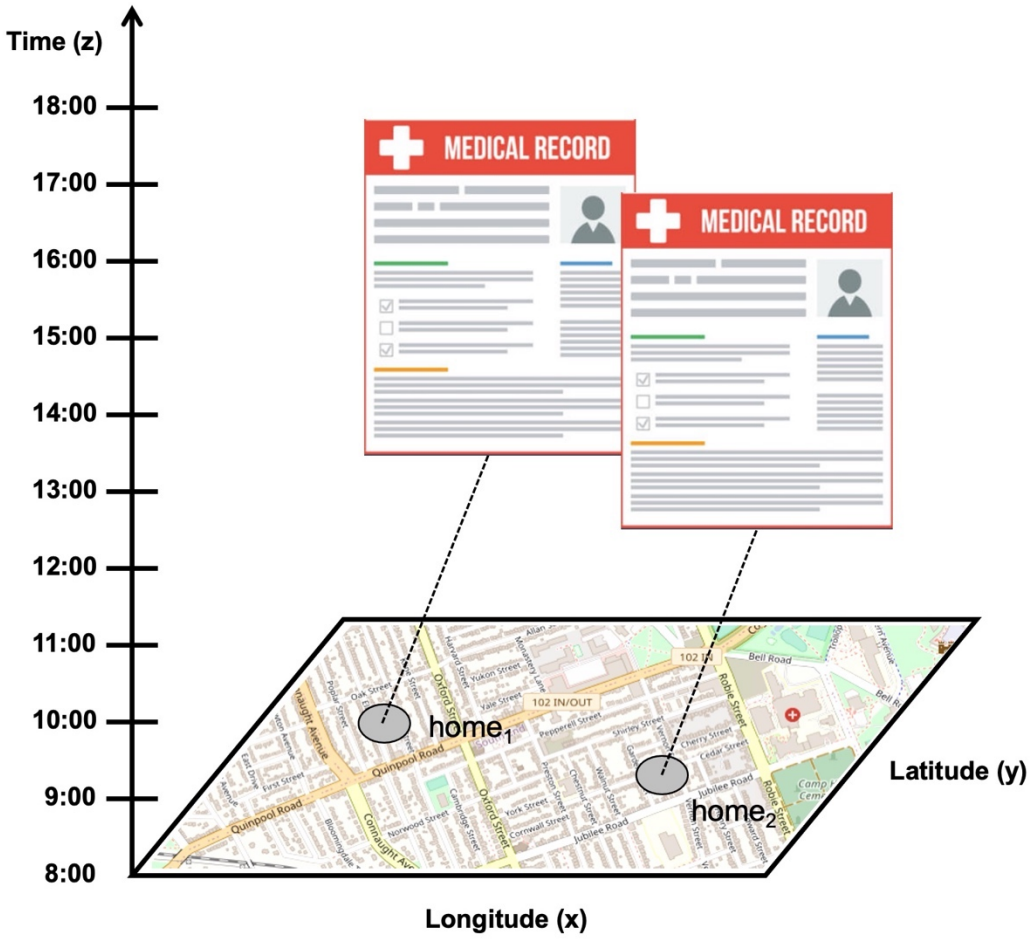


Figure 2.2.1 Patient Medical Records. Typically capture unidimensional measures of place based on where patients live.

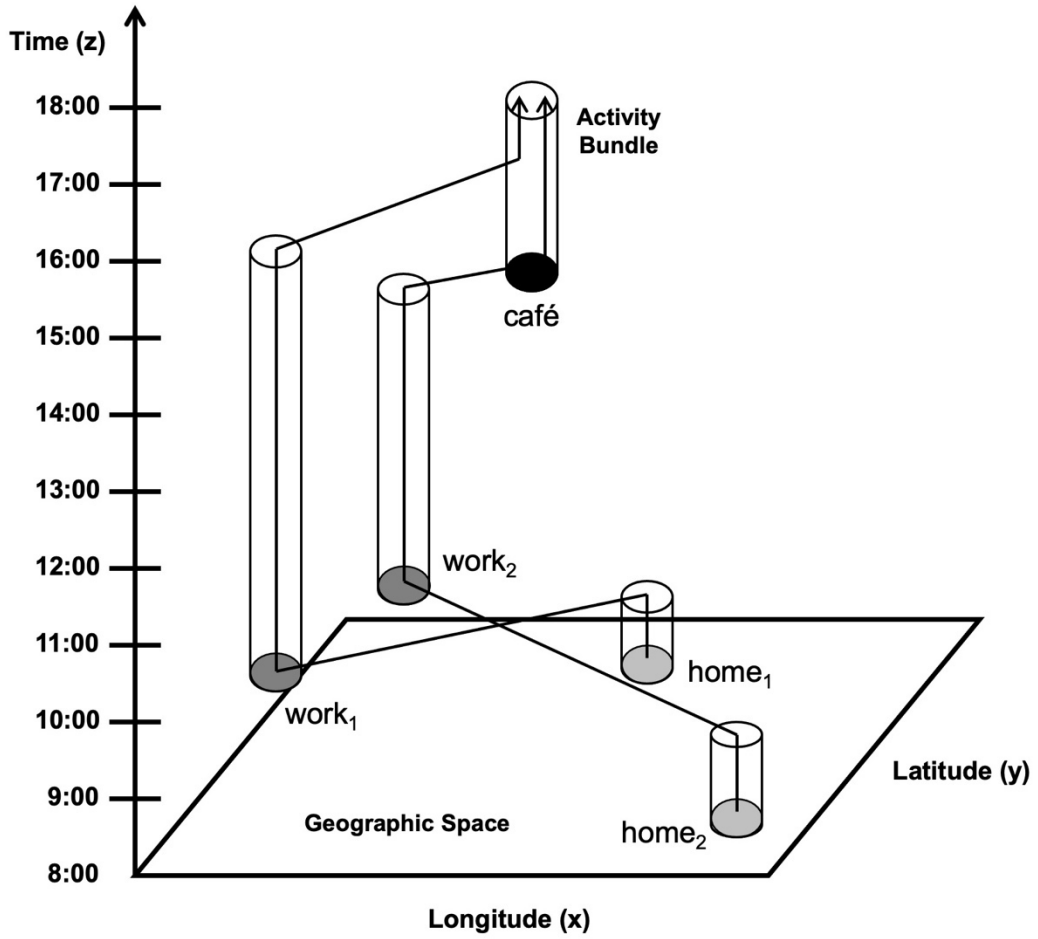


Figure 2.2.2 Spatiotemporal Activity Paths of Two Individuals.
Time spent at café represents the 'convergence' of two paths and is also called an activity bundle. The sharing of moments in space-time provides insight into the spatiality of social interaction.

This figure is adapted from original work published within: Rainham, D., McDowell, I., Krewski, D., & Sawada, M. (2010). Conceptualizing the healthscape: Contributions of time geography, location technologies and spatial ecology to place and health research. *Social Science & Medicine,* (70). 668-676.

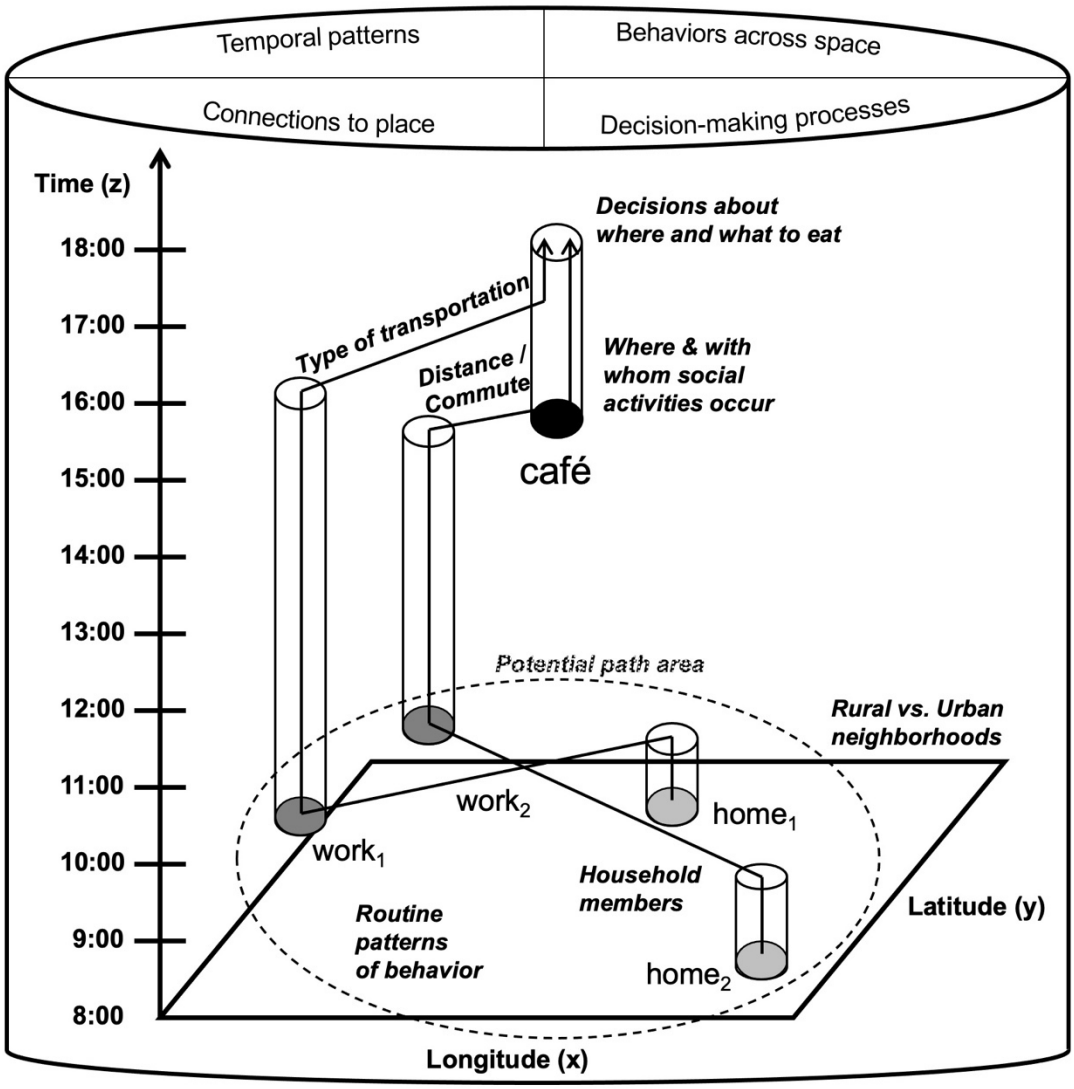


Figure 2.2.3 Ecological Factors Influencing How and Why People Make Decisions About Their Activities. Traditional models of space-time paths do not account for contexts of the environment that influence where behaviors occur as well as factors influencing how and why people make decisions about their day-to-day activities.

This figure is adapted from original work published within: Rainham, D., McDowell, I., Krewski, D., & Sawada, M. (2010). Conceptualizing the healthscape: Contributions of time geography, location technologies and spatial ecology to place and health research. *Social Science & Medicine,* (70). 668-676.

Figure 2.2 Four-Dimensions of Health Behaviors

2.6 Four-Dimensions of Health Behaviors

Health care systems have typically been designed to document characteristics of patients' medical record through fields like occupation, demographics, medical history, diagnoses, or laboratory tests (Figure 2.2.1). These data points comprise unidimensional records of patient profiles and are used to support a health care professional with assessment, diagnosis, and treatment of disease over time. As illustrated within Figure 2.2.1, medical records are linked to one patient at one point in space and time based on where patients live. However, there are critical details about patient health behaviors and day-to-day activities that are not captured within typical health records but are important for informing health interactions between patient and provider. While health records provide a snapshot in time, health behaviors are constantly in flux day-to-day and involve multiple dimensions outside clinical settings such as how individuals interact across built environments and how health decisions about everyday activities are connected to where individuals live, work, and play (Tunstall, Shaw, & Dorling, 2004).

Figure 2.2.2 illustrates how health behaviors can be viewed three-dimensionally when accounting for spatiotemporal contexts such as how activities occur across space, place, and time (Rainham et al., 2010). Methods for capturing three-dimensional measures of individual health behaviors have been advanced by global positioning systems (GPS) whereby accurate measures of point locations can track movement of an individual's spatiotemporal activity (Rainham et al., 2008). While GPS technology has transformed the way data can generate visualizations of activity space, quantitative methods alone do not capture contextual explanations about the social and environmental settings that give meaning to individual interactions. There are limitations of only

including point locations and failing to account for the interaction of an individual within their environment and contextual factors about their activities (Cummins et al., 2007; Mennis, Mason, & Cao, 2013). We propose there is a need to conceptualize a fourth dimension of activity space defined by ecological contexts like decisions about day-to-day activities, routine behaviors over time, potential activity space areas, and social interactions that influence where and why individuals behave the way they do.

Figure 2.2.3 provides examples of contextual factors influencing an individual's activity space such as access to public transit, walkability of neighbourhood, access to healthy foods, or access to health promoting features or built environments like green spaces. These contextual factors provide details that add depth to activity space, such as how and why individuals make decisions about their everyday activities considering a range of potential path areas. Thinking about ecological contexts as a fourth dimension of activity space provides insight for behavior change interventions to target opportunities available within potential path areas for small incremental changes to routine patterns of behavior. By talking about how we spend our time everyday individuals can reflect upon the decisions they make, either knowingly or not, and learn how small behaviors have developed into habitual patterns of behavior. For instance, as shown in Figure 2.2.3, how much of our day-to-day behaviors are habitual? Do individuals take the same route from home to work every day or have social interactions at the same neighbourhood café? Yet there are a range of potential paths within this activity space, such as choosing an active transportation route to cycle or walk to work, or meeting for social activities while walking at a local park. Identifying these key insights about individual level health behaviors could inform public health interventions and nudge small incremental changes,

such as incentivizing individuals to park for free or at a reduced cost further away from work to encourage a 15-minute walk before and after a workday.

Further, while patient medical records are commonly associated with individual-level outcomes, we suggest that multiple dimensions of health and behaviors (Figure 2.2.3) should be considered a reflection of community environments that reinforce development of healthy or unhealthy behaviors (Kephart et al., 2016). While individual behaviors are often influenced by their environments, such as accessible sidewalks in neighborhoods (Shashank & Schuurman, 2019) or the high density of fast-food restaurants near schools (Laxer & Janssen, 2014), interventions can bring awareness to the choices individuals have and opportunities for making better decisions that increase health improving activities. When facing everyday challenges of time management and responsibilities to maintain activities for daily living, it can seem overwhelming to find opportunities for adapting routine habits and increasing healthy activities. What option does Patient A have to convey how complex their day-to-day decisions are with a health provider? How can Patient A discuss factors influencing why and how they make decisions that negatively affect their health, such as deciding what to eat or when to exercise. Although health care providers cannot be responsible for monitoring patient behaviors in community settings, health care providers are critical partners for connecting patients with public health resources that offer a variety of health and wellness programs and the potential for tailoring behavioral interventions to individual needs (Martin-Misener et al., 2012).

2.7 Bringing Behavioral Interventions into Community Settings

Public health services are one ideal setting for collecting patient information on spatiotemporal contexts and implementing behavioral economic techniques to nudge behavior change. These services typically deliver a range of resources that include, but are not limited to, youth health centres, sexual health clinics, women and children health programs, immunization clinics, substance abuse and mental health services, chronic disease management programs, and networks of primary health care professionals that provide a regular source of care (Stover & Bassett, 2003). Public health services are commonly organized by a range of governmental and non-governmental organizations that have an important role for improving health outcomes and preventing disease through early interventions (Stover & Bassett, 2003). Public health interventions include increasing patient adherence to behavioral counselling for smoking cessation, increasing population wide immunizations, reducing sexually transmitted diseases, and improving the health of women and children (Centers for Disease Control and Prevention, 2015).

Health care providers across public health services are important players for implementing behavioral interventions and should be viewed as key stakeholders for integrating existing interventions within care settings to engage with patients outside clinical settings in their day-to-day routines. For instance, in the context of clinical care settings there is a traditional power dynamic where care providers are seen as the experts of health information and define patient relationships based on how they deliver care (McCullough, 2016). There are opportunities to build upon the influence that providers have within patient care and patient relationships to encourage positive health behavior change. For example, by implementing the principle of ‘messenger’ health providers

have the potential to be powerful social influencers (Kreuter, Chheda, & Bull, 2000). Patients that received an individualized text message from their healthcare provider to remind them of influenza vaccines available at the clinic were 30 percent more likely to be vaccinated within 3-months (adjusted odds ratio = 1.30; 95% confidence interval = 1.003, 1.69) in comparison to patients within a control group that did not receive a text message (Stockwell et al., 2014).

To enhance an integrated public health approach, health care providers need to be equipped with different tools and methods to gather information about an individual's spatiotemporal contexts and day-to-day routines. The tools and methods required to gather spatiotemporal contexts could involve mixed method approaches to identify a patient's typical activity space, how they manage time, and detailed explanations of factors influencing how they make decisions about their activities. Geo-ethnography is one mixed-methods approach used to gather locational information of day-to-day activities along with supplemental open-ended questions to contextualize details like what, where, when, why, and with whom activities occur (Matthews et al., 2005; Milton et al., 2015). Prior to an appointment, if a patient were asked to answer survey questions on the types of activities they typically engage in day-to-day, then health providers would gain insight into how their daily life is structured. Asking an individual how they spend their time everyday versus how they would like their routines to change (Rollnick & Miller, 1995) also encourages self-reflection on the accuracy of their estimations of how much time is spent in sedentary activities like watching television and overestimating the time or effort required to engage in some form of PA every day.

There are opportunities to integrate spatiotemporal contexts and behavioral economic principles within existing behavioral interventions and to scale up these strategies across populations to strengthen prevention of chronic disease. For example, the Carrot Rewards Program (CRP) is an intervention designed using behavioral economic principles to increase PA by incentivizing users with reward points to achieve their individualized daily step goals (Mitchell et al., 2017; 2018). The CRP targets individual level behavior change but has been successfully scaled across populations in Canada and has shown positive effects for increasing PA (average increase of 1000 steps/day, $p<0.001$) by offering very small but immediate daily reward points (worth $0.04 CAD) over a 12-week and 12-month trial (Mitchell et al., 2018; Rondina et al., 2020). CRP is one of many cost-effective digital interventions (Rondina et al., 2021) using gamification (Zhao, Etemad, & Arya, 2016) and incentive techniques that could be tailored to improve the effectiveness and sustainability of behavioral interventions. For example, behavioral interventions could tailor the CRP using spatiotemporal information about when and where patients' day-to-day routines occur to identify the most opportune time and place to disrupt automatic routines and increase PA. The timing and location of patients' existing routines is important for identifying opportunities to increase light and moderate to vigorous PA by breaking up long periods of sedentary activity when patients are at home or working day-to-day. Interventions that rely on a traditional approach to behavior change such as delivering education sessions on exercise would be strengthened by integrating a low-cost strategy like the CRP to engage patients day-to-day, tailor program design to individual goals, and scale intervention outcomes across populations.

2.8 Conclusion

Interventions for prevention of chronic disease requires a multi-dimensional understanding of patient behaviors within the contexts of community environments so that behavioral interventions can be tailored and scaled across populations. We have suggested how the application of principles from health geography and behavioral economics provide the potential to improve behavioral interventions that bring clinical interventions into community settings where individuals live, work, and play. Partnerships with health care professionals across public health services also provide additional resources for both patients and providers that may lack awareness of how to support behavior change such as identifying opportunities to make small incremental changes in day-to-day routines. To support a viable health care system in the future a collaborative approach will be required between health care services and community-based public health resources. The importance of behavioral interventions needs to be prioritized to improve the health of populations and prevent burden of disease and health costs into the future. Planning for more sustainable health resources requires public health research and clinical practice to integrate spatiotemporal contexts and behavioral economic techniques so that intervention strategies are responsive to the health needs, constraints, opportunities, and environments of patient populations.

References

Al-Ubaydli, O., List, J., & Suskind, D. (2019). *The science of using science: Towards an understanding of the threats to scaling experiments.* National Bureau of Economic Research. Retrieved from https://www.nber.org/system/files/working_papers/w25848/w25848.pdf

Anstiss, T. (2009). Motivational Interviewing in Primary Care. *Journal of Clinical Psychology in Medical Settings*, *16*(1), 87–93. https://doi.org/10.1007/s10880-009-9155-x

Atkins, L., Francis, J., Islam, R., O'Connor, D., Patey, A., Ivers, N., Foy, R., … & Michie, S. (2017). A guide to using the Theoretical Domains Framework of behaviour change to investigate implementation problems. *Implementation Science*, *12*(77), 1–18. https://doi.org/10.1186/s13012-017-0605-9

Bandura, A. (1999). A Sociocognitive Analysis of Substance Abuse: An Agentic Perspective. *Psychological Science*, *10*(3), 214–217. https://doi.org/10.1111/1467-9280.00138

Becker, M., Maiman, L., Kirscht, J., Haefner, D., & Drachman, R. (1977). The health belief model and prediction of dietary compliance: A field experiment. *Journal of Health and Social Behavior, 18*(4). 348-366. https://doi.org/10.2307/2955344

Behavioral Insights Team. (2018). *Sugaring the bill: Why lower revenue from the sugar tax is probably a good thing.* Behavioral Insights Team. Retrieved from https://www.bi.team/blogs/sugaring-the-bill-why-lower-revenue-from-the-sugar-tax-is-probably-a-good-thing/

Beshears, J., & Kosowsky, H. (2020). Nudging: Progress to date and future directions. *Organizational Behavior and Human Decision Processes*, *161*, 3–19. https://doi.org/10.1016/j.obhdp.2020.09.001

Bissonnette, L., Wilson, K., Bell, S., & Shah, T. I. (2012). Neighborhoods and potential access to health care: The role of spatial and aspatial factors. *Health & Place*, *18*(4), 841–853. https://doi.org/10.1016/j.healthplace.2012.03.007

Bodenheimer, T., Wagner, E., & Grumbach, K. (2002). Improving Primary Care for Patients with Chronic Illness: The Chronic Care Model, Part 2. *JAMA*, *288*(15), 1909–1912. doi:10.1001/jama.288.15.1909

Centers for Disease Control and Prevention. (2015). *Health-related programs.* Centers for Disease Control and Prevention. Retrieved from https://www.cdc.gov/workplacehealthpromotion/model/implementation/programs.html

Chatzitheochari, S., Fisher, K., Gilbert, E., Calderwood, L., Huskinson, T., Cleary A., & Gershuny, J. (2018). Using new technologies for time diary data collection: Instrument design and data quality findings from a mixed-mode pilot survey. *Soc Indic Res, 137*(1). 379-390. doi:10.1007/s11205-017-1569-5

Comber, A. J., Brunsdon, C., & Radburn, R. (2011). A spatial analysis of variations in health access: Linking geography, socio-economic status and access perceptions. *International Journal of Health Geographics*, *10*(1), 44. https://doi.org/10.1186/1476-072X-10-44

Cummins, S., Curtis, S., Diez-Roux, A. V., & Macintyre, S. (2007). Understanding and representing 'place' in health research: A relational approach. *Social Science & Medicine*, *65*(9), 1825–1838. https://doi.org/10.1016/j.socscimed.2007.05.036

Curtis, S., & Jones, I. R. (1998). Is There a Place for Geography in the Analysis of Health Inequality? *Sociology of Health & Illness*, *20*(5), 645–672. https://doi.org/10.1111/1467-9566.00123

Edlind, M., Mitra, N., Grande, D., Barg, F. K., Carter, T., Turr, L., Glanz, K… & Kangovi, S. (2018). Why Effective Interventions Do Not Work for All Patients: Exploring Variation in Response to a Chronic Disease Management Intervention. *Medical Care*, *56*(8), 719–726. https://doi.org/10.1097/MLR.0000000000000939

Emrich, T., Qi, Y., Lou, W., & L'Abbe, M. (2017). Traffic-light labels could reduce population intakes of calories, total fat, saturated fat, and sodium. *PLOS One, 12*(2). e0171188. https://doi:10.1371/journal.pone.0171188

Ersche, K. D., Lim, T.-V., Ward, L. H. E., Robbins, T. W., & Stochl, J. (2017). Creature of Habit: A self-report measure of habitual routines and automatic tendencies in everyday life. *Personality and Individual Differences*, *116*, 73–85. https://doi.org/10.1016/j.paid.2017.04.024

Evans, R., & Stoddart, G. (1990). Producing health, consuming health care. *Social Science & Medicine*, *31*(12), 1347–1363. https://doi.org/10.1016/0277-9536(90)90074-3

Fagan, A. A., Bumbarger, B. K., Barth, R. P., Bradshaw, C. P., Cooper, B. R., Supplee, L. H., & Walker, D. K. (2019). Scaling up Evidence-Based Interventions in US Public Systems to Prevent Behavioral Health Problems: Challenges and Opportunities. *Prevention Science*, *20*(8), 1147–1168. https://doi.org/10.1007/s11121-019-01048-8

Fehily, C., Hodder, R., Bartlem, K., Wiggers, J., Wolfenden, L., Dray, J., Bailey, J., … & Bowman, J. (2020). The effectiveness of interventions to increase preventive care provision for chronic disease risk behaviors in mental health settings: A systematic review and meta-analysis. *Preventive Medicine Reports*, *19*, 101108. https://doi.org/10.1016/j.pmedr.2020.101108

Frank, R. G. (2004). *Behavioral Economics and Health Economics*. Yrjo Jahnsson Foundation 50th Anniversary Conference on Economic Institutions and Behavioral Economics. Retrieved from https://www.nber.org/system/files/working_papers/w10881/w10881.pdf

Fries, J. F., Bruce, B., & Chakravarty, E. (2011). Compression of Morbidity 1980–2011: A Focused Review of Paradigms and Progress. *Journal of Aging Research*, *2011*, 1–10. https://doi.org/10.4061/2011/261702

Gaziano, T. A., & Pagidipati, N. (2013). Scaling Up Chronic Disease Prevention Interventions in Lower- and Middle-Income Countries. *Annual Review of Public Health*, *34*(1), 317–335. https://doi.org/10.1146/annurev-publhealth-031912-114402

Goodchild, M., Perucic, A. M., & Nargis, N. (2016). Modelling the impact of raising tobacco taxes on public health and finance. *Bulletin of the World Health Organization*, *94*(4), 250–257. https://doi.org/10.2471/BLT.15.164707

Government of United Kingdom. (2018). *Sugar tax revenue helps tackle childhood obesity.* Gov.UK Press Release. Retrieved from https://www.gov.uk/government/news/sugar-tax-revenue-helps-tackle-childhood-obesity

Grady, P., & Gough, L. (2014). Self-management: A comprehensive approach to management of chronic conditions. *American Journal of Public Health, 104*(8), 25-31. doi:10.2105/AJPH.2014.302041

Hägerstrand, T. (1970). *What about people in regional science? 24*(1), 7–24.

Hägerstrand, T. (1985). Time-geography: Focus on the corporeality of man, society, and environment. In S. Aida (Ed.), *The Science and Praxis of Complexity: Contributions to the Symposium held at Montpellier* (pp. 193–216). The United Nations University.

Hagger, M., & Weed, M. (2019). DEBATE: Do interventions based on behavioral theory work in the real world? *International Journal of Behavioral Nutrition and Physical Activity, 16*(36). 1-10. https://doi.org/10.1186/s12966-019-0795-4

Halpern, D., & Sanders, M. (2016). *Nudging by government: Progress, impact, & lessons learned.* Behavioral Science & Policy. Retrieved from https://behavioralpolicy.org/wp-content/uploads/2017/06/Sanders-web.pdf

Kahneman, D., & Tversky, A. (1984). *Choices, values, and frames*. *39*(4), 341–350. https://doi.org/10.1037/0003-066X.39.4.341

Kaplan, R. (2009). Health Psychology: Where are we and where do we go from here? *Mens Sana Monographs*, *7*(1), 3–9. https://doi.org/10.4103/0973-1229.43584

Kelly, M., & Barker, M. (2016). Why is changing health-related behavior so difficult? *Public Health, 136.* 109-116. https://doi:10.1016/j.puhe.2016.03.030

Kephart G, Asada Y, Atherton F, Burge F, Campbell LA, Campbell M, Dowling L, … & Terashima M (2016). *Small area variation in rates of high-cost healthcare use across Nova Scotia.* Maritime SPOR SUPPORT Unit. Halifax, Nova Scotia. Retrieved from https://mssu.ca/wp-content/uploads/2021/06/SARV-Final.pdf

Kreuter, M., Chheda, S., & Bull, F. (2000). How does physician advice influence patient behavior? Evidence for a priming effect. *Arch Fam Med, 9*(5). 426-433. doi:10.1001/archfami.9.5.426

Kwan, M.P., & Ren, F. (2008). Analysis of human space-time behavior: Geovisualization and geocomputational approaches. In Hornsby, K.S., & Yuan, M. (Eds.), *Understanding Dynamics of Geographic Domains* (pp. 93-113). CRC Press.

Laxer, R., & Janssen, I. (2014). The proportion of excessive fast-food consumption attributable to the neighborhood food environment among youth living within 1km of their school. *Applied Physiology, Nutrition, and Metabolism, 39*(4). 480-486. https://doi.org/10.1139/apnm-2013-0208

Lenntorp, B. (1999). *Time-geography: At the end of its beginning*. *48*(3), 155–158.

Manton, Stallard, E., & Corder, L. (1997). Changes in the age dependence of mortality and disability: Cohort and other determinants. *Demography*, *34*(1), 135–157. https://doi.org/10.2307/2061664

Marmot, M. G., Kogevinas, M., & Elston, M. A. (1987). *Social/Economic Status and Disease*. *8,* 111-135. https://doi:10.1146/annurev.pu.08.050187.000551

Martin-Misener, R., Valaitis, R., Wong, S., MacDonald, M., Meagher-Stewart, D., Kaczorowski, J., O-Mara, L., … & Austin, P. (2012). A scoping literature review of collaboration between primary care and public health. *Cambridge University Press, 13*(4). 327-346. https://doi.org/10.1017/S1463423611000491

Matthews, S. A., Detwiler, J. E., & Burton, L. M. (2005). Geo-ethnography: Coupling Geographic Information Analysis Techniques with Ethnographic Methods in Urban Research. *Cartographica: The International Journal for Geographic Information and Geovisualization*, *40*(4), 75–90. https://doi.org/10.3138/2288-1450-W061-R664

May, R., Tofler, G. H., Bartrop, R., Heinrich, P., Baird, J., Jozefiak, E., & de Burgh, S. (2010). Smoking Cessation Through a Novel Behavior Modification Technique. *The American Journal of Cardiology*, *106*(1), 44–46. https://doi.org/10.1016/j.amjcard.2010.02.010

McCullough, L. B. (2016). Physicians' Professionally Responsible Power: A Core Concept of Clinical Ethics. *Journal of Medicine and Philosophy*, *41*, 1–9. https://doi.org/10.1093/jmp/jhv034

McQuoid, J., Jowsey, T., & Talaulikar, G. (2017). Contextualising renal patient routines: Everyday space-time contexts, health service access, and wellbeing. *Social Science & Medicine*, *183*, 142–150. https://doi.org/10.1016/j.socscimed.2017.04.043

Mennis, J., Mason, M. J., & Cao, Y. (2013). Qualitative GIS and the visualization of narrative activity space data. *International Journal of Geographical Information Science*, *27*(2), 267–291. https://doi.org/10.1080/13658816.2012.678362

Michie, S., van Stralen, M. M., & West, R. (2011). The behavior change wheel: A new method for characterizing and designing behavior change interventions. *Implementation Science*, *6*(1), 42. https://doi.org/10.1186/1748-5908-6-42

Michie, S., Atkins, L., & West, R. (2014). *The Behavior Change Wheel: A Guide to Designing Interventions.* London: Silverback Publishing.

Milat, A., King, L., Newson, R., Wolfenden, L., Rissel, C., Bauman, A., & Redman, S. (2014). Increasing the scale and adoption of population health interventions: Experiences and perspectives of policy makers, practitioners, and researchers. *Health Research Policy and Systems, 12*(18). 1-11. https://doi.org/10.1186/1478-4505-12-18

Milton, S., Pliakas, T., Hawkesworth, S., Nanchahal, K., Grundy, C., Amuzu, A., Casas, J.-P., & Lock, K. (2015). A qualitative geographical information systems approach to explore how older people over 70 years interact with and define their neighborhood environment. *Health & Place*, *36*, 127–133. https://doi.org/10.1016/j.healthplace.2015.10.002

Mitchell, M., White, L., Paul, O., Alter, D., Leahey, T., Kwan, M., & Faulkner, G. (2017). Uptake of an incentive-based mHealth App: Process evaluation of the Carrot Rewards App. *JMIR Mhealth and Uhealth, 5*(5), e70. https://doi:10.2196/mhealth.7323

Mitchell, M., White, L., Lau, E., Leahey, T., Adams, M. A., & Faulkner, G. (2018). Evaluating the Carrot Rewards App, a Population-Level Incentive-Based Intervention Promoting Step Counts Across Two Canadian Provinces: Quasi-Experimental Study. *JMIR MHealth and UHealth*, *6*(9), e178. https://doi:10.2196/mhealth.9912

Mitchell, J., Hagg, J., Klavetter, E., Beldo, R., Shah, N., Baumbach, L., Sobolik, G., Rutten, L., Stroebel, R. (2019). Development and implementation of a team-based, primary care delivery model: Challenges and opportunities. *Mayo Clin Proc, 94*(7). 1298-1303. https://doi.org/10.1016/j.mayocp.2019.01.038

Mitchell, M., Lau, E., White, L., & Faulkner, G. (2020). Commercial app use linked with sustained physical activity in two Canadian provinces: A 12-month quasi-experimental study. *International Journal of Behavioral Nutrition and Physical Activity*, *17*(1). https://doi.org/10.1186/s12966-020-00926-7

Mobekk, H., Hessen, D., Fagerstrom, A., & Jacobsen, H. (2020). For your eyes only: A field experiment on nudging hygienic behavior. *Front. Psychology, 11*(603440). 1-8. https://doi:10.3389/fpsyg.2020.603440

Mollenkamp, M., Zoppernick, M., & Schreyogg, J. (2019). The effectiveness of nudges in improving the self-management of patients with chronic diseases: A systematic literature review. *Health Policy, 123*(12). 1199-1209. https://doi:10.1016/j.healthpol.2019.09.008

Nilsen, P., Roback, K., Broström, A., & Ellström, P. E. (2012). Creatures of habit: Accounting for the role of habit in implementation research on clinical behavior change. *Implementation Science*, *7*(1), 53. https://doi.org/10.1186/1748-5908-7-53

Nyberg ST, Singh-Manoux A, Pentti J, Madsen, I., Sabia, S., Alfredsson, L., Bjorner, J., … & Kivimaki, M. (2020). Association of Healthy Lifestyle with Years Lived Without Major Chronic Diseases. *JAMA Intern Med, 180*(5), 760–768. https://doi:10.1001/jamainternmed.2020.0618

O'Donoghue, T., & Rabin, M. (2000). The economics of immediate gratification. *Journal of Behavioral Decision Making*, *13*(2), 233–250. https://doi:10.1002/(SICI)1099-0771(200004/06)13:23.0.CO;2-U

Odorico, M., Le Goff, D., Aerts, N., Bastiaens, H., & Le Reste, J. Y. (2019). How To Support Smoking Cessation in Primary Care and The Community: A Systematic Review Of Interventions For The Prevention Of Cardiovascular Diseases. *Vascular Health and Risk Management*, *Volume 15*, 485–502. https://doi.org/10.2147/VHRM.S221744

Orrow, G., Kinmonth, A.-L., Sanderson, S., & Sutton, S. (2012). Effectiveness of physical activity promotion based in primary care: Systematic review and meta-analysis of randomized controlled trials. *BMJ*, *344*(mar26 1), e1389–e1389. https://doi.org/10.1136/bmj.e1389

Public Health Agency of Canada. (2015). *Chronic disease risk factors.* Public Health Agency of Canada. Retrieved from https://www.canada.ca/en/public-health/services/chronic-diseases/chronic-disease-risk-factors.html

Rainham, D., Krewski, D., McDowell, I., Sawada, M., & Liekens, B. (2008). Development of a wearable global positioning system for place and health research. *International Journal of Health Geographics*, *7*(1), 59. https://doi.org/10.1186/1476-072X-7-59

Rainham, D., McDowell, I., Krewski, D., & Sawada, M. (2010). Conceptualizing the healthscape: Contributions of time geography, location technologies and spatial ecology to place and health research. *Social Science & Medicine*, *70*(5), 668–676. https://doi.org/10.1016/j.socscimed.2009.10.035

Reynolds, R., Dennis, S., Hasan, I., Slewa, J., Chen, W., Tian, D., Bobba, S., & Zwar, N. (2018). A systematic review of chronic disease management interventions in primary care. *BMC Family Practice*, *19*(1), 11. https://doi.org/10.1186/s12875-017-0692-3

Riera-Sampol, A., Bennasar-Veny, M., Tauler, P., & Aguilo, A. (2021). Effectiveness of physical activity prescription by primary care nurses using health assets: A randomized controlled trial. *Journal of Advanced Nursing*, *77*(3), 1518–1532. https://doi.org/10.1111/jan.14649

Roberto, C., Bragg, M., Schwartz, M., Seamans, M., Musicus, A., Novak, N., & Brownell, K. (2012). Facts up front versus traffic light food labels: A randomized controlled trial. *American Journal of Preventive Medicine, 43*(2). 134-141. https://doi.org/10.1016/j.amepre.2012.04.022

Rollnick, S., & Miller, W. (1995). What is Motivational Interviewing? *Behavioral and Cognitive Psychotherapy, 23*(4), 325-334. doi:10.1017/S135246580001643X

Rolls, B. J., Roe, L. S., Kral, T. V. E., Meengs, J. S., & Wall, D. E. (2004). Increasing the portion size of a packaged snack increases energy intake in men and women. *Appetite*, *42*(1), 63–69. https://doi.org/10.1016/S0195-6663(03)00117-X

Rondina, R., Hong, M., Sarma, S., & Mitchell, M. (2021). Is it worth it? Cost-effectiveness analysis of a commercial physical activity app. *BMC Public Health*, *21*(1), 1950. https://doi.org/10.1186/s12889-021-11988-y

Rose, G. (1992). The strategy of preventive medicine. Oxford: Oxford University Press.

Shashank, A., & Schuurman, N. (2019). Unpacking walkability indices and their inherent assumptions. *Health & Place*, *55*, 145–154. https://doi.org/10.1016/j.healthplace.2018.12.005

Sox, H. C. (2013). Resolving the tension between population health and Individual Health Care. *JAMA*, *310*(18), 1933–1934. doi:10.1001/jama.2013.281998

Stallard, E. (2016). Compression of Morbidity and Mortality: New Perspectives. *North American Actuarial Journal*, *20*(4), 341–354. https://doi.org/10.1080/10920277.2016.1227269

Stockwell, M., Westhoff, C., Kharbanda, E., Vargas, C., Camargo, S., Vawdrey, D., & Castano, P. (2014). Influenza vaccine text message reminders for urban, low-income pregnant women: A randomized controlled trial. *American Journal Public Health, 104*(1). 7-12. https://doi:10.2105/AJPH.2013.301620

Stover, G., & Bassett, M. (2003). Practice is the purpose of public health. *American Journal of Public Health, 93*(11). 1799-1801. https://doi.org/10.2105/AJPH.93.11.1799

Strazdins, L., Welsh, J., Korda, R., Broom, D., & Paolucci, F. (2016). Not all hours are equal: Could time be a social determinant of health? *Sociology of Health and Illness, 38*(1). 21-42. https://doi.org/10.1111/1467-9566.12300

Sunstein, C., & Thaler, R. (2003). *Libertarian Paternalism Is Not an Oxymoron*. *70*(4), 1159–1202. https://www.jstor.org/stable/1600573

Sui, D. (2012). Looking through Hägerstrand's dual vistas: Towards a unifying framework for time geography. *Journal of Transport Geography*, *23*, 5–16. https://doi.org/10.1016/j.jtrangeo.2012.03.020

Thaler, R., & Sunstein, C. (2008). Nudge: Improving decisions about health, wealth, and happiness. New Haven, CT: Yale University Press.

