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**Providing Further Construct Validity for a Newly Developed  
Measure of Functional-Living:  
The Movement and Activity in Physical Space (MAPS) Score**

A Thesis Presented

By

ANDREA MORAND

Submitted to the Graduate School of the  
University of Massachusetts Amherst in partial fulfillment  
of the requirements for the degree of

MASTER OF SCIENCE

September 2012

Department of Kinesiology

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ABSTRACT  
PROVIDING CONSTRUCT VALIDITY FOR A NEWLY DEVELOPED MEASURE  
OF FUNCTIONAL-LIVING:  
THE MOVEMENT AND ACTIVITY IN PHYSICAL SPACE (MAPS) SCORE

MASTER OF SCIENCE

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Directed by: Professor Erin M. Snook

Older adults face many age-related changes affecting functional ability. Function is defined as the interaction between a person and their real-world environment. Currently, no objective measures of function exist assessing the environmental component. A newly-developed measure of functional-living, the Movement and Activity in Physical Space (MAPS) score, combines accelerometer and geospatial data providing quantitative measurement of real-world function. Because MAPS is a new measure of functional-living, the purpose of the current study was to provide further construct validity for MAPS as a functional-living measure in older adults and to determine what combination of 3 days, using weekend and week days, are needed to obtain reliable MAPS scores in older adults.

While there are many factors known to impact function, cognitive function has a well-known relationship with physical activity. One aspect of what MAPS assesses is physical activity. Therefore, a relationship between cognitive function and functional-living was expected. Physical activity and physical function were also expected to be related to functional-living.

Thirty community-dwelling older adults aged 72.6 ( $\pm$  7.0) years completed the study. Five measures of cognitive function were used, each assessing a different cognitive domain (i.e., executive function, working memory, processing speed, reaction time, and spatial visualization). A physical function test and a measure of physical activity were also administered. Pearson  $r$  correlations were conducted among all measures to assess the correlations between MAPS scores and the measures of cognitive function, physical activity, and physical function. If a correlation was found to be significant between the MAPS intensity score (MAPS<sub>I</sub>) and MAPS volume score (MAPS<sub>V</sub>) with any of the cognitive function measures, physical activity questionnaire, or physical function test, then further construct validity would be provided for MAPS as a functional-living measure in older adults.

Processing speed scores were significantly correlated with MAPS<sub>I</sub> ( $r = .46, p = .01$ ) and MAPS<sub>V</sub> ( $r = .39, p = .03$ ) scores. Scores from the spatial visualization measure were also significantly correlated with MAPS<sub>I</sub> ( $r = .42, p = .02$ ) and MAPS<sub>V</sub> ( $r = .39, p = .03$ ) scores. The physical function score was also significantly correlated with MAPS<sub>I</sub> scores ( $r = -.48, p = .01$ ). The remaining measures of cognitive function and the physical activity questionnaire were not found to be associated with functional-living, as measured by MAPS, due to several limitations in the measures used. Wearing the activity monitors during any 3-day combination of days provided reliable MAPS data. Results of the study provided evidence of construct validity for MAPS as a functional-living measure.

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# CHAPTER 1

## INTRODUCTION

The population of adults aged 65 years and older is projected to double by the year 2050, making up 20% of the total U.S. population (U.S. Bureau of the Census, 2008). The exponential rise in the number of older adults is largely due to the baby boomer generation entering old age (Whitbourne & Whitbourne, 2011). With age comes a series of physiological changes (e.g., decreased strength due to loss of muscle tissue) and cognitive changes (e.g., memory problems). Age-related changes can increase the severity of existing health conditions, increase the risk of falling and losing independence, and increase the risk for many diseases (e.g., diabetes, heart disease) that could be reduced if older adults engaged in physical activity (Nelson, et al., 2007). Common chronic health conditions in older adults include hypertension (55.7%), heart disease (31.0%), arthritis (49.5%), cancer (22.5%), and diabetes (18.6%) (National Health Statistics Report, 2009). These statistics highlight the need to improve the health and quality of life of the aging population because age-related changes and chronic health conditions contribute to how often and to what extent older adults function in their everyday life. One way to help assess changes in function is to use more accurate ways of measuring the everyday function of older adults.

Function is defined as all body functions, activities, and participation and their interaction with environmental factors (World Health Organization, 2001); that is, function is the person-environment interaction. Subjective measures (e.g., questionnaires) of function in older adults are easy to administer, relatively inexpensive, and are often used in large-scale studies. However, subjective measures are limited because they rely

on the participant