The Behavioral Insights Team. (2015). *MINDSPACE: Influencing behavior through public policy.* Report for Cabinet Office. Retrieved from https://www.bi.team/wp-content/uploads/2015/07/MINDSPACE.pdf

Tunstall, H., Shaw, M., & Dorling, D. (2004). Places and health. *Journal of Epidemiology & Community Health, 58*(1). 6-10. http://dx.doi.org/10.1136/jech.58.1.6

Vallis, M., Lee-Baggley, D., Sampalli, T., Ryer, A., Ryan-Carson, S., Kumanan, K., Edwards, L. (2018). Equipping providers with principles, knowledge, and skills to successfully integrate behavior change counselling into practice: A primary healthcare framework. *Public Health, 175*(154). 43-53. https://doi.org/10.1016/j.puhe.2019.06.009

Vlaev, I., & Makki, F. (2018). *Applying behavioral insights in health: Tackling key non communicable diseases.* Report of the WISH Policy Briefing on Behavioral Insights. Retrieved from http://www.b4development.org/wp-content/uploads/2019/07/WISH-REPORT-..pdf

Vlaev, I., King, D., Dolan, P., & Darzi, A. (2016). The Theory and Practice of "Nudging": Changing Health Behaviors. *Public Administration Review*, *76*(4), 550–561. https://doi.org/10.1111/puar.12564

Von Korff, M., Koepsell, T., Curry, S., & Diehr, P. (1992). Multi-level Analysis in Epidemiologic Research on Health Behaviors and Outcomes. *American Journal of Epidemiology*, *135*(10), 1077–1082. https://doi.org/10.1093/oxfordjournals.aje.a116207

Wagner, E. (1998). Chronic disease management: What will it take to improve care for chronic illness? *Effective Clinical Practice*, *1*(1), 2–4. Retrieved from https://www.yearofcare.co.uk/sites/default/files/pdfs/What%20will%20it%20take%20to%20improve%20care%20for%20chronic%20illnesses%20Aug-Sept%201998.pdf

Wagner, G. J., & Ryan, G. W. (2004). Relationship Between Routinization of Daily Behaviors and Medication Adherence in HIV-Positive Drug Users. *AIDS Patient Care and STDs*, *18*(7), 385–393. https://doi.org/10.1089/1087291041518238

Wagner, E. H., Flinter, M., Hsu, C., Cromp, D., Austin, B., Etz, R., Crabtree, B., & Ladden, M. (2017). Effective team-based primary care: Observations from innovative practices. *BMC Family Practice, 18*(13). 1-9. https://doi:10.1186/s12875-017-0590-8

Wryobeck, J., & Chen, Y. (2003). Using priming techniques to facilitate health behaviors. *Clinical Psychologist, 7*(2). 105-108. https://doi.org/10.1080/13284200410001707553

World Health Organization. (2020a). *The top 10 causes of death.* WHO Newsroom Report. Retrieved from https://www.who.int/news-room/fact-sheets/detail/the-top-10-causes-of-death#:~:text=The%20world's%20biggest%20killer%20is,8.9%20million%20deaths%20in%202019.

World Health Organization. (2020b). *World health statistics 2020: monitoring health for the SDGs, sustainable development goals.* World Health Organization. Retrieved from https://apps.who.int/iris/rest/bitstreams/1277753/retrieve

World Health Organization. (2021). *World Health Statistics 2021: Monitoring health for the sustainable development goals.* World Health Organization. Retrieved from https://apps.who.int/iris/bitstream/handle/10665/342703/9789240027053-eng.pdf

Zelko, A., Bukova, A., Kolarcik, P., Bakalar, P., Majercak, I., Potocnikova, J., Reijneveld, S. A., & van Dijk, J. P. (2018). A randomized controlled trial to evaluate utilization of physical activity recommendations among patients of cardiovascular healthcare centres in Eastern Slovakia: Study design and rationale of the AWATAR study. *BMC Public Health*, *18*(1). https://doi.org/10.1186/s12889-018-5349-1

Zhao, Z., Etemad, S., & Arya, A. (2016). Gamification of exercise and fitness using wearable activity trackers. In: Chung, P., Soltoggio, A., Dawson, C., Meng, Q., Pain, M. (eds) *Proceedings of the 10th International Symposium on Computer Science in Sports.* Advances in Intelligent Systems and Computing, vol 392. Springer, Cham. https://doi:10.1007/978-3-319-24560-7_30

Zisberg, A., Young, H. M., Schepp, K., & Zysberg, L. (2007). A concept analysis of routine: Relevance to nursing. *Journal of Advanced Nursing*, *57*(4), 442–453. https://doi.org/10.1111/j.1365-2648.2007.04103.x

CHAPTER 3

WHAT CAN GEO-SEQUENCES OF TIME-ACTIVITY DATA TELL US ABOUT STRENGTHENING BEHAVIORAL INTERVENTIONS?

Chapter 3 is formatted for publication with Journal of Preventive Reports. This work has not yet been submitted for publication.

- Behavioral interventions lack important contextual information about where, when, and how routine health activities occur.
- Geo-ethnography methods provide insights for collecting spatiotemporal information about patient day-to-day routines and health activities.
- Behavioral interventions can be strengthened with contextual information about the most opportune time and place to adapt patient routines.

3.0 Abstract

Behavioral interventions are critical for secondary prevention of cardiovascular disease and reducing risk of a repeat event or mortality. However, the effectiveness of behavioral interventions is challenged by poor maintenance of behavior change and lack of spatiotemporal contexts that influence the timing and location in which day-to-day activities occur. This study explored how behavioral interventions could be altered to incorporate spatiotemporal contexts of patient activities for modifying behaviors. Using adapted geo-ethnography techniques and a mixed methods approach, detailed descriptions were collected about patient day-to-day routines, including where, when, and how patients spend time. Data were gathered from patients in one cardiac intervention program in Nova Scotia, Canada, from June to September 2021. A total of 29 individuals (19 men and 10 women) between the ages of 45 to 81 and referred to the program after a cardiac event participated. Results show heterogeneity between patients' behaviors as patients experienced very different space-time contexts. Most patients exceeded minimum guidelines of 30-minutes of daily physical activity but were sedentary for long periods of time. By visualizing behaviors on a space-time continuum this study demonstrates the potential for using adapted geo-ethnography methods to develop a tool

for collecting and communicating spatial and temporal contexts of patient routines, such as the types of activities that characterize how patients spend significant portions of time. Time-use patterns provide insight for tailoring behavioral interventions so that clinic-based settings are generalizable to the contexts of where, when, and how patient routines could be disrupted to mitigate cardiovascular risk factors.

3.1 Introduction

Secondary and tertiary behavioral interventions for cardiovascular disease are critical for management of risk factors and prevention of future cardiac events (Graham et al., 2020). Cardiovascular disease (CVD) (including both ischemic and cerebrovascular disease) is a leading cause of death in the United States and Canada and responsible for more than 30% of all deaths worldwide (Joseph et al., 2017; World Health Organization, 2021a; 2021b). CVD is largely preventable, and interventions focused on sustained modification of high-risk factors through lifestyle and pharmaceutical therapy would significantly curtail risk of CVD and improve population health (Roth et al., 2020; World Health Organization, 2015; 2021c). Reducing the prevalence of risk factors associated with CVD, including high blood pressure, high cholesterol, poor nutrition, smoking, obesity, physical inactivity, and medication adherence, are critical even post-cardiac event to reduce the probability of a repeat event and mortality (World Health Organization, 2015; 2021b).

3.1.1 Advancements to Behavioral Interventions

Characteristics of successful behavioral interventions that reduce risk of CVD or a repeat event most often adopt a theoretical framework, incorporate strategies tailored to individual needs of patients, and use technologies to support adherence to behavior

change. Behavioral interventions that use a theoretically informed intervention design have shown improved outcomes for physical activity (PA) (Room et al., 2017), weight loss, smoking cessation, and management of hypertension, lipids, and blood glucose (Winter, Sheats & King, 2016). Most frequently cited theories within CVD interventions include Social Cognitive Theory, Transtheoretical Model, and Theory of Planned Behavior/ Reasoned Action (Room et al., 2017; Winter, Sheats & King, 2016). Effective behavioral interventions are also flexible enough to incorporate strategies tailored to individuals needs and characteristics (Graham et al., 2020; Guiraud et al., 2012; Nieuwlaat et al., 2013). For example, interventions that use a tailored multifaceted approach with educational resources, mobile text reminders, and individualized counseling from a case manager have been found to improve reduction of CVD risk after a cardiac event (Berwanger et al., 2012). Technology-based interventions have increased adherence to PA using mobile texts, gamified applications, wearable sensors, and telehealth counseling (Ghandi et al., 2017; Winter, Sheats & King, 2016). For example, the use of innovative gamified mobile applications within CVD interventions have shown to improve self-management, knowledge of medications, and reduce risk factors like physical inactivity (Davis, Parker & Gallagher, 2021). Gamification features that were most effective included elements of surprise/ novelty, having teammates, individualized challenges, and stimulating graphic design (Davis, Parker & Gallagher, 2021). While some interventions with these characteristics have shown improved effectiveness for reduction of CVD risk, evaluating the effectiveness of intervention characteristics is complex due to varied design and outcome measures. There is continual debate as to whether interventions focused on single behaviors versus those focused on multiple

behaviors are more effective in promoting health and reducing CVD risk (Nigg & Long, 2012).

3.1.2 Limitations of Behavioral Interventions

Even with advances to improve intervention design (theoretical, tailoring, and technologies), interventions are challenged by poor maintenance of behavior change and lack of spatiotemporal contexts that influence the timing and location in which individual behaviors occur. Clinic-based interventions, in comparison to community-based interventions, are effective when being delivered within organised settings that provide regular contact with healthcare professionals and supportive peer-to-peer interactions. However, when an intervention ends, and patients return to the contexts of their day-to-day lives, they are challenged to maintain health improving routines (Graham et al., 2020). Patients are most challenged by disruptions to routines (McQuoid, Jowsey & Talaulikar, 2017), time management (Alageel et al., 2018), recall of intervention information (Gregory, Bostock & Backett-Milburn, 2006; Guiraud et al., 2012), and diminished motivation without regular contact from healthcare professionals and peers (Bray, Brawley & Millen, 2006). These challenges have been countered by tailoring individualized approaches (Coorey et al., 2020; Nieuwlaat et al., 2013). Yet it is less evident how the majority of these interventions are tailored to the contexts outside clinic-based settings that influence where, when, and how health activities occur. For example, PA prescriptions within clinic-based settings (Leijon et al., 2010; 2011), use generic recommendations and are focused on individuals without accounting for the unique contexts of day-to-day activities that occur within environments (physical or social) sometimes beyond their control. Yet, we know social and physical environments play an

important role in promoting or inhibiting health behaviors (Macintyre, Ellaway & Cummins, 2002), including contexts that influence the timing and location of day-to-day activities. Assessing the unique spatiotemporal contexts of patients' day-to-day activities is critical for tailoring interventions strategies so that clinic-based settings are generalizable to the contexts around patients.

3.1.3 Methods to Assess Contexts Influencing Behaviors

Different ways to assess contexts of health activities include time-use techniques, map-based questionnaires, accelerometers (and other activity monitoring sensors), global positioning system (GPS) data loggers, or combinations of techniques. Time-use measurements provide a way to examine temporal dimensions of activities, commonly through diaries or survey-based methods that identify patterns in activities of daily living (Bauman, Bittman & Gershuny, 2019; Chau et al., 2019). For example, time-use diaries have been used to assess how individuals adjusted daily activities during different phases of COVID-19 public health restrictions in the United Kingdom (Sullivan et al., 2021). Time-use surveys have also been used to improve national surveillance of PA, like the American Time-Use Survey, assessing the amount of time people spend engaging in various activities including paid employment, unpaid caregiving, and leisure (Tudor-Locke, Johnson & Katzmarzyk, 2010). Map-based questionnaires gather context through a combination of online mapping software for collecting locational coordinates of activities in addition to survey questions for gathering context (Hinrichs et al., 2020; Rantanen & Kahila, 2009). For example, map-based questionnaires have advanced disease surveillance in rural areas of Philippines and Indonesia by locating households of clinic attendees to estimate the magnitude and heterogeneity of malaria transmission

where formal addresses are unavailable (Fornace et al., 2018). Wearable motion-sensing technologies like accelerometers have commonly been used to gather more reliable estimates of PA and sedentary behaviors (Sasaki et al., 2016). For example, accelerometers have been useful for measuring the level of exertion according to cut points associated with metabolic equivalents (MET scores) for large scale epidemiologic studies (Lee & Shiroma, 2014). Wearable GPS data loggers can accurately record movement patterns and can assist in identifying the contexts and timing of health-related behaviors (Perchoux, Chaix & Kestens, 2019; Rainham et al., 2008). For example, GPS data have been used to estimate exposures to both health promoting (e.g., interactions with green spaces) and health harming (e.g., areas with poor air quality) contexts (Fuller & Stanley, 2019; Nethery et al., 2014). Innovative methods using a combination of the approaches mentioned above contribute enriched understanding of the contexts in which health-related behaviors occur. For example, GPS and accelerometer data have been used to contextualize supportive environments of PA for youth by identifying where, when, and how much PA they engage in (Oreskovic et al., 2012). Another method known as ecological momentary assessment (EMA) uses an electronic device to notify participants at fixed or random times throughout the day to respond to survey questions about when, where, what and with whom behaviors occur (Dunton, 2017; Stone & Shiffman, 1994). EMA generates real-time information on participants' behaviors, perceptions, and emotions, when they occur in natural environments with repeated occurrence and observations of events over time (Degroote et al., 2020). For example, EMA has been used to explore daily patterns of park use, leisure-time physical activity, and perceptions of stress (Park et al., 2022). EMA daily surveys indicate that when participants visited a

park during the day they reported less stress in the evening in comparison to participants that did not visit parks (OR=0.67; 95% CI=0.58-0.77), and when daily park use occurred with leisure-time physical activity participants reported less stress (OR=0.58; 95% CI=0.59-0.69) in comparison to participants engaging in only 1 of the 2 activities (Park et al., 2022).

The previously discussed examples are some of the possible ways to assess context of health-related activities yet, behavioral interventions delivered through clinical settings rarely have the resources to obtain valuable information about patient behaviors at different times and locations. Geospatial methods provide an opportunity to strengthen the effectiveness of behavioral interventions by tailoring strategies based on information about patients' spatiotemporal patterns of health behaviors. However, in the context of clinic-based behavioral interventions there may be challenges for integrating different geospatial methods. For example, time-activity diaries require daily reminders for patients, experience under-reporting of short duration activities, and are not always designed to capture locations of activities (Chau et al., 2019). Wearable accelerometer sensors require specialized expertise to prepare, distribute and analyze data, and are not yet advanced enough to reliably measure different types of physical activity (e.g., weightlifting, sitting, standing) (Lee & Shiroma, 2014). Wearable GPS loggers also require expertise to prepare and analyze data, are costly, require multiple sensors to link health behaviors to locations, and lack information on the types of health behaviors performed (e.g., nutrition behaviors, sedentary activities) (Oreskovic et al., 2012). Despite these challenges, a visualization of spatiotemporal patterns of health behaviors

are important for tailoring intervention strategies by identifying opportunities or constraints for behavior change and supporting patients across diverse contexts.

3.1.4 Aim and Objectives

In this paper we explore the application of a mixed-methods approach known as geo-ethnography to gather spatiotemporal information about the contexts influencing patients' day-to-day routines and identify opportunities for adapting modifying behaviors. The aim of this study is to explore how behavioral interventions can solicit information from patients about the spatiotemporal contexts in which their health behaviors occur and how this information can be used to influence the design of interventions. To achieve this aim, this study answers two specific research objectives:

1.) Develop an approach for collecting spatiotemporal information about patients' day-to-day health activities
2.) Identify how interventions can use spatiotemporal information about patients' day-to-day health activities to overcome challenges within clinical interventions

3.2 Methods

3.2.1 Research Setting

This study took place at a cardiac prevention and rehabilitation intervention program for patients at high risk for CVD or having recently experienced a cardiac event. Patients are referred to the program by a primary care provider or by hospital outpatient services after experiencing an event. The goal of cardiac prevention and rehabilitation intervention programs is to support patients with behavior change to improve nutrition and increase PA. Programs deliver a series of health education and PA classes that are led

by a collaborative team of healthcare professionals including a dietician, nurse practitioner, physiotherapist, and cardiologist.

The cardiac program purposively selected as the research setting has a heterogenous patient population that lives across urban and rural communities. Previously delivered in-person over 12-weeks, when data collection began in June 2021, due to COVID-19 the cardiac program was condensed to a 6-week hybrid model comprising in-person PA and virtual education classes.

Prior to enrollment in the cardiac program, patients complete an intake assessment to gather baseline health measures from blood work, a PA stress test, medical records, and current level of PA and eating habits. Patients attend a weekly 1-hour virtual education class via Zoom and 1-hour in-person PA class. The education sessions focus on a range of health topics incorporating evidence-based guidelines for PA, nutrition, risk factors, stress, and medications. PA classes are structured as circuit training, with a 15-minute warm up and cool down, and 30-minute rotation between a stationary bicycle, treadmill, and weighted strengthening exercises. Patients receive an individualized bi-weekly phone-call with a healthcare professional to discuss any questions or medical concerns. At the end of the 6-week program, patients complete a follow-up assessment to compare blood work, level of PA and dietary habits.

3.2.2 Geo-ethnography Techniques

There are a range of geospatial methodologies that can be employed to gather critical insights into contexts connecting people, time, and place (Tunstall, Shaw, & Dorling, 2004). Geo-ethnography is one mixed-methods approach used to identify locational information along with contextual descriptions of what, when, why and with

whom activities occur (Matthews et al., 2005; Milton et al., 2015). The significance of mixed-method techniques like geo-ethnography is that they contribute to a comprehensive understanding of quantitative patterns of behavior with qualitative contexts of perceptions, experiences, and social relationships that influence why individuals make decisions about their activities (Matthews et al., 2005; MacNell, 2018). For example, geo-ethnographic methods have been employed to explore how food insecurity affects low-income urban and rural women by exploring spatial patterns and contexts of food shopping behaviors (MacNell, 2018). The coupling of ethnographic data with geospatial techniques provides a different approach for contextualizing the complexity of patients' daily activities.

Geo-ethnographic techniques include visualizing routine activity patterns that interviews alone would not represent, such as locations of resources and different routes individuals must travel to navigate healthcare appointments, childcare, or commuting for employment (Matthews et al., 2005). Furthermore, an in-depth understanding about the contexts that influence activity patterns provides details about activities that maps alone would not represent, such as having fewer social supports, concern of neighborhood safety, or access to transportation (MacNell, 2018). To answer each research objective, first this study explored a way of adapting geo-ethnographic methods to collect spatiotemporal contexts of patient health behaviors, and second, how this information could be used within an intervention as a data collection and communication tool to modify behavior change.

3.2.3 Study Design

To solicit patients' spatiotemporal patterns of health activities, we applied a mixed-methods approach to gather detailed descriptions about day-to-day routines, including where, when, and how patients spend their time. This study design was adapted from the geo-ethnographic methods proposed by Matthews et al., 2005 by engaging patients in two semi-structured qualitative interviews supported by a digital mapping tool. The ESRI Field Maps application was used to create a customized digital mapping tool for capturing locations of patients' activities during in-person interviews. The online mapping tool was developed for field data collection activities where data are geocoded and stored in a database for further analysis. This digital map tool was customized through an ArcGIS online account that was used to create individual layers of the features and fields for data collection (see Table 3.1). Each layer was assigned a field value to further define the types of activities each patient described. Table 3.1 presents each layer name, feature class, field ID, and value ID that was assigned to patient activities during interviews. A visualization of the Field Maps application is included as supplemental material in Appendix A.

Table 3.1 Data Attributes in Esri Field Maps

Layer Name	Feature Class	Field ID	Value ID	
Patient ID	Point	ID	P01-P29	
Activity	Point	Activity	Walking	Running/Jogging
			Bicycling	Yoga/ Stretching
			Strength Training	Playing Sport
			Swimming	Gardening
			Housework	Watching TV
			Cooking/ Baking	Shopping
		Food	Grocery Store	Restaurant
			Fast Food	Local Market
			Convenience Store	Specialty Store
			Bar/ Brewery	Meal at home
			Café	
		Social	Family	Friends
		Occupational	Employment	Volunteer
			Caregiver	
		Place of Exercise	Gym Membership	Park
			Community Rec Centre	Home
			Mall/ Shopping Centre	Senior Centre
			Outdoor place	Home Condo Facilities
		Healthcare	Health Care Appointment	Hospital
Transportation	Point	Mode of Transportation	Car	Public Bus
			Walk	Bike
Home	Point	Dwelling Type	House	Condo
			Apartment	

Patients were interviewed in-person by the first author at the cardiac program between June to September 2021. Patients interacted with the online mapping tool and were asked to identify the exact locations where they live and work, and the types of activities that comprise their day-to-day routine. Interviews were audio-recorded and structured to gather contextual information about patients' time-use patterns, including where and when activities occurred, how much time was spent during each activity, as well as whether the activity was performed alone or with others. Patients were asked, "How would you describe your typical routine on a given day, beginning with what time

you wake up in the morning?" "What can you tell me about how your routine changes in a week?"

3.2.4 Patient Recruitment

Patient cohorts enrolled in the cardiac program were purposively selected to participate in this research study. Purposeful recruitment began with cohorts of 8 to 10 patients in week 2 or 3 of the 6-week program. Potential patients were first approached for recruitment by a healthcare professional who provided information about the purpose of the study and what would be required to participate. Patients who agreed to be contacted by the primary researcher provided their phone number and first name. The recruitment process was repeated with 5 different patient cohorts, recruiting 6 patients from each cohort, to gather a sample size sufficient for qualitative saturation (Hennink & Kaiser, 2022). To acknowledge the time commitment required for patients to be interviewed in this study, every patient was offered an honorarium in the form of a $25 (CAD) gift certificate to a grocery store.

3.2.5 Ethical Approval

Ethics approval for this study was obtained from Nova Scotia Health Authority (REB#1026722). All patients provided informed consent for their personal health information to be included in research results.

3.2.6 Analysis

Interviews were audio-recorded, transcribed verbatim, and then coded by the first author with the aid of QSR NVivo12 qualitative data analysis software (QSR International Pty Ltd, 2020). Interview transcripts were openly coded by grouping patient activities into categories of time-use. The first author coded patient activities and time

expenditure directly from interview transcripts so that the time and location of each activity could be stacked within a 24-hour period to create a sequence of routine time-use. Supplemental information on distances and locations retrieved from data in Field Maps. Approximate commute times between two locations were verified using Google maps.

Geo-ethnographic mixed-method analyses have previously been used to develop map-based visualizations of spatiotemporal contexts where activities take place including locations of points of interest, neighborhood boundaries, built environments, and routine distances travelled (Matthews et al., 2005; MacNell, 2018). For example, MacNell (2018) used geo-ethnographic methods to analyze quantitative data from patient interviews by geo-coding the locations of grocery stores and patients' home address to calculate the distances patients travelled outside their neighborhood to shop at a preferred grocery store. This study adapted geo-ethnographic analyses to develop a clinical tool that could visually represent important contextual information about what, when, where, and with whom activities occur.

Using quantitative data in Field Maps and qualitative interview data, the first author created map-based visualizations of the first five patients' routine activities. The research team held regular meetings to discuss ways of visually representing sequencing of activity times and locations, including the contexts of what activities occurred at different locations, when and for how long activities took place, and with whom activities occurred. The research team deliberated the complexity and applicability of map outputs within clinic-based settings and discussed challenges of interpreting map-based visualizations of patients' day-to-day routines such as limitations of identifying the

sequences of time to depict when and for how long certain health activities occurred. The idea of representing time-use patterns within a stacked bar chart was reached by discussing how spatiotemporal data from geo-ethnographic techniques could be combined with time-use diaries (Sullivan et al., 2021) to represent the sequencing of timing and locations of patients' day-to-day activities. A visualization of stacked bar charts was customized by ordering patient activities into a 24-hour time sequence and then coding by location to depict unique geo-sequence patterns of behavior.

Emergent activity categories included sleep, sedentary behavior, light PA, and MVPA. Definitions of activity categories (see Table 3) were created by comparing descriptions of patient activities with evidence-based guidelines of PA (ParticipACTION, 2021; The Canadian Association for Exercise Physiology, 2021; Tremblay et al., 2017). The first author completed coding of data twice, 1-week apart, to ensure intra-coder reliability of results (Moore et al., 2019). Coding of time-use patterns was completed by manually entering time-use data into a Microsoft Excel spreadsheet to record the length of time and location each activity was performed for all patients. Results of coding were reviewed by two researchers (DR, GK), then compared to detect inaccuracies, and a final version of validated results was used to create a stacked bar chart of patient routine activities. The process of coding and validating time-use data was repeated for patients' atypical routine activities. Each stacked bar chart was manually edited within Excel to color code patient activity categories and provide labels with a corresponding legend to specify different types of activities.

Table 3.2 Levels of Activity Terms and Definitions

Term	Definition
Sleep (S)	Sleep routine is an important component of health that affects attention, behavior, memory, and overall mental and physical health. Not getting enough quality sleep is linked to a wide variety of health problems including obesity, type 2 diabetes, cardiovascular disease, and depression.[1] Canadian guidelines recommend getting 7 to 9-hours of quality sleep on a regular basis, with consistent bed and wake-up times.[1,2]
Sedentary Behavior (SED)	Sedentary behavior is any waking behavior characterized by very low energy expenditure below 1.5 METs (i.e., less than 1.5-times the intensity of rest) while standing, sitting, reclining, or lying down.[1,3] Canadian guidelines recommend limiting sedentary time to 8-hours or less including no more than 3-hours of recreational screen time and breaking up long periods of sitting as often as possible.[1,2]
Light Physical Activity (LT)	Light intensity activities require low levels of energy and effort performed between 1.5 and 3 METs (i.e., greater than 1.5 but less than 3-times the intensity of rest). Light physical activity includes walking at a slower pace, standing work, or light housework.[1] Canadian guidelines recommend getting at least 3-hours of light physical activity per day.[1]
Moderate to Vigorous Physical Activity (MV)	Moderate to vigorous physical activity is movement that requires substantial energy expenditure above resting levels performed above 3 METs (i.e., greater than 3-times the intensity of rest).[1,2] Moderate to vigorous physical activity includes a variety of activities and intensities like swimming, brisk walking, jogging, rowing, weightlifting, or bicycling. Canadian guidelines recommend participating in at least 30-minutes per day or 150-minutes per week of moderate-to-vigorous physical activity.[1,2]

[1] ParticipACTION. The future is physical: Moving to a better normal. The 2021 ParticipACTION Report Card on Physical Activity for Adults. Toronto: ParticipACTION; 2021. Retrieved from ParticipACTION.com
[2] The Canadian Society for Exercise Physiology. The Canadian 24-Hour Movement Guidelines for Adults. 2021. Retrieved from csepguidelines.ca
[3] Tremblay MS, Aubert S, Barnes JD, *et al.* Sedentary Behavior Research Network (SBRN) – Terminology Consensus Project Process and Outcome. *Int J Behav Nutr Phys Act* **14,** 75 (2017).

3.3 Results

We conducted 58 interviews with 29 patients (19 men and 10 women). Two interviews were conducted with each patient, lasting on average 71 minutes (range of 37 to 110 minutes). A total of 31 individuals were recruited as potential patients however, 2

dropped out of the study before the first interview due to lack of time to participate. A summary of patient characteristics is provided within Table 3.3. Almost all patients were between the ages of 45 to 81, married/ common-law, and had a college or university degree. Most patients were employed full-time or retired. Approximately half of patients were a non-smoker or previous smoker, and only 1 patient was a current smoker. Patients were typically referred to the cardiac program after experiencing myocardial infarction. Two patients were referred to the program for prevention with no self-reported comorbidity. All patients completed the entire 6-week program.

Table 3.3 Description of Patient Characteristics

Age	**n**	**%**
45-54	7	24%
55-64	7	24%
65-74	9	31%
75-84	6	21%
Sex		
Male	19	66%
Female	10	34%
Education Level		
High School	5	18%
College / Trades	12	41%
University / Graduate Degree	12	41%
Marital Status		
Married / Common-law	22	76%
Single / Widow	7	24%
Household Composition		
Alone	7	24%
With partner	15	52%
Partner and children	7	24%
Employment Status		
Part-time	2	7%
Full-time	15	52%
Retired	12	41%
Smoking Status		
No	14	48.5%
Current smoker	1	3%
Previous smoker	14	48.5%
Reason for Referral		
Prevention – no comorbidity	2	7%
Heart attack / Stroke – no comorbidity	14	48.5%
Heart attack – comorbidities	13	44.5%

3.3.1 Sequencing and Visualization of Time-use Patterns

Results from patients' spatiotemporal patterns of health activities are presented visually as time-use patterns (See Figures 3.1 & 3.2). Two stacked bar charts were used to represent differences between patients' routine and atypical time-use patterns. The visualization of spatiotemporal sequences enables quick insight of the patterns in timing and location of health behaviors across patient groups, with details of individual differences in health behaviors between patients. A summary of total time spent in each activity category was calculated for each patient, with boxes to indicate when patients' activity levels were less than the minimum or greater than the maximum recommended guideline per day. Activity levels were converted to a percentage of 24-hours. Commute times were accounted for when they could be estimated between two known locations, otherwise irregular commute times were grouped within activity time. Participants were asked to describe their routine activities in a week and how their routines might change in a week to depict atypical routines. Patients' typical and atypical time-use sequences are presented in Figure 3.1 and 3.2 in order of when they were assigned a unique ID. Additional ways of stratifying patients' typical time-use sequences are presented by stratifying patients' reported time spent engaging in MVPA from highest to lowest based on sex in Figure 3.3 and employment status in Figure 3.4.

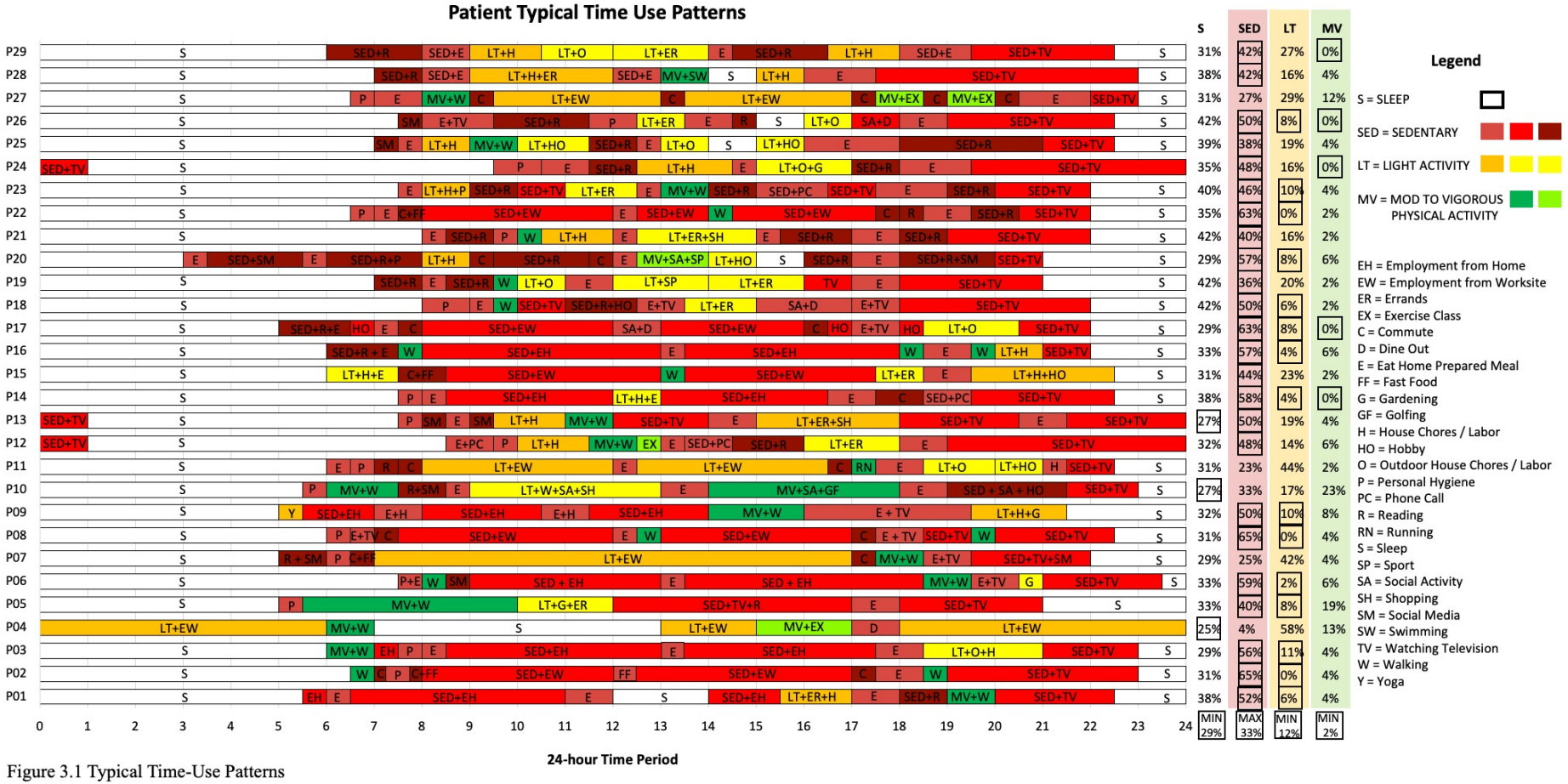


Figure 3.1 Typical Time-Use Patterns

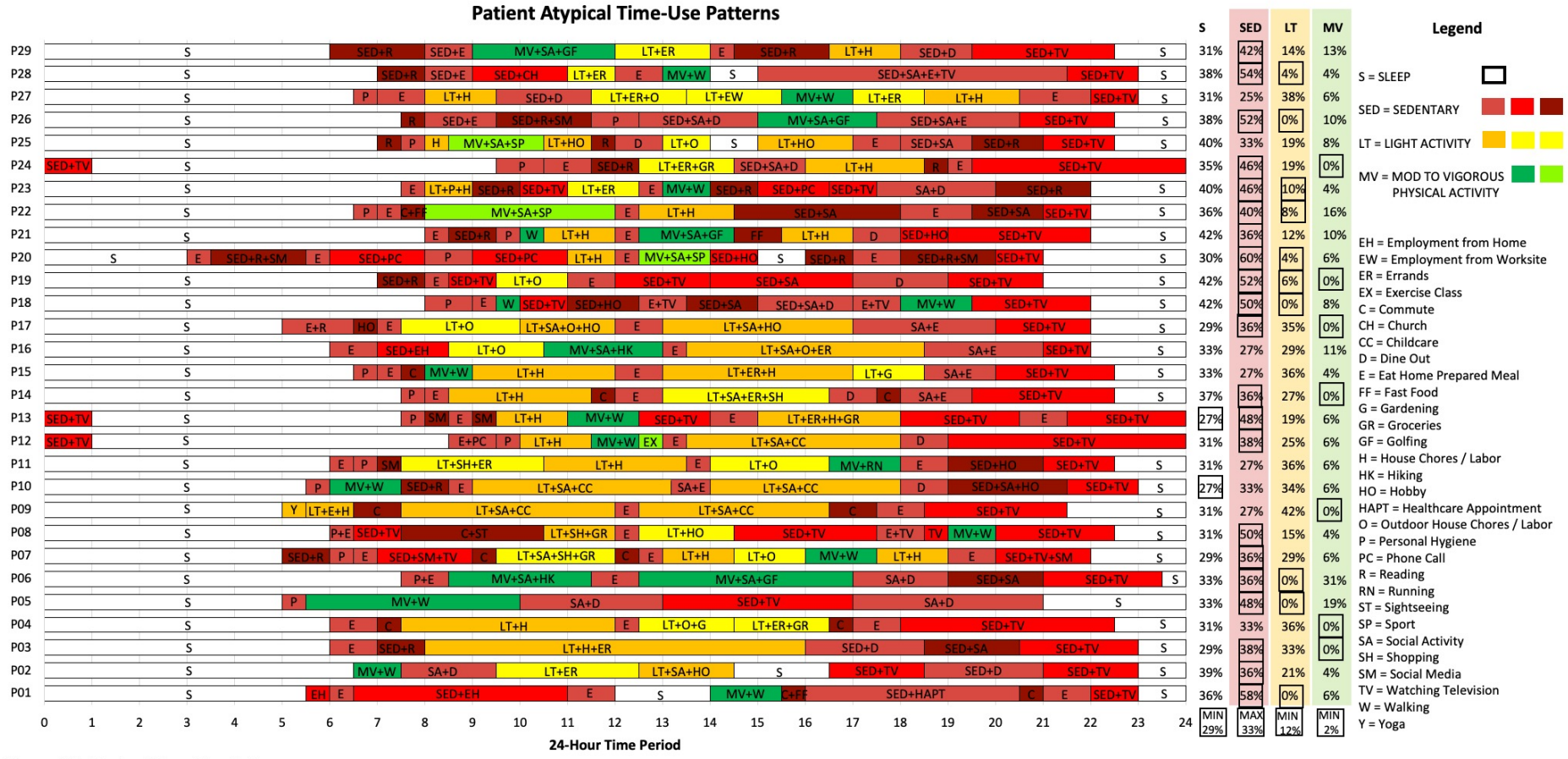


Figure 3.2 Atypical Time-Use Patterns

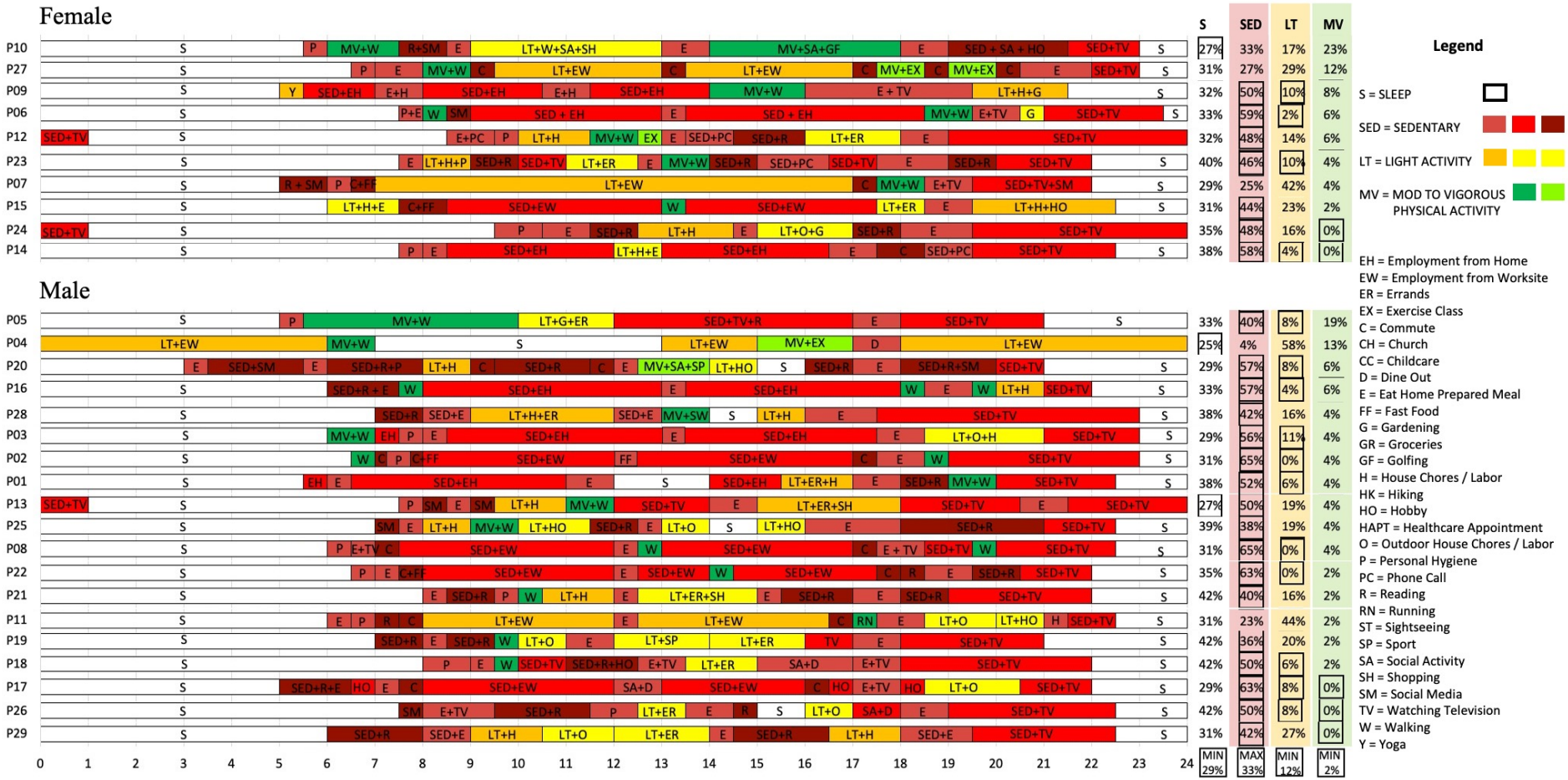


Figure 3.3 Typical Time-Use Patterns By Sex

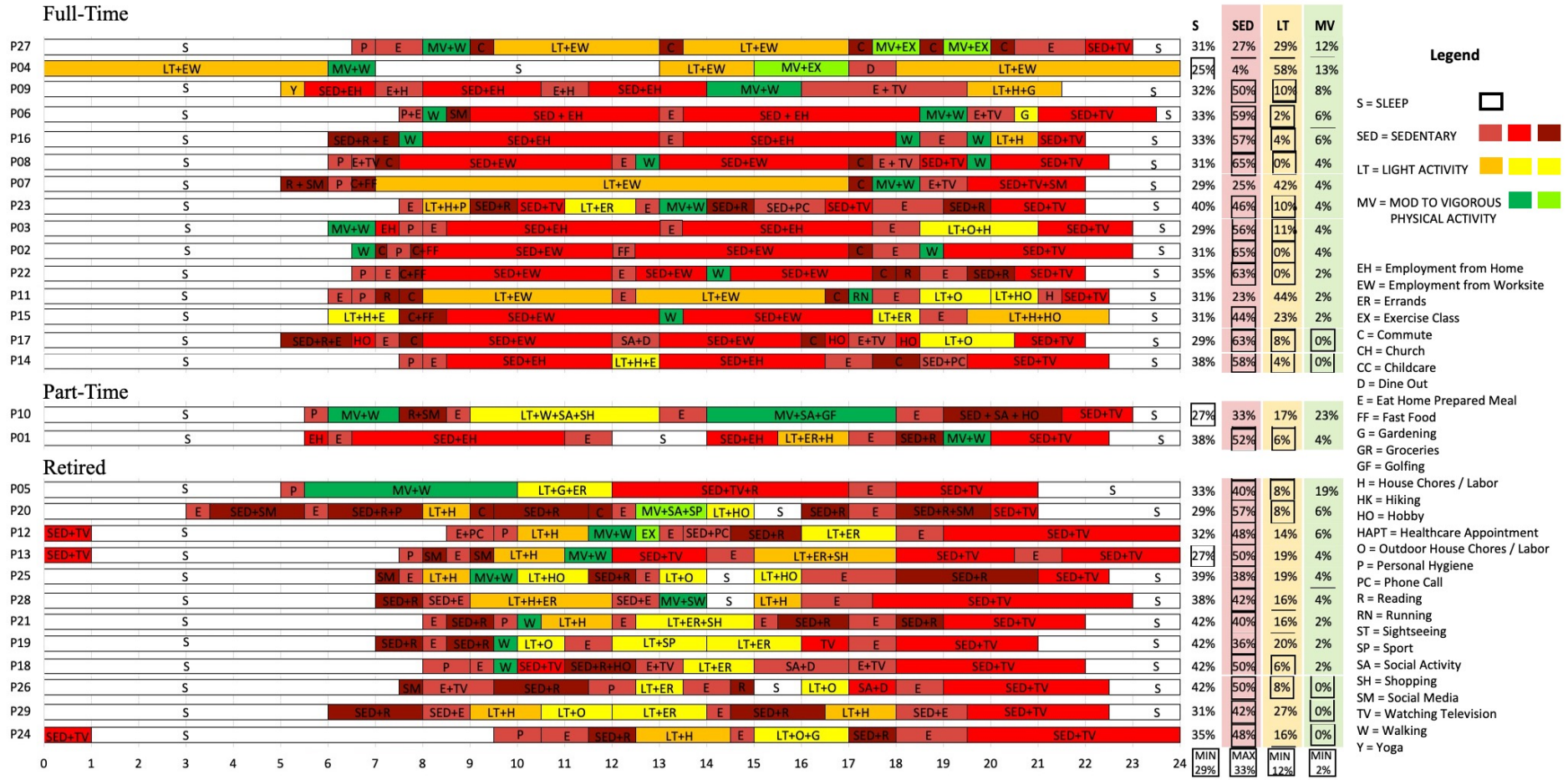


Figure 3.4 Typical Time-Use Patterns By Employment Status

3.3.2 Summary of Time-use Findings

A summary of patients' time-use results is presented within Table 3.4.

Table 3.4 Summary of Time-Use Patterns

	Routine			Atypical		
	n	Av. Time (range)	Av. %	n	Av. Time (range)	Av. %
Sleep						
>= 7-hour Minimum Guideline	26	8.25 (7 – 10)	34%	27	8.25 (7 – 10)	34%
< 7-hour Minimum Guideline	3	6.25 (6 – 6.5)	26%	2	6.5 (6.5)	27%
Total Sleep Activity	29	8 (6 – 10)	33%	29	8.15 (6.5 – 10)	34%
Sedentary Activity						
>= 8-hour Maximum Guideline	24	12.25 (8.5 – 15.5)	51%	21	10.6 (8.5 – 14.5)	45%
< 8-hour Maximum Guideline	5	5.4 (1 – 8)	22.5%	8	7 (6 – 8)	29%
Total Sedentary Activity	29	11 (1 – 15.5)	46%	29	9.6 (6 – 14.5)	40%
Employment from Home	6	7 (5 – 9)	29%	1	4.5	19%
Employment from Worksite	5	8 (7 – 8.5)	33%			
Watching Television	27	3.5 (1 – 8)	14.5%	29	3.2 (1 – 7.5)	13%
Reading	19	2 (0.5 – 3.5)	8%	13	2 (1 – 4)	8%
Social Activities	4	1.6 (1 – 2.5)	7%	15	3 (1.5 – 7)	12.5%
Light Physical Activity						
>= 3-hour Minimum Guideline	14	6.25 (4 – 14)	26%	19	6.5 (3.5 – 10)	27%
< 3-hour Minimum Guideline	15	1.4 (0 – 2.5)	6%	10	0.8 (0 – 2.5)	3%
Total Light Physical Activity	29	3.7 (0 – 14)	15%	29	4.5 (0 – 10)	19%
Employment from Worksite	4	9.75 (7 – 14)	40%			
House Chores / Labor	14	2 (1 – 2.5)	8%	17	3 (0.5 – 8)	12.5%
Moderate to Vigorous Physical Activity (MVPA)						
>= 30-min Minimum Guideline	24	1.5 (0.5 – 5.5)	6%	22	2.15 (1 – 7.5)	9%
< 30-min Minimum Guideline	5	0	0%	7	0	0%
Total MVPA	29	1.2 (0.5 – 4.5)	5%	29	1.6 (0 – 7.5)	7%
Walking	21	1.2 (0.5 – 4.5)	5%	14	1.4 (0.5 – 4.5)	6%
Exercise Class	3	1.5 (0.5 – 2)	6%	1	0.5	2%
Golf	1	4	16.5%	4	3 (2 – 4.5)	12.5%

3.3.3 Routine Time-use Patterns

Patients' time-use patterns in Figure 3.1 show close to all patients engaged in a minimum of 30-minutes of MVPA when walking alone in their neighborhood early morning or around dinner time in the evening. Few patients engaged in MVPA social activities like exercise classes or sports as part of their routine. Substantial amounts of time were spent in sedentary activities. Patients were sedentary for long periods of time mid-day while working at home or at a worksite, and end-of-day while watching television or reading. Most sedentary activities occurred after dinner when patients were at home and watching television alone or with family. Periods of light PA occurred mid-day while at work, running errands or shopping, with some light PA occurring at home for house chores, outdoor labor, or gardening. Almost all patients met the daily minimum guidelines for sleep every day. A typical routine for P01 includes working from home for 6-hours, eating meals at home, having a nap in the afternoon, doing errands and housework, walking for 1-hour in the evening, and watching television for 2.5-hours before bed.

3.3.4 Atypical Time-Use Patterns

Results from atypical time-use patterns in Figure 3.2 show that patients were less sedentary overall (Table 3.4) during the day when they were not working. In comparison to routine time patterns, patients were sedentary in the morning while at home, or during the evening for social activities like dining-out with family and friends. Almost all patients were sedentary at home after eating dinner and watching television alone or with family. Atypical time patterns show there were small differences between routine and atypical time patterns (Table 3.4) however, more patients were engaged in light PA mid-

day while at home for house chores/ labor, or out running errands and shopping. Patients spent more time engaging in MVPA in the morning and mid-day when walking alone in their neighborhood or when playing a sport or hiking with friends or family. There were very small differences in patients' average sleep patterns between typical and atypical time patterns (Table 3.4). An atypical routine for P01 includes working from home for 5-hours, eating meals at home, having a nap in the afternoon, walking for 1.5-hours, eating take-out on the way to a healthcare appointment lasting 4.5 hours, and returning home to watch television before bed.

3.3.5 Stratifying Typical Time-Use Patterns

Results from typical time-use patterns could be stratified to visualize differences in patient behaviors. Stratifying typical time-use patterns by sex in Figure 3.3 shows female identifying patients (n=10) were on average more active with 1.5 hours of MVPA in comparison to male identifying patients (n=19) that reported on average 1 hour of MVPA. Female and male identifying patients participated in similar types of MVPA such as walking and exercise class or sports. There were small differences in behaviors between female and male identifying patients, as female identifying patients engaged in similar sedentary and light physical activity like reading, watching television, running errands, and house chores/ labor. There were small differences in sleep patterns and male identifying patients reported on average 1 hour of sleep during the day whereas female identifying patients did not report sleeping during the day.

Stratifying typical time-use patterns by employment status in Figure 3.4 shows variability between patients that were employed full-time (n=15), part-time (n=2), and retired (n=12). Patients employed full-time had less variability in activities throughout

their day and were sedentary for longer periods of time while working in comparison to patients that were employed part-time or retired and were engaged in many different light physical activities for shorter periods of time throughout their day. Patients employed full-time engaged in less MVPA throughout their day by walking in their neighborhood at the start or end of their day. Retired patients engaged in more MVPA and light activities throughout their day, including different activities like sports, swimming, running errands, and house chores/ labor. Retired patients were sedentary for longer periods of time at the end of their day while watching television in comparison to patients that were employed full-time and part-time.

3.4 Discussion

The aim of this study was to explore how behavioral interventions could gather spatiotemporal information about the contexts influencing patients' day-to-day routines and identify opportunities for adapting modifying behaviors. A visualization of spatiotemporal patterns of patient health activities provides important insight for interventions to use information about unique contexts of where, when, and how patients spend time. Results show most patients were engaged in MVPA by walking alone in their neighborhood but were largely sedentary at home while working or watching television for long periods of time day-to-day. Time-use patterns provide a visualization of patients' unique geo-sequencing of activities (Abbott, 1995; Shoval & Isaacson, 2007), including important contextual information that influence how routines are developed day-to-day. The use of geo-ethnographic techniques was useful for identifying contexts surrounding patient day-to-day activities and understanding how spatiotemporal patterns could be

used to adapt secondary interventions by tailoring context specific strategies to the most opportune time and place for disrupting routines and modifying behavior change.

3.4.1 Clinical Relevance of Time-Use Patterns

Intervention strategies like prescribed PA have been used in clinic-based settings for over 15 years (Leijon et al., 2010) yet, have shown limited effectiveness for sustained increases in PA (Muller-Riemenshneider et al., 2020; Leijon et al., 2011; Orrow et al., 2012; Riera-Sampol et al., 2020). Poor adherence to generic recommendations like PA prescriptions presents an opportunity for tailoring clinic-based intervention strategies by using information about contexts of patient day-to-day routines that are amenable to change. Results from this study have clinical relevance for identifying where, when, and how to support patients with different behavior change goals. An example of four patient time-use patterns (see Figure 3.3) illustrates how time-use patterns could be applied within a clinic-based behavioral intervention.

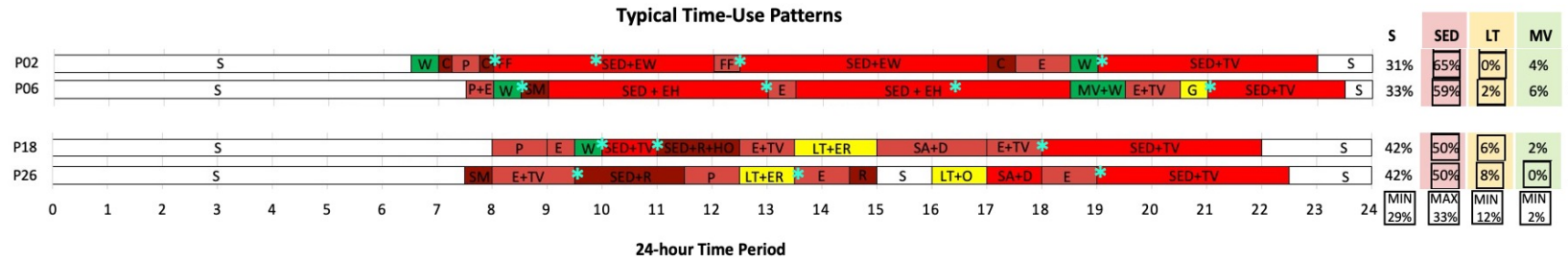


Figure 3.5 Clinical Relevance of Time-Use Patterns

* Opportunity for Intervention

The unique contexts of time-use patterns are shown in Figure 3.3 for two patients employed full-time (P01, P06) and two patients retired (P18, P26). These patients spend significant portions of time sedentary with very little time spent in light PA. The light blue stars within Figure 3.3 demonstrate when and where intervention strategies could be used to disrupt routines and encourage patients with adapting habits, such as breaking up long periods of sedentary activity. For example, time-use patterns for P18 show that after a morning walk in their neighborhood, they are sedentary while at home watching television and reading. Knowing that P18 watches the same television show at 10:00 on weekdays provides context for tailoring specific recommendations, such as encouraging P18 to gradually increase the pace and distance covered without changing the amount of activity time spent walking. P18 could also be encouraged to adapt sedentary activity during 11:00 to 12:30 when they are usually reading. Tailored recommendations could include encouraging P18 to listen to an audiobook while engaging in some form of light to MVPA like a leisurely walk or housework/ labor. Lastly, P18 is largely sedentary at home during the evening after dinner when they are watching television. Integrating some form of light to MVPA like engaging in stretching and strengthening exercises while watching television could encourage small incremental changes to established routines.

Understanding the context surrounding where and when day-to-day routines occur is important for providing tailored recommendations that can be integrated within established routines. For example, patients that spend significant portions of time at home are more likely to adhere to specific recommendations for integrating home-based light PA or MVPA into existing routines versus generic recommendations that require new

routines like going to a recreation facility to engage in PA (Leijon et al., 2010). The potential opportunities for disrupting routines represented within Figure 3.3 emphasize the importance of meeting patients where they are by engaging with patients that are at different stages of readiness to change (Mauriello, Johnson, & Prochaska, 2017).

Visually displaying patients' time-use sequences provides insight into how data could be organized and stratified so that differences in patient behaviors can be easily interpreted. Stratifying patients' time-use patterns by age, sex, employment status, time spent at home or away from home, and level of PA could be powerful for identifying intervention strategies that could be integrated into existing routines for as many patients as possible. For example, understanding how much time patients spend at home or away from home is important for working with patients to develop context specific intervention strategies based on where and when opportunities exist to disrupt day-to-day routines.

In addition to stratifying patient results, different color-code schemes could be used to highlight time-use patterns specific to behavior change goals like medication adherence, diet, or other self-management of chronic illness tasks. For example, identifying where and when patients take medications could inform how interventions could be tailored to improve medication adherence based on knowledge of where and what patients are doing, or whether medication times could be adjusted to a more opportune time and place based on patient routines. The color-coding schematic chosen for time-use patterns was intended to emphasize levels of PA so that at first glance a healthcare provider could quickly gather information about the time of day, place, and types of activities that could be adapted to increase PA.

3.4.2 Strengthening Behavior Interventions

Eliciting information on patient spatiotemporal activity is useful for identifying where, when, and how high-risk activities are part of day-to-day routines. While this study focused on physical activity, multiple health behaviors are connected in space, place, and time (Spring, Moller & Coons, 2012). Most behavioral interventions have focused on single health behaviors (Nigg & Long, 2012), and further investigation is required to identify what strategies can improve tailoring of interventions targeting multiple health behaviors (Tzelepis et al., 2021). Geo-ethnographic techniques were useful in this study for identifying the contexts of where, when, and how multiple health behaviors intersect in space, place, and time. Time-use sequences that were developed in this study could be strengthened by integrating contexts about social relationships and connections to place that influence patients' day-to-day behaviors. Expanding upon the spatiality of patient behaviors beyond location and time is important for behavioral interventions to understand why patients choose certain behaviors, such as who they are with and perceptions of barriers that inhibit PA like neighborhood safety and walkability. Time-use sequences could also be strengthened by highlighting patients' social relationships influencing constraints and opportunities for behavior change. Behavioral interventions commonly focus on educating patients with PA training and nutritional counselling however, these approaches do not adequately consider the importance of patients' social relationships, including who prepares meals or who interactions typically occur with. Knowing who patients spend their time with is important for behavioral interventions, so that patients' social networks can be included within intervention

strategies and patients can be supported by their social network with maintaining health improving behaviors.

Results also contribute to our understanding that overemphasizing one activity, like minimum thresholds for MVPA, may impose unnecessary expectations and barriers for individuals that would benefit from increased activity at lower levels (Warburton & Bredin, 2017; Wen et al., 2011). Evidence indicates even small amounts of light PA are associated with reduced risk of premature mortality and secondary prevention of a repeat event (Chastin et al., 2019; Wen et al., 2011). However, messaging around minimum guidelines for daily MVPA could negatively influence patients' self-awareness about the importance of staying active throughout the day, aside from small portions of MVPA (Schwartz et al., 2019). A visualization of time-use patterns could be useful within clinic-based settings for informing conversations between patient and provider, increasing information available for discussing when and where specific strategies could be adopted to solicit change, and improving continuity of care using contexts of day-to-day routines as a guide for monitoring and following-up with health behavior change between appointments.

Understanding contexts of opportunities or constraints of patients' existing routines is important for supporting patients across diverse contexts, especially patients with diverse backgrounds that experience barriers from chronic time deficits. For example, generic intervention strategies that encourage patients to spend more time exercising requires existing routines to be disrupted and time to be allocated away from other activities. Developing different routines is challenging and unrealistic for patients constrained by chronic time deficits (McQuoid, Jowsey & Talaulikar, 2017; Strazdins et

al., 2016). Behavioral interventions could be strengthened by improving healthcare professionals' awareness of different time constraints patients face day-to-day, and how constraints of limited time and resources influence automatic versus reflective decisions about day-to-day activities. For example, it is not evident how behavioral interventions are adapted to meet the needs of patients in diverse and marginalized populations that experience unique contextual barriers and time deficits (Stuart-Shor et al., 2012). Geo-ethnography techniques could be a useful tool for exploring when and where patients are challenged with disrupting routines, such as times of the day patients have depleted self-regulating control for switching between activities and commonly rely on automatic decisions about engaging in habitual day-to-day routines. Disrupting routines to develop different habits requires an understanding of time-use patterns to determine when, where and how different activities could be integrated into a new routine. Use of geo-ethnography contributes knowledge of potential techniques for monitoring changes to patient routines and maintenance of new routines over time (Gardner, 2015). For example, evidence that new habits require a minimum of 6-weeks to form (Kaushal et al., 2017; Gardner, Lally & Wardle, 2012) suggests a need for behavioral interventions to integrate time-use patterns for monitoring how patients adjust to different habits and maintain new routines beyond 6-weeks. Further research is required to investigate what types of intervention strategies could be implemented to disrupt routines and support patients with developing different health improving habits and routines that mitigate risk of chronic disease.

A strength of this study was using geo-ethnography mixed-method techniques to understand how clinic-based interventions can be modified to gather information about

the spatiotemporal contexts that surround patients' day-to-day routines. The visual reference of a digital map was helpful during interviews for enriching conversations about day-to-day routines and encouraging patients to recall information about the timing and location of their day-to-day activities. An adapted geo-ethnographic approach that integrates participatory techniques could potentially improve the quality and accuracy of spatiotemporal data in comparison to techniques that use survey-based questions. Future research is required to assess the clinical utility of the visualization tool that was developed.

The geo-ethnographic approach that was used to develop a visualization tool of patients' time-use patterns could be automated to facilitate routine clinical use within interventions. For example, information about patients' time-use patterns could be collected using an online questionnaire guiding patients to fill in details about their typical day-to-day routines, beginning with what time they wake up and activities that occur until they go to bed. Automated outputs of patients' time-use patterns, like Figures 3.1 and 3.2, could be collected at different times throughout an intervention to monitor how patients adapt day-to-day routines and what context specific behavior change techniques could be used at the most opportune time and place to support patients with individual behavior change goals.

3.4.3 Limitations

Although this study contributes knowledge of using spatiotemporal data in the context of a clinic-based secondary behavioral intervention, the patients were from one cardiac program and their health behaviors are unlikely to be transferable to larger and more diverse populations at risk of CVD. A limitation of this study was generating static

time-use patterns that could quickly be out of date depending on changes to patients' day-to-day routines over time. Furthermore, geo-ethnography techniques were time intensive and required lengthy interviews with patients to gather the contexts of spatiotemporal patterns of activity. Automating data entry of patients' time-use patterns would strengthen the integration of geo-ethnography techniques into healthcare settings that have limited human resources and time to interact with patients. Further research is required to investigate how spatiotemporal oriented data like time-use patterns could be automated within healthcare settings to produce clinically relevant outputs.

3.5 Conclusion

Improving the effectiveness of clinic-based behavioral interventions requires new approaches to integrate information about spatiotemporal contexts that influence day-to-day routines such as where, when, and how activities occur. Geo-ethnographic techniques are one way of gathering information about spatiotemporal contexts that influence patient day-to-day activities. Results of time-use patterns contribute to understanding potential strategies for modifying secondary interventions to incorporate the contexts of patient activities when recommending interventions. Although this study contributes evidence of techniques for identifying the most opportune time and place to disrupt day-to-day routines, further research is required to explore what strategies would be most effective for encouraging sustained behavior change and modifying behaviors that reduce CVD risk.

References

Abbott, A. (1995). Sequence Analysis: New Methods for Old Ideas. *Annual Rev. Sociology, 21.* 93-113. https://www.jstor.org/stable/2083405

Alageel, S., Gulliford, M. C., McDermott, L., & Wright, A. J. (2018). Implementing multiple health behaviour change interventions for cardiovascular risk reduction in primary care: A qualitative study. *BMC Family Practice*, *19*, 171. https://doi.org/10.1186/s12875-018-0860-0

Bauman, A., Bittman, M., & Gershuny, J. (2019). A short history of time-use research; implications for public health. *BMC Public Health*, *19*(S2), 607. https://doi.org/10.1186/s12889-019-6760-y

Bray, S., Brawley, L., & Millen, J. (2006). Relationship of Proxy Efficacy and Reliance to Home-based Physical Activity After Cardiac Rehabilitation. *Rehabilitation Psychology*, *51*(3), 224–231. https://doi.org/10.1037/0090-5550.51.3.224

Canadian Society for Exercise Physiology. (2021). *24-Hour Movement Guidelines – Canadian 24-Hour Movement Guidelines*. Retrieved from: https://csepguidelines.ca/

Chastin, S. F. M., De Craemer, M., De Cocker, K., Powell, L., Van Cauwenberg, J., Dall, P., Hamer, M., & Stamatakis, E. (2019). How does light-intensity physical activity associate with adult cardiometabolic health and mortality? Systematic review with meta-analysis of experimental and observational studies. *British Journal of Sports Medicine*, *53*(6), 370–376. https://doi.org/10.1136/bjsports-2017-097563

Chau, J. Y., Gomersall, S. R., van der Ploeg, H. P., & Milton, K. (2019). The evolution of time-use approaches for understanding activities of daily living in a public health context. *BMC Public Health*, *19*(Suppl 2), 451. https://doi.org/10.1186/s12889-019-6759-4

Coorey, G., Peiris, D., Neubeck, L., & Redfern, J. (2020). A realist evaluation approach to explaining the role of context in the impact of a complex eHealth intervention for improving prevention of cardiovascular disease. *BMC Health Services Research*, *20*(1), 764. https://doi.org/10.1186/s12913-020-05597-5

Davis, A. J., Parker, H. M., & Gallagher, R. (2021). Gamified applications for secondary prevention in patients with high cardiovascular disease risk: A systematic review of effectiveness and acceptability. *Journal of Clinical Nursing*, *30*(19–20), 3001–3010. https://doi.org/10.1111/jocn.15808

Degroote, L., DeSmet, A., De Bourdeaudhuij, I., Van Dyck, D., & Crombez, G. (2020). Content validity and methodological considerations in ecological momentary assessment studies on physical activity and sedentary behaviour: A systematic review. *International Journal of Behavioral Nutrition and Physical Activity*, *17*(1), 35. https://doi.org/10.1186/s12966-020-00932-9

Dunton, G. F. (2017). Ecological Momentary Assessment in Physical Activity Research. *Exercise and Sport Sciences Reviews, 45*(1), 48-58. https://doi.org/10.1249/JES.0000000000000092

Fornace, K. M., Surendra, H., Abidin, T. R., Reyes, R., Macalinao, M. L. M., Stresman, G., Luchavez, J., Ahmad, R. A., Supargiyono, S., Espino, F., Drakeley, C. J., & Cook, J. (2018). Use of mobile technology-based participatory mapping approaches to geolocate health facility attendees for disease surveillance in low resource settings. *International Journal of Health Geographics*, *17*, 21. https://doi.org/10.1186/s12942-018-0141-0

Fuller, D., & Stanley, K. (2019). The future of activity space and health research. *Health & Place*, *58*(102131), 3. https://doi.org/10.1016/j.healthplace.2019.05.009

Gandhi, S., Chen, S., Hong, L., Sun, K., Gong, E., Li, C., Yan, L. L., & Schwalm, J.-D. (2017). Effect of Mobile Health Interventions on the Secondary Prevention of Cardiovascular Disease: Systematic Review and Meta-analysis. *Canadian Journal of Cardiology*, *33*(2), 219–231. https://doi.org/10.1016/j.cjca.2016.08.017

Gardner, B. (2015). A review and analysis of the use of 'habit' in understanding, predicting and influencing health-related behavior. *Health Psychology Review*, *9*(3), 277–295. https://doi.org/10.1080/17437199.2013.876238

Gardner, B., Lally, P., & Wardle, J. (2012). Making health habitual: The psychology of 'habit-formation' and general practice. *The British Journal of General Practice*, *62*(605), 664–666. https://doi.org/10.3399/bjgp12X659466

Grady, P. A., & Gough, L. L. (2014). Self-Management: A Comprehensive Approach to Management of Chronic Conditions. *American Journal of Public Health*, *104*(8), 7. doi:10.2105/AJPH.2014.302041

Graham, H., Prue-Owens, K., Kirby, J., & Ramesh, M. (2020). Systematic Review of Interventions Designed to Maintain or Increase Physical Activity Post-Cardiac Rehabilitation Phase II. *Rehabilitation Process and Outcome*, *9*, 1179572720941833. https://doi.org/10.1177/1179572720941833

Gregory, S., Bostock, Y., & Backett-Milburn, K. (2006). Recovering from a heart attack: A qualitative study into lay experiences and the struggle to make lifestyle changes. *Family Practice*, *23*(2), 220–225. https://doi.org/10.1093/fampra/cmi089

Guiraud, T., Granger, R., Gremeaux, V., Bousquet, M., Richard, L., Soukarié, L., Babin, T., Labrunée, M., Sanguignol, F., Bosquet, L., Golay, A., & Pathak, A. (2012). Telephone Support Oriented by Accelerometric Measurements Enhances Adherence to Physical Activity Recommendations in Noncompliant Patients After a Cardiac Rehabilitation Program. *Archives of Physical Medicine and Rehabilitation*, *93*(12), 2141–2147. https://doi.org/10.1016/j.apmr.2012.06.027

Hamermesh, D. S., Frazis, H., & Stewart, J. (2005). Data Watch The American Time-use Survey. *Journal of Economic Perspectives*, *19*(1), 221–232. https://doi.org/10.1257/0895330053148029

Heart and Stroke Foundation. (2019). (Dis)connected: How unseen links are putting us at risk. 2019 Report on Heart, Stroke and Vascular Cognitive Impairment. Retrieved from https://www.heartandstroke.ca/-/media/pdf-files/canada/2019-report/heartandstrokereport2019.ashx

Hennink, M., & Kaiser, B. N. (2022). Sample sizes for saturation in qualitative research: A systematic review of empirical tests. *Social Science & Medicine*, *292*, 114523. https://doi.org/10.1016/j.socscimed.2021.114523

Hinrichs, T., Zanda, A., Fillekes, M. P., Bereuter, P., Portegijs, E., Rantanen, T., Schmidt-Trucksäss, A., Zeller, A. W., & Weibel, R. (2020). Map-based assessment of older adults' life space: Validity and reliability. *European Review of Aging and Physical Activity*, *17*(1), 21. https://doi.org/10.1186/s11556-020-00253-7

Joseph, P., Leong, D., McKee, M., Anand, S. S., Schwalm, J.-D., Teo, K., Mente, A., & Yusuf, S. (2017). Reducing the Global Burden of Cardiovascular Disease, Part 1. *Circulation Research*, *121*(6), 677–694. https://doi.org/10.1161/CIRCRESAHA.117.308903

Kaushal, N., Rhodes, R. E., Meldrum, J. T., & Spence, J. C. (2017). The role of habit in different phases of exercise. *British Journal of Health Psychology*, *22*(3), 429–448. https://doi.org/10.1111/bjhp.12237

Kwan, M. (2004). GIS methods in time-geographic research: Geocomputation and geovisualization of human activity patterns. *Series B, Human Geography*, *86*(4), 267–280. https://doi.org/10.1111/j.0435-3684.2004.00167.x

Kwan, M.-P. (2012). How GIS can help address the uncertain geographic context problem in social science research. *Annals of GIS*, *18*(4), 245–255. https://doi.org/10.1080/19475683.2012.727867

Kwan, M.-P., & Ding, G. (2008). Geo-Narrative: Extending Geographic Information Systems for Narrative Analysis in Qualitative and Mixed-Method Research∗. *The Professional Geographer*, *60*(4), 443–465. https://doi.org/10.1080/00330120802211752

Lee, I.-M., & Shiroma, E. J. (2014). Using Accelerometers to Measure Physical Activity in Large-Scale Epidemiologic Studies: Issues and Challenges. *British Journal of Sports Medicine*, *48*(3), 197–201. https://doi.org/10.1136/bjsports-2013-093154

Leijon, M. E., Bendtsen, P., Ståhle, A., Ekberg, K., Festin, K., & Nilsen, P. (2010). Factors associated with patients self-reported adherence to prescribed physical activity in routine primary health care. *BMC Family Practice*, *11*(1). https://doi.org/10.1186/1471-2296-11-38

Leijon, M. E., Faskunger, J., Bendtsen, P., Festin, K., & Nilsen, P. (2011). Who is not adhering to physical activity referrals, and why? *Scandinavian Journal of Primary Health Care*, *29*(4), 234–240. https://doi.org/10.3109/02813432.2011.628238

Macintyre, S., Ellaway, A., & Cummins, S. (2002). Place effects on health: How can we conceptualise, operationalise and measure them? *Social Science & Medicine*, *55*(1), 125–139. https://doi.org/10.1016/S0277-9536(01)00214-3

MacNell, L. (2018). A geo-ethnographic analysis of low-income rural and urban women's food shopping behaviors. *Appetite*, *128*, 311–320. https://doi.org/10.1016/j.appet.2018.05.147

Matthews, S. A., Detwiler, J. E., & Burton, L. M. (2005). Geo-ethnography: Coupling Geographic Information Analysis Techniques with Ethnographic Methods in Urban Research. *Cartographica: The International Journal for Geographic Information and Geovisualization*, *40*(4), 75–90. https://doi.org/10.3138/2288-1450-W061-R664

McQuoid, J., Jowsey, T., & Talaulikar, G. (2017). Contextualising renal patient routines: Everyday space-time contexts, health service access, and wellbeing. *Social Science & Medicine*, *183*, 142–150. https://doi.org/10.1016/j.socscimed.2017.04.043

Milton, S., Pliakas, T., Hawkesworth, S., Nanchahal, K., Grundy, C., Amuzu, A., Casas, J.-P., & Lock, K. (2015). A qualitative geographical information systems approach to explore how older people over 70 years interact with and define their neighbourhood environment. *Health & Place*, *36*, 127–133. https://doi.org/10.1016/j.healthplace.2015.10.002

Moore, C. J., Williams, T. N., Berg, A. C., & Durward, C. M. (2019). An Evaluation of Inter-coder and Intra-coder Reliability for 24-Hour Dietary Recall Data Entered in WebNEERS. *Journal of Nutrition Education and Behavior*, *51*(4), 432–439. https://doi.org/10.1016/j.jneb.2019.01.005

Müller-Riemenschneider, F., Petrunoff, N., Yao, J., Ng, A., Sia, A., Ramiah, A., Wong, M., Han, J., Tai, B. C., & Uijtdewilligen, L. (2020). Effectiveness of prescribing physical activity in parks to improve health and wellbeing—The park prescription randomized controlled trial. *International Journal of Behavioral Nutrition and Physical Activity*, *17*(1), 42. https://doi.org/10.1186/s12966-020-00941-8

Nethery, E., Mallach, G., Rainham, D., Goldberg, M. S., & Wheeler, A. J. (2014). Using Global Positioning Systems (GPS) and temperature data to generate time-activity classifications for estimating personal exposure in air monitoring studies: An automated method. *Environmental Health*, *33*(13), 11. http://www.ehjournal.net/content/13/1/33

Nieuwlaat, R., Schwalm, J.-D., Khatib, R., & Yusuf, S. (2013). Why are we failing to implement effective therapies in cardiovascular disease? *European Heart Journal*, *34*(17), 1262–1269. https://doi.org/10.1093/eurheartj/ehs481

Nigg, C. R., & Long, C. R. (2012). A systematic review of single health behavior change interventions vs. Multiple health behavior change interventions among older adults. *Translational Behavioral Medicine*, *2*(2), 163–179. https://doi.org/10.1007/s13142-012-0130-y

Nyberg, S. T., Singh-Manoux, A., Pentti, J., Madsen, I. E. H., Sabia, S., Alfredsson, L., Bjorner, … & Kivimäki, M. (2020). Association of Healthy Lifestyle With Years Lived Without Major Chronic Diseases. *JAMA Internal Medicine*, *180*(5), 760. https://doi.org/10.1001/jamainternmed.2020.0618

Oreskovic, N. M., Blossom, J., Field, A. E., Chiang, S. R., Winickoff, J. P., & Kleinman, R. E. (2012). Combining global positioning system and accelerometer data to determine the locations of physical activity in children. *Geospatial Health, 6*(2), 263. https://doi.org/10.4081/gh.2012.144

Orrow, G., Kinmonth, A., Sanderson, S., & Sutton, S. (2012). Effectiveness of physical activity promotion based in primary care: Systematic review and meta-analysis of randomised controlled trials. *BMJ, 344*(1), e1389. https://doi.10.1136/bmj.e1389

Park, S., Petrunoff, N., Wang, N., van Dam, R., Sia, A., Tan, C.S., & Muller-Riemenschneider, F. (2022). Daily park use, physical activity, and psychological stress: A study using smartphone-based ecological momentary assessment amongst a multi-ethnic Asian cohort. *Mental Health and Physical Activity, 22*(100440), 1-7. https://doi.org/10.1016/j.mhpa.2022.100440

ParticipACTION Report Card on Physical Activity for Adults (p. 80). (2021). Retrieved from www.ParticipACTION.com

Perchoux, C., Chaix, B., & Kestens, Y. (2019). Activity spaces in place and health research: Novel exposure measures, data collection tools, and designs. *Health & Place*, *58*(102130), 3. https://doi.org/10.1016/j.healthplace.2019.05.008

Phipps, P. A., & Vernon, M. K. (2009). Chapter 7, Twenty-four hours: An Overview of the Recall Diary Method and Data Quality in the American Time-use Survey. In *Calendar and Time Diary: Methods in Life Course Research* (p. 21). SAGE Publications. https://www.bls.gov/tus/phippsvernon09.pdf

Public Health Agency of Canada. (2015). *Chronic disease risk factors.* Public Health Agency of Canada. Retrieved from https://www.canada.ca/en/public-health/services/chronic-diseases/chronic-disease-risk-factors.html

Public Health Agency of Canada. (2018). *Report from the Canadian chronic disease surveillance system: Heart disease in Canada, 2018.* Retrieved from https://www.canada.ca/content/dam/phac-aspc/documents/services/publications/diseases-conditions/report-heart-disease-canada-2018/pub1-eng.pdf

QSR International Pty Ltd. (2020). Nvivo (Version 12 Released March 2020). Retrieved from https://www.qsrinternational.com/nvivo-qualitative-data-analysis-software/home

Rantanen, H., & Kahila, M. (2009). The SoftGIS approach to local knowledge. *Journal of Environmental Management, 90*(6), 1981-1990. https://doi.10.1016/j.jenvman.2007.08.025

Riera-Sampol, A., Bennasar-Veny, M., Tauler, P., & Aguilo, A. (2021). Effectiveness of physical activity prescription by primary care nurses using health assets: A randomized controlled trial. *Journal of Advanced Nursing*, *77*(3), 1518–1532. https://doi.org/10.1111/jan.14649

Rollo, S., Lang, J., Roberts, K., Bang, F., Carson, V., Chaput, J.-P., Colley, R., Janssen, I., & Tremblay, M. (2022). Health Associations with Meeting the Canadian 24-Hour Movement Guidelines for Adults: Results from the Canadian Health Measures Survey. *Health Reports*, *33*(82), 13. https://www.doi.org/10.25318/82-003-x202200100002-eng

Room, J., Hannink, E., Dawes, H., & Barker, K. (2017). What interventions are used to improve exercise adherence in older people and what behavioural techniques are they based on? A systematic review. *BMJ Open*, *7*(12), e019221. https://doi.org/10.1136/bmjopen-2017-019221

Roth, G. A., Mensah, G. A., Johnson, C. O., Addolorato, G., Ammirati, E., Baddour, L. M., Barengo, N. C., … & Fuster, V. (2020). Global Burden of Cardiovascular Diseases and Risk Factors, 1990–2019. *Journal of the American College of Cardiology*, *76*(25), 2982–3021. https://doi.org/10.1016/j.jacc.2020.11.010

Schwartz, J., Rhodes, R., Bredin, S. S. D., Oh, P., & Warburton, D. E. R. (2019). Effectiveness of Approaches to Increase Physical Activity Behavior to Prevent Chronic Disease in Adults: A Brief Commentary. *Journal of Clinical Medicine*, *8*(3), 295. https://doi.org/10.3390/jcm8030295

Shoval, N., & Isaacson, M. (2007). Sequence Alignment as a Method for Human Activity Analysis in Space and Time. *Annals of the Association of American Geographers*, *97*(2), 282–297. https://doi.org/10.1111/j.1467-8306.2007.00536.x

Spring, B., Moller, A. C., & Coons, M. J. (2012). Multiple health behaviors: Overview and implications. *Journal of Public Health (Oxford, England)*, *34*(Suppl 1), i3–i10. https://doi.org/10.1093/pubmed/fdr111

Stone, A. A., & Shiffman, S. (1994). Ecological Momentary Assessment (EMA) in Behavioral Medicine. *Annals of Behavioral Medicine*, *16*(3), 199-202. https://doi.org/10.1093/abm/16.3.199

Strazdins, L., Welsh, J., Korda, R., Broom, D., & Paolucci, F. (2016). Not all hours are equal: Could time be a social determinant of health? *Sociology of Health & Illness*, *38*(1), 21–42. https://doi.org/10.1111/1467-9566.12300

Stuart-Shor, E. M., Berra, K., Kamau, M. W., & Kumanyika, S. (2012). Behavioral Strategies for Cardiovascular Risk Reduction in Diverse and Underserved Racial/Ethnic Groups. *Circulation*, *125*(1), 171–184. https://doi.org/10.1161/CIRCULATIONAHA.110.968495

Sullivan, O., Gershuny, J., Sevilla, A., Foliano, F., Vega-Rapun, M., Lamote de Grignon, J., Harms, T., & Walthéry, P. (2021). Using time-use diaries to track changing behavior across successive stages of COVID-19 social restrictions. *Proceedings of the National Academy of Sciences of the United States of America*, *118*(35), e2101724118. https://doi.org/10.1073/pnas.2101724118

The Canadian Society for Exercise Physiology. (2021). *The Canadian 24-Hour Movement Guidelines for Adults*. Retrieved from https://csepguidelines.ca/guidelines/adults-18-64/

Tremblay, M. S., Aubert, S., Barnes, J. D., Saunders, T. J., Carson, V., Latimer-Cheung, A. E., Chastin, S. F. M., … & Chinapaw, M. J. M. (2017). Sedentary Behavior Research Network (SBRN) – Terminology Consensus Project process and outcome. *International Journal of Behavioral Nutrition and Physical Activity*, *14*(1), 75. https://doi.org/10.1186/s12966-017-0525-8

Tudor-Locke, C., Johnson, W., & Katzmarzyk, P. (2010). Frequently reported activities by intensity for U.S. Adults: The American time-use survey. *American Journal of Preventive Medicine, 39*(4), 13-20. https://doi.10.1016/j.amepre.2010.05.017

Tuomilehto, J., Lindström, J., Eriksson, J. G., Valle, T. T., Hämäläinen, H., Ilanne-Parikka, P., Keinänen-Kiukaanniemi, S., … & Uusitupa, M. (2001). Prevention of Type 2 Diabetes Mellitus by Changes in Lifestyle among Subjects with Impaired Glucose Tolerance. *New England Journal of Medicine*, *344*(18), 1343–1350. https://doi.org/10.1056/NEJM200105033441801

Tunstall, H. V. Z. (2004). Places and health. *Journal of Epidemiology & Community Health*, *58*(1), 6–10. https://doi.org/10.1136/jech.58.1.6

Tzelepis, F., Mitchell, A., Wilson, L., Byrnes, E., Haschek, A., Leigh, L., & Oldmeadow, C. (2021). The Long-Term Effectiveness of Internet-Based Interventions on Multiple Health Risk Behaviors: Systematic Review and Robust Variance Estimation Meta-analysis. *Journal of Medical Internet Research*, *23*(12), e23513. https://doi.org/10.2196/23513

Vandelanotte, C., Müller, A. M., Short, C. E., Hingle, M., Nathan, N., Williams, S. L., Lopez, M. … & Maher, C. A. (2016). Past, Present, and Future of eHealth and mHealth Research to Improve Physical Activity and Dietary Behaviors. *Journal of Nutrition Education and Behavior*, *48*(3), 219-228.e1. https://doi.org/10.1016/j.jneb.2015.12.006

Warburton, D. E. R., & Bredin, S. S. D. (2017). Health benefits of physical activity: A systematic review of current systematic reviews. *Current Opinion in Cardiology*, *32*(5), 541–556. https://doi.org/10.1097/HCO.0000000000000437

Wen, C. P., Wai, J. P. M., Tsai, M. K., Yang, Y. C., Cheng, T. Y. D., Lee, M.-C., Chan, H. T., … & Wu, X. (2011). Minimum amount of physical activity for reduced mortality and extended life expectancy: A prospective cohort study. *The Lancet*, *378*(9798), 1244–1253. https://doi.org/10.1016/S0140-6736(11)60749-6

Winter, S. J., Sheats, J. L., & King, A. C. (2016). The Use of Behavior Change Techniques and Theory in Technologies for Cardiovascular Disease Prevention and Treatment in Adults: A Comprehensive Review. *Progress in Cardiovascular Diseases*, *58*(6), 605–612. https://doi.org/10.1016/j.pcad.2016.02.005

World Health Organization. (2015). *Cardiovascular diseases: Avoiding heart attacks and strokes.* World Health Organization. Retrieved from https://www.who.int/news-room/questions-and-answers/item/cardiovascular-diseases-avoiding-heart-attacks-and-strokes

World Health Organization. (2021a). *Noncommunicable diseases.* World Health Organization. Retrieved from https://www.who.int/news-room/fact-sheets/detail/noncommunicable-diseases

World Health Organization. (2021b). *Cardiovascular diseases (CVDs)*. World Health Organization. Retrieved from https://www.who.int/news-room/fact-sheets/detail/cardiovascular-diseases-(cvds)

World Health Organization. (2021c). *Report of the first meeting of the Strategic and Technical Advisory Group for Noncommunicable Diseases: Virtual meeting, 27–28 October 2021*. World Health Organization. Retrieved from https://apps.who.int/iris/handle/10665/352097

CHAPTER 4

EXPLORING THE USE OF CONTEXT SPECIFIC BEHAVIORAL ECONOMIC PRINCIPLES TO ENABLE PATIENTS TO CHANGE THEIR PHYSICAL ACTIVITY PATTERNS

Chapter 4 is formatted for publication with Journal of Health Behavior Change. This work has not yet been submitted for publication.

- Behavioral change interventions lack contexts of decision-making processes
- Behavioral economic principles provide insights for enabling patients to tailor their physical activity patterns
- Identifying context specific behavioral economic principles that can influence opportunities to disrupt day-to-day routines and enable patients to identify opportunities to increase their physical activity

4.0 Abstract

Digital health tools are critical for behavioral interventions for prevention of cardiovascular disease by modifying behaviors and reducing repeat cardiac events. However, the effectiveness of behavioral interventions is impeded by digital tools that do not adequately consider spatiotemporal contexts within which health behaviors occur nor are they tailored to common decisions patients make as part of their day-to-day routines. This study explores how context-specific behavioral economic principles can be employed to tailor interventions to support patients' efforts to modify day-to-day routines. Semi-structured interviews were used to gather in-depth descriptions about facilitators and barriers to increasing physical activity (PA) and contexts influencing decisions about day-to-day activities. Data were analyzed using the COM-B model for behavior change and MINDSPACE framework of behavioral economic principles as coding frameworks. Data were gathered from patients at one cardiac prevention and rehabilitation intervention in Nova Scotia, Canada. A total of 29 patients (19 men and 10 women) between the ages of 45 to 81 who were referred to the program after a cardiac event participated in this study. Findings indicate patients were capable and motivated to

increase their PA but were challenged to identify opportunities to adapt day-to-day routines for increasing PA. Patients described disrupting default routines, increasing commitments, changing the messenger, and introducing incentives as potentially useful behavioral economic principles that could be applied to improve day-to-day decisions about increasing PA. This study demonstrates patients had insight into potential behavioral economic principles, although they were not previously educated, and could be valuable partners in developing research and clinic-based behavioral economic intervention strategies.

4.1 Introduction

Cardiovascular diseases (CVD) are the leading cause of death worldwide, accounting for more than 17 million deaths annually (Joseph et al., 2017; World Health Organization, 2021), and one fifth of all deaths in Canada (Statistics Canada, 2020). These deaths are largely preventable through modification of lifestyle risk factors such as smoking, physical inactivity, obesity, poor nutrition, high blood pressure, and excessive consumption of alcohol (Roth et al., 2020; World Health Organization, 2015). Behavioral interventions for modifying risk factors are critical for reducing risk of CVD or a repeat event.

The effectiveness of interventions to reduce risk of CVD is hindered by poor maintenance of behaviors after an intervention (Graham et al., 2020) (McQuoid, Jowsey & Talaulikar, 2017) when patients no longer have regular contact with healthcare professionals and peers (Bray, Brawley & Millen, 2006). Digital tools have been shown to improve intervention effectiveness by sustaining interaction between patients and clinicians, through individualized monitoring and feedback, and by tailoring interventions

to acknowledge the unique requirements of patients to maintain behavior change in real-world settings (Inglis et al., 2010; Santo & Redfern, 2020; Schorr et al., 2021). However, the success of these digital tools can be limited when they do not adequately consider the spatiotemporal contexts within which patient health behaviors occur. This additional knowledge is critical to ensure intervention strategies are tailored to incorporate the timing and location that seemingly automatic decisions patients make as part of their daily routines.

Spatiotemporal contexts play an important role in promoting or inhibiting health behaviors (Macintyre, Ellaway & Cummins, 2002). Identifying the unique social and environmental contexts that influence the timing and location of individual health-related activities is critical for tailoring intervention strategies (Barber et al., 2022). Spatiotemporal contexts of day-to-day health behaviors previously explored by our research team identify when and where routine health activities can be disrupted to increase physical activity (PA) within a clinic-based intervention for CVD (Barber et al., 2022). We adapted geo-ethnography mixed-method techniques (Matthews et al., 2005; Milton et al., 2015) to develop a data collection and communication tool for collecting geospatial and temporal contexts of patient PA behaviors. This study identified the context and timing of health promoting activities (i.e., walking in neighborhood in morning or early evening) as well as opportunities for disrupting health inhibiting sedentary activities (i.e., watching television in evening) (Barber et al., 2022). Time-use patterns provide a visualization of patients' unique spatiotemporal sequencing of day-to-day activities and understanding of when and where interventions can be tailored for disrupting routines and modifying behavior change. The aim of this research is to explore

how interventions can be tailored using context specific strategies to improve decision-making processes that make adapting day-to-day routines easier and more automatic.

4.1.1 Limitations of Behavioral Interventions

Behavioral interventions are often designed with a theoretical framework that emphasizes individual motivation, capability, and cognitive restraint for behavior change (Jacob et al., 2018; Liu et al., 2021; Room et al., 2017; Winter, Sheats, & King, 2016). For example, interventions using cognitive-behavioral strategies for weight management often target underlying motivation, beliefs, and emotions through cognitive restraint training that encourages slow and deliberate decision-making processes towards modifying eating behaviors (Amiri et al., 2020; Jacob et al., 2018). The COM-B model is one approach used to inform the design of interventions by explaining how decisions about behaviors are driven by individual capability, opportunity, and motivation (Michie, van Stralen & West, 2011). Yet routine health behaviors are influenced by seemingly automatic decisions about day-to-day activities under constraints of limited time and resources (Betsch, Fiedler & Brinkmann, 1998; Marteau, Hollands & Fletcher, 2012). These automatic decisions are known as fast thinking and result in health behavior choices that are made in an unconscious manner (Kahneman & Tversky, 1984). Health behaviors are not solely driven by intrinsic, reflective thought processes, and when executive functions are compromised from factors like fatigue, individuals commonly default to automatic decision-making processes that are influenced by environmental contexts and unconscious habits (Kahneman, 2011; Marteau, Hollands, Fletcher, 2012).

Understanding the contexts that influence automatic decision-making processes is critical for tailoring intervention strategies so that behavior change techniques are

individualized to the contexts in which patients make choices about their health activities. Strategies from other disciplines like behavioral economics provide insight into cognitive biases that influence automatic decision-making processes and strategies to improve decisions about engaging in health promoting activities.

4.1.2 Contexts of Decision-Making Processes

Behavioral economics is an evolving field, rooted in psychology and economics, that offers insights about cognitive biases that influence decision-making processes (Mollenkamp et al., 2019; Tversky & Kahneman, 1974; Vlaev et al., 2016). Behavioral economic principles have become widely applied within interventions and are distinct from behavioral science techniques (Gilovich, Griffin & Kahneman, 2002; Kahneman & Tversky, 1984). Behavioral economic principles identify that individuals commonly default to heuristics, known as fast-thinking processes, that are automatic and emotionally charged and less commonly use slow, deliberate, and analytic thinking processes to make decisions day-to-day (Kahneman, 2003; Korteling, Brouwer & Toet, 2018). Nine of the most common cognitive principles that have been used to improve the design of behavioral interventions are outlined by the MINDSPACE framework including messenger, incentives, norms, defaults, salience, priming, affect, commitments, and ego (Institute for Government, 2015; Vlaev & Makki, 2018). A more detailed definition of each principle within the MINDSPACE framework is outlined within Table 4.1.

Table 4.1 MINDSPACE Framework: Definition of 9 Constructs

Construct	Definition
1. Messenger	We are heavily influenced by who communicates information. We are affected by the perceived *authority* of the messenger (whether formal or informal). Demographic and behavioral *similarities* between the expert and the recipient can improve the effectiveness of the intervention. We are also affected by the *feelings* we have for the messenger. We also use more rational and cognitive means to assess how convincing a messenger is.
2. Incentives	Our responses to incentives are shaped by predictable mental shortcuts such as *strongly* avoiding losses (we dislike losses more than we like gains), referencing points (the value of something depends on where we see it from), *overweighting* small probabilities (hence why lotteries may act as a powerful motivation), *mental* budgets (allocating money to discrete bundles), *present bias* (we prefer more immediate payoffs).
3. Norms	We are strongly influenced by what others do. Social and cultural norms are the behavioral expectations, or rules, within a society or group. Norms can be explicitly stated or implicit in observed behavior. People often take their understanding of social norms from the behavior of others. Relate the norm to your target audience as much as possible and consider social networks.
4. Defaults	We "go with the flow" of pre-set options. Many decisions we take every day have a default option, whether we recognise it or not. Defaults are the options that are pre-selected if an individual does not make an active choice. Defaults exert influence as individuals regularly accept whatever the default setting is, even if it has significant consequences.
5. Salience	Our attention is drawn to what is novel and seems relevant to us. Our behavior is greatly influenced by what our attention is drawn to. People are more likely to register stimuli that are *novel* (messages in flashing lights), *accessible* (items on sale next to checkouts), *simple* (a snappy slogan), and *relevant* (easier to grab attention at moments when people enter a new situation or life-stage such as moving house, going to university, pregnancy etc.). We also look for a prominent *anchor* (such as unusual or extreme experiences, price, and advice) on which to base our decisions.
6. Priming	Our acts are often subconsciously influenced by cues in the environment. People's subsequent behavior may be altered if they are first exposed to certain sights, words or sensations, which activate associated concepts in memory. In other words, people behave differently if they have been 'primed' by certain cues beforehand.
7. Affect	Our emotional associations can powerfully shape our actions. Emotional responses to words, images, and events can be very rapid and automatic. Moods, rather than deliberate decisions, can therefore influence judgements. People in good moods make unrealistically optimistic judgements, whilst those in bad moods make unrealistically pessimistic judgements.

Construct	Definition
8. Commitments	We seek to be consistent with our public promises and reciprocate acts. We use commitments devices to achieve long-term goals. It has been shown that commitments usually become more effective as the costs for failure increase. One common method for increasing such costs is to make commitments public, since breaking the commitment will lead to significant reputational damage. Even the very act of writing a commitment is our strong instinct for reciprocity, which is linked to a desire for fairness.
9. Ego	We act in ways that make us feel better about ourselves. We tend to behave in a way that supports the impression of a positive and consistent self-image. We think the same way for groups that we identify with. We also like to think of ourselves as self-consistent. So, what happens when our behavior and our self-beliefs are in conflict? Interestingly, often it is our beliefs that get adjusted, rather than our behavior.

1. Vlaev I, Makki F. (2018). Applying behavioral insights in health: Tackling key non communicable diseases. *Report of the WISH Policy Briefing on Behavioral Insights.* Retrieved from https://www.b4development.org/wp-content/uploads/2019/07/WISH-REPORT-..pdf
2. Dolan P, Hallsworth M, Halpern D, & Vlaev I. (2015). MINDSPACE: Influencing behavior through public policy. Accessed January 5, 2021. Retrieved from https://www.bi.team/wp-content/uploads/2015/07/MINDSPACE.pdf

Changing default settings, peer comparison, and introducing incentives are the most widely applied behavioral economic principles that have shown to improve the effectiveness of behavioral interventions targeting healthcare professional and patient behaviors. Changing default settings and peer comparison have most commonly been applied within interventions for changing behaviors of healthcare professionals (Wang & Groene, 2020). For example, changing the default was used to increase efficiency of online referral booking services and reduce demand of oversubscribed healthcare services at certain hospitals across the United Kingdom (Behavioral Insights Team, 2018). Wait times were reduced by 20 percent by removing a healthcare provider's default option within the online referral system, requiring providers to see a list of hospital wait-times within a pop-up reminder of clinics with limited capacity (Behavioral Insights Team, 2018). Incentives are the most widely adopted behavioral economic principle used to target patient PA behaviors (Hare et al., 2021; Waddell et al., 2020). For example, patients who received a FitBit watch for monitoring PA and cash-based financial

incentives engaged in significantly more minutes (29 minutes per week) of moderate to vigorous PA compared to patients that received a FitBit watch and charity-based financial incentive, or a FitBit watch alone (Finkelstein et al., 2016).

Interventions tailored to individual needs of patients (Santo & Redfern, 2020) and underlying motivation and cognitive restraint for behavior change (Jacob et al., 2018) do not adequately account for fast thinking and automatic habits that influence decisions about day-to-day health behaviors. Behavioral economic principles provide insight of contexts influencing automatic and fast thinking decisions however, the timing and location of patients' day-to-day routines are critical for tailoring interventions by identifying opportunities to disrupt routines based on knowledge of when and where health activities occur. It is not evident how behavioral economic principles can be applied to tailor intervention strategies based on contexts of patients' day-to-day routines and automatic decision-making processes for modifying behaviors.

4.1.3 Aim and Objectives

The aim of this study was to identify opportunities for incorporating context specific behavioral economic principles into patients' PA routines. To achieve this aim, this study answers two more specific research objectives:

1.) to identify contexts of facilitators and barriers influencing patients' capability, opportunity and motivation to increasing PA;
2.) to identify what context specific behavioral economic principles could be used to tailor secondary interventions for CVD

4.2 Methods

4.2.1 Research Setting

This study took place in the context of a voluntary cardiac prevention and rehabilitation intervention program for patients presenting risk factors for CVD, or patients that have recently experienced a cardiac event. A more detailed description of the research setting can be found in a previous publication (Barber et al., 2022).

4.2.2 Study Design

This study used a qualitative description approach to gather detailed descriptions about patients' day-to-day PA routines, including perceptions about factors that influence decisions about activities. Qualitative description is a particularly useful design to gather patients' experiences and allows first person accounts to be described directly from those experiencing the phenomenon (Bradshaw, Atkinson & Doody, 2017; Kim, Sefcik & Bradway, 2016; Neergaard et al., 2009).

4.2.3 Patient Recruitment and Data Collection

Purposeful recruitment of potential patients was conducted with patient cohorts enrolled in the cardiac program. Cohorts of 8 to 10 patients were purposively selected for recruitment if they were in week 2 or 3 of the 6-week program. Recruitment was carried out by a healthcare professional at the cardiac program by first approaching patients with information about the purpose of the study and what would be required to participate. The recruitment process was repeated with 5 different patient cohorts, with 6 patients agreeing to participate from each cohort, to generate a sample size sufficient for qualitative saturation (Hennink & Kaiser, 2022). To acknowledge the time commitment required for patients to be interviewed, every patient was offered an honorarium of a 25-dollar (CAD) gift certificate to a grocery store.

Interviews were conducted in-person by the first author at the cardiac program between June to September 2021. Interviews were structured to gather contextual information about patients' activities, including what, where, and when routine activities occur, why they occur, relationships that influence activities, and perceptions about adapting routine activities. Patients were also asked to discuss their health goals and factors that support or prevent them from reaching health goals. Interview questions included, "How would you describe your typical activities on a given day?" "What sorts of activities do you do in your neighborhood?" "What are some of your health goals you are working towards?" "Are there times during the day you find it difficult to stay on track with your goals?" "How might your activities be influenced by who you are with?"

4.2.4 Ethical Approval

This study obtained ethics approval from Nova Scotia Health Authority (REB#1026722). All patients provided informed consent for their de-identified and anonymous personal health information and direct quotes to be included in research results.

4.2.5 Analysis

Interviews were audio-recorded, transcribed verbatim, and then coded by the first author with the aid of QSR NVivo12 qualitative data analysis software (QSR International Pty Ltd, 2020). To answer the first research objective this study integrated the COM-B model as a coding framework to identify facilitators and barriers to increasing PA (Michie, van Stralen & West, 2011). A more detailed definition of each principle within the COM-B framework is outlined within Table 4.2.

Table 4.2 Definition of COM-B Constructs

Construct	Definition
Capability Physical	Skills, abilities, or proficiencies acquired through practice
Capability Psychological	Knowledge, memory, attention, decision processes, behavioral regulation
Motivation Reflective	Beliefs about capabilities and consequences, roles, identity, intentions, goals, optimism
Motivation Automatic	Emotions, reinforcement such as rewards, incentives, punishment
Opportunity Social	Social influences such as social pressure, norms, conformity, social comparisons
Opportunity Physical	Environmental context and resources

McDonagh, L., Saunders, J., Cassell, J., Curtis T., Bastaki, H., Hartney, T., & Rait, G. (2018). Application of the COM-B model to barriers and facilitators to chlamydia testing in general practice for young people and primary care practitioners: A systematic review. *Implementation Science, 13*(130). 1-19. doi:https://doi.org/10.1186/s13012-018-0821-y
Michie, S., van Stralen, M., & West, R. (2011). The Behavior Change Wheel: A new method for characterising and designing behavior change interventions. *Implementation Science, 6*(42). 1-12. doi:http://www.implementationscience.com/content/6/1/42

To answer the second research objective this study integrated the MINDSPACE framework (Table 4.1) as a coding framework to understand patients' cognitive biases and what context specific behavioral economic techniques could be applied to improve decision-making processes towards increasing PA (Institute for Government, 2015; Vlaev & Makki, 2018). The COM-B model and MINDSPACE framework (see Tables 4.1 & 4.2) were coding frameworks to structure emergent themes from patient responses.

Data analysis involved generating initial codes, searching for themes, reviewing themes, and defining and naming themes that represented patient responses (Braun & Clarke, 2006; Fereday & Muir-Cochane, 2006). Interviews were first coded by the first author and initial codes and themes reviewed and discussed collaboratively by another member of the research team (MV). Using the COM-B model as a coding structure, emergent themes were categorized as facilitators and barriers under each construct of capability, opportunity, and motivation. The same analysis process was repeated using

the MINDSPACE framework as a coding structure to generate codes and themes from patient responses that corresponded to behavioral economic principles.

4.3 Results

A total of 58 interviews were conducted with 29 patients (19 men and 10 women). Two interviews were conducted with each patient, lasting on average 71 minutes (range 37 to 110 minutes). A total of 31 individuals were recruited to participate in this study, however, 2 dropped out of the study before the first interview due to lack of time to participate. A detailed description of patient characteristics has been previously published (Barber et al., 2022) and a summary provided within Table 4.3.

Table 4.3 Description of Patient Characteristics

Age	**n**	**%**
45-54	7	24%
55-64	7	24%
65-74	9	31%
75-84	6	21%
Sex		
Male	19	66%
Female	10	34%
Education Level		
High School	5	18%
College / Trades	12	41%
University / Graduate Degree	12	41%
Marital Status		
Married / Common-law	22	76%
Single / Widow	7	24%
Household Composition		
Alone	7	24%
With partner	15	52%
Partner and children	7	24%
Employment Status		
Part-time / Retired working part-time	3	10%
Full-time	11	39%
Retired	12	41%
Sick Leave – Previous Full-time	3	10%
Smoking Status		
No	14	48.5%
Current smoker	1	3%
Previous smoker	14	48.5%

Reason for Referral	n	%
Prevention – no comorbidity	2	7%
Heart attack / Stroke – no comorbidity	14	48.5%
Heart attack – comorbidities	13	44.5%

The findings are presented by drawing from patient accounts to describe: 1) facilitators and barriers to increasing PA, and 2) context specific behavioral economic principles for tailoring secondary interventions. A representation of patient barriers and facilitators are discussed as they correspond to constructs of capability, opportunity, and motivation from the COM-B model. A summary of findings is presented within Figures 4.1 and 4.2, and a detailed account of patient quotes presented within Tables 4.4, and 4.5. Results of behavioral economic principles that emerged as themes from the MINDSPACE framework are discussed as disrupting default routines, increasing commitments, changing the messenger, and introducing incentives. The interconnections between COM-B barriers to PA and behavioral economic principles is presented within Figure 4.3, and a detailed account of patient quotes presented within Table 4.6.

4.3.1 Facilitators to Increasing Physical Activity

The following facilitators to PA are presented as health promoting abilities and knowledge, supportive social and environmental influences, and positive beliefs about capabilities and reinforcement. A detailed account of patient quotes describing facilitators to increasing PA is presented within Table 4.4.

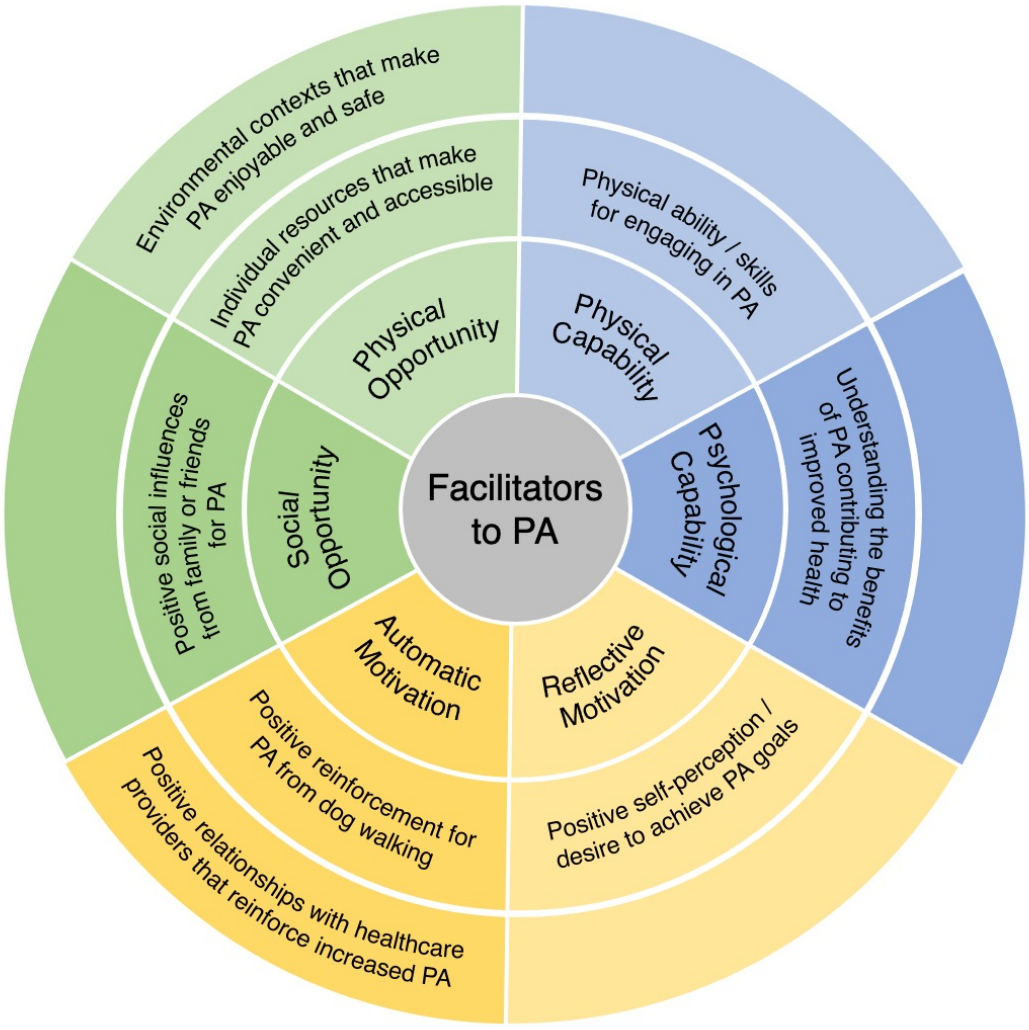


Figure 4.1 Facilitators to Physical Activity

Capability – Physical: "At least three and a half hours, every day" (P05)

All patients discussed their physical ability and skills for engaging in PA every day. As described by P11, "I run again. I do that every other day. Walking would be on the days I don't run… Obviously we take kayaks out on the lake."

Capability – Psychological: "Being more physically fit has no downsides." (P02)

Most patients (*n=22*) described understanding the benefits of different PA contributing to improved health. As P15 described, "I'm supposed to get my heart rate up

for thirty minutes, five times a week. Just doing housework or gardening isn't going to help me target specific areas, so I guess specific exercises with particular muscle groups."

Opportunity – Social: "I just wanted to see what yoga was all about, cause a lot of my friends are doing it" (P27)

Many patients (*n=21*) discussed positive perceptions towards engaging in PA in connection to social influences from family or friends. Relationships with others often provided opportunities for patients to engage in PA, for instance spending time with friends or family who walk or play sports. Some patients described how observing others engage in PA positively influenced whether they would participate in the same activity. Discussing the influence of their spouse, P17 described, "she's better at exercising than I am… I'm thinking wow, can I do that? I'm trying to do it every day, even for ten minutes."

Opportunity – Physical: "We don't want to walk out in the snow or ice anymore, so we bought a treadmill and both of us use it every day" (P01)

When discussing opportunities for PA, patients (*n=23)* described the benefits of having resources that made opportunities for PA convenient and accessible on a regular basis. Individual resources included having equipment available at home or living within a building that provided resources for PA. Access to PA equipment was described by P20, "we've got three treadmills in our little gym, so I've learned how to use that…so if it's going to rain … I'll put my name on the sign-up sheet for the gym."

Opportunities for PA were also discussed as resources within neighborhood environments that made it enjoyable and safe to engage in PA. Most patients (*n=26)* described benefits of living close to parks or engaging in PA within their neighborhood.

Having sidewalks around the neighborhood was described by P09, "to get out for my walk I really appreciate having sidewalks because otherwise it could be a dangerous road. It's quite busy."

Motivation – Reflective: "I'm motivated to do more every week… I try to push myself… to be motivated you gotta want something" (P19)

All patients described positive self-perceptions, beliefs about capabilities, and desire to achieve PA goals. Patients described feeling capable of increasing PA within their routine and used strategies to stay motivated for reaching different PA goals. Strategies for increasing PA were described by P13, "what I tried to do is use the time when I left… First day I tried it, I go around in half an hour. The next time I go down to twenty-five minutes. I did do it… Same distance, so I keep going a little faster every day."

Motivation – Automatic: "It has more weight coming from your doctor, I have a huge amount of trust" (P06)

Relationships with healthcare providers was perceived by most patients (n=21) as a positive source of reinforcement for changing behaviors. When patients sought advice or were provided a recommendation, they described feeling an automatic incentive to make a change. When discussing why they walk more, P05 stated, "yes, my doctor asked me. I was doing two hours and she said, can you give me three hours? I've stuck to it… They have more invested in me than anybody else."

Positive reinforcement for PA was also discussed when patients (n=12) walked their dog. Patients described feeling motivated to get out for daily walks to take care of their dog and discussed the unlikelihood of walking as much if they did not have a dog.

As illustrated by P07, “that’s really my exercise is walking the dog… But you don’t really have a choice with the dog. It’s only fair to her, she has to have a walk. The motivation is different because of her.”

Table 4.4 Patient Facilitators to Increasing Physical Activity

Construct	Facilitator Theme and Participant Examples
Capability Physical	**1) Physical ability/ skills for engaging in PA** **P11** "Walking. I run, now that they've fixed me, I run again. I do that every other day. Walking would be maybe on the days I don't run, or when my wife's schedule and we don't always align. So typically, if I'm walking, we'll walk together. Okay. Obviously, we take kayaks out on the lake." **P05** *Do you walk every day?* "Yes, for three and a half hours or at least three and a half hours every day. Tomorrow we'll be doing a little bit over four." **P06** "Usually I'll try to do a couple of kilometers before I start work, and then I'll try to do two or three kilometers, after."
Capability Psychological	**1) Understanding the benefits of PA contributing to improved health** **P02** "Would I like to see my overall weight go down? Yeah, from a fitness point of view or a health point of view having less gut fat is better for you, being, you know, lighter, is healthier, the more exercise I do burns off, you know it's good for my cholesterol, like, being more physically fit, has no downsides, short of, you know, wear and tear on your joints, but even that's offset because if you take off the weight, then it's not as bad on your joints. So that's sort of the long-term fitness but I also know if I burn off fat and replace it with muscle my weight may not drop, but I'm still more physically fit, than I would be if I didn't, right?" **P15** "If you're doing purposeful exercise that targets specific muscle groups, for example, one of my targets I really tried to get ten thousand steps a day, whatever that looks like but for example I might get ten thousand steps a day, but I may not get my heart rate. Right, and therefore I'm supposed to get my heart rate up for, I don't know, thirty minutes, five times a week. Even if I'm walking like that's great but it might not get the targets. So for example, if my, you know I've got extra weight on my belly. Want to get rid of that like, just doing housework or gardening isn't necessarily going to help me target specific areas so I guess specific exercises with particular muscle groups, and certain stretches or things like that."
Opportunity Social	**1) Positive social influences from family or friends for PA** **P16** *Are your activities influenced by who you're with?* "Well, I mean some people, we may go to different places with people. We do have different groups of friends I guess, some friends are more active than others. So, we do different things with them depending on who it is. I might bike in the evening some place, we'd go 10 kilometers. Some of my friends like the bike more than others. it depends on who you are with…. I spend a lot of time with my wife and we'll either go for a hike or walk together on evenings or weekends type things." **P17** *So do you talk about health goals together?* "Oh yeah, she's better at exercising than I am. She does an hour and a half on the treadmill every day. She's steady, she just gets on there and she doesn't slow either she goes a good clip." *And does that influence what you think?* "I might say yes, I suppose it embarrasses me, somewhat embarrassing. I'll go down the stairs and she's on the treadmill going just lickety split. And I'm thinking wow, can I do that? Cause if I get on it, it's maybe ten minutes, you know, it's not regular so. I'm trying to do it every day, even for ten minutes. She knows that yeah, I have said that to her. And she reminds me to do your exercise, you know. Or she'll ask me how I'm doing with it." **P27** *So what made you join that activity?* "I just wanted to see what yoga was all about. Cause a lot of my friends are doing it but I didn't want to have to drive into town. So yeah, and with spin, so me and two other girlfriends were going. So anyway, my other friend and I keep going."

Construct	Facilitator Theme and Participant Examples
Opportunity Physical	**1) Individual resources that make PA convenient and accessible** **P01** "Yeah, last autumn. We said it does not look good for the [name] center. And we don't want to walk out in the snow and the ice anymore. Yeah. So, we bought a treadmill and both of us walk on it every day, every single day. In fact, I keep a calendar on my wall, and I write down the kilometers every day and I total them up every month…I mean that [treadmill] has been such a boom to, as I mentioned to you last week, it's so easy. When I can decide one minute I'm gonna walk and then next minute I'm walking, I don't have to change my clothes for the weather and I don't have to drive somewhere and all that nonsense, I can just do it." **P20** "We've got three nice treadmills in our little gym, right, so I've learned how to use that. I've learned how to use the bikes. You know we've got a recumbent bike and regular bikes and that sort of thing, so I've developed my own little schedule if for lack of a better word, of, you know I'm trying to mirror what I do here, it's twenty minutes on the treadmill twenty minutes on the bike, but with different intervals throughout that twenty minutes, three days a week…. if it was going to rain today because it said it was going to be thunderstorms and that sort of thing. Then what I did was I put my name on the sign in sheet for the gym for four o'clock today to go on the treadmill." **P18** "I walk in the building. I walked about twenty laps up and down the hallway, and there's a railing so if I get dizzy… Well, there are a lot of times I can't get outside if it's too cold, so I have to walk inside. And my walk inside is done every day. If it's rain or snow, it doesn't matter, even sunlight, like today, rain, I'll do my walk after I leave here at home. I'll do my walk inside cause the rain." **2) Environmental contexts that make PA enjoyable and safe** **P22** *How would you describe your neighborhood?* "So, I have what's called it's [name] park up the hill. And then we're not far from [park], which was one of the main parks, and then we're not far at all and again from [name], you know the lakes and there's all kinds of walking trails along there and [name] pond so access to lots of facilities like that." *What sorts of things do you do in your neighborhood?* "I would just walk out the front door exactly because based on my schedule whether I have more conference calls that are break at certain time. Yeah, I go just leave my front door and go on my route around the neighborhood kind of thing. And then on the weekend if I was going for that walk, that's when I use the extended neighborhood either go down to [park] or go along the lakes." **P09** *What would you tell me about the area that you live in, how would you describe it?* "Well, it's residential the street is quite busy. There's sidewalks, and so I can go for a walk safely. It's close to a number of different businesses that I could walk to if I wanted to. Fairly quiet. I didn't feel safe in my other neighborhood." *Are sidewalks important to you?* "Yes, you know, to get out for my walks, I really appreciate having sidewalks because otherwise it could be dangerous road. It's quite busy."

Construct	Facilitator Theme and Participant Examples
Motivation Reflective	**1) Positive self-perception / desire to achieve PA goals** **P09** "Well, I thought that I could incorporate it, couple of weeks ago, and although I wasn't feeling up to it. Until recently, I just started incorporating it and I found that I certainly had the time. Before that I didn't have the time because I was saying to myself. Well, if I have a walk. I have to do in five minutes and so I just decided, well I'm gonna do a second walk and the second walk is going to be a little bit shorter but I can incorporate that and still have time to come back and grab something for lunch at my desk." **P13** "What I tried to do is that I use the time when I left, and the time I returned back before the first day I tried it, I go around it in half an hour. The next time I go back on it. I go down to twenty-five minutes, right. I did do it. First time in half an hour. Second time twenty-five minutes. And the third time I go to and every day, a little more faster. Yeah. For me, that is what I check out. Yeah, the same distance, so I keep going a little more faster every day." **P19** I'm motivated to do more every week, so if I did eight this week on that bike. Next week I want to do nine right because when I was coming out, I was doing six and then I went to seven now eight. Next week I'm going to try to get to nine and do my twenty minutes at nine. And if I can't do twenty minutes at nine. I'll do fifteen minutes at nine and the last five or six or something like that to get my wind back right yeah so that's what I try to do like I try to push myself. I don't know if that's, I think that's a good thing I really, it is, you know to be motivated you gotta want something in order to push yourself to motivate yourself."
Motivation Automatic	**1) Positive relationships with healthcare providers that reinforce increased PA** **P05** *Do you talk about your health goals with your doctor?* "Yes, my doctor asked me, I was doing two hours back about two or three years ago, she said, can you give me three hours? Sure, why not give it a try. So that was my doctor's suggestion and they said, you've got two hours but I'm looking for three. I said ok, fine, I've stuck to it." *What's the difference if I were to say could you add another hour?* "They have more invested in me than anybody else." **P06** *How do you feel about that information coming from your doctor versus your partner?* "It has more weight coming from your doctor and yeah, she's a doctor, she's been to Med school, and I haven't. So, and I mean she's been my doctor for many years now. So, I have a huge amount of trust. Yeah, because we've built up that relationship where, you know she just got me through cancer. **2) Positive reinforcement for PA from dog walking** **P08** *If it's not very nice out. Do you still take your dog out for a v* /ays, always, it could be a blizzard out there. He doesn't care. I just take him." *Would you still go for a walk every day if you didn't have your dog?* "Honestly, probably zero. And why is that because I've been used to, I thought by getting a dog, it would be an addition to the family. A great companion, but also someone to get me out the house, and walk around, meet neighbors, whatever. And that's what [dog name] has done. Yeah, so he's there for us, for me, and more." **P07** *Are you out every day with the dog?* "You know, that's really my exercise is walking the dog. I'll usually take the dog for a walk immediately when I get home, if it's, if it's summer, she gets walked and even if it's winter, when I come home from work, or I'll pick her up automatically and take her for a walk. Yeah, so that's the first thing that gets done." *If you didn't have the dog, would you walk?* "I'd like to say yes, but it wouldn't be an everyday thing, it would just be fulfilling like going out, right, but you don't really have a choice, with the dog. You gotta get the dog out. Yeah, so it's only fair to her she has to have a walk, right. Yeah, the motivation is different because of her."

4.3.2 Barriers to Increasing Physical Activity

The following barriers to PA are presented as limiting abilities and knowledge, restricting social and environmental influences, and negative perceptions and accountability. A detailed account of patient quotes describing barriers to increasing PA is presented in Table 4.5.

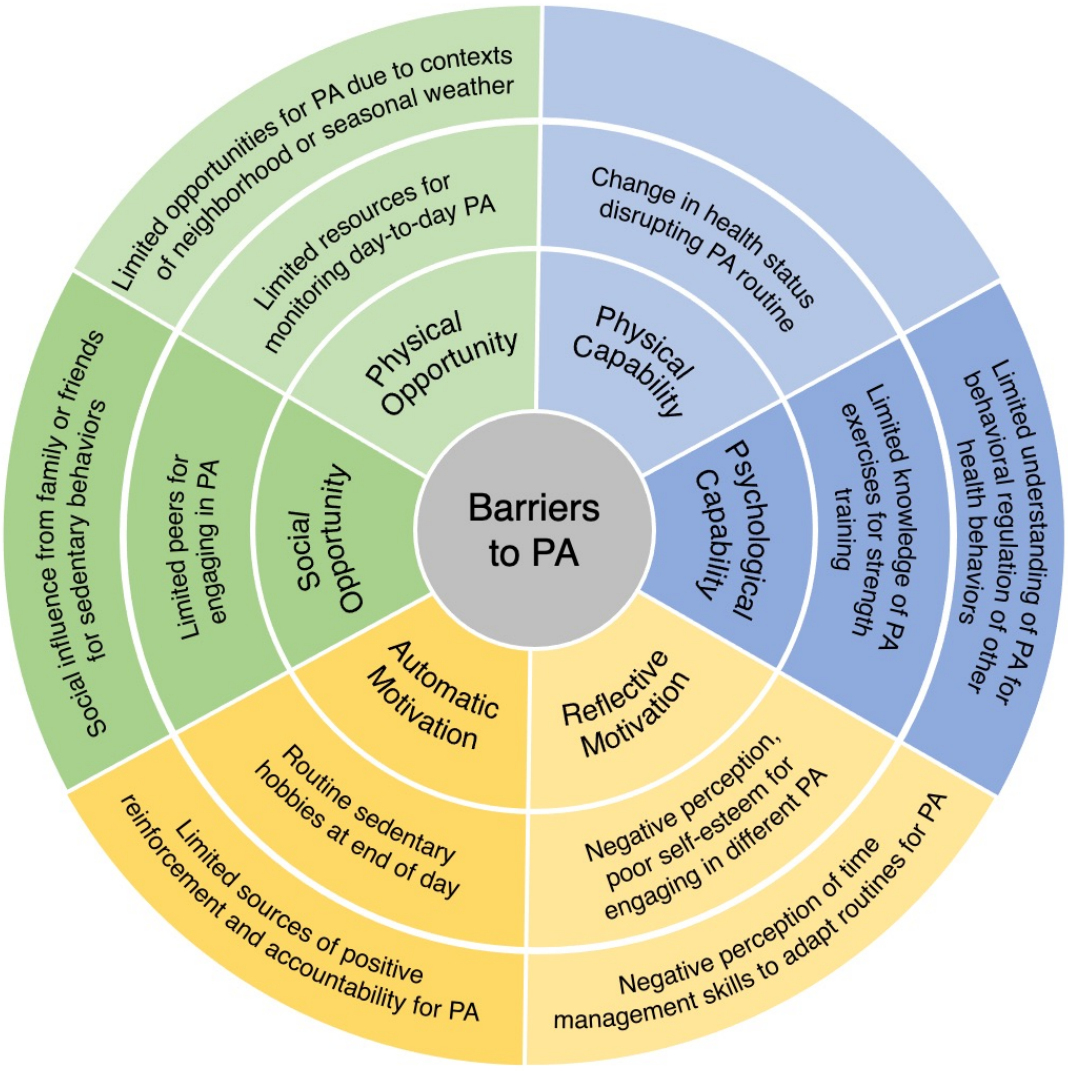


Figure 4.2 Barriers to Physical Activity

Capability – Physical: "It's my physical condition that prevents me from doing as much as I would like" (P24)

All patients described a change in health status as a barrier disrupting PA routines. Reduced physical capability for PA resulted from new or worsening health conditions, an acute injury, or physical limitations from reduced mobility. Adjusting to an acute injury was discussed from P01, "so I used to walk six kilometers, and then it was knocked down to more like two. I had a bad injury for eight months… that really cut into my physical activity."

Capability – Psychological: "I was nervous to do anything strenuous, in terms of any weights" (P15)

Many patients (*n*=22) described limited knowledge of strength training exercises, including what types of exercises were considered strength training and how strength training exercises could be integrated into their routine. When asked whether strength training was part of their routine P25 stated, "I don't know I haven't really thought… Arm, you know with the dumbbells, I don't know, biceps and that sort of thing. Maybe sit ups. I've got to write it down what I plan to do."

Another barrier to increasing PA included limited understanding of PA for behavioral regulation of other health behaviors. Many patients (*n=27*) described having poor diets while trying to increase PA. As illustrated by P14, "I think I need to prioritize physical exercise… I'm plateaued… if I eat less, I'm gonna be starving to death."

Opportunity – Social: "They don't really like to do exercises" (P10)

Social influences from family or friends to engage in sedentary behaviors was a common barrier discussed (*n=24*). Opportunities for PA were limited from time spent during social activities with friends and family that were not interested in engaging in PA. Spending time with a spouse that prefers to watch television was a barrier for P11,

"she likes to sit down and watch TV…I'm probably more active when I'm on my own… if she's gonna sit down, watch TV, so that we can spend some time together I'll go and sit down with her."

Patients (*n=26*) also described having limited peers to engage in PA as a barrier to increasing PA. Patients discussed most PA occurred alone and having peers would increase social opportunities for PA such as going for walks or trying new activities. As illustrated by P26, "I wish I had a couple of friends that were going to do the same thing or we could join to be sociable… I don't know anybody; it means I have to go by myself."

Opportunity – Physical: "Well in winter I don't walk as much, mainly because of the ice" (P28)

Limited resources for monitoring day-to-day PA were described as a barrier for increasing PA, such as monitoring intensity of activity. Patients (*n=15*) discussed limited resources to monitor PA intensity and were unaware if they were staying within recommended heart rate targets. For P23, a barrier to increasing PA intensity at home was described as, "They would come over and do your heart rate and if I was pushing it too much they were watching. But doing that on my own, I don't trust myself, I would just go too hard… It would be amazing if there was a button and I look at it and go okay, so this is what I'm at, because that's too high. So, take it back."

Limited opportunities for PA due to contexts of neighborhood or seasonal weather was also discussed by most patients (*n=24*). Limiting opportunities for PA within neighborhoods included unsafe roads and parks for walking and hazards from ice and

snow during winter months. As discussed by P17, “I don’t walk much… It’s not a good road to walk on, it’s very narrow shoulders. It’s actually dangerous.”

Motivation – Reflective: “I’m a skinny white guy, you sort of get that bias or thought in your head” (P02)

Negative perceptions and poor self-esteem for engaging in different PA was discussed as a barrier for increasing PA (*n*=23). Patients described limiting beliefs about capability to engage in different PA based on negative self-perceptions of age and appearance. Attending an exercise class geared for seniors was important for P09, “the main thing that I would think about whether or not I could keep up with that class, because if you don’t all have the same issues then they’re waiting, and I would annoy them.”

Patients also described negative perceptions of their capability for managing time to adapt routines for increased PA. Patients discussed scheduling PA around their existing routines and were challenged with identifying opportunities to adapt routines for PA. As illustrated by P03, “unless it’s integrated into other things that my family is doing… I get to be motivated to fit it in and when I was younger, it was nothing to do something at nine o’clock at night… well, it’s not that simple anymore.”

Motivation – Automatic: “Watch TV, I don’t have much more to do” (P13)

Sedentary hobbies at the end of the day were described by all patients (*n=29)* as a barrier for increasing PA. Watching television, playing cards, or reading were described as examples of sedentary activities part of patients’ routine in the evening. As described by P12, “if I can read, with nothing else to do, I can spend all afternoon reading. In the evening if when I watch TV, any time after seven p.m.”

Limited sources of positive reinforcement and accountability for PA was another barrier that made it challenging to maintain motivation for increased PA. Patients (*n=19*) described limited sources of external motivation, such as positive reinforcement from healthcare professionals or accountability from family and friends. Limited sources of positive reinforcement were described by P29 as, "I'll go do it at a gym with someone over me or just nodding… My wife or someone checking in at the gym, I think positive reinforcement goes a long way for me."

Table 4.5 Patient Barriers to Increasing Physical Activity

Construct	Barrier Theme and Participant Examples
Capability Physical	**1) Change in health status disrupting PA routine** **P01** "So I used to walk six kilometers, and then it was knocked down to more like two. I had a bad injury for eight months last year when I was feeling quite weak and that really cut, cut into my physical activity, but I'm more or less back to where he was… Now I can't go swimming. I can't go in the lake because of this central line that I have. But I still go out in the canoe, and I just make sure that the water's fairly calm. So that's what activity looks like." **P24** "It's my physical condition that prevents me from doing as much of that as I would like. And I don't know that it's ever going to be any better.…I mean I go out and I poke around, have a little patch in the backyard in the garden and I do that, and I pull some weeds and I move around, but it's not the kind of exercise that I was used to. Right. But it is still it's moving. Yeah, I don't just sit and sleep all day but, I'm not as active as I would like but I can't be. The body doesn't doesn't allow it."
Capability Psychological	**1) Limited knowledge of PA exercises for strength training** **P25** "Well the people at the health thing think I should. Strength training, I have dumbbells and I might start doing that on my own here. I don't know I haven't really thought. Arm, you know with the dumbbells, I don't know, biceps and that sort of thing. Maybe sit ups. I've got to write it down what I plan to do. There's sit up and plank and the others are mostly arm exercises with the dumbbells." **P15** "Like one of the things I was nervous to do when I first came home was anything that was like really strenuous in terms of any weights or even, you know I used to do planks or, you know, workouts and stuff like that, I was always kind of nervous now to think about, okay, how am I going to build in, you know, a little bit of strength training, I'm not going to be lifting heavy, heavy weights or anything but, You know, starting with like, well push ups and then moving down to modified push ups and things like that so I guess starting to get my head around how am I gonna work in a little bit of strength training, in terms of function and toning as opposed to, you know I'm not aspiring to be, you know, heavy weight lifter of any kind." **2) Limited understanding of PA for behavioral regulation of other health behaviors** **P14** *If weight loss is one of your goals, how are you making changes to achieve that?* "Yeah. I think I need to prioritize the physical exercise right now, because while I've changed a lot of the dietary things, nothing's like, I'm plateaued. So, I think what I need to do is stay where I am eating wise, but add in more exercise, because I think, if I eat less, I'm gonna be starving to death." **P04** "Because I want to feel better. Okay, take the strain off my heart. Yeah, I want to get my blood sugar's down, so I'm not classified as a diabetic because if I'm a diabetic, then I don't go back to work ever. … but I'm addicted to food. Okay, definitely, I got a sweet tooth since I was a little kid."
Opportunity Social	**1) Social influence from family or friends for sedentary behaviors** **P10** *Within your building, would you be organizing any events that are more activity focused?* "No, no, they're not. A lot of them are mostly seniors. So they don't really like to do exercises. So no, we don't do anything like that. The only thing we do is eat. We go for a drive and eat. So that's about it. So, we have tea on Friday afternoon. So usually, you know we have like somebody makes cookies or cupcakes or something like that so we're having food." **P11** *What sorts of activities would you do with your wife?* "We'll go for a walk but once that walk is done, she likes to sit down and watch TV. So, I'm probably more active when I'm on my own, right, because I like to spend time with each other. And if she's gonna sit down, watch TV, and that's okay it might be eight o'clock by that point. But yeah, so that we can spend some time together. I'll go and sit down with her. Yeah, whereas if I was on my own, maybe out in the yard. If it's dark, I may decide to go reorganize my garage or something." **2) Limited peers for engaging in PA** **P26** *What's holding you back from joining a gym now while you're in the program?* "There's nothing I just, I think about, you don't have the social life you used to have and there's always lots of people, lots of friends and we'd meet different places. Now, I wish I had a couple of friends that were going to do the same thing or we should join to be sociable, you know, and do something constructive like that. I don't know anybody, it means I have to go by myself, and start out, it's I think it's like me sitting in the tavern I kind of look at myself sitting there nobody talking to me."

Construct	Barrier Theme and Participant Examples
Opportunity Social	**P14** "I don't know many people like we do have friends, they live on my street, and then in the subdivision. But they're my husband's friends, do you know what I mean? Like he went to high school with them. I'm not from Halifax, he is. So, yeah, like I didn't really make any friends, they are friends, but I'm not close enough, I mean, I'm not close with anybody so that's. I have people that I'm close to now, but not, but not in the neighborhood. Yeah, just nice to have people to go for walks with and, but there's nobody I would just pick up the phone and say hey how you doing? So, I wish I'd maybe done that. Maybe I still can." **P03** *Would you go walking with anyone else?* "No, not really. Yeah, now I've thought about that. Only one of my close friends that lives within the neighborhood, the other ones live far so it's not, you know, readily available. There's nobody in the neighborhood that really would be the right fit for that I'm friends with. I have thought about that." *What do you mean by, they're not the right fit?* "Because they're not exercising, they're not likely to from the friends I have, you know. Kind of the same scenario middle class lifestyle kids and busy and, you know, where do they fit that in. I've never, I've never come across somebody I thought was the right fit, I guess for that as a casual acquaintance."
Opportunity Physical	**1) Limited resources for monitoring day-to-day PA** **P23** *Do you monitor your heart rate when you're walking?* "They were doing it, but no I wasn't paying attention to it. They would come over and do your blood pressure, heart rate. That was great. And I knew if I was, if I was pushing it too much, they were watching. And they would say something to me. But doing that on my own, I don't trust myself, I would just go too hard." *So, how do you feel about like a watch that would monitor your heart rate?* "I think it would be an amazing thing to do. Yeah, I think if, there was an alarm or there was just, you know, tap a button and I look at it and go okay, so this is what I'm at, because that's too high. So, take it back." **P14** *Do you measure or monitor how much you're walking?* "I don't. I just yeah just I'm gonna go and I'm out walking for half hour, and I try to you know make sure that I'm breathing heavy at some point, but I don't monitor it." **2) Limited opportunities for PA due to contexts of neighborhood or seasonal weather** **P17** *What would you tell me about the neighborhood that you live in?* "Rural for sure. It's close to the water. It's close to [name] Bay here. Not much in the neighborhood, other than housing, there is a store, from my place to the store is a five-minute walk. Actually, there's a liquor store there as well. So, I go probably to the liquor store more than a little… Nothing really goes on in the neighborhood as far as things to do. I don't walk much, my wife does, she goes for walks. I don't because my knees hurt and it's not a good road to walk on it's very narrow shoulders. Not very good. We're on the main road and as I say the roads are not very good for walking on so yeah, it's actually dangerous." **P13** *Looking at the map, do you do anything in your neighborhood?* "No, I don't go, don't like walking at night. They got a trail by the lake there. But no sir, I just go around, where there's people around, you know, I don't want say lateral or near like wooded area especially, I don't want to go into a wooded area. Yeah. Okay, going through that trail is like, what people are going to be there, what people are walking through? Yeah, it's more safe, out, out in the street." **P28** *So how does your activities change in the winter?* "Well in winter. I don't walk as much, mainly because of the ice. Yeah, you know, I don't want to fall and break something. And so, but I could walk inside the building." **P03** "This winter was really cold or just snowy, so probably half of what I would normally do now. If it's not raining most days then I'm out five days a week, so in winter that probably got cut two to three days a week, depending on weather and temperature."

Construct	Barrier Theme and Participant Examples
Motivation Reflective	**1) Negative perception, poor self-esteem for engaging in different PA** **P02** "It's not to say that I've never wanted to do yoga, just getting over the initial discomfort of starting, and it's not from a physical because I'm about as flexible as a board, it's more just going to a yoga class for the first time and being, you know this, uncoordinated [age] year old guy. I just haven't sort of gotten through that mental block yet to say to give it a try, but I definitely think that there would be some real value in it… I'm dealing with my own sort of biases of going into different things, you know, same reason. I'm probably not going to start joining, like a gym where I'm punching a bunch of weights. Just because you know I'm a skinny white guy, [age] year old white guy and just, you know, you sort of get that bias or thought in your head and everyone there is you know, pushing massive amounts of weights or stuff like that so not really my, my thing, you know, the, the meat head jock thing so, and that's all internal." **P09** "Because, I mean it's no good really to attend to a class that is for younger people because it just doesn't seem to fit and needs to be focused towards seniors who are having perhaps a little bit of health issue and need to have a change of pace. Right? *Do you worry that you wouldn't be able to keep up in an exercise class?* "Possibly, that would be the main thing that I would think about whether or not I could keep up with that class, because if you don't have the same issues then they're just waiting for those people, and I would annoy them." **2) Negative perception of time management skills to adapt routines for PA** **P03** "I'd like to think I can, but, you know, historically it's been tough to add that piece in, unless it's integrated into other things that my family is doing. So for me that piece for myself is tough. It goes back to the you know, where do I fit that into a schedule, and whether that's nine or ten o'clock at night. How do I fit that in. You know, I get to be motivated to fit it in and I should say, when I was younger, it was nothing to do something at nine o'clock at night and still get up at six in the morning. Well, you know, It's not that simple anymore." **P21** *If you miss your morning walk would you be able to make up that time at a different part of the day?* "Sometimes I have. It depends on what's going to happen for the rest of the day, like if I don't go for a walk in the morning, I got a golf game at ten o'clock. By the time I get home, probably around twelve o'clock. I won't go for a walk." **P11** *Have you thought about exercising in the morning?* "I'm not sure. I think I would have to, I would probably have to make a plan, initially, yeah. I need this extra little bit of time, I know, time seems to keep coming up. Yeah. So, I have to make sure I go to bed like half hour earlier. So I get good sleep, I can get up earlier. And then I could do. Maybe some moving and exercising, and then still fit in my normal coffee break and breakfast. All the rest of it. Yeah."
Motivation Automatic	**1) Routine sedentary hobbies at end of day** **P12** *Do you have any hobbies that you do at home?* "I read. It would be any, it would be in the afternoon, I try to read at least an hour. I mean if I can read, with nothing else to do, I can spend all afternoon reading. And my husband reads a lot now." *And what about TV?* "In the evening, is when I watch TV, I have to structure myself to that. Any time after seven p.m. And if I want to watch, the home improvement programs, I have to wait until after twelve p.m. because my husband doesn't watch." **P04** *What sorts of things do you do during the day?* "I have a patio garden with vegetables so watering and tending to them. Then zone out. A lot of couch potato. Yeah, there's just nothing, I'll be so glad when Netflix and Amazon Prime and these other stations, get some new seasons of the shows I like on." *Do you watch a lot of TV?* Oh my god TV's on all day. Well, I might be in the kitchen doing dishes or preparing food or something like that. Yeah, good chance that I'm in the living room sitting." **P13** *And then what happens, what does your afternoon look like?* "Afternoon, I watch some soaps. Yeah. Like I watch Price is Right. Days of our lives. Yeah, not just there watch everything from twelve o'clock till night. No, I get up I go, you know, move around a little bit." *Between dinner and one o'clock when you go to bed, what are you typically doing?* "Watch TV, got not more to do."

Construct	Barrier Theme and Participant Examples
Motivation Automatic	**2) Limited sources of positive reinforcement and accountability for PA** **P25** "I Feel a lot more confident let's put it that way, in what I was doing because after my heart attack I didn't know for sure whether I should walk or not walk, and then I did it on my own." *Since you have increased confidence, how do you feel about adding more to your route?* "Well, I thought of that and then I thought no, I'll stay with five K, I don't know whether I should. I might ask them at the center if I should consider that. I sort of made up my mind and I stay at five." **P29** *So you've had a gym membership in the past. Is there incentive for you to join again?* "Like literally no. Now that I'm talking to you, because I'll forget about it but no, it's probably. You know, the idea of continuing is probably good. And I think, however I'll do it at a gym with someone over me or just nod or whatever." *Are you talking about if there was someone checking in on you?* "I think that would help a lot. My wife or someone checking in at the gym, I think positive reinforcement goes a long way for me."

4.3.3 Behavioral Economic Principles

The following behavioral economic principles are presented as changing the default, increasing commitments, changing the messenger, and introducing incentives. A detailed account of patient quotes describing insights of behavioral economic principles is presented in Table 4.6.

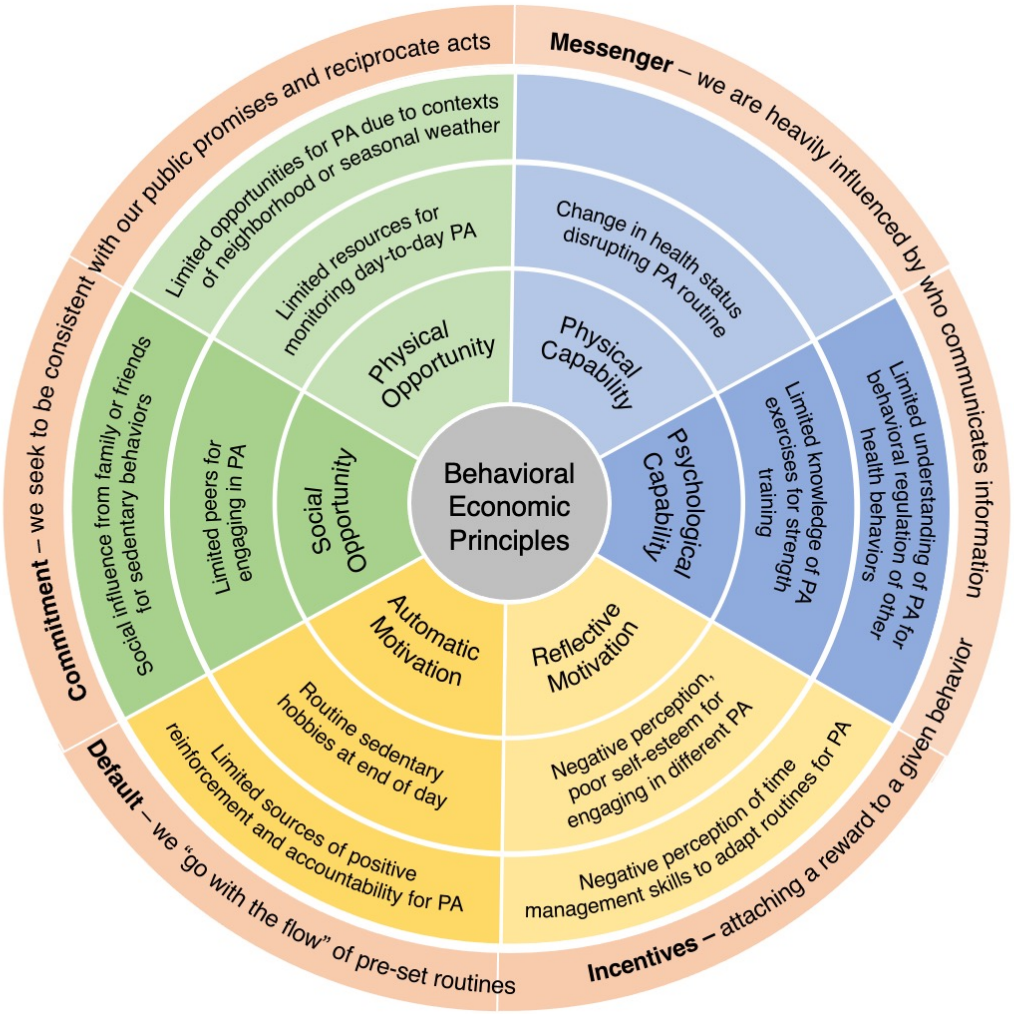


Figure 4.3 Behavioral Economic Principles

Changing the Default: "It's really easy to just do the routine" (P15)

Disrupting default habits were discussed as a potential strategy for increasing PA. Adapting default routines and changing perceptions that PA required a pre-set amount of time were described as ways patients could break free from default routines and identify opportunities for PA. Breaking free from default routines was described by P15,

> *"The problem is that if you're not thinking about it all the time, you're really intentional, it's really easy to just do the routine of, you know, go in here and do whatever and then shoot I didn't get my walk in today… Like if I'm thinking about my day and when I do, I find that works. Like when am I going to work in some exercise, will that be at the gym next door? Will it be walking at lunchtime? … I'll have to be more intentional."*

The perception that PA requires a pre-set amount of time was described by P11, "when you think of it as a time thing, and ten minutes, obviously that makes it sound easier. So, already I'm thinking like it's easy, I could fit ten minutes into my schedule as it is, by just being more efficient in the mornings."

Increasing Commitments: "If you signed up to do something, there's more of a commitment" (P02)

Sources of commitment were described as potential strategies for increasing PA. Signing up for an exercise class, scheduling PA time, and accountability of public promises for PA were described as intrinsic and extrinsic commitments that could influence opportunities for increased PA. Committing to an exercise class was described by P02,

> *"It does matter. I think there is. If you signed up to do something, there's more of a commitment, saying okay, I've committed to this. It's at eight o'clock. I got to be there, versus saying yeah you know tonight I'll go walking. But then you know something comes up it's easier to slow down. I think anything that you sort of committed to that is outside, it's definitely more important to do that."*

Commitments were also described as being accountable to public promises, as P06 stated,

> *"I think it definitely helps because it's like they say when you have a goal, you should tell someone. It makes you sort of accountable to them, even though you may not be, just because you share that goal publicly, you kind of go. Okay I said I was gonna walk ten thousand steps a day, so I better get up and do it. I think there's a lot of power in that."*

Changing the Messenger: "Having a healthcare provider check in on my results…that would be enough for me" (P20)

Individualized messages from healthcare professionals were described as potential strategies for increasing PA. Receiving information about adapting health activities and having follow-up messages to monitor results of health tests were described as opportunities that would influence increased PA. Regular communication with a healthcare professional was described by P20, "having to give her my results and maybe having a check-in done… I think for me the benefit is, and I don't know whether it's because I'm single. I live alone and don't have somebody in my sphere… I think to me that would be more than enough to motivate me to do things." The influence of a healthcare provider following-up on test results and monitoring changes in behavior was described by P05,

> *"I'm looking to see the blood stuff, your records. And how each thing, you know, your lipids are at this level… It's the little pieces of the puzzle trying to get people to change their whole lifestyle. That's not gonna happen. Taking little pieces of your lifestyle, and I think by doing that individually. You're better when someone calls you, that's my feeling."*

Introducing Incentives: "Everybody likes rewards, don't matter whether you're a kid or not, to be told you're doing a good job" (P04)

Incentives from achieving individualized PA goals was described as a potential strategy that would influence increased PA. Thirteen patients that used a digital health watch to monitor PA described incentives as a potentially useful strategy to individualize a PA goal. Sixteen patients that did not use technology or a digital watch to monitor PA described incentives as a potentially useful strategy, but discussed the importance of intrinsic motivation to drive increased PA. The influence of incentives was described by P21 as, "I would have no problem with doing that, I wouldn't expect a reward at the end, my reward would be myself. I met the goal or close to the goal." Using incentives as a gamification strategy was described by P02 as, "you know the whole gamer theory. I find that even sort of incentivizes me… I think it would have value in and of itself would be the reason I would do it."

Table 4.6 Patient Behavioral Economic Principles

Construct	Participant Examples
Default	**P15** "The problem is that if you're not thinking about it all the time, you're really intentional, it's really easy to just do the routine of, you know, go in here and do whatever and then go shoot I didn't get a walk in today, you know, you know, while you're not being intentional about, okay, I'm gonna do five sets or three sets, you know this many reps that exercise and you have to be intentional about, okay, like if I'm thinking about my day and when I do, I find that works, it's okay. Like when am I going to work in some exercise, will that be the gym next door? Will it be walking at lunchtime? And we're going to get up early to exercise before I leave? Certainly not getting exercise when I'm wandering, it will become even more. I'll have to be more intentional." **P11** *Is that how you perceive scheduling exercise? What if you thought of it as maybe I'll add ten minutes of some activity versus it having to be a chunk of time. Would that change anything?* "It's when you think of it as a time thing, and ten minutes, obviously, that makes it sound easier. So, already I'm thinking like it's easy, I could fit ten minutes into my schedule as it is, by just being more efficient in the mornings. Right. I think it would just be something I would have to work out initially before I made it my routine. I seem to be able to do things quite easily once it's a routine item for me. Yeah, but I think it would need some work and dedication. To start with, even if it's only ten minutes." **P04** "I'll either watch tick tock or put on the TV while I'm drinking my coffee." *How does the TV on first thing in the morning influence your day?* "Probably negatively influences it right? Cause I'm not up and moving around, not being active. I'm kind of just, yeah, okay I guess the day started." *And what would happen if you don't turn the TV on?* "My brain doesn't get sidetracked by TV. *What would need to change to stop that routine?* "Having a schedule."
Commitment	**P02** "It does matter. I think there is. If you signed up to do something, there's more of a commitment, saying okay, I've committed to this. It's at eight o'clock. I got to be there, versus saying yeah you know tonight I'll go walking. But then you know something comes up it's easier to slow down. Yeah. I think anything that you sort of committed to that is outside, it's definitely more important to do that." **P06** "I think it definitely helps because you're almost, it's like they say when you have a goal, you should tell someone. Yeah, because then it makes you sort of accountable to them, even though you may not be, but just because you share that goal publicly, you kind of go, Okay, I said I was gonna walk ten thousand steps a day, so I better get up and do it, right? Yeah, I think there's a lot of power in that." **P18** *Are you using any strategies to remember to do your exercises?* "I write them in my appointment book, same as I did for here… The best way to remember things. Every day I look at it before, just after I get up. Exercise, eat breakfast, the time the workers come in first. Yeah, then I work around that. I have to work around that. They're coming at this time, that gives me a lot of time do my exercises before they come."
Messenger	**P20** "Having a healthcare provider checking in on me, and having to give her, you know, my results and that sort of thing and maybe having a check-in done. You know you're at your target. Yeah, that would be enough for me personally. I think for me the benefit is, and I don't know whether it's because I'm single. I live alone and don't have somebody in my sphere. Monitoring me, not monitoring but you know, checking in on me, how you doing this and that. I think to me that would be more than enough to motivate me to do things." **P05** *So what individualised things are you looking for?* "I'm looking to see the blood stuff, your records. And how each thing, you know, your lipids are at this level and if you did stop doing that and you eat this and don't eat that, then this will change. Now come back in three month's time. Let's have a look. Okay, you have to stop doing that that that. It's the little pieces at a time, little pieces of the puzzle trying to get people to change their whole lifestyle. That's not gonna happen, but if you take little pieces of your lifestyle. That would be a better step forward, and I think by doing that individually. You're better when someone calls you, that's my feeling. **P25** "I would do it. At the end of it if somebody says you're capable of, like the doctor or nurse practitioner would say instead of doing eighty steps per minute, trying to do one hundred, I would do it, I would try it."

Construct	Participant Examples
Incentives	**P04** “Everybody likes rewards, don't matter whether you’re a kid or not. Yeah, I know everybody likes to be rewarded and told you're doing a good job.” **P21** “I have no problem doing that, I wouldn't expect a reward at the end, my reward would be myself. I met the goal or close to the goal. To see the goal, that would be my goal. Okay, if somebody wanted to track that I would certainly do that.” **P02** “You know the whole gamer theory. I find that even sort of incentivizes me so, you know, a game or something like that. I think it would have value in and of itself would be the reason I would do it. But, you know, getting recognition, saying that you've done this would be something that I would support.”

4.4 Discussion

Contexts that influence patients day-to-day decision-making processes provide important insight for identifying what behavioral economic principles could be used to influence seemingly automatic decisions about increasing PA. Results from this study indicate patients had capability and were motivated for increasing PA, but were challenged with identifying opportunities, such as when, where, and how they could adapt day-to-day routines to increase PA. Facilitators to PA are important for understanding patient capability for PA, such as where patients are at along different stages of readiness to change (Mauriello, Johnson, & Prochaska, 2017). Barriers to PA provide insight of contextual factors influencing decisions about PA, such as patients' perceptions of intrinsic and extrinsic constraints influencing opportunities for increasing PA. Although the COM-B model is useful for understanding individual drivers of behavior, the COM-B model is not useful for identifying factors that influence common automatic decisions about day-to-day activities. The integration of behavioral economic principles is critical for understanding patients' cognitive biases and identifying potential strategies that can support automatic decisions towards increasing PA like disrupting default routines of watching television, increasing commitments by signing up for exercise classes, changing the messenger with texts from healthcare professionals, and introducing incentives to reach daily step count goals. The use of behavioral economic principles as a coding framework provides useful information about tailoring strategies to the spatiotemporal contexts of patients' automatic decision-making processes. For example, timing and location sequences of patient routine activities provide import information of when and where patients are challenged with task-switching, such as

disrupting automatic sedentary routines of watching television after dinner. Future research should continue to explore suitability of behavioral economic principles before they are integrated into an intervention to ensure strategies are tailored to the contexts of barriers influencing patients' cognitive biases and resources and opportunities of different patient populations for reaching behavioral goals.

Behavioral interventions could be improved by identifying context specific opportunities that make decisions for adapting routines easier and more automatic. Behavioral economic principles are one example of intervention strategies that target fast-paced decision-making processes, such as adding environmental cues to support development of routines that are habitual and automatic (Marteau, Hollands & Fletcher, 2012). Framing, incentives, and social norms are some of the most applied behavioral economic principles within interventions for PA (Blaga et al., 2018; Hare et al., 2021; Waddell et al., 2020). For example, a Nintendo Wii video game using threat-framed messages has shown to improve positive PA attitudes, self-efficacy, and perceived behavioral control among adolescents (Lwin & Malik, 2014). Furthermore, the use of incentives has shown to increase population-wide PA for users of the Carrot Rewards mobile app in British Columbia and Newfoundland and Labrador, Canada (Mitchell et al., 2018). Our study confirms evidence that incentives are an appealing intervention strategy for achieving daily PA goals, however, more than half of patients (*n=16*) described their intrinsic motivation for PA and did not perceive that an incentive was required to initiate a change in behavior. Although patients had positive perceptions of their motivation and capability for PA, our study patients did not reflect on how their motivation and capability for PA fluctuated throughout the day, such as when they were

more likely to default to sedentary activities. When executive functions are fatigued, and patients have diminished self-regulating control for making goal-directed decisions about their behaviors; incentives may be critical for encouraging automatic decisions about adapting routines to reach an individualized goal for PA before the end of the day.

Incentives have shown to positively influence PA (Barte & Wendel-Vos, 2017) yet it is less evident whether incentives have been tailored using information about the timing and location of behaviors, such as incentivizing increased PA during times when patients are prone to defaulting to sedentary activities. For example, results from our previous study (Barber et al., 2022) provide insight of when and where behavioral interventions could be applied to adapt sedentary routines, such as after 18:00 when most patients were at home watching television. Geo-spatial contexts provide important insight about the most opportune time and place to influence automatic decisions and show intervention strategies would be most effective if they were targeted towards changing patient' activities at home.

4.4.1 Tailoring Individualized Interventions

The significance of applying behavioral economic principles within this study was to understand the contexts influencing decision-making processes and identify what strategies could be applied to tailor interventions to the individual needs and health goals of patients. Results from this study provide insight of the importance of tailoring digital tools to the common decisions patients make as part of their daily routines. For example, information that patients are challenged by limited knowledge of PA exercises for strength training provides an opportunity for healthcare professionals to work with patients to develop their own intervention strategies like scheduling calendar notifications

with instructions of different strength training exercises. Calendar notifications could be tailored and delivered at the most opportune time and place based on patients' existing day-to-day routines, access to equipment, and capability for engaging in different strength training exercises.

An example of four patient time-use patterns (Figure 4.4) from our previous study (Barber et al., 2022) illustrates how the timing and location of day-to-day activities provide critical information of what behavioral economic principles could be applied to disrupt routines and increase PA. Time-use patterns for P18 and P26 show that after eating dinner they are sedentary while at home watching television until they go to bed. Knowing that P18 and P26 remain sedentary after eating dinner provides context of the timing and location for tailoring behavioral economic principles. For example, interventions could introduce incentives for light PA before patients begin watching regularly scheduled television shows. Patients could also be supported with developing their own strategies for disrupting routines such as having exercise equipment Infront of the television to prime strength training or scheduling a walk with friends of family after dinner.

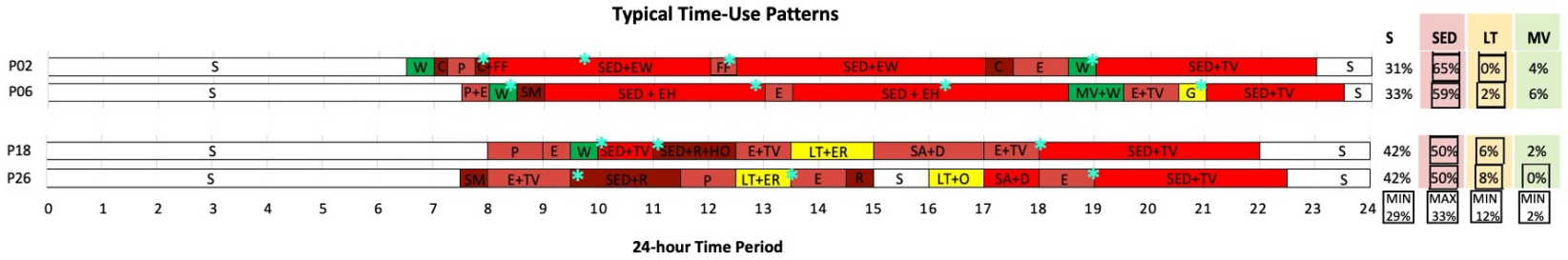


Figure 4.4 Clinical Relevance of Time-Use Patterns

* Opportunity for Intervention

Although digital health tools provide a means of delivering behavior change techniques, it is unclear whether technology-based strategies would have the same effectiveness for all patients. For example, thirteen patients within this study were using digital tools, including watches or mobile applications for self-monitoring PA, and sixteen patients were not using any technology for self-monitoring PA. It is unlikely digital tools used to deliver behavioral economic intervention strategies would have the same impact on patients that regularly interact with technology-based stimuli versus patients that do not use technology. For example, a meta-analysis of interventions using prompts to increase patient engagement with technology-based interventions found small-to-moderate positive effects that prompting reminders increased patient engagement in technology-based interventions in comparison to no prompting strategy (Alkhaldi et al., 2016). To increase effectiveness of interventions using digital tools it is critical interventions are flexible enough to adapt behavior change techniques, so they are specific to individual needs and preferences. For example, interventions could be tailored by delivering individualized counselling via mobile text messages with patients that have high engagement with using technology tools versus offering counselling via phone calls with patients that have low engagement with using technology tools. CVD interventions using mobile text messages to send motivational and educational information that encourage specific PA goals have shown to significantly increase peak aerobic capacity from baseline after 24 weeks post-intervention (Frederix et al., 2015) and increase moderate to vigorous PA minutes (>105 minutes/week) from baseline after 2 weeks post intervention (Legler et al., 2020). Additional research is required to assess long-term

effectiveness of digital health tools such as identifying whether digital health tools lose novelty when patients are exposed to the same stimuli over time (Mobekk et al., 2020).

Individualizing digital health tools is also critical for tailoring interventions across diverse patient populations that experience unique facilitators and barriers to behavior change, including chronic time deficits and limited knowledge of self-management strategies (McQuoid, Jowsey & Talaulikar, 2017; Stuart-Shor et al., 2012). CVD disproportionately affects marginalized populations (Mensah, 2018), including African Nova Scotian populations within communities where this study took place (Kisely, Terashima & Langille, 2008). It is not evident how behavioral interventions are adapted to target recruitment of diverse populations and what contextually relevant strategies are used to meet the needs of diverse and marginalized populations (Stuart-Shor et al., 2012). Research methods used in this study could be applied to advance equity, diversity, and inclusion goals by adapting the design of interventions specific to the contexts of diverse populations and community settings. For example, patient populations that experience chronic time deficits are unlikely to participate in a clinic-based intervention (Stuart-Shor et al., 2012), however, digital technologies provide a means of delivering interventions remotely using individualized health education and counselling strategies. By integrating geo-ethnographic techniques that were applied in our previous study (Barber et al., 2022), interventions could gather information of patients' time-use patterns and tailor strategies to the unique social and environmental contexts influencing opportunities for adapting health behaviors. For example, patients challenged by lack of transportation may be encouraged to participate in an intervention using incentives for daily PA goals, such as encouraging patients to walk to a public transportation stop further away from home.

Incentive strategies could also be tailored to encourage patients to watch educational health videos during opportune times when commuting on public transportation.

4.4.2 Integrating Strategies from Other Disciplines

Improving the effectiveness of behavioral interventions to prevent chronic disease and associated risk factors will require evidence from other disciplines and methodologies (Bacon, Campbell & Lavoie, 2020; Nieuwlaat et al., 2013). This study explored why behavioral economic principles are important for understanding contexts influencing decision-making processes and what strategies are potentially useful for improving automatic decisions towards increasing PA. Behavioral economic principles have not yet, to our knowledge, been integrated with geo-spatial contexts to identify the most opportune time and place to deliver behavioral economic principles.

When geo-ethnographic techniques and behavioral economic principles are combined, the effectiveness of behavioral interventions can be strengthened by identifying where, when, and how to disrupt routine activities with context specific strategies that improve automatic decisions to increase PA. Figure 4.5 provides a visualization of how time-use patterns interconnect with results from this study to identify contexts of where, when, how, and what behavioral economic principles could be applied to support patients with different behavior change goals. Results from our previous geo-ethnography study (Barber et al., 2022) show that patients were sedentary at home while working or watching television and would benefit from intervention strategies tailored to increase PA at home. For example, interventions could be tailored to deliver messages from healthcare providers about specific strength training exercises based on individual capabilities and resources during specific times of the day patients

are routinely sedentary, like while working or watching television. The sustainability of intervention strategies will depend upon using information about the timing and place of existing routines to support decisions about adapting health activities that are easy and automatic.

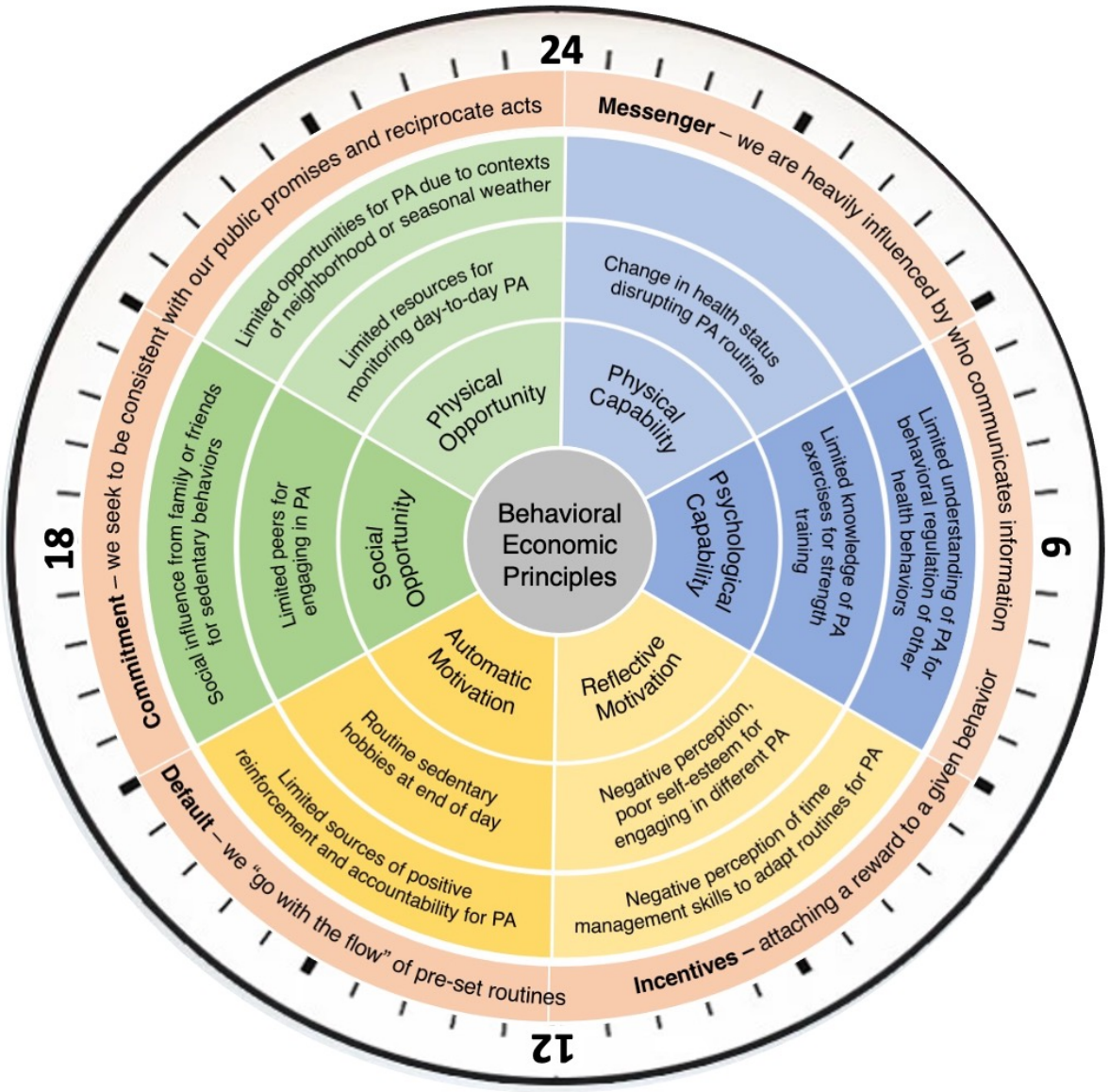


Figure 4.5 Visualization of Time-Use Techniques with Behavioral Economic Principles

4.4.3 Limitations

A limitation of this study was gathering patient perceptions about their decision-making processes without testing whether the identified behavioral economic principles are effective for increasing PA. Future research should consider integrating the APEASE framework to assess implementation of behavioral economic principles and factors influencing uptake of intervention strategies within the contexts of clinic-based interventions (Michie, van Stralen & West, 2011). The APEASE criteria outline important context-based decisions that need to be considered when adapting interventions including: 1) affordability, 2) practicality, 3) effectiveness and cost-effectiveness, 4) acceptability, 5) side-effects/ safety, and 6) equity. Many behavioral economic principles are cost-effective, however, without considering the contexts of existing health interventions, including human and financial resources available, the feasibility of implementing novel intervention strategies may be overlooked.

4.5 Conclusion

Improving the effectiveness of behavioral interventions requires strategies that are individualized, specific to clinic-based contexts, and adaptive to evidence from other disciplines. This study explores facilitators and barriers to increasing PA and how behavioral economic principles could be used to tailor secondary interventions for CVD. Results indicate patients were capable and motivated for PA, but were challenged with identifying opportunities for adapting routines to increase PA. Disrupting default routines, increasing commitments, changing the messenger, and introducing incentives were identified as potential behavioral economic principles that could be applied to influence patient decision-making processes for increasing PA. Coupling behavioral

economic principles with spatiotemporal contexts of patient day-to-day routines provides critical information of what behavioral economic principles can be tailored based on knowledge of when and where patients' health activities occur. Further research is required to implement and test the use of behavioral economic principles identified in this study to explore whether the identified methods are effective at improving the design of CVD interventions.

References

Alageel, S., Gulliford, M. C., McDermott, L., & Wright, A. J. (2018). Implementing multiple health behaviour change interventions for cardiovascular risk reduction in primary care: A qualitative study. *BMC Family Practice*, *19*, 171. https://doi.org/10.1186/s12875-018-0860-0

Alkhaldi, G., Hamilton, F., Lau, R., Webster, R., Michie, S., & Murray, E. (2016). The Effectiveness of Prompts to Promote Engagement with Digital Interventions: A Systematic Review. *Journal of Medical Internet Research, 18*(1), e4790. https://doi.10.2196/jmir.4790

Amiri, P., Jalai-Farahani, S., Zarkesh, M., Gharibzadeh, S., Hedayati, M., & Azizi, F. (2020). Behavioral Interventions for Weight Management in Overweight and Obese Adolescents: A Comparison Between a Motivation-based Educational Program and Conventional Dietary Counseling. *International Journal of Endocrinology and Metabolism, 18*(1), e88192. https://doi.105812/ijem.88192

Bacon, S. L., Campbell, T. S., & Lavoie, K. L. (2020). Rethinking How to Expand the Evidence Base for Health Behavior Change in Cardiovascular Disease Prevention. *Journal of the American College of Cardiology*, *75*(20), 2619–2622. https://doi.org/10.1016/j.jacc.2020.03.055

Bakr, O., Afsar-Manesh, N., Raja, N., Dermenchyan, A., Goldstein, N. J., Shu, S. B., & May, F. P. (2020). Application of Behavioral Economics Principles Improves Participation in Mailed Outreach for Colorectal Cancer Screening. *Clinical and Translational Gastroenterology*, *11*(1), e00115. https://doi.org/10.14309/ctg.0000000000000115

Barte, J., & Wendel-Vos, W. (2017). A Systematic Review of Financial Incentives for Physical Activity: The Effects on Physical Activity and Related Outcomes. *Behavioral Medicine, 43*(2), 79-90. https://doi.10.1080/08964289.2015.1074880

Behavioral Insights Team. (2018). *The Behavioural Insights Team: Annual Report 2017-2018*. https://www.bi.team/wp-content/uploads/2019/01/Annual-update-report-BIT-2017-2018.pdf

Betsch, T., Fiedler, K., & Brinkmann, J. (1998). Behavioral routines in decision making: The effects of novelty in task presentation and time pressure on routine maintenance and deviation. *European Journal of Social Psychology*, *28*(6), 861–878. https://doi.org/10.1002/(SICI)1099-0992(1998110)28:6<861::AID-EJSP899>3.0.CO;2-D

Blaga, O. M., Vasilescu, L., & Chereches, R. M. (2018). Use and effectiveness of behavioral economics in interventions for lifestyle risk factors of non-communicable diseases: A systematic review with policy implications. *Perspectives in Public Health*, *138*(2), 100–110. https://doi.org/10.1177/1757913917720233

Bradshaw, C., Atkinson, S., & Doody, O. (2017). Employing a Qualitative Description Approach in Health Care Research. *Global Qualitative Nursing Research*, *4*, 2333393617742282. https://doi.org/10.1177/2333393617742282

Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative Research in Psychology*, *3*(2), 77–101. https://doi.org/10.1191/1478088706qp063oa

Bray, S., Brawley, L., & Millen, J. (2006). Relationship of Proxy Efficacy and Reliance to Home-based Physical Activity After Cardiac Rehabilitation. *Rehabilitation Psychology*, *51*(3), 224–231. https://doi.org/10.1037/0090-5550.51.3.224

Cho, I., & Bates, D. W. (2018). Behavioral Economics Interventions in Clinical Decision Support Systems. *Yearbook of Medical Informatics*, *27*(1), 114–121. https://doi.org/10.1055/s-0038-1641221

Curran, F., Blake, C., Cunningham, C., Perrotta, C., van der Ploeg, H., Matthews, J., & O'Donoghue, G. (2021). Efficacy, characteristics, behavioural models and behaviour change strategies, of non-workplace interventions specifically targeting sedentary behaviour; a systematic review and meta-analysis of randomised control trials in healthy ambulatory adults. *PLOS ONE*, *16*(9), e0256828. https://doi.org/10.1371/journal.pone.0256828

Davis, R., Campbell, R., Hildon, Z., Hobbs, L., & Michie, S. (2015). Theories of behaviour and behaviour change across the social and behavioural sciences: A scoping review. *Health Psychology Review*, *9*(3), 323–344. https://doi.org/10.1080/17437199.2014.941722

Dohle, S., Diel, K., & Hofmann, W. (2018). Executive functions and the self-regulation of eating behavior: A review. *124,* 4-9. https://doi.10.1016/j.appet.2017.05.041

Dolan, P., Hallsworth, M., Halpern, D., King, D., & Ivo Vlaev. (2015). *MINDSPACE: Influencing behavior through public policy* [Report for Cabinet Office]. Retrieved from https://www.bi.team/wp-content/uploads/2015/07/MINDSPACE.pdf

Fereday, J., & Muir-Cochrane, E. (2006). Demonstrating Rigor Using Thematic Analysis: A Hybrid Approach of Inductive and Deductive Coding and Theme Development. *International Journal of Qualitative Methods*, *5*(1), 80–92. https://doi.org/10.1177/160940690600500107

Finkelstein, E. A., Haaland, B. A., Bilger, M., Sahasranaman, A., Sloan, R. A., Nang, E. E. K., & Evenson, K. R. (2016). Effectiveness of activity trackers with and without incentives to increase physical activity (TRIPPA): A randomised controlled trial. *The Lancet Diabetes & Endocrinology*, *4*(12), 983–995. https://doi.org/10.1016/S2213-8587(16)30284-4

Frederix, I., Hansen, D., Coninx, K., Vandervoort, P., Vandijck, D., Hens, N., Van Craenenbroeck, E., Van Driessche, N., & Dendale, P. (2015). Medium-Term Effectiveness of a Comprehensive Internet-Based and Patient-Specific Telerehabilitation Program with Text Messaging Support for Cardiac Patients: Randomized Controlled Trial. *Journal of Medical Internet Research*, *17*(7), e185. https://doi.org/10.2196/jmir.4799

Friedman, N., & Miyake, A. (2017). Unity and Diversity of Executive Functions: Individual Differences as a Window on Cognitive Structure. *Cortex, 86*, 186-204. https://doi:10.1016/j.cortex.2016.04.023

Gilovich, T., Griffin, D. W., & Kahneman, D. (Eds.). (2002). *Heuristics and biases: The psychology of intuitive judgment*. Cambridge University Press.

Graham, H., Prue-Owens, K., Kirby, J., & Ramesh, M. (2020). Systematic Review of Interventions Designed to Maintain or Increase Physical Activity Post-Cardiac Rehabilitation Phase II. *Rehabilitation Process and Outcome*, *9*, 1179572720941833. https://doi.org/10.1177/1179572720941833

Hailey, V., Rojas-Garcia, A., & Kassianos, A. P. (2022). A systematic review of behaviour change techniques used in interventions to increase physical activity among breast cancer survivors. *Breast Cancer*, *29*(2), 193–208. https://doi.org/10.1007/s12282-021-01323-z

Hare, A. J., Patel, M. S., Volpp, K., & Adusumalli, S. (2021). The Role of Behavioral Economics in Improving Cardiovascular Health Behaviors and Outcomes. *Current Cardiology Reports*, *23*(11), 153. https://doi.org/10.1007/s11886-021-01584-2

Hennink, M., & Kaiser, B. N. (2022). Sample sizes for saturation in qualitative research: A systematic review of empirical tests. *Social Science & Medicine*, *292*, 114523. https://doi.org/10.1016/j.socscimed.2021.114523

Inglis, S. C., Clark, R. A., McAlister, F. A., Ball, J., Lewinter, C., Cullington, D., Stewart, S., & Cleland, J. G. (2010). Structured telephone support or telemonitoring programmes for patients with chronic heart failure. *Cochrane Database of Systematic Reviews*, *CD007228*(8). https://doi.org/doi:10.1002/14651858.CD007228.pub2.

Jacob, A., Moullec, G., Lavoie, K. L., Laurin, C., Cowan, T., Tisshaw, C., Kazazian, C., Raddatz, C., & Bacon, S. L. (2018). Impact of cognitive-behavioral interventions on weight loss and psychological outcomes: A meta-analysis. *Health Psychology*, *37*(5), 417–432. https://doi.org/10.1037/hea0000576

Joseph, P., Leong, D., McKee, M., Anand, S. S., Schwalm, J.-D., Teo, K., Mente, A., & Yusuf, S. (2017). Reducing the Global Burden of Cardiovascular Disease, Part 1. *Circulation Research*, *121*(6), 677–694. https://doi.org/10.1161/CIRCRESAHA.117.308903

Kahneman, D. (2003). A perspective on judgment and choice: Mapping bounded rationality. *American Psychologist*, *58*(9), 697–720. https://doi.org/10.1037/0003-066X.58.9.697

Kahneman, D. (2011). Thinking, Fast and Slow. *Anchor Canada.*

Kahneman, D., & Tversky, A. (1984). Choices, values, and frames. *American Psychologist*, *39*(4), 341–350.

Kim, H., Sefcik, J. S., & Bradway, C. (2017). Characteristics of Qualitative Descriptive Studies: A Systematic Review. *Research in Nursing & Health*, *40*(1), 23–42. https://doi.org/10.1002/nur.21768

Kisely, S., Terashima, M., & Langille, D. (2008). A population-based analysis of the health experience of African Nova Scotians. *CMAJ : Canadian Medical Association Journal*, *179*(7), 653–658. https://doi.org/10.1503/cmaj.071279

Korteling, J. E., Brouwer, A.-M., & Toet, A. (2018). A Neural Network Framework for Cognitive Bias. *Frontiers in Psychology*, *9*(1561), 1–12. https://doi.org/10.3389/fpsyg.2018.01561

Last, B. S., Schriger, S. H., Timon, C. E., Frank, H. E., Buttenheim, A. M., Rudd, B. N., Fernandez-Marcote, S., Comeau, C., Shoyinka, S., & Beidas, R. S. (2021). Using behavioral insights to design implementation strategies in public mental health settings: A qualitative study of clinical decision-making. *Implementation Science Communications*, *2*(1), 6. https://doi.org/10.1186/s43058-020-00105-6

Legler, S., Celano, C. M., Beale, E. E., Hoeppner, B. B., & Huffman, J. C. (2020). Use of text messages to increase positive affect and promote physical activity in patients with heart disease. *Current Psychology (New Brunswick, N.J.)*, *39*, 648–655. https://doi.org/10.1007/s12144-018-9785-y

Liu, M. G., Davis, G. M., Kilbreath, S. L., & Yee, J. (2021). Physical activity interventions using behaviour change theories for women with breast cancer: A systematic review and meta-analysis. *Journal of Cancer Survivorship: Research and Practice*. https://doi.org/10.1007/s11764-021-01104-9

Lwin, M. O., & Malik, S. (2014). Can Exergames Impart Health Messages? Game Play, Framing, and Drivers of Physical Activity Among Children. *Journal of Health Communication*, *19*(2), 136–151. https://doi.org/10.1080/10810730.2013.798372

Macintyre, S., Ellaway, A., & Cummins, S. (2002). Place effects on health: How can we conceptualise, operationalise and measure them? *Social Science & Medicine*, *55*(1), 125–139. https://doi.org/10.1016/S0277-9536(01)00214-3

Marteau, T. M., Hollands, G. J., & Fletcher, P. C. (2012). Changing Human Behavior to Prevent Disease: The Importance of Targeting Automatic Processes. *Science*, *337*(6101), 1492–1495. https://doi.org/10.1126/science.1226918

Matthews, S. A., Detwiler, J. E., & Burton, L. M. (2005). Geo-ethnography: Coupling Geographic Information Analysis Techniques with Ethnographic Methods in Urban Research. *Cartographica: The International Journal for Geographic Information and Geovisualization*, *40*(4), 75–90. https://doi.org/10.3138/2288-1450-W061-R664

Mauriello, L. M., Johnson, S. S., & Prochaska, J. M. (2017). Meeting patients where they are at: Using a stage approach to facilitate engagement. In *Practical strategies and tools to promote treatment engagement* (W. O'Donohue, L. James, C. Snipes, pp. 25–44). Springer International Publishing. https://doi.org/10.1007/978-3-319-49206-3_3

McDonagh, L. K., Saunders, J. M., Cassell, J., Curtis, T., Bastaki, H., Hartney, T., & Rait, G. (2018). Application of the COM-B model to barriers and facilitators to chlamydia testing in general practice for young people and primary care practitioners: A systematic review. *Implementation Science*, *13*(1), 130. https://doi.org/10.1186/s13012-018-0821-y

McQuoid, J., Jowsey, T., & Talaulikar, G. (2017). Contextualising renal patient routines: Everyday space-time contexts, health service access, and wellbeing. *Social Science & Medicine*, *183*, 142–150. https://doi.org/10.1016/j.socscimed.2017.04.043

Mensah, G. A. (2018). Cardiovascular Diseases in African Americans: Fostering Community Partnerships to Stem the Tide. *American Journal of Kidney Diseases : The Official Journal of the National Kidney Foundation*, *72*(5 Suppl 1), S37–S42. https://doi.org/10.1053/j.ajkd.2018.06.026

Michie, S., van Stralen, M. M., & West, R. (2011). The behaviour change wheel: A new method for characterising and designing behaviour change interventions. *Implementation Science*, *6*(42), 1–11. https://doi.org/10.1186/1748-5908-6-42

Milton, S., Pliakas, T., Hawkesworth, S., Nanchahal, K., Grundy, C., Amuzu, A., Casas, J.P., & Lock, K. (2015). A qualitative geographical information systems approach to explore how older people over 70 years interact with and define their neighbourhood environment. *Health & Place*, *36*, 127–133. https://doi.org/10.1016/j.healthplace.2015.10.002

Mitchell, M., White, L., Lau, E., Leahey, T., Adams, M. A., & Faulkner, G. (2018). Evaluating the Carrot Rewards App, a Population-Level Incentive-Based Intervention Promoting Step Counts Across Two Canadian Provinces: Quasi-Experimental Study. *JMIR MHealth and UHealth*, *6*(9), e178. https://doi.org/10.2196/mhealth.9912

Mobekk, H., Hessen, D., Fagerstrom, A., & Jacobsen, H. (2020). For your eyes only: A field experiment on nudging hygienic behavior. *Front. Psychology, 11*(603440). 1-8. doi:10.3389/fpsyg.2020.603440

Mollenkamp, M., Zeppernick, M., & Schreyogg, J. (2019). The Effectiveness of Nudges in Improving the Self-Management of Patients with Chronic Diseases: A Systematic Literature Review. *Health Policy, 123*(12), 1199-1209. https://doi.10.1016/j.healthpol.2019.09.008

Neergaard, M. A., Olesen, F., Andersen, R. S., & Sondergaard, J. (2009). Qualitative description – the poor cousin of health research? *BMC Medical Research Methodology*, *9*(1), 52. https://doi.org/10.1186/1471-2288-9-52

Nieuwlaat, R., Schwalm, J.-D., Khatib, R., & Yusuf, S. (2013). Why are we failing to implement effective therapies in cardiovascular disease? *European Heart Journal*, *34*(17), 1262–1269. https://doi.org/10.1093/eurheartj/ehs481

Patterson, K., Davey, R., Keegan, R., Kunstler, B., Woodward, A., & Freene, N. (2022). Behaviour change techniques in cardiovascular disease smartphone apps to improve physical activity and sedentary behaviour: Systematic review and meta-regression. *International Journal of Behavioral Nutrition and Physical Activity*, *19*(1), 81. https://doi.org/10.1186/s12966-022-01319-8

QSR International Pty Ltd. (2020). Nvivo (Version 12 Released March 2020). Retrieved from https://www.qsrinternational.com/nvivo-qualitative-data-analysis-software/home

Room, J., Hannink, E., Dawes, H., & Barker, K. (2017). What interventions are used to improve exercise adherence in older people and what behavioural techniques are they based on? A systematic review. *BMJ Open*, *7*(12), e019221. https://doi.org/10.1136/bmjopen-2017-019221

Roth, G. A., Mensah, G. A., Johnson, C. O., Addolorato, G., Ammirati, E., Baddour, L. M., Barengo, N. C., Beaton, A. Z., Benjamin, E. J., Benziger, C. P., Bonny, A., Brauer, M., Brodmann, M., Cahill, T. J., Carapetis, J., Catapano, A. L., Chugh, S. S., Cooper, L. T., Coresh, J., … Fuster, V. (2020). Global Burden of Cardiovascular Diseases and Risk Factors, 1990–2019. *Journal of the American College of Cardiology*, *76*(25), 2982–3021. https://doi.org/10.1016/j.jacc.2020.11.010

Santo, K., & Redfern, J. (2020). Digital Health Innovations to Improve Cardiovascular Disease Care. *Current Atherosclerosis Reports*, *22*(12), 71. https://doi.org/10.1007/s11883-020-00889-x

Schorr, E. N., Gepner, A. D., Dolansky, M. A., Forman, D. E., Park, L. G., Petersen, K. S., Still, C. H., Wang, T. Y., Wenger, N. K., & null, null. (2021). Harnessing Mobile Health Technology for Secondary Cardiovascular Disease Prevention in Older Adults: A Scientific Statement From the American Heart Association. *Circulation: Cardiovascular Quality and Outcomes*, *14*(5), e000103. https://doi.org/10.1161/HCQ.0000000000000103

Statistics Canada. (2020). *The Daily – Deaths, 2019.* Statistics Canada. Retrieved from https://www150.statcan.gc.ca/n1/daily-quotidien/201126/dq201126b-eng.htm

Stuart-Shor, E. M., Berra, K., Kamau, M. W., & Kumanyika, S. (2012). Behavioral Strategies for Cardiovascular Risk Reduction in Diverse and Underserved Racial/Ethnic Groups. *Circulation*, *125*(1), 171–184. https://doi.org/10.1161/CIRCULATIONAHA.110.968495

Tversky, A., & Kahneman, D. (1974). Judgment under uncertainty: Heuristics and biases. *Science*, *185*(4157), 1124–1131.

Vlaev, I., & Makki, F. (2018). *Applying behavioral insights in health: Tackling key non communicable diseases* [Report of the WISH Policy Briefing on Behavioral Insights]. http://www.b4development.org/wp-content/uploads/2019/07/WISH-REPORT-..pdf

Waddell, K. J., Shah, P. D., Adusumalli, S., & Patel, M. S. (2020). Using Behavioral Economics and Technology to Improve Outcomes in Cardio-Oncology. *JACC: CardioOncology*, *2*(1), 84–96. https://doi.org/10.1016/j.jaccao.2020.02.006

Wang, S. Y., & Groene, O. (2020). The effectiveness of behavioral economics-informed interventions on physician behavioral change: A systematic literature review. *PLoS ONE*, *15*(6), e0234149. https://doi.org/10.1371/journal.pone.0234149

Willmott, T. J., Pang, B., & Rundle-Thiele, S. (2021). Capability, opportunity, and motivation: An across contexts empirical examination of the COM-B model. *BMC Public Health*, *21*(1), 1014. https://doi.org/10.1186/s12889-021-11019-w

Winter, S. J., Sheats, J. L., & King, A. C. (2016). The Use of Behavior Change Techniques and Theory in Technologies for Cardiovascular Disease Prevention and Treatment in Adults: A Comprehensive Review. *Progress in Cardiovascular Diseases*, *58*(6), 605–612. https://doi.org/10.1016/j.pcad.2016.02.005

World Health Organization. (2015). *Cardiovascular diseases: Avoiding heart attacks and strokes.* World Health Organization. Retrieved from https://www.who.int/news-room/questions-and-answers/item/cardiovascular-diseases-avoiding-heart-attacks-and-strokes

World Health Organization. (2021). *Noncommunicable diseases*. https://www.who.int/news-room/fact-sheets/detail/noncommunicable-diseases

CHAPTER 5

INTEGRATED DISCUSSION

5.1 Introduction

This thesis expands knowledge of behavior change and behavioral interventions by demonstrating how spatiotemporal contexts and behavioral economic principles can be coupled to improve cardiovascular disease (CVD) interventions. Specifically, it integrates mixed methods techniques from geo-ethnography and theory from behavioral economics to conceptualize how CVD interventions can solicit spatiotemporal patterns of patients' day-to-day health activities and tailor interventions with context specific strategies. Each chapter of this thesis builds upon previous work to provide insights and evidence of how spatiotemporal contexts and behavioral economic principles could be employed to strengthen CVD intervention approaches. This final chapter of the thesis provides an integrated discussion of findings from Chapters 2, 3, and 4 as they relate to expanding behavior change frameworks, techniques for collecting and visually displaying spatiotemporal data, and context specific behavioral economic intervention strategies. This integrated discussion highlights novel contributions of this thesis, strengths and limitations, and recommendations for future research.

This thesis begins by introducing how theoretical and methodological insights from health geography and behavioral economics are important for conceptualizing spatiotemporal contexts of behaviors, routine time-use patterns, and decisions about when, where, and with who activities occur (Chapter 2). Chapter 2 contributes a new way of thinking about the type of spatiotemporal information research and clinic-based interventions should be collecting from patients, and how four-dimensions of health behaviors provides insight into strategies for tailoring interventions specific to the contexts in which routine health activities occur. Adaptations to the Behavior Change

Wheel (BCW) were conceptualized by integrating spatiotemporal contexts as sources of behavior and behavioral economic strategies as intervention functions. This second chapter discusses what types of questions research and health care settings should be asking about patients' day-to-day activities, and why behavioral economic principles could be used by healthcare providers and patients to develop more effective strategies to increase health promoting activities.

Building upon previous theoretical contributions of four-dimensions of health behaviors, Chapter 3 explores how research, and potentially behavioral interventions, could collect and communicate spatiotemporal information through development of a visualization tool representing patients' time-use sequences. Patients' time-use sequences provide rich contextual details characterizing day-to-day routines, showing almost all patients described being physically active by walking alone in their neighborhood but were largely sedentary at home while working or watching television for long periods of time day-to-day. A visualization of the timing and location of patients' day-to-day routines could support healthcare professionals and patients with identifying opportunities to adjust behaviors, such as incorporating physical activity (PA) when patients are sedentary at home watching television. Time-use sequences may assist healthcare professionals' and patients' awareness of why certain routines have developed, either knowingly or not and identify specific times and locations that routine behaviors could be disrupted to achieve a desired health goal.

Contexts of patient time-use sequences were applied in Chapter 4 and patients reflected upon their day-to-day routines by describing facilitators and barriers affecting their PA. The use of behavioral economic principles as a coding framework within

Chapter 4 provided important insights into context specific strategies to increase PA. Patient insights were often consistent with behavioral economic principles that could be applied to develop intervention strategies for disrupting routines and cognitive processes to improve decisions for increasing PA. Patients were capable and motivated for increasing PA but were challenged with identifying opportunities to adapt their day-to-day routines, such as understanding when, where, and how they could make better decisions to increase PA. Patients implicitly identified strategies like disrupting default routines by encouraging smaller amounts of time for PA throughout their day, increasing commitments by scheduling PA with a friend, changing the messenger by having a healthcare professional send follow-up text messages to monitor health tests results, and introducing incentives for achieving individualized PA goals using smartphone applications.

Patients had critical insights into behavioral economic principles, although they were not educated on behavioral economics. This suggests that patients could be valuable partners in developing research and clinic-based behavioral economic intervention strategies. Chapters 3 and 4 contribute insights that intervention strategies may be more effective if they were targeted towards working with patients to understand their own spatiotemporal patterns and decision-making processes that influence why certain routines have developed, knowingly or not. Patients would benefit from learning about behavioral economic principles that can be applied to develop their own intervention strategies that disrupt their routines and improve decision-making processes when switching between tasks. For example, almost all patients described challenges with disrupting evening routines when they are at home and habitually transition from eating

dinner to watching television until they go to bed. Education of behavioral economic principles could support patients with developing individualized strategies like scheduling a short walk with friends or family after dinner, having household members hide the television remote, or placing exercise equipment infront of the couch to prime strength training while watching television.

5.2 Contributions to Measuring and Reporting Behavioral Context

This thesis takes an important first step in developing a tool with the potential to measure and communicate spatiotemporal contexts of health behaviors. Methods for measuring and reporting patients' behavioral contexts were explored using adapted geo-ethnography techniques (Chapter 3) by combining a digital map application with semi-structured interviews to collect and interpret the timing and location of patients' day-to-day routines. During the first interview patients reported information on when and where health behaviors occurred. Patient's reported day-to-day routines were discussed during a second interview (Chapter 4), using the digital map application as a visual guide to remind patients of when, where, and for how long they described certain health activities occurring. Patients demonstrated the ability to reflect on the timing and location of their health behaviors to gain insight into potential strategies that could disrupt their routines and increase PA. This information was used to develop a data communication tool by categorizing emergent time-use activities like sleep, sedentary behavior, light PA, and moderate-to-vigorous PA, and ordering activities into a 24-hour time sequence stacked-bar chart to visually display patients' unique geo-sequence patterns of behavior (Figures 3.1 & 3.2). This thesis developed a way of combining geo-ethnographic techniques with time-use diaries to represent the timing and locations of patients' day-to-day activities,

demonstrating an important first step and potentially useful approach for developing more automated tools to measure and report patients' behavioral contexts within research and integrate these methods into clinic-based settings.

The effectiveness and sustainability of behavioral interventions would likely benefit from methods to measure and report the contexts influencing health behaviors (May, Johnson & Finch, 2016; Rogers, De Brun & McAuliffe, 2020). Improving methods to measure and report behavioral contexts within research settings would entail identifying the types of questions patients could be asked to collect spatiotemporal contexts of health behaviors and methods for automating data collection, such as online-map-based surveys and ecological momentary assessment (EMA). Improving methods within clinic-based settings would entail integrating a visual tool for representing patients' time-use patterns and education of spatiotemporal contexts and behavioral economic principles so that healthcare professionals could work with patients to interpret time-use patterns and help them to develop and implement strategies to improve decisions for increasing PA within their day-to-day routines. Approaches for automating data collection provide research and clinic-based settings opportunities for reducing human resources, time, and effort required to gather spatiotemporal information from patients. However, automated approaches do not account for in-depth descriptions of patients' experiences and perceptions surrounding spatiotemporal contexts. For example, patients' experiences and perceptions of where they live and previous residential history is an important factor influencing how patients experience place and changes in their behavior over time as they move to different spaces and have opportunities to establish new day-to-day routines. My personal experience is that interviews were a powerful way

of connecting and listening to patients and provided a therapeutic approach where patients could share and reflect upon why their perceptions, experiences, and emotions are connected to their behaviors. Interviews have been valuable for generating a deeper understanding of behaviors and illustrate how context involves deeper spatial and temporal scale that quantitative methods could not capture on their own.

The importance of measuring and reporting contexts of health behaviors is supported by existing research. For example, measuring and reporting contexts of health behaviors is critical for self-management of blood glucose levels for patients with diabetes (Type 1 and 2) (Wagner, Tennen & Wolpert, 2012). Wearable digital sensor-based glucose monitors continuously report blood glucose levels and provide near real-time monitoring of spikes or drops in glucose, so that patients can adjust diet and activity patterns to stabilize blood glucose and use of insulin (Hermanns et al., 2022). Continuous glucose monitors have increased precision of detecting changes using a sensor-based glucose monitor linked to a smartphone application (Freestyle Libre, 2022). Patients can enter additional information about the timing of health activities like meals, PA, rapid-acting insulin, long-acting insulin, and are notified of immediate changes to glucose measures (Freestyle Libre, 2022; Hermanns et al., 2022). Although technology advancements have improved precise measures and reporting of changes in blood glucose, the effectiveness of sensor-based continuous glucose monitors is challenged by limited patient adherence to enter information on health activities and limited understanding of how to adapt daily activities to improve stable glucose levels (Deeb et al., 2019; Hood et al., 2015).

If continuous blood glucose monitoring was integrated with the type of spatiotemporal data and reporting demonstrated in this thesis, it could potentially improve their effectiveness. For example, temporal changes in glucose are the primary measures used to monitor glucose, yet we know the contexts in which health behaviors occur are critical for identifying when, where, and how health activities can be modified. Behavior change techniques for diabetes self-management would be strengthened. For example, by monitoring location-tracking on smartphone devices and sending notifications for patients to report the contexts of their health activities, generating information on the timing, location, and type of health activities that cause a spike or drop in blood glucose. Patients' spatiotemporal patterns of day-to-day routines would enhance precise measures and reporting of glucose changes including when and where patients are challenged with stabilizing glucose, and what behavioral modifications are required to improve glucose measures. For example, the timing of PA after meals is important for preventing glucose spikes, as evidence shows 15-minutes of moderate PA after a meal can reduce glucose spikes by 0.44mmol/L (likelihood ratio chi-square= 31.47, $p<0.01$) (Reynolds & Venn, 2018).

Measuring and reporting spatiotemporal information about the timing and location of meals could inform what behavioral economic principles, such as introducing incentives or changing the messenger, could be delivered at the most opportune time and place to improve self-management of glucose levels. Knowing that patients are likely to eat foods high in sugar at certain times of the time, such as when arriving home from work or after dinner while watching television, would be useful for supporting patients to develop individualized strategies that disrupt their routine decisions and overindulging

habits that are difficult to break. For example, putting post-it notes on cupboard doors with information about food options that stabilize glucose levels compared to foods that spike glucose could support improved decision making when patients are fatigued and likely to consume packaged foods with high sugar content. Removing temptation of sugary foods at home could also be targeted by improving patients' grocery shopping behaviors using daily priming text messages of recipes with minimal preparation time and itemized grocery shopping lists of meals and snacks that stabilize glucose levels. Furthermore, monitoring spatiotemporal contexts associated with glucose spikes could inform when and where patients are likely to be influenced by cognitive heuristics like present bias (O'Donoghue & Rabin, 2000), leading patients to give greater weight to decisions with immediate gratification (i.e., eating high sugary deserts) versus thinking of trade-offs between future costs (i.e., spike in glucose, feeling fatigue, stomach pain, headache). Combining spatiotemporal contexts of health behaviors with behavioral economic strategies could enhance the effectiveness of interventions and improve patient decisions at the most opportune time and place when they are most challenged with stabilizing blood glucose.

5.3 Contributions to Behavioral Interventions

A primary contribution of this thesis is operationalizing a new way of thinking about the type of spatiotemporal information research and clinic-based interventions should collect from patients, and how information on the timing and location of behaviors could be used by healthcare professionals and patients to develop individualized behavioral economic intervention strategies. Chapters 3 and 4 demonstrate how spatiotemporal contexts and behavioral economic principles could be coupled to increase

awareness of healthcare professionals' and patients' knowledge of specific times and locations that behavioral economic strategies could be used to increase PA. Patients are important partners for identifying how interventions could be tailored to their individual needs and what strategies could overcome barriers to behavior change. Patient perspectives are also critical for identifying how intervention strategies adopt resources patients currently use (e.g., smart watch, smartphone applications, exercise equipment) and delivered based on patients' preferences for engaging with technology (i.e., text messages, emails, phone calls).

Improvements to behavioral interventions include technology-based techniques that integrate either spatiotemporal contexts of health behaviors or behavioral economic principles; however, it is less evident how these interventions can integrate both. Interventions that adopt technologies for feedback and monitoring of health activities most often use smartphone applications and smart watch devices within behavioral interventions for PA and nutrition (Martin-Martin et al., 2021; Taj, Klein & van Halteren, 2019). A meta-analysis of interventions adopting smart watch devices found that Fitbit-based interventions significantly increased daily step count (mean difference 950 steps/day, $p<0.001$), moderate-to-vigorous PA (mean difference 6.16 minutes/day, $p<0.001$), and a significant decrease in weight (mean difference -1.48kg, $p=0.03$) (Ringeval et al., 2020). Although technologies like smart watch devices have the capability of monitoring PA, rewarding PA goals, and providing feedback by sensing sedentary activity; these technologies generally lack integration of contextual information influencing behaviors.

Integration of information on patients' spatiotemporal patterns and adoption of behavioral economic strategies could strengthen smartphone-based interventions. The Carrot Rewards Program (CRP) is an example of an intervention delivered through a smartphone application targeting participant PA behaviors using incentives (Mitchell et al., 2017; 2018). A novelty of the CRP is the use of behavioral economic principles to incentivize PA with individualized daily step count goals that result in immediate daily reward points (worth $0.04 CAD), resulting in significant increases to participant PA (average increase of 1000 steps/day from baseline during 12-week intervention, $p<0.001$) (Rondina et al., 2020; 2021). The CRP targets individual level behaviors and is successfully scaled across populations in British Columbia and Newfoundland and Labrador, Canada (Mitchell et al., 2018). Behavioral economic incentives are the foundation of this intervention, yet CRP lacks important spatiotemporal contexts of participants behaviors that could inform when and where incentives should be delivered to enhance PA outcomes. Coupling CRP incentives with spatiotemporal contexts of patient daily routines has the potential to increase PA and improve intervention effectiveness by identifying the most opportune time and place for increasing PA. For example, location-tracking on smartphone applications could provide important spatiotemporal information for monitoring when and where participants engage in PA and how levels of PA change after CRP delivers an incentive. By tracking the length of time spent engaging in PA, the CRP also has an opportunity to tailor incentives by encouraging patients to engage in smaller amounts of PA at different times and locations when participants are routinely sedentary. Coupling behavioral economic incentives with spatiotemporal contexts of patient day-to-day routines provides insight into potential

ways behavioral economic strategies can be tailored to the contexts of participants' day-to-day routines and improve maintenance of behavior change after an intervention.

Another example of the potential to integrate behavioral economic contextual information with smartphone technologies is Pokémon Go, an augmented reality game. Pokémon Go uses location-tracking technology to provide a personalized and immersive experience by encouraging participants to walk around their physical environment including streets, parks, and public spaces to catch Pokémon characters appearing in real-world settings using their smartphone camera (Khamzina et al., 2020). Pokémon Go uses gamification techniques to encourage participants to walk distances of 2-kilometers, 5-kilometers, and 10-kilometers to retrieve Pokémon characters (Nigg, Mateo & An, 2017). Although Pokémon Go is not promoted as a PA intervention, participants show significant increases in moderate to vigorous physical activity (MVPA) over 30 days in comparison to previous activity levels (25% increase in average steps/day, $p<0.001$) (Althoff, White & Horvitz, 2016). A novelty of the Pokémon Go game is the use of location-tracking technology to tailor features of the game to the contexts of participants' environments. However, when the novelty of the game wears off, Pokémon Go is challenged with retaining participants (Khamzina et al., 2020).

Spatiotemporal contexts are a critical part of the individualized and immersive experience playing Pokémon Go. However, this gamification strategy does not adequately consider barriers to increasing PA, such as contexts influencing participants decisions about engaging in PA by playing the game. Patient insight into behavioral economic principles like increasing commitments and changing default routines (Chapter 4), could potentially strengthen the design of Pokémon Go to improve decisions about

engaging in PA and increase participant retention. For example, Pokémon Go could use existing information about the timing and location of participant PA to encourage peer interactions with other participants by scheduling game challenges with other players. Changing default settings within the game could also support increased engagement by creating new stimuli and challenges at different times of the day, such as notifying participants about a challenge when participants' smartphone location-trackers indicate they are sedentary at home. Coupling behavioral economic principles with Pokémon Go spatiotemporal contexts provides new strategies for tailoring gaming applications. The effectiveness of Pokémon Go gaming strategies offers insight into potential technologies that could be tailored to the contexts of research and clinic-based interventions to support patients with increasing PA through gaming applications that would continue after an intervention.

5.4 Strengths and Limitations

The contributions of this thesis need to be considered in the context of its strengths and potential methodological limitations. This thesis is strengthened by mixed-method study design to solicit enriching conversations and in-depth descriptions of the timing and location of activities and contexts influencing how patients make decisions about their day-to-day routines. Moreover, the digital map application used during interviews was helpful for engaging patients and encouraging recall of information about the timing and location of their day-to-day activities. Participatory methods using a visualization of a digital map could potentially improve quality and accuracy of spatiotemporal data in comparison to survey-based questions. A potential limitation of using patient self-reported data includes bias from recall and socially desirability

(Althubaiti, 2016). Response bias challenges the accuracy of patient self-reported data, particularly when patients recall information about past events or overestimate participation in behaviors perceived as socially desirable (Althubaiti, 2016; Latkin et al., 2016). Social desirability response bias was mitigated by building rapport with patients over two interviews, at the start of which patients were reminded there are no right or wrong answers and personal health information that is discussed is private, confidential, and will not be shared publicly or with the intervention program. Recall response bias was mitigated using unstructured interview questions by asking patients to verify the timing and location of activities and provide in-depth descriptions about the contexts of their behaviors. After the first interview the primary researcher (BB) listened to patient audio-recordings and made notes of patient day-to-day routine activities, behavior goals, and barriers or facilitators for increasing PA. The second interview began with reviewing details of patient time-use patterns to provide patients an opportunity to reflect on anything they missed during the first interview and verify information about the timing and location of their activities entered in the map application. Inconsistencies in time-use patterns were questioned during the second interview and adjustments to routine activities were made in the map application.

Second, results from this thesis are strengthened by a sufficiently large sample size of 29 patients participating in two interviews (total 58 interviews). There is continual debate of how many participants constitute a sufficient sample size within qualitative research (Dworkin, 2012; Sandelowski, 1995; Vasileiou et al., 2018). A review characterizing qualitative sample sizes found that samples ranging from 5 to 24 participants were sufficient for achieving data saturation (Hennink & Kaiser, 2022).

Despite a sufficient sample size, patients were predominately Caucasian, and results from this thesis represent the perspectives and experiences of a homogenous sample. A lack of diverse patient population in this thesis is reflective of the largely homogenous and Caucasian patient population typically enrolled in the cardiac intervention (Cardiac Intervention Nurse, personal communication, 2021). Results of this thesis were generated from the experiences of a small proportion of total patients at risk for CVD or a repeat cardiac event in Nova Scotia, Canada. However, the research methods and techniques employed to collect patient time-use patterns can be replicated across diverse populations to investigate unique time-use patterns and contexts influencing facilitators and barriers to behavior change.

Third, to the best of my knowledge, this thesis is the first to explore how techniques from two disciplines, health geography and behavioral economics, can be employed within the context of existing research and clinic-based interventions. A strength of this thesis is the development of time-use sequences as a tool for collecting spatiotemporal information about patients' day-to-day activities and when and where context specific behavioral economic principles could be delivered to disrupt routine activities. Furthermore, to the best of my knowledge, this thesis is the first to use behavioral economic principles as a coding structure and identified the potential for educating patients of behavioral economic principles that could be applied to develop individualized intervention strategies specific to the contexts of patients' day-to-day routines so that decisions for increasing PA become automatic.

Despite these contributions, this thesis is exploratory and did not test the feasibility of a tool for clinical use. This thesis also did not assess the clinical utility of

the time-use sequence visualization tool, acceptability in a clinical setting, or improvements to the effectiveness of clinic-based interventions. Patients implicitly identified behavioral economic insights like changing the default, increasing commitments, changing the messenger, and introducing incentives (Chapter 4); however, this thesis did not assess whether behavioral economic principles could be used to educate patients or providers of potential strategies to disrupt day-to-day routines and how these insights could be applied to develop effective intervention strategies. Further research is required to assess the feasibility and clinical utility of a visualization tool and effectiveness of behavioral economic principles for developing strategies to disrupt routines and improve decisions to increase PA.

5.5 Recommendations for Future Research

Results of this thesis highlight directions for future research related to assessing the utility of spatiotemporal data collection tools in research and clinic-based settings, coupling of behavioral economic principles with spatiotemporal data for improving interventions, and scaling of CVD interventions.

5.5.1 Assessing Spatiotemporal Data Collection Tools in Clinic-Based Settings

This thesis developed methods for soliciting spatiotemporal information from patients and visually displaying their time-use sequences of day-to-day activities. Future research should assess how these methods can be automated and used within research and clinic-based settings to inform and tailor effective behavior change strategies. The development of an automated spatiotemporal data collection tool should address key questions and components of clinical value including: 1) Feasibility – can the spatiotemporal tool be automated and integrated into clinical workflows? 2)

Interpretability – can healthcare providers and patients understand information being communicated? 3) Clinical utility – does use of data from the spatiotemporal tool provide insights and improve interactions between healthcare providers and patients, leading to identification of new behavior change strategies? 4) Outcomes – does the spatiotemporal tool improve effectiveness and sustainability of interventions and improve patient outcomes, such as maintenance of behavior change?

5.5.2 Coupling Behavioral Economic Principles with Spatiotemporal Data Collection Tools

Coupling spatiotemporal techniques with behavioral economic principles contributes a new way of thinking about potential tools to collect and communicate contexts influencing patients' day-to-day activities and how this information could be applied to develop context specific intervention strategies to improve patients' decisions for increasing PA. Further research is required to assess whether education about behavioral economic principles and cognitive processes can be combined with spatiotemporal data collection tools to advance research and clinic-based intervention strategies. Modifying a CVD intervention to incorporate spatiotemporal data collection tools and behavioral economic techniques would require technological tools or online applications to engage with patients and potentially significant resources (i.e., financial resources, technology, time, expertise) for testing the effectiveness of different data collection tools and behavioral economic strategies. Future research and clinic-based interventions would benefit from testing whether spatiotemporal data collection tools and education of behavioral economic principles would lead to new insights and intervention

strategies that patients can integrate into their daily lives to support different behavior change goals.

5.5.3 Replicating and Scaling Interventions

There is limited evidence of what intervention strategies are likely to succeed in different research and clinic-based settings (Roth et al., 2020). Future research would benefit from building upon results of this thesis to investigate how spatiotemporal information and behavioral economic principles can inform development of effective intervention strategies that can be replicated and scaled across behavioral interventions. Research and clinic-based settings require more information about the contexts of patients' existing health behaviors to compare how the timing and location of different behavioral economic strategies influences a change in patients' day-to-day behaviors. Future research in this area would benefit from identifying how to systematically collect this information across different research and clinic-based settings, such as through computer programming and machine learning techniques that automate map-based surveys into visual outputs of patients' time-use sequences as demonstrated in Chapter 3. Systematically collecting spatiotemporal contexts of patients' health behaviors is important for identifying the time and location of behavioral economic strategies that are effective and comparing whether these strategies can be replicated across different research and clinic-based settings. Future research would also benefit from investigating how behavioral economic principles can be replicated across diverse community contexts, so that interventions can be scaled to reach heterogenous populations at risk of CVD or a repeat event.

5.6 Conclusion

Increasing the effectiveness and sustainability of behavioral interventions is critical for disease prevention and risk reduction of CVD. This thesis expands what is known about behavior change and behavioral interventions. A primary contribution is the coupling of spatiotemporal contexts and behavioral economic principles to conceptualize a new understanding of strategies to improve the effectiveness of different behavioral interventions. Mixed-method techniques were applied to conceptualize how CVD interventions can solicit spatiotemporal patterns of patients' day-to-day health behaviors and applied to inform context specific behavioral economic intervention strategies. Another primary contribution of this thesis is improving the way behavioral interventions measure and report contexts of patient behaviors. Behavioral interventions currently lack a systematic process for measuring and reporting contexts of behaviors and are challenged with identifying characteristics of interventions that can be replicated to improve effectiveness of interventions in different research and clinic-based settings. This thesis takes an important first step in developing a potential tool for measuring and reporting spatiotemporal contexts of patient health behaviors. Findings demonstrate there is value in future research exploring how healthcare professionals and patients can work together to develop behavioral economic strategies that disrupt day-to-day decision-making processes and routines that are difficult to break. Spatiotemporal contexts of patients' health behaviors and patients' insights into behavioral economic principles for tailoring intervention strategies demonstrate potential for working with patients to develop intervention strategies that can be integrated into the contexts of their day-to-day routines and support maintenance of behavior change after an intervention.

References

Althoff, T., White, R. W., & Horvitz, E. (2016). Influence of Pokémon Go on Physical Activity: Study and Implications. *Journal of Medical Internet Research*, *18*(12), e315. https://doi.org/10.2196/jmir.6759

Althubaiti, A. (2016). Information bias in health research: Definition, pitfalls, and adjustment methods. *Journal of Multidisciplinary Healthcare*, *9*, 211–217. https://doi.org/10.2147/JMDH.S104807

Deeb, A., Ziaullah, M., Akle, M., & Strauss, K. (2018). Utilization and Challenges of Continuous Glucose Monitoring in Sensor-Augmented Pump Therapy: A Patient Experience Analysis. *Journal of Diabetes Science and Technology*, *13*(1), 146–147. https://doi.org/10.1177/1932296818801361

Dworkin, S. L. (2012). Sample Size Policy for Qualitative Studies Using In-Depth Interviews. *Archives of Sexual Behavior*, *41*(6), 1319–1320. https://doi.org/10.1007/s10508-012-0016-6

FreeStyle Libre. (2022). FreeStyle Abbott Canada. Retrieved from https://www.freestyle.abbott/ca-en/home.html

Hennink, M., & Kaiser, B. N. (2022). Sample sizes for saturation in qualitative research: A systematic review of empirical tests. *Social Science & Medicine*, *292*, 114523. https://doi.org/10.1016/j.socscimed.2021.114523

Hermanns, N., Ehrmann, D., Shapira, A., Kulzer, B., Schmitt, A., & Laffel, L. (2022). Coordination of glucose monitoring, self-care behaviour and mental health: Achieving precision monitoring in diabetes. *Diabetologia*, *65*(11), 1883–1894. https://doi.org/10.1007/s00125-022-05685-7

Hood, K. K., Hilliard, M., Piatt, G., & Ievers-Landis, C. E. (2015). Effective strategies for encouraging behavior change in people with diabetes. *Diabetes Management (London, England)*, *5*(6), 499–510.

Khamzina, M., Parab, K. V., An, R., Bullard, T., & Grigsby-Toussaint, D. S. (2020). Impact of Pokémon Go on Physical Activity: A Systematic Review and Meta-Analysis. *American Journal of Preventive Medicine*, *58*(2), 270–282. https://doi.org/10.1016/j.amepre.2019.09.005

Latkin, C. A., Mai, N. V. T., Ha, T. V., Sripaipan, T., Zelaya, C., Le Minh, N., Morales, G., & Go, V. F. (2016). Socially desirability response bias and other factors that may influence self-reports of substance use and HIV risk behaviors: A qualitative study of drug users in Vietnam. *AIDS Education and Prevention: Official Publication of the International Society for AIDS Education*, *28*(5), 417–425. https://doi.org/10.1521/aeap.2016.28.5.417

Martín-Martín, J., Roldán-Jiménez, C., De-Torres, I., Muro-Culebras, A., Escriche-Escuder, A., Gonzalez-Sanchez, M., …& Cuesta-Vargas, A. I. (2021). Behavior Change Techniques and the Effects Associated with Digital Behavior Change Interventions in Sedentary Behavior in the Clinical Population: A Systematic Review. *Frontiers in Digital Health*, *3*. https://www.frontiersin.org/articles/10.3389/fdgth.2021.620383

May, C. R., Johnson, M., & Finch, T. (2016). Implementation, context and complexity. *Implementation Science*, *11*(1), 1–12. https://doi.org/10.1186/s13012-016-0506-3

Mitchell, M., White, L., Lau, E., Leahey, T., Adams, M. A., & Faulkner, G. (2018). Evaluating the Carrot Rewards App, a Population-Level Incentive-Based Intervention Promoting Step Counts Across Two Canadian Provinces: Quasi-Experimental Study. *JMIR MHealth and UHealth*, *6*(9), e178. https://doi.org/10.2196/mhealth.9912

Mitchell, M., White, L., Oh, P., Alter, D., Leahey, T., Kwan, M., & Faulkner, G. (2017). Uptake of an Incentive-Based mHealth App: Process Evaluation of the Carrot Rewards App. *JMIR MHealth and UHealth*, *5*(5), e70. https://doi.org/10.2196/mhealth.7323

Nigg, C. R., Mateo, D. J., & An, J. (2017). Pokémon GO May Increase Physical Activity and Decrease Sedentary Behaviors. *American Journal of Public Health*, *107*(1), 37–38. https://doi.org/10.2105/AJPH.2016.303532

O'Donoghue, T., & Rabin, M. (2000). The economics of immediate gratification. *Journal of Behavioral Decision Making, 13*(2). 233-250. doi:10.1002/(SICI)1099-0771(2000004/06)13:23.0.CO;2-U

Reynolds, A. N., & Venn, B. J. (2018). The Timing of Activity after Eating Affects the Glycaemic Response of Healthy Adults: A Randomised Controlled Trial. *Nutrients*, *10*(11), 1743. https://doi.org/10.3390/nu10111743

Ringeval, M., Wagner, G., Denford, J., Pare, G., & Kitsiou, S. (2020). Fitbit-Based interventions for healthy lifestyle outcomes: Systematic review and meta-analysis. *JMIR Publications, 22*(10), e23954. doi:10.2196/23954

Rogers, L., De Brún, A., & McAuliffe, E. (2020). Defining and assessing context in healthcare implementation studies: A systematic review. *BMC Health Services Research*, *20*(1), 591. https://doi.org/10.1186/s12913-020-05212-7

Rondina, R., Hong, M., Sarma, S., & Mitchell, M. (2021). Is it worth it? Cost-effectiveness analysis of a commercial physical activity app. *BMC Public Health*, *21*(1), 1950. https://doi.org/10.1186/s12889-021-11988-y

Rondina, R., Pearson, E. K., Prapavessis, H., White, L., Richard, S., & Mitchell, M. S. (2020). Bright spots, physical activity investments that (almost) worked: Carrot Rewards app, driving engagement with pennies a day. *British Journal of Sports Medicine*, *54*(15), 927–929. https://doi.org/10.1136/bjsports-2019-100969

Roth, G. A., Mensah, G. A., Johnson, C. O., Addolorato, G., Ammirati, E., Baddour, L. M., Barengo, N. C., … & Fuster, V. (2020). Global Burden of Cardiovascular Diseases and Risk Factors, 1990–2019. *Journal of the American College of Cardiology*, *76*(25), 2982–3021. https://doi.org/10.1016/j.jacc.2020.11.010

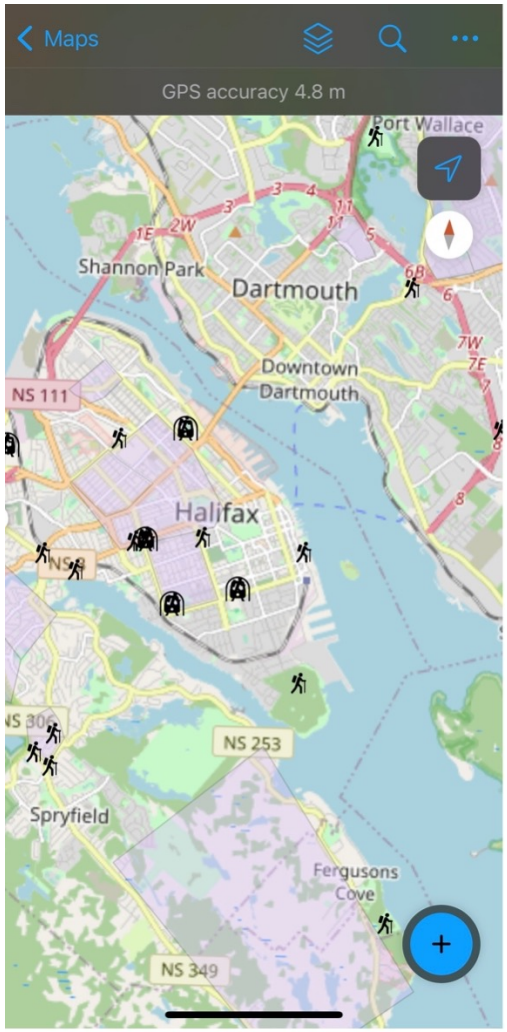
Sandelowski, M. (1995). Sample size in qualitative research. *Research in Nursing & Health*, *18*(2), 179–183. https://doi.org/10.1002/nur.4770180211

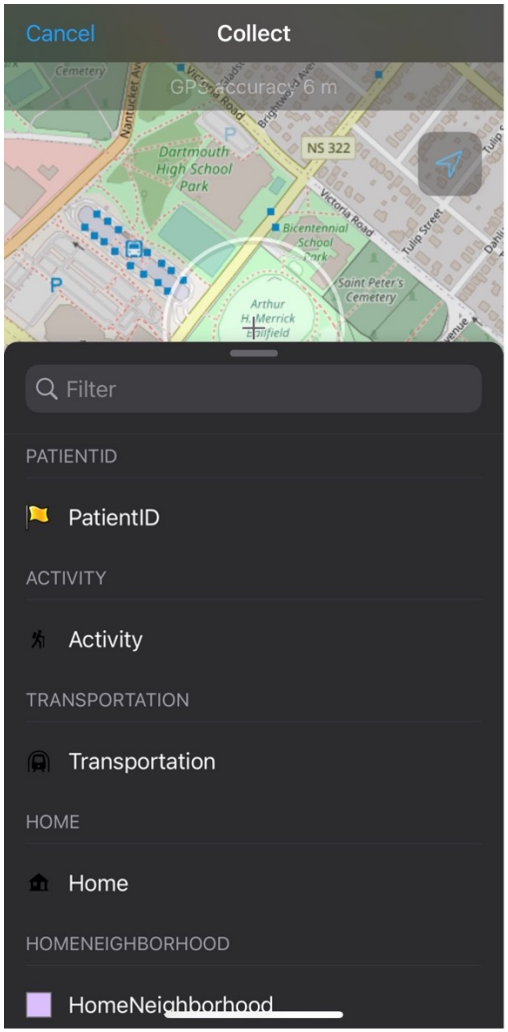
Taj, F., Klein, M. C. A., & van Halteren, A. (2019). Digital Health Behavior Change Technology: Bibliometric and Scoping Review of Two Decades of Research. *JMIR MHealth and UHealth*, *7*(12), e13311. https://doi.org/10.2196/13311

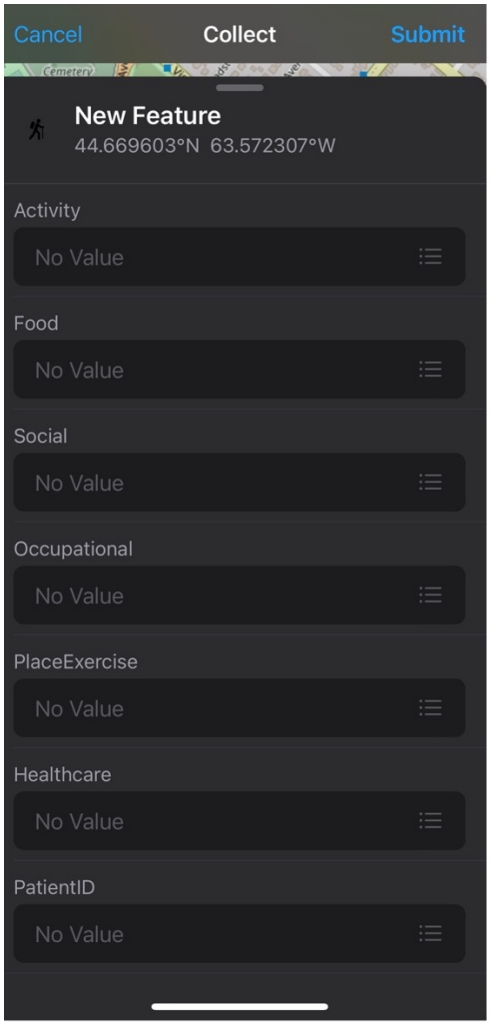
Vasileiou, K., Barnett, J., Thorpe, S., & Young, T. (2018). Characterising and justifying sample size sufficiency in interview-based studies: Systematic analysis of qualitative health research over a 15-year period. *BMC Medical Research Methodology*, *18*(1), 148. https://doi.org/10.1186/s12874-018-0594-7

Wagner, J., Tennen, H., & Wolpert, H. (2012). Continuous glucose monitoring: A review for behavioral researchers. *Psychosomatic Medicine*, *74*(4), 356–365. https://doi.org/10.1097/PSY.0b013e31825769ac

Appendix A Field Maps Application







Appendix B Research Ethics Approval

Nova Scotia Health Research Ethics Board
Centre for Clinical Research, Room 118
5790 University Avenue
Halifax, Nova Scotia, Canada B3H 1V7
shelleyl.macdonald@nshealth.ca

April 09, 2021

Ms. Brittany Barber
Health Professions
Faculty of Health Room 316, 5968 College Street.
PO BOX 15000 Halifax, N.S. Canada B3H 4R2

Delegated Review
Full Approval Letter
(April 09, 2021 to April 9, 2022)

Dear Ms. Barber:

RE: Integrating Population Health Approaches to Enhance Interventions for Prevention of Cardiovascular Disease

REB File #: 1026722

Thank you for your response regarding your proposed study.

Document Name	Comments	Version Date
Investigator Response/Revisions	Response Letter	2021/04/08
Letter of Support	Letter of Support - SI	2021/04/08
Consent Form - paper version	Consent Form Healthcare Professional - VERS 2	2021/04/08
Consent Form - paper version	Consent Form Patient VERS 2	2021/04/08
Research Protocol	Protocol Guidelines VERSION 2	2021/04/08
Supporting Materials	Recruitment Script VERS 2	2021/04/08
Supporting Materials	Recruitment Guide VERS 2	2021/04/08

I have reviewed these documents on behalf of the Nova Scotia Health Research Ethics Board and note that all requested changes have been incorporated.

I am now pleased to confirm the Board's full approval for this research study, effective today. This includes approval / favorable opinion for the following study documents:

Document Name	Comments	Version Date
Researcher's Checklist for Submission	Researcher's Checklist	2021/03/04
Investigator Response/Revisions	Response Letter	2021/04/08
Letter of Support	Letter Support - PI Department	2021/03/04
Letter of Support	Letter of Support - SI	2021/04/08
Researcher's Commitment Form	Researcher's Commitments - SI Daniel Rainham	2021/03/01
Consent Form - paper version	Consent Form Healthcare Professional - VERS 2	2021/04/08
Consent Form - paper version	Consent Form Patient VERS 2	2021/04/08
Waiver of Consent Addendum	Request for Waiver of Consent Addendum	2005/03/04
Research Protocol	Protocol Guidelines VERSION 2	2021/04/08
Supporting Materials	Recruitment Script VERS 2	2021/04/08
Supporting Materials	Recruitment Guide VERS 2	2021/04/08
Supporting Materials	Honorarium Consent Form	2021/03/05
Supporting Materials	Honorarium Tracking Form	2021/03/05
Supporting Materials	Privacy and Confidentiality Agreement	
Supporting Materials	Table 1: Theoretical Domains Framework	2021/03/04
Supporting Materials	Table 2: MINDSPACE Framework	2021/03/04
Supporting Materials	Appendix A: Phase 1 Interview Guide Patient	2021/03/04
Supporting Materials	Appendix B - Phase 2 Interview Guide Patient	2021/03/04
Supporting Materials	Appendix C - Phase 3 Interview Guide Patient	2021/03/04
Supporting Materials	Appendix D - Phase 4 Interview Guide Healthcare Prof	2021/03/04
Supporting Materials	Figure 1: ArcField Collector Tool	2021/03/04
Certificate of Completion TCPS 2: CORE	TCPS2 Core Certificate Brittany Barber	2015/09/28
Certificate of Completion TCPS 2: CORE	TCPS2-SI-certificate Daniel Rainham	2021/02/18
Curriculum Vitae (CV)	Abbreviated CV - PI Brittany Barber	2021/03/04
Curriculum Vitae (CV)	Abbreviated CV - SI- Daniel Rainham	2021/03/03
Initial Letter - REB Use Only		2021/03/26

Continuing Review

1. The Board's approval for this study will expire one year from the date of this letter **April 9, 2022.** To ensure continuing approval, submit a Request for Annual Approval to the Board 2-4 weeks prior to this date. If approval is not renewed prior to the anniversary date, the Board will close your file and you must cease all study activities immediately. To reactivate a study, you must submit a new Initial Submission (together with the usual fee) to the REB and await notice of re-approval.

2. Please be sure to notify the Board of any:
* Proposed changes to the initial submission (i.e., new or amended study documents or supporting materials),
* Additional information to be provided to study participants,
* Material designed for advertisement or publication with a view to attracting participants,
* Serious unexpected adverse reactions experienced by local participants,
* Unanticipated problems involving risks to participants or others,
* Sponsor-provided safety information,
* Additional compensation available to participants,
* Upcoming audits /inspections by a sponsor or regulatory authority,
* Premature termination / closure of the study (within 90 days of the event).

3. Approved studies may be subject to internal audit. Should your research be selected for audit, the Board will advise you and indicate any other requests at that time.

Important Instructions and Reminders

1. Submit all correspondence to Ethics Coordinator, Shelley MacDonald at the address listed at the top of this letter (do not send your response to the REB Chair or Co-Chair).
2. Login to the Research Portal; click Applications (Post Review), browse through files to locate the study in which you wish to make revisions to; click the Events Button and choose the type of revision you wish to make from the table provided; complete the electronic form and attach document under the attachments tab if required and Click on the Submit button.
3. Be sure to reference the Board's assigned file number, 1026722, on all communications.
4. Highlight all changes on revised documents, and remember to update version numbers and/or dates.

Best wishes for a successful study.

Sincerely,

Gredi Patrick, RN, BSc, MSN, MHSA, CHE
Co-Chair, Research Ethics Board

This statement is in lieu of Health Canada's Research Ethics Board Attestation:
The Research Ethics Board for Nova Scotia Health operates in accordance with:

- Part C Division 5 of the *Food and Drug Regulations* or with the definition in the *Interim Order Respecting Clinical Trials for Medical Devices and Drugs Relating to COVID-19*

- *Natural Health Products Regulations, Part 4 "Clinical Trials Involving Human Subjects"*
- *Tri-Council Policy Statement: Ethical Conduct for Research Involving Humans (TCPS 2)*
- *ICH Good Clinical Practice: Consolidated Guideline (ICH-E6)*

Appendix C Informed Consent Form

STUDY TITLE:	Integrating Population Health Approaches to Enhance Interventions for Prevention of Cardiovascular Disease
PRINCIPAL INVESTIGATOR:	Brittany Barber, PhD candidate, MA Faculty of Health, Dalhousie University 5968 College St. PO Box 15000, Halifax NS Phone 782-882-0552
FUNDER:	This study is being funded by Nova Scotia Graduate Scholarship and Maritime SPOR Support Unit

---

1. Introduction

You have been invited to take part in a research study. A research study is a way of gathering information on a treatment, procedure or medical device or to answer a question about something that is not well understood. Taking part in this study is voluntary. It is up to you to decide whether to be in the study or not. Before you decide, you need to understand what the study is for, what risks you might take and what benefits you might receive. This consent form explains the study.

You may take as much time as you wish to decide whether or not to participate. Feel free to discuss it with your friends and family, or your family doctor.

Please ask the research team or the principal investigator to clarify anything you do not understand or would like to know more about. Make sure all your questions are answered to your satisfaction before deciding whether to participate in this research study.

The researchers will:

- Discuss the study with you;
- Answer your questions;
- Be available during the study to deal with problems and answer questions.

You are being invited to participate in this research study because you are a person participating in the [Name] clinical intervention for prevention of cardiovascular disease.

If you decide not to take part or if you leave the study early, your usual health care will not be affected.

2. Why is there a need for this study?

This study is being conducted to learn how to improve the design and delivery of behavioral interventions for prevention of chronic disease. [Name] program is a behavioral change intervention that supports people with changing lifestyle behaviors, like exercising and eating healthy to reduce risk for cardiovascular disease. Existing intervention programs like [Name] program lack information about external factors within the community where people live, work, and play that influence someone's ability to make decisions about changing their lifestyle behaviors. The results will be used to develop new intervention strategies for assessing environmental factors and supporting people with making different decisions about their day-to-day activities to prevent risk for cardiovascular disease.

3. How long will I be in this study?

The length of time required for this study is about 2 to 3 hours of your time over 2 interviews that are approximately 1 hour to 1.5 hours each. Participation in this study will occur at the same time as your participation in the [Name] program, and the results should be known in 2 to 3 months after the final interviews are completed.

4. How many people can take part in this study?

It is anticipated that about 35 people will participate in this study. There will be approximately 25 patients invited to participate in three separate interviews. We will also interview up to 10 healthcare professionals that are involved in delivering the [Name] program. You may participate in this study if you are currently enrolled in the [Name] program, are at risk for developing cardiovascular disease but have not yet experienced a heart attack or stroke. Interviews will occur during the same time that people participate in the [Name] program, and the results should be known in 2 to 3 months after the final interviews are completed.

5. How is the study being done?

If you agree to participate, you will be asked to take part in 2 face-to-face or telephone interviews that will take approximately 1.5 hours of your time for each interview. Interviews that are in-person or by telephone will be audio-recorded for research purposes only and will consist of personal questions for discussion about your health. Some of the questions will focus on your day-to-day activities, where you live, work, and spend leisure time. You will also be asked about your participation in the [Name] program and experience of changing your lifestyle behaviors. Some of the questions are sensitive and could ask you to discuss changes in your health or challenges of changing your behavior. If you feel uncomfortable at any time with the questions being asked, you can skip interview questions and continue participating in the interview or withdraw from the study. The interview will take place in a private space at the [Name] program, such as a meeting room.

If you agree to participate, we will ask for your consent to gather key information from your health record about your age, sex, education level, marital status, occupation status, and smoking status. If you do not agree then this information will not be provided from your health record.

6. What will happen if I take part in this study?

If you agree to participate in this study, then the principal researcher will organize a time to meet at the [Name] clinic to discuss interview questions. In-person interviews will be audio-recorded and virtual interviews will be video-recorded. All interview discussions will be typed word-for-

word into a document and any personal information that identifies you, such as your name, address, or place of work, will be removed.

You are free to withdraw at any point in time from the research study, and your audio-recording information will be destroyed and not used further in the study.

7. Are there risks to the study?

There are no medical risks to you from participating in this study but taking part in this study may make you feel uncomfortable. You may refuse to answer questions or stop the interview at any time if you experience any discomfort. As with all research, there is a chance that confidentiality could be compromised; however, we are taking precautions to minimize this risk.

8. Are there benefits of participating in this study?

This research may not benefit you directly. However, your participation could provide important information that could help strengthen behavioral interventions and help people with behavior change that are participating in the [Name] program.

9. What happens at the end of the study?

It is anticipated that the results of this study will be published and or presented in a variety of forums. In any publication and/or presentation, information will be provided in such a way that you cannot be identified, except with your express permission.

If the results of the study are published, your name will not be used, nor any information that may identify or re-identify you. If you would like to receive a copy of study results, please contact the principal researcher Brittany Barber - brittany.barber@dal.ca

10. What are my responsibilities?

As a study participant you will be expected to:

- Follow the directions of the research team;
- Report any changes in your health to the research team;
- Report any problems that you experience that you think might be related to participating in the study;

11. Can my participation in this study end early?

Yes. If you chose to participate and later change your mind, you can say no and stop the research at any time. If you wish to withdraw your consent, please inform the research team. If you choose to withdraw from this study, your decision will have no effect on your current or future medical treatment, such as your participation within the [Name] program.

Participation in this study is voluntary. You have the right to not participate, not answer specific questions, and you can also choose to end your participation during the interview. If you choose to withdraw your data from this study, you can do so up until approximately 3 months after data collection is complete and results are available.

Also, the Nova Scotia Health Research Ethics Board and the principal researcher Brittany Barber have the right to stop patient recruitment or cancel the study at any time.

Lastly, the principal investigator may decide to remove you from this study without your consent for any of the following reasons:

- You do not follow the direction of the research team,
- You are experiencing side effects that are harmful to your health or well-being,

If you are withdrawn from the study, the principal researcher Brittany will discuss the reasons with you, and you will continue to participate in the [Name] program.

12. What will happen to my personal information after the study is over?

The research team will keep any personal health information about you in a secure and confidential location for seven years and then destroy it according to Nova Scotia Health Authority policy.

13. What about new information?

You will be told about any other new information that might affect your health, welfare, or willingness to stay in the study and will be asked whether you wish to continue taking part in the study or not.

14. Will it cost me anything?

There are no additional costs beyond the time required to participate in an interview for this study.

Compensation

You will be offered an honorarium as a token of appreciation for participation in this study. This honorarium will be $25 gift certificate to Sobeys, determined according to average hourly pay estimates for all patient participants. Honorariums will be provided at the end of the second interview once data collection is complete. If the second interview is by telephone, then honorarium gift certificates will be mailed to the patient's home address.

Research Related Injury

If you become ill or injured as a direct result of participating in this study, necessary medical treatment will be available at no additional cost to you. Your signature on this form only indicates that you have understood to your satisfaction the information regarding your participation in the study and agree to participate as a subject. In no way does this waive your legal rights nor release the principal investigator, the research staff, the study sponsor or involved institutions from their legal and professional responsibilities.

15. What about my privacy and confidentiality?

Protecting your privacy is an important part of this study. Every effort to protect your privacy will be made. If the results of this study are presented to the public, nobody will be able to tell that you were in the study.

However, complete privacy cannot be guaranteed. For example, the principal investigator may be required by law to allow access to research records.

If you decide to participate in this study, a research team will look at your personal information and collect only the information they need for this study. "Personal health information" is health information about you that could identify you because it includes information such as your;

- Name,
- Address,
- Telephone number,
- Age or month/year of birth (MM/YY),
- Information from the study interviews and questionnaires,
- New and existing medical records.

Access to Records

Other people may need to look at your personal information to check that the information collected for the study is correct and to make sure the study followed the required laws and guidelines. These people might include:

- The Nova Scotia Health Authority Research Ethics Board (NSHA REB) and people working for or with the NSHA REB because they oversee the ethical conduct of research studies within the Nova Scotia Health Authority.

Use of your study information

Any study data about you that is sent outside of the Nova Scotia Health Authority will have a code and will not contain your name or address, or any information that directly identifies you.

De-identified interview data from you and healthcare provider will be transferred to:

- Members of the research team at Dalhousie University

Study data sent to Dalhousie University will be protected and stay in the custody of Brittany Barber and used only for the research purposes explained in this consent form.

The research team will keep the information they see or receive about you confidential, to the extent permitted by applicable laws. Even though the risk of identifying you from the study data is very small, it can never be completely eliminated.

The research team will keep any personal health information about you in a secure and confidential location for seven years and then destroy it. Your personal health information will not be shared with others without your permission.

You have the right to be informed of the results of this study once the entire study is complete.

The Research Ethics Board and people working for or with the Research Ethics Board may also contact you personally for quality assurance purposes.

Your Access to Records

You have the right to access, review, and request changes to your study data.

You also have the right to review interview transcripts for accuracy. If you wish to do so, please contact the principal researcher Brittany Barber at brittany.barber@dal.ca

16. Declaration of financial interest

The Nova Scotia Graduate Scholarship and Maritime SPOR Support Unit is reimbursing the principal investigator's institution to conduct this study. The amount of payment is sufficient to cover the costs of conducting the study.

17. What about Questions or Problems?

For further information about the study, you may call the principal researcher who is the person in charge of this study and/or any other research team member listed below.

The principal investigator is **Brittany Barber**
Telephone: 782-882-0552

18. What are my rights?

You have the right to all information that could help you make a decision about participating in this study. You also have the right to ask questions about this study and your rights as a research participant, and to have them answered to your satisfaction before you make any decision. You also have the right to ask questions and to receive answers throughout this study. You have the right to withdraw your consent at any time.

If you have questions about your rights as a research participant, and/or concerns or complaints about this research study, you can contact the Nova Scotia Health Authority Research Ethics Board manager at 902-473-8426 or Patient Relations at (902) 473-2133 or 1-855-799-0990 or healthcareexperience@nshealth.ca

In Nova Scotia, medical records are subject to the *Personal Health Information Act*, which governs the collection, use, disclosure, retention, disposal and destruction of personal health information. If you have questions about your rights under the *Personal Health Information Act*, please call the Nova Scotia Department of Health and Wellness Privacy Office (902)-424-5419 or
Toll free 1-855-640-4765.

In the next part you will be asked if you agree (consent) to join this study. If the answer is "yes", please sign the form.

19. Consent Form Signature Page

I have reviewed all of the information in this consent form related to the study called:

Integrating Population Health Approaches to
Enhance Interventions for Prevention of Cardiovascular Disease

I have been given the opportunity to discuss this study. All of my questions have been answered to my satisfaction.

☐ I **agree** that key demographic information about my age, sex, education level, marital status, occupation status, and smoking status will be provided from my health record for research purposes.

This signature on this consent form means that I agree to take part in this study. I understand that I am free to withdraw at any time without affecting my future participation in the [Name] program.

☐ I **agree** to allow collection of interview data, and audio recordings as described in this consent form.

_____	_____	____ / _____ / ___
Signature of Participant	Name (Printed)	Year Month Day*
_____	_____	____ / _____ / ___
Signature of Principal Researcher Conducting Consent Discussion	Name (Printed)	Year Month Day*

Note: Please fill in the dates personally

I will be given a signed copy of this consent form.
Thank you for your time and patience!

Appendix D Semi-Structured Interview Guide for Phase 1: Geo-ethnography

Turn on tape recorder.

"Thank you for agreeing to participate in this study and discuss with me details of your day-to-day activities. I want to remind you that this study is not part of the program and everything we discuss together will remain confidential and will not have any impact on your participation in the program. I will be asking you questions about your day-to-day activities and you will be making an impact by contributing knowledge towards improving intervention programs to help people adapt their health behaviors. This is an open conversation and there is no judgment towards any of the topics we discuss or judgment towards any of the activities you engage in day-to-day.

Today we will be using this electronic tablet to interact with a map in order for you to show me some of your routine activities. The visual map may help you remember some of your activities or the places you frequently go. Please let me know if you don't understand a question or you want me to repeat something I have said. As outlined in the consent form, this interview will be audio recorded and I will be taking some notes while we talk. If you want to skip any questions or stop the interview at any time, please let me know."

Do you have any questions before we begin?

If yes, answer questions and make notes.
If no, "Okay, let's begin."

1. We are going to start by looking at the map of the Halifax area on this tablet. Can you point out where you live?
    a. What type of home do you live in? (house, apartment, condo)
    b. Who do you live with?
    c. Do you have any pets?

2. What can you tell me about the neighborhood where you live?
    a. How long have you been living here? Where did you live before?
    b. Looking at this map can you draw a boundary on the map of what you consider to be your neighborhood?
    c. What sorts of activities do you do in your neighborhood?
    d. How much time do you spend in your neighborhood?
    e. What relationships do you have with people in your neighborhood?
    f. Looking at the map of your neighborhood, is there anything you see that reminds you of activities you do and may have forgotten to mention?

3. How would you describe your typical activities on a given day?
    a. What time does your day typically start?
    b. Are you currently working anywhere? - Probe what they do there (i.e., strenuous or sedentary behavior)
        i. Where do / did you work? How much time do you spend at work?

If not working; Are you currently volunteering anywhere? – Probe what they do there (i.e., strenuous or sedentary behavior)

ii. Where do you volunteer? How much time do you spent volunteering?

c. How do you get to work?
d. Do you stop anywhere along your route to pick up a snack or something quick to eat? Where would you stop? How many times a week would you say you go there?
e. Do you go anywhere before work? What about after work?
f. What do your typical evenings look like? What activities might you find yourself doing?
g. What makes you choose to do [this activity]?
h. How much time do you have to yourself in the evenings?
i. When do you typically go to bed?

4. What can you tell me about your routine activities in a given week?
    a. Do you have time off, say on the weekends?
    b. What sorts of activities do you do on your days off? (i.e., weekend)
    c. How do you typically get there? Do you drive, ride a bicycle or walk?
    d. Are you doing these activities alone? Who would you typically be with?
    e. What about your routine in a 2-week period? What activities are consistent? What activities may arise that are out of routine?
    f. Are some of your routine activities influenced by other people? How so? Can you tell me more?

5. Now that we have a good idea of your activities in a day and week. How might your routine change during winter?

6. Are your activites influenced by who you are with?
    a. How do your activities change based on who you are with?

7. Based on what you've described, it sounds like you mainly (drive) most places. Is that correct?
    a. Do you ever bike or take public transit?
    b. Why do you decide to drive instead of walking or riding a bike?
    c. Is your transportation influenced by other people?

8. Where do you typically go to shop for groceries?
    a. Who typically shops for groceries in your household?
    b. Who is involved in deciding what to eat or meal planning?
    c. How many times a week do you get groceries?
    d. What time of day do you typically get groceries?
    e. How do you typically get there? How long does it take to get there?
    f. Who are you typically shopping for?
    g. Are there reasons you do to this store?

9. Where do you typically eat your meals?

10. How often do you eat at home? How often do you eat out?
    a. What do you typically order when eating out?

11. Where do you typically go if you were to eat out?
    a. Are you typically alone when you eat out? Who would be with you?
    b. Do your choices of where to eat change if you are alone?
    c. How do you typically get there?

12. What are some of the activities you do with other people like your friends or family?
    a. What are some places you go together? What makes you go there?
    b. How do you typically get there? Do you drive, ride a bicycle or walk?

13. Now that we've discussed some of your typical or routine activities, can you think of any unexpected things that have come up to change your daily activities?
    a. Probe: For example, have any unpredictable needs or issues, such as helping family or friends, tending to your own health needs, unexpected things that throw your daily or weekly activities off?

14. Lastly, can you tell me why you think you were referred to this cardiac program?
        i. Are you diagnosed with having … ?
        ii. When were you first aware you experience … ?
        iii. Does your (health condition) influence some of the activities you do?
        iv. Do you have a family doctor? Where do you go to see your healthcare provider? How often do you have an appointment?
        v. Do you feel your healthcare provider plays an active role in the management of your health condition?

15. Do you have any health goals you are working towards?
    a. How do you make decisions to achieve this goal?
    b. Are there specific day-to-day actions that you take?
    c. How would you describe any challenges that get in the way of achieving this goal?
    d. How are you overcoming these challenges?
    e. How would you describe factors that support you in achieving your goals?

16. We've been talking about your current day-to-day activities. How has your routine changed over the past year due to COVID?
    a. What are some examples of activities that you stopped doing?
    b. What are some examples of new or different activities you started doing?
    c. How do you feel you've been able to adapt to external changes from COVID?

We are almost done the interview but before we end …

17. Are there any other comments you would like to make?

18. Is there anything I should have asked that you think I should know about?

Those are all of the questions that I had so unless there is anything else, that is the end of our interview. Thank you for your time."

Appendix E Semi-Structured Interview Guide for Phase 2: Behavioral Economics

Turn on tape recorder.

"Thank you for agreeing to participate in the second interview together. Today we will be reviewing previous interview topics and discuss how you could adapt your activities while participating in the program. Please let me know if you don't understand a question or you want me to repeat something I have said. As outlined in the consent form, this interview will be audio recorded and I will be taking some notes while we talk. If you want to skip any questions or stop the interview at any time, please let me know."

Do you have any questions before we begin?

If yes, answer questions and make notes.
If no, "Okay, let's begin."

"In the previous two interviews we've discussed your routine patterns of activity and some of the decision-making processes that influence activities you participate in."

1. How are you doing since we last spoke? Do you have any reflections or thoughts since our first interview?

2. This is a visualization of the neighborhood boundary you drew during the last interview. Do you feel this is still an accurate representation of your neighborhood?
    a. Are there any changes to the activities you participate in that we did not discuss last time?
    b. Do you feel your activities would be different if you lived somewhere else?
    c. How are your activities influenced by where you live?

3. Looking at the visualization of routine activities you described two weeks ago. Have your routines changed in any way since starting the program?
    a. How have your activities changed in the past month?
    b. What are some factors that have influenced your choice of activities?
    c. Can you explain how you make decisions about changing your routine activities?

4. We also discussed some of your health goals. Can you describe your goals again?
    a. Have you adjusted your goals since you started the program?
    b. How do you feel it is going as you work towards these goals?
        a. What is working well? What do you find challenging?
    c. How do you feel about yourself, or your self-image, since making these health goals?
    d. Has what you think about your self-image changed since starting the program? Can you describe how your self-image has changed?
    e. Does anyone else know about your goals (include specific health goal)?

f. How would you feel about sharing your goals publicly? For example, publicly through the clinic or on your social media account?

5. How have you felt since starting the program? (Can you explain more as to <u>why</u> you feel this way?)
    a. Do you feel there are certain materials or resources you refer to while at home in-between weekly sessions?
    b. Are there materials or resources that would support you at home in-between weekly sessions?

6. How do you feel about the health information that is communicated from healthcare professionals at the program?
    a. Is the information the program provides different from information you come across on your own?
    b. Do you think the information from the program is relevant to you?
        a. Why do you think so? Why or why not?

7. How do you feel day-to-day about changing your behavior to (insert specific health goals) (e.g., exercise more, changing diet)?
    a. Why do you feel …. (e.g. good, bad, it is a lot of work, it is easy)?
    b. Do you feel you are gaining anything by changing your behaviors? Can you explain more about what you are gaining?
    c. Do you feel you are losing anything by changing your behaviors? Can you explain more about what you are losing?

8. How do you feel about achieving your healthy diet goals while grocery shopping?
    a. How have your grocery shopping habits changed?
    b. What information are you seeking to support your healthy diet goal?
    c. Are there any strategies you use while grocery shopping to support buying foods that meet your healthy diet goal?
        a. Can you think of any strategies that would support you while shopping for foods aligned with your healthy eating goals?
        b. (Provide example of simple recipes emailed or texted to them)
    d. Can you think of an example of food items that you would have regularly purchased and no longer do?
    e. Can you think of any factors that have influenced this decision?

9. Are there times during the day you find it difficult to achieve your goals for (exercise or eating healthy)?
    a. Why do you think that is the case?
    b. Can you provide an example of your decision-making process when you face a challenge? (i.e., why you don't follow through with exercise or why you buy/ eat the junk food)
    c. How do you feel about reinforcement to support you with your day-to-day goals?

d. Can you think of an example of a type of reinforcement that could support you throughout the week?
    e. (e.g., encourage brainstorming by asking if a patient prefers texting, phone call, email at a challenging time of day)

10. How do you feel about receiving an incentive to support you with your exercise goal?
    a. An example of an incentive could be if you achieve a daily step count then you would receive points towards a reward or cash.
    b. How do you think an incentive would influence you with achieving daily exercise goals?

11. Are there any challenges you experience during your routine activities that make it difficult to achieve your goals (include specific goals)?
    a. How could you be supported to overcome the challenges you mention?
    b. What supports or resources could the clinic provide to you at home?
    c. How would your behavior change if you faced a consequence like paying a fine if you did not follow through with activities for achieving your goal?

12. Do you feel your family or friends influence your activities for (specific goal)?
    a. How do you feel they influence your decisions about daily activities?
    b. How would you feel about being connected with peers from the program that were working towards a similar goal as you?
        i. What do you think about a peer support group?
    c. How would you feel if the program shared activities of other peers, such as their exercise achievements or pictures of healthy meals?

We are almost done the interview but before we end …

13. Are there any other comments you would like to make?

14. Is there anything I should have asked but didn't that you think I should know about?

Those are all of the questions that I had so unless there is anything else, that is the end of our interview. Thank you for your time."

References

Abaluck, J., Kwong, L. H., Styczynski, A., Haque, A., Kabir, Md. A., Bates-Jefferys, E., … & Mobarak, A. M. (2022). Impact of community masking on COVID-19: A cluster-randomized trial in Bangladesh. *Science*, *375*(6577), eabi9069. https://doi.org/10.1126/science.abi9069

Adams, M. A., Hurley, J. C., Todd, M., Bhuiyan, N., Jarrett, C. L., Tucker, W. J., Hollingshead, K. E., & Angadi, S. S. (2017). Adaptive goal setting and financial incentives: A 2 × 2 factorial randomized controlled trial to increase adults' physical activity. *BMC Public Health*, *17*, 286. https://doi.org/10.1186/s12889-017-4197-8

Althoff, T., White, R. W., & Horvitz, E. (2016). Influence of Pokémon Go on Physical Activity: Study and Implications. *Journal of Medical Internet Research*, *18*(12), e315. https://doi.org/10.2196/jmir.6759

Althubaiti, A. (2016). Information bias in health research: Definition, pitfalls, and adjustment methods. *Journal of Multidisciplinary Healthcare*, *9*, 211–217. https://doi.org/10.2147/JMDH.S104807

Ball, K., Hunter, R. F., Maple, J.-L., Moodie, M., Salmon, J., Ong, K.-L., Stephens, L. D.,… & Crawford, D. (2017). Can an incentive-based intervention increase physical activity and reduce sitting among adults? The ACHIEVE (Active Choices IncEntiVE) feasibility study. *International Journal of Behavioral Nutrition and Physical Activity*, *14*(1), 35. https://doi.org/10.1186/s12966-017-0490-2

Bandy, L. K., Scarborough, P., Harrington, R., Rayner, M., & Jebb, S. (2020). Reductions in sugar sales from soft drinks in the UK from 2015 to 2018. *BMC Med*, *18*(20). https://doi.org/10.1186/s12916-019-1477-4

Bauman, A., Bittman, M., & Gershuny, J. (2019). A short history of time use research; implications for public health. *BMC Public Health*, *19*(S2), 607. https://doi.org/10.1186/s12889-019-6760-y

Baur, N., Hering, L., Raschke, A. L., & Thierbach, C. (2014). Theory and Methods in Spatial Analysis. Towards Integrating Qualitative, Quantitative and Cartographic Approaches in the Social Sciences and Humanities. *Historical Social Research, 39*(2), https://doi.org/10.12759/hsr.39.2014.2.7-50

Becker, M., Kirscht, J., Haefner, D., & Drachman, R. (1977). The health belief model and prediction of dietary compliance: A field experiment. *Journal of Health and Social Behavior*, *4*(18), 348–366. https://doi.org/10.2307/2955344

Betsch, T., Fiedler, K., & Brinkmann, J. (1998). Behavioral routines in decision making: The effects of novelty in task presentation and time pressure on routine maintenance and deviation. *European Journal of Social Psychology*, *28*(6), 861–878. https://doi.org/10.1002/(SICI)1099-0992(1998110)28:6<861::AID-EJSP899>3.0.CO;2-D

Bissonnette, L., Wilson, K., Bell, S., & Shah, T. I. (2012). Neighbourhoods and potential access to health care: The role of spatial and aspatial factors. *Health & Place*, *18*(4), 841–853. https://doi.org/10.1016/j.healthplace.2012.03.007

BMJ. (2021). *Consumption of sugar from soft drinks falls within a year of UK sugar tax | BMJ*. https://www.bmj.com/company/newsroom/consumption-of-sugar-from-soft-drinks-falls-within-a-year-of-uk-sugar-tax/

Boruchowicz, C., Lopez Boo, F., Pfeifer, F., Russo, G., & Pacheco, T. (2020). *Are Behaviorally Informed Text Messages Effective in Promoting Compliance with COVID-19 Preventive Measures?: Evidence from an RCT in the City of São Paulo*. Retrieved from https://publications.iadb.org/publications/english/document/Are-Behaviorally-Informed-Text-Messages-Effective-in-Promoting-Compliance-with-COVID-19-Preventive-Measures-Evidence-from-an-RCT-in-the-City-of-Sao-Paulo.pdf

Burns, C. M., & Inglis, A. D. (2007). Measuring food access in Melbourne: Access to healthy and fast foods by car, bus and foot in an urban municipality in Melbourne. *Health & Place*, *13*(4), 877–885. https://doi.org/10.1016/j.healthplace.2007.02.005

Canadian Institutes of Health Research. (2019). *Healthy Cities Research Initiative—CIHR*. Retrieved from https://cihr-irsc.gc.ca/e/51570.html

Castillo, E. G., Ijadi-Maghsoodi, R., Shadravan, S., Moore, E., Mensah, M. O., Docherty, M., Aguilera Nunez, M. G.,… & Wells, K. B. (2019). Community Interventions to Promote Mental Health and Social Equity. *Current Psychiatry Reports*, *21*(5), 35. https://doi.org/10.1007/s11920-019-1017-0

Comber, A. J., Brunsdon, C., & Radburn, R. (2011). A spatial analysis of variations in health access: Linking geography, socio-economic status and access perceptions. *International Journal of Health Geographics*, *10*(1), 44. https://doi.org/10.1186/1476-072X-10-44

Curtis, S., & Jones, I. R. (1998). Is There a Place for Geography in the Analysis of Health Inequality? *Sociology of Health & Illness*, *20*(5), 645–672. https://doi.org/10.1111/1467-9566.00123

Cutler, D. (2004). Behavioral Health Interventions: What Works and Why? In *Critical Perspectives in Racial and Ethnic Differences in Health and Late Life* (Anderson NB, Bulatao RA, Cohen B (Editors)). National Academies Press (US). https://www.ncbi.nlm.nih.gov/books/NBK25527/

Deeb, A., Ziaullah, M., Akle, M., & Strauss, K. (2018). Utilization and Challenges of Continuous Glucose Monitoring in Sensor-Augmented Pump Therapy: A Patient Experience Analysis. *Journal of Diabetes Science and Technology*, *13*(1), 146–147. https://doi.org/10.1177/1932296818801361

Dohle, S., Diel, K., & Hofmann, W. (2018). Executive functions and the self-regulation of eating behavior: A review. *Appetite*, *124*, 4–9. https://doi.org/10.1016/j.appet.2017.05.041

Dummer, T. J. B. (2008). Health geography: Supporting public health policy and planning. *Canadian Medical Association Journal*, *178*(9), 1177–1180. https://doi.org/10.1503/cmaj.071783

Dunn, J. R., & Hayes, M. V. (1999). Toward a Lexicon of Population Health. *Canadian Journal of Public Health, 90*(1), S7–S10. https://doi.org/10.1007/BF03403570

Dworkin, S. L. (2012). Sample Size Policy for Qualitative Studies Using In-Depth Interviews. *Archives of Sexual Behavior*, *41*(6), 1319–1320. https://doi.org/10.1007/s10508-012-0016-6

Edwards, N. (1999). Population Health: Determinants and Interventions. *Canadian Journal of Public Health*, *90*(1), 10–12. https://doi.org/10.1007/BF03404090

Elia, F., Calzavarini, F., Bianco, P., Vecchietti, R. G., Macor, A. F., D'Orazio, A., Dragonetti, A., D'Alfonso, A., Belletrutti, L., Floris, M., Bert, F., Crupi, V., & Aprà, F. (2022). A nudge intervention to improve hand hygiene compliance in the hospital. *Internal and Emergency Medicine*. https://doi.org/10.1007/s11739-022-03024-7

Elias, R. R., Jutte, D. P., & Moore, A. (2019). Exploring consensus across sectors for measuring the social determinants of health. *SSM - Population Health*, *7*, 100395. https://doi.org/10.1016/j.ssmph.2019.100395

Emrich, T., Qi, Y., Lou, W., & L'Abbe, M. (2017). Traffic-light labels could reduce population intakes of calories, total fat, saturated fat, and sodium. *PLOS One*, *12*(2), e0171188. https://doi.org/doi:10.1371/journal.pone.0171188

Evans, R., & Stoddart, G. (1990). Producing Health, Consuming Health Care. *Social Science & Medicine*, *31*(12), 1347–1363. https://doi.org/10.1016/0277-9536(90)90074-3

Farquhar, J., Fortmann, S., Maccoby, N., Haskell, W., Williams, P., Flora, J., Taylor, B., … & Hulley, S. (1985). The Stanford Five-City Project: Design and Methods. *American Journal of Epidemiology*, *122*(2), 323–334. https://doi.org/10.1093/oxfordjournals.aje.a114104

Farquhar, J. W., Fortmann, S., Flora, J., Taylor, B., Haskell, W., Willams, P., Maccoby, N., & Wood, P. (1990). Effects of communitywide education on cardiovascular disease risk factors. The Stanford Five-City Project. *JAMA: The Journal of the American Medical Association*, *264*(3), 359–365. https://doi.org/10.1001/jama.264.3.359

FreeStyle Libre. (2022). FreeStyle Abbott Canada. Retrieved from https://www.freestyle.abbott/ca-en/home.html

Friedman, D. J., & Starfield, B. (2003). Models of Population Health: Their Value for US Public Health Practice, Policy, and Research. *American Journal of Public Health*, *93*(3), 366–369.

Friedman, N. P., & Miyake, A. (2017). Unity and Diversity of Executive Functions: Individual Differences as a Window on Cognitive Structure. *Cortex*, *86*, 186–204. https://doi.org/10.1016/j.cortex.2016.04.023

Friis, R., Skov, L. R., Olsen, A., Appleton, K. M., Saulais, L., Dinnella, C., Hartwell, H., Depezay, L., Monteleone, E., Giboreau, A., & Perez-Cueto, F. J. A. (2017). Comparison of three nudge interventions (priming, default option, and perceived variety) to promote vegetable consumption in a self-service buffet setting. *PLOS ONE*, *12*(5), e0176028. https://doi.org/10.1371/journal.pone.0176028

Gao, Z., & Lee, J. E. (2019). Emerging Technology in Promoting Physical Activity and Health: Challenges and Opportunities. *Journal of Clinical Medicine*, *8*(11), 1830. https://doi.org/10.3390/jcm8111830

Gold, N., Yau, A., Rigby, B., Dyke, C., Remfry, E. A., & Chadborn, T. (2021). Effectiveness of Digital Interventions for Reducing Behavioral Risks of Cardiovascular Disease in Nonclinical Adult Populations: Systematic Review of Reviews. *Journal of Medical Internet Research*, *23*(5), e19688. https://doi.org/10.2196/19688

Gotto, A. M., Jr. (1997). The Multiple Risk Factor Intervention Trial (MRFIT): A Return to a Landmark Trial. *JAMA*, *277*(7), 595–597. https://doi.org/10.1001/jama.1997.03540310093041

Government of United Kingdom. (2018). *Sugar tax revenue helps tackle childhood obesity*. Government of United Kingdom. Retrieved from https://www.gov.uk/government/news/sugar-tax-revenue-helps-tackle-childhood-obesity

Graham, H., Prue-Owens, K., Kirby, J., & Ramesh, M. (2020). Systematic Review of Interventions Designed to Maintain or Increase Physical Activity Post-Cardiac Rehabilitation Phase II. *Rehabilitation Process and Outcome*, *9*, 1179572720941833. https://doi.org/10.1177/1179572720941833

Hagerstrand, T. (1970). *What about people in regional science? 24*(1), 7–24.

Hallsworth, M., Berry, D., Sanders, M., Sallis, A., King, D., Vlaev, I., & Darzi, A. (2015). Stating Appointment Costs in SMS Reminders Reduces Missed Hospital Appointments: Findings from Two Randomised Controlled Trials. *PLOS ONE*, *10*(9), e0137306. https://doi.org/10.1371/journal.pone.0137306

Hallsworth, M., Snijders, V., Burd, H., Prestt, J., Judah, G., Huf, S., & Halpern, D. (2016). *Applying Behavioral Insights: Simple ways to improve health outcomes* (pp. 1–48) [World Innovation Summit for Health]. https://www.bi.team/wp-content/uploads/2016/11/WISH-2016_Behavioral_Insights_Report.pdf

Halpern, S. D., Ubel, P. A., & Asch, D. A. (2007). Harnessing the Power of Default Options to Improve Health Care. *New England Journal of Medicine*, *357*(13), 1340–1344. https://doi.org/10.1056/NEJMsb071595

Hare, A. J., Patel, M. S., Volpp, K., & Adusumalli, S. (2021). The Role of Behavioral Economics in Improving Cardiovascular Health Behaviors and Outcomes. *Current Cardiology Reports*, *23*(11), 153. https://doi.org/10.1007/s11886-021-01584-2

Hennink, M., & Kaiser, B. N. (2022). Sample sizes for saturation in qualitative research: A systematic review of empirical tests. *Social Science & Medicine*, *292*, 114523. https://doi.org/10.1016/j.socscimed.2021.114523

Hermanns, N., Ehrmann, D., Shapira, A., Kulzer, B., Schmitt, A., & Laffel, L. (2022). Coordination of glucose monitoring, self-care behaviour and mental health: Achieving precision monitoring in diabetes. *Diabetologia*, *65*(11), 1883–1894. https://doi.org/10.1007/s00125-022-05685-7

Hinrichs, T., Zanda, A., Fillekes, M. P., Bereuter, P., Portegijs, E., Rantanen, T., Schmidt-Trucksäss, A., Zeller, A. W., & Weibel, R. (2020). Map-based assessment of older adults' life space: Validity and reliability. *European Review of Aging and Physical Activity*, *17*(1), 21. https://doi.org/10.1186/s11556-020-00253-7

Hong, P., Chen, K., Chang, Y., Cheng, S., & Chiang, H. (2021). Effectiveness of Theory-Based Health Information Technology Interventions on Coronary Artery Disease Self-Management Behavior: A Clinical Randomized Waitlist-Controlled Trial. *Journal of Nursing Scholarship*, *53*(4), 418–427. https://doi.org/10.1111/jnu.12661

Hood, K. K., Hilliard, M., Piatt, G., & Ievers-Landis, C. E. (2015). Effective strategies for encouraging behavior change in people with diabetes. *Diabetes Management (London, England)*, *5*(6), 499–510.

Hughes, J., Lysikowski, J., Acharya, R., Phelps, E., & Kandil, E. (2020). A Multi-year Analysis of Decision Fatigue in Opioid Prescribing. *Journal of General Internal Medicine*, *35*(4), 1337–1339. https://doi.org/10.1007/s11606-019-05217-x

Hyseni, L., Elliot-Green, A., Lloyd-Williams, F., Kypridemos, C., O'Flaherty, M., McGill, R., Orton, L., … & Capewell, S. (2017). Systematic review of dietary salt reduction policies: Evidence for an effectiveness hierarchy? *PLoS ONE*, *12*(5), e0177535. https://doi.org/10.1371/journal.pone.0177535

Inglis, S. C., Clark, R. A., McAlister, F. A., Ball, J., Lewinter, C., Cullington, D., Stewart, S., & Cleland, J. G. (2010). Structured telephone support or telemonitoring programmes for patients with chronic heart failure. *Cochrane Database of Systematic Reviews*, *CD007228*(8). https://doi.org/doi:10.1002/14651858.CD007228.pub2.

Janz, N. K., & Becker, M. H. (1984). The Health Belief Model: A Decade Later. *Health Education Quarterly*, *11*(1), 1–47. https://doi.org/10.1177/109019818401100101

Kahneman, D., & Tversky, A. (1984). Choices, values, and frames. *American Psychologist*, *39*(4), 341–350.

Kindig, D., & Stoddart, G. (2003). What Is Population Health? *American Journal of Public Health*, *93*(3), 380–383.

King, D., Vlaev, I., Everett-Thomas, R., Fitzpatrick, M., Darzi, A., & Birnbach, D. J. (2016). "Priming" hand hygiene compliance in clinical environments. *Health Psychology*, *35*(1), 96–101. https://doi.org/10.1037/hea0000239

Khamzina, M., Parab, K. V., An, R., Bullard, T., & Grigsby-Toussaint, D. S. (2020). Impact of Pokémon Go on Physical Activity: A Systematic Review and Meta-Analysis. *American Journal of Preventive Medicine*, *58*(2), 270–282. https://doi.org/10.1016/j.amepre.2019.09.005

Kjelsberg, M., Cutler, J., & Dolecek, T. (1997). Brief description of the multiple risk factor intervention trial. *American Journal of Clinical Nutrition*, *65*(1), 191–195. https://doi.1093/ajcn/65.1.191S

Knigge, L., & Cope, M. (2006). Grounded Visualization: Integrating the Analysis of Qualitative and Quantitative Data through Grounded Theory and Visualization. *Environment and Planning A: Economy and Space*, *38*(11), 2021–2037. https://doi.org/10.1068/a37327

Krawiec, J. M., Piaskowska, O. M., Piesiewicz, P. F., & Białaszek, W. (2021). Tools for public health policy: Nudges and boosts as active support of the law in special situations such as the COVID-19 pandemic. *Globalization and Health*, *17*(1), 132. https://doi.org/10.1186/s12992-021-00782-5

Krewski, D., Hogan, V., Turner, M. C., Zeman, P. L., McDowell, I., Edwards, N., & Losos, J. (2007). An Integrated Framework for Risk Management and Population Health. *Human and Ecological Risk Assessment: An International Journal*, *13*(6), 1288–1312. https://doi.org/10.1080/10807030701655798

Kulldorff, M., Feuer, E. J., Miller, B. A., & Freedma, L. S. (1997). Breast Cancer Clusters in the Northeast United States: A Geographic Analysis. *American Journal of Epidemiology*, *146*(2), 161–170. https://doi.org/10.1093/oxfordjournals.aje.a009247

Kwan, M., & Ren, F. (2008). Analysis of human space-time behavior: Geovisualization and geocomputational approaches. In *Understanding Dynamics of Geographic Domains* (In Hornsby, K.S., Yuan, M. (Eds.), pp. 93–113). CRC Press.

Laatikainen, T., Nissinen, A., Kastarinen, M., Jula, A., & Tuomilehto, J. (2016). Blood Pressure, Sodium Intake, and Hypertension Control: Lessons from the North Karelia Project. *Global Heart*, *11*(2), 191–199. https://doi.org/10.1016/j.gheart.2016.04.011

Latkin, C. A., Mai, N. V. T., Ha, T. V., Sripaipan, T., Zelaya, C., Le Minh, N., Morales, G., & Go, V. F. (2016). Socially desirability response bias and other factors that may influence self-reports of substance use and HIV risk behaviors: A qualitative study of drug users in Vietnam. *AIDS Education and Prevention: Official Publication of the International Society for AIDS Education*, *28*(5), 417–425. https://doi.org/10.1521/aeap.2016.28.5.417

Laxer, R. E., & Janssen, I. (2014). The proportion of excessive fast-food consumption attributable to the neighbourhood food environment among youth living within 1 km of their school. *Applied Physiology, Nutrition, and Metabolism*, *39*(4), 480–486. https://doi.org/10.1139/apnm-2013-0208

Luong, M.-L. N., Hall, M., Bennell, K. L., Kasza, J., Harris, A., & Hinman, R. S. (2021). The Impact of Financial Incentives on Physical Activity: A Systematic Review and Meta-Analysis. *American Journal of Health Promotion: AJHP*, *35*(2), 236–249. https://doi.org/10.1177/0890117120940133

Lv, J., Liu, Q.-M., Ren, Y.-J., He, P.-P., Wang, S.-F., Gao, F., Li, L.-M., & on behalf of the Community Interventions for Health (CIH) collaboration. (2014). A community-based multilevel intervention for smoking, physical activity and diet: Short-term findings from the Community Interventions for Health programme in Hangzhou, China. *Journal of Epidemiology and Community Health*, *68*(4), 333–339. https://doi.org/10.1136/jech-2013-203356

Macintyre, S., Ellaway, A., & Cummins, S. (2002). Place effects on health: How can we conceptualise, operationalise and measure them? *Social Science & Medicine*, *55*(1), 125–139. https://doi.org/10.1016/S0277-9536(01)00214-3

MacNell, L. (2018). A geo-ethnographic analysis of low-income rural and urban women's food shopping behaviors. *Appetite*, *128*, 311–320. https://doi.org/10.1016/j.appet.2018.05.147

Marteau, T. M., Hollands, G. J., & Fletcher, P. C. (2012). Changing Human Behavior to Prevent Disease: The Importance of Targeting Automatic Processes. *Science*, *337*(6101), 1492–1495. https://doi.org/10.1126/science.1226918

Martín-Martín, J., Roldán-Jiménez, C., De-Torres, I., Muro-Culebras, A., Escriche-Escuder, A., Gonzalez-Sanchez, M., …& Cuesta-Vargas, A. I. (2021). Behavior Change Techniques and the Effects Associated with Digital Behavior Change Interventions in Sedentary Behavior in the Clinical Population: A Systematic Review. *Frontiers in Digital Health*, *3*. https://www.frontiersin.org/articles/10.3389/fdgth.2021.620383

Matthews, S. A., Detwiler, J. E., & Burton, L. M. (2005). Geo-ethnography: Coupling Geographic Information Analysis Techniques with Ethnographic Methods in Urban Research. *Cartographica: The International Journal for Geographic Information and Geovisualization*, *40*(4), 75–90. https://doi.org/10.3138/2288-1450-W061-R664

May, C. R., Johnson, M., & Finch, T. (2016). Implementation, context and complexity. *Implementation Science*, *11*(1), 1–12. https://doi.org/10.1186/s13012-016-0506-3

McDowell, I., Spasoff, R. A., & Kristjansson, B. (2004). On the Classification of Population Health Measurements. *American Journal of Public Health*, *94*(3), 388–393.

McQuoid, J., Jowsey, T., & Talaulikar, G. (2017). Contextualising renal patient routines: Everyday space-time contexts, health service access, and wellbeing. *Social Science & Medicine*, *183*, 142–150. https://doi.org/10.1016/j.socscimed.2017.04.043

Michie, S., van Stralen, M. M., & West, R. (2011). The behaviour change wheel: A new method for characterising and designing behaviour change interventions. *Implementation Science*, *6*(42), 1–11. https://doi.org/10.1186/1748-5908-6-42

Milton, S., Pliakas, T., Hawkesworth, S., Nanchahal, K., Grundy, C., Amuzu, A., Casas, J.P., & Lock, K. (2015). A qualitative geographical information systems approach to explore how older people over 70 years interact with and define their neighbourhood environment. *Health & Place*, *36*, 127–133. https://doi.org/10.1016/j.healthplace.2015.10.002

Mitchell, M., White, L., Lau, E., Leahey, T., Adams, M. A., & Faulkner, G. (2018). Evaluating the Carrot Rewards App, a Population-Level Incentive-Based Intervention Promoting Step Counts Across Two Canadian Provinces: Quasi-Experimental Study. *JMIR MHealth and UHealth*, *6*(9), e178. https://doi.org/10.2196/mhealth.9912

Mitchell, M., White, L., Oh, P., Alter, D., Leahey, T., Kwan, M., & Faulkner, G. (2017). Uptake of an Incentive-Based mHealth App: Process Evaluation of the Carrot Rewards App. *JMIR MHealth and UHealth*, *5*(5), e70. https://doi.org/10.2196/mhealth.7323

Mitchell, M. S., Orstad, S. L., Biswas, A., Oh, P. I., Jay, M., Pakosh, M. T., & Faulkner, G. (2020). Financial incentives for physical activity in adults: Systematic review and meta-analysis. *British Journal of Sports Medicine*, *54*(21), 1259–1268. https://doi.org/10.1136/bjsports-2019-100633

Mohebbi, B., Sabouri, M., & Tol, A. (2021). Application of health education and promotion theory-based interventions on patients with cardiovascular disease: A systematic review. *Journal of Education and Health Promotion*, *10*(236), 14. https://doi.10.4103/jehp.jehp_173_21

Ndejjo, R., Hassen, H. Y., Wanyenze, R. K., Musoke, D., Nuwaha, F., Abrams, S., Bastiaens, H., & Musinguzi, G. (2021). Community-Based Interventions for Cardiovascular Disease Prevention in Low-and Middle-Income Countries: A Systematic Review. *Public Health Reviews*, *42*, 1604018. https://doi.org/10.3389/phrs.2021.1604018

Nigg, C. R., Mateo, D. J., & An, J. (2017). Pokémon GO May Increase Physical Activity and Decrease Sedentary Behaviors. *American Journal of Public Health*, *107*(1), 37–38. https://doi.org/10.2105/AJPH.2016.303532

O'Donoghue, T., & Rabin, M. (2000). The economics of immediate gratification. *Journal of Behavioral Decision Making, 13*(2). 233-250. doi:10.1002/(SICI)1099-0771(2000004/06)13:23.0.CO;2-U

Patel, M. S., Small, D. S., Harrison, J. D., Fortunato, M. P., Oon, A. L., Rareshide, C. A. L., Reh, G., Szwartz, G., Guszcza, J., Steier, D., Kalra, P., & Hilbert, V. (2019). Effectiveness of Behaviorally Designed Gamification Interventions With Social Incentives for Increasing Physical Activity Among Overweight and Obese Adults Across the United States. *JAMA Internal Medicine*, *179*(12), 1624–1632. https://doi.org/10.1001/jamainternmed.2019.3505

Patel, M. S., Volpp, K. G., Rosin, R., Bellamy, S. L., Small, D. S., Fletcher, M. A., Osman-Koss, R., Brady, J. L., Haff, N., Lee, S. M., Wesby, L., Hoffer, K., Shuttleworth, D., Taylor, D. H., Hilbert, V., Zhu, J., Yang, L., Wang, X., & Asch, D. A. (2016). A Randomized Trial of Social Comparison Feedback and Financial Incentives to Increase Physical Activity. *American Journal of Health Promotion: AJHP*, *30*(6), 416–424. https://doi.org/10.1177/0890117116658195

Pearson, T. A. (2011). Public Policy Approaches to the Prevention of Heart Disease and Stroke. *Circulation*, *124*(23), 2560–2571. https://doi.org/10.1161/CIRCULATIONAHA.110.968743

Pell, D., Mytton, O., Penney, T. L., Briggs, A., Cummins, S., Penn-Jones, C., Rayner, M., … & Adams, J. (2021). Changes in soft drinks purchased by British households associated with the UK soft drinks industry levy: Controlled interrupted time series analysis. *BMJ*, *372*, n254. https://doi.org/10.1136/bmj.n254

Prevent Epidemics. (2021). *Promoting mask-wearing during the COVID-19 pandemic: A policymaker's guide* (pp. 1–18). Retrieved from https://preventepidemics.org/wp-content/uploads/2020/08/Promoting-Mask-Wearing-During-COVID-19.pdf

Public Health Agency of Canada. (2001). *Social determinants of health and health inequalities*. Retrieved from https://www.canada.ca/en/public-health/services/health-promotion/population-health/what-determines-health.html

Public Health Agency of Canada. (2016). *Canadian Best Practices Portal – CBPP*. Retrieved from https://cbpp-pcpe.phac-aspc.gc.ca/chronic-diseases/cardiovascular-disease/

Puska, P., & Jaini, P. (2020). The North Karelia Project: Prevention of Cardiovascular Disease in Finland Through Population-Based Lifestyle Interventions. *American Journal of Lifestyle Medicine*, *14*(5), 495–499. https://doi.org/10.1177/1559827620910981

Rantanen, H., & Kahila, M. (2009). The SoftGIS approach to local knowledge. *Journal of Environmental Management*, *90*(6), 1981–1990. https://doi.org/10.1016/j.jenvman.2007.08.025

Reynolds, A. N., & Venn, B. J. (2018). The Timing of Activity after Eating Affects the Glycaemic Response of Healthy Adults: A Randomised Controlled Trial. *Nutrients*, *10*(11), 1743. https://doi.org/10.3390/nu10111743

Ringeval, M., Wagner, G., Denford, J., Pare, G., & Kitsiou, S. (2020). Fitbit-Based interventions for healthy lifestyle outcomes: Systematic review and meta-analysis. *JMIR Publications, 22*(10), e23954. doi:10.2196/23954

Rogers, L., De Brún, A., & McAuliffe, E. (2020). Defining and assessing context in healthcare implementation studies: A systematic review. *BMC Health Services Research*, *20*(1), 591. https://doi.org/10.1186/s12913-020-05212-7

Rondina, R., Hong, M., Sarma, S., & Mitchell, M. (2021). Is it worth it? Cost-effectiveness analysis of a commercial physical activity app. *BMC Public Health*, *21*(1), 1950. https://doi.org/10.1186/s12889-021-11988-y

Rondina, R., Pearson, E. K., Prapavessis, H., White, L., Richard, S., & Mitchell, M. S. (2020). Bright spots, physical activity investments that (almost) worked: Carrot Rewards app, driving engagement with pennies a day. *British Journal of Sports Medicine*, *54*(15), 927–929. https://doi.org/10.1136/bjsports-2019-100969

Room, J., Hannink, E., Dawes, H., & Barker, K. (2017). What interventions are used to improve exercise adherence in older people and what behavioural techniques are they based on? A systematic review. *BMJ Open*, *7*(12), e019221. https://doi.org/10.1136/bmjopen-2017-019221

Rosenstock, I. M., Strecher, V. J., & Becker, M. H. (1988). Social Learning Theory and the Health Belief Model. *Health Education Quarterly*, *15*(2), 175–183. https://doi.org/10.1177/109019818801500203

Roth, G. A., Mensah, G. A., Johnson, C. O., Addolorato, G., Ammirati, E., Baddour, L. M., Barengo, N. C., … & Fuster, V. (2020). Global Burden of Cardiovascular Diseases and Risk Factors, 1990–2019. *Journal of the American College of Cardiology*, *76*(25), 2982–3021. https://doi.org/10.1016/j.jacc.2020.11.010

Sandelowski, M. (1995). Sample size in qualitative research. *Research in Nursing & Health*, *18*(2), 179–183. https://doi.org/10.1002/nur.4770180211

Santo, K., & Redfern, J. (2020). Digital Health Innovations to Improve Cardiovascular Disease Care. *Current Atherosclerosis Reports*, *22*(12), 71. https://doi.org/10.1007/s11883-020-00889-x

Santos, J. A., Tekle, D., Rosewarne, E., Flexner, N., Cobb, L., Al-Jawaldeh, A., Kim, W. J., Breda, J., Whiting, S., Campbell, N., Neal, B., Webster, J., & Trieu, K. (2021). A Systematic Review of Salt Reduction Initiatives Around the World: A Midterm Evaluation of Progress Towards the 2025 Global Non-Communicable Diseases Salt Reduction Target. *Advances in Nutrition*, *12*(5), 1768–1780. https://doi.org/10.1093/advances/nmab008

Satcher, D. (2010). Include a Social Determinants of Health Approach to Reduce Health Inequities. *Public Health Reports*, *125*(Suppl 4), 6–7.

Seguin, M. L., Rangnekar, A., Renedo, A., Palafox, B., McKee, M., & Balabanova, D. (2020). Systematic review of frameworks used to conceptualise health pathways of individuals diagnosed with cardiovascular diseases. *BMJ Global Health*, *5*(9), e002464. https://doi.org/10.1136/bmjgh-2020-002464

Shashank, A., & Schuurman, N. (2019). Unpacking walkability indices and their inherent assumptions. *Health & Place*, *55*, 145–154. https://doi.org/10.1016/j.healthplace.2018.12.005

Silva, J. P., Gunathunga, M. W., & Jayasinghe, S. (2016). Mapping Unhealthy Behavior Among Economically Active Men Using GIS in Suburban and Rural Areas of Sri Lanka. *Asia-Pacific Journal of Public Health / Asia-Pacific Academic Consortium for Public Health*, *28*(1 Suppl), 10S-16S. https://doi.org/10.1177/1010539515611723

Solaki, A., Berto, F., & Smets, S. (2021). The Logic of Fast and Slow Thinking. *Erkenntnis*, *86*(3), 733–762. https://doi.org/10.1007/s10670-019-00128-z

Sonnenberg, L., Gelsomin, E., Levy, D. E., Riis, J., Barraclough, S., & Thorndike, A. N. (2013). A traffic light food labeling intervention increases consumer awareness of health and healthy choices at the point-of-purchase. *Preventive Medicine*, *57*(4), 253–257. https://doi.org/10.1016/j.ypmed.2013.07.001

Stafford, M., Cummins, S., Ellaway, A., Sacker, A., Wiggins, R. D., & Macintyre, S. (2007). Pathways to obesity: Identifying local, modifiable determinants of physical activity and diet. *Social Science & Medicine*, *65*(9), 1882–1897. https://doi.org/10.1016/j.socscimed.2007.05.042

Stanovich, K. E. (2012). Environments for fast and slow thinking. *Trends in Cognitive Sciences*, *16*(4), 198–199. https://doi.org/10.1016/j.tics.2012.01.009

Statistics Canada. (2022). *Time Use Survey*. Retrieved from https://www23.statcan.gc.ca/imdb/p2SV.pl?Function=getSurvey&SDDS=4503

Strazdins, L., Welsh, J., Korda, R., Broom, D., & Paolucci, F. (2016). Not all hours are equal: Could time be a social determinant of health? *Sociology of Health & Illness*, *38*(1), 21–42. https://doi.org/10.1111/1467-9566.12300

Taj, F., Klein, M. C. A., & van Halteren, A. (2019). Digital Health Behavior Change Technology: Bibliometric and Scoping Review of Two Decades of Research. *JMIR MHealth and UHealth*, *7*(12), e13311. https://doi.org/10.2196/13311

Tamura, K., Wilson, J. S., Goldfeld, K., Puett, R. C., Klenosky, D. B., Harper, W. A., & Troped, P. J. (2019). Accelerometer and GPS Data to Analyze Built Environments and Physical Activity. *Research Quarterly for Exercise and Sport*, *90*(3), 395–402. https://doi.org/10.1080/02701367.2019.1609649

Thaler, R. H., & Sunstein, C. R. (2003). Libertarian Paternalism. *The American Economic Review*, *93*(2), 175–179. https://www.jstor.org/stable/3132220

Tudor-Locke, C., Johnson, W. D., & Katzmarzyk, P. T. (2010). Frequently Reported Activities by Intensity for U.S. Adults: The American Time Use Survey. *American Journal of Preventive Medicine*, *39*(4), e13–e20. https://doi.org/10.1016/j.amepre.2010.05.017

Tuomilehto, J., Puska, P., Tanskanen, A., Karppanen, H., Pietinen, P., Nissinen, A., Enlund, H., & Ruotsalainen, P. (1981). A community-based intervention study on the feasibility and effects of the reduction of salt intake in North Karelia, Finland. *Acta Cardiologica*, *36*(2), 83–104.

Tversky, A., & Kahneman, D. (1974). Judgment under uncertainty: Heuristics and biases. *Science*, *185*(4157), 1124–1131.

Vande Velde, F., Overgaard, H., & Bastien, S. (2021). Nudge strategies for behavior-based prevention and control of neglected tropical diseases: A scoping review and ethical assessment. *PLOS Neglected Tropical Diseases*, *15*(11), 27. https://doi.org/10.1371/journal.pntd.0009239

Vartiainen, E. (2018). The North Karelia Project: Cardiovascular disease prevention in Finland. *Global Cardiology Science & Practice*, *2*(13), 1–9. https://doi.org/10.21542/gcsp.2018.13

Vasileiou, K., Barnett, J., Thorpe, S., & Young, T. (2018). Characterising and justifying sample size sufficiency in interview-based studies: Systematic analysis of qualitative health research over a 15-year period. *BMC Medical Research Methodology*, *18*(1), 148. https://doi.org/10.1186/s12874-018-0594-7

Waddell, K. J., Shah, P. D., Adusumalli, S., & Patel, M. S. (2020). Using Behavioral Economics and Technology to Improve Outcomes in Cardio-Oncology. *JACC: CardioOncology*, *2*(1), 84–96. https://doi.org/10.1016/j.jaccao.2020.02.006

Wagner, J., Tennen, H., & Wolpert, H. (2012). Continuous glucose monitoring: A review for behavioral researchers. *Psychosomatic Medicine*, *74*(4), 356–365. https://doi.org/10.1097/PSY.0b013e31825769ac

Wang, H., Naghavi, M., Allen, C., Barber, R. M., Bhutta, Z. A., Carter, A., Casey, D. C., … & Murray, C. J. L. (2016). Global, regional, and national life expectancy, all-cause mortality, and cause-specific mortality for 249 causes of death, 1980–2015: A systematic analysis for the Global Burden of Disease Study 2015. *The Lancet*, *388*(10053), 1459–1544. https://doi.org/10.1016/S0140-6736(16)31012-1

Wilkinson, R. G., & Marmot, M. G. (2003). *Social determinants of health: The solid facts (pp. 1–33).* World Health Organization. Retrieved from https://www.euro.who.int/__data/assets/pdf_file/0005/98438/e81384.pdf

Willmott, T. J., Pang, B., & Rundle-Thiele, S. (2021). Capability, opportunity, and motivation: An across contexts empirical examination of the COM-B model. *BMC Public Health*, *21*(1), 1014. https://doi.org/10.1186/s12889-021-11019-w

Winter, S. J., Sheats, J. L., & King, A. C. (2016). The Use of Behavior Change Techniques and Theory in Technologies for Cardiovascular Disease Prevention and Treatment in Adults: A Comprehensive Review. *Progress in Cardiovascular Diseases*, *58*(6), 605–612. https://doi.org/10.1016/j.pcad.2016.02.005

Wongvibulsin, S., Martin, S. S., Steinhubl, S. R., & Muse, E. D. (2019). Connected Health Technology for Cardiovascular Disease Prevention and Management. *Current Treatment Options in Cardiovascular Medicine*, *21*(6), 29. https://doi.org/10.1007/s11936-019-0729-0

World Health Organization. (2015). *Cardiovascular diseases: Avoiding heart attacks and strokes*. Retrieved from https://www.who.int/news-room/questions-and-answers/item/cardiovascular-diseases-avoiding-heart-attacks-and-strokes

World Health Organization. (2020). *The top 10 causes of death*. WHO Newsroom Report. Retrieved from https://www.who.int/news-room/fact-sheets/detail/the-top-10-causes-of-death#:~:text=The%20world's%20biggest%20killer%20is,8.9%20million%20deaths%20in%202019.

World Health Organization. (2021). *Cardiovascular diseases (CVDs)*. Retrieved from https://www.who.int/news-room/fact-sheets/detail/cardiovascular-diseases-(cvds)

Yousuf, H., Reintjens, R., Slipszenko, E., Blok, S., Somsen, G. A., Tulevski, I. I., & Hofstra, L. (2019). Effectiveness of web-based personalised e-Coaching lifestyle interventions. *Netherlands Heart Journal*, *27*(1), 24–29. https://doi.org/10.1007/s12471-018-1200-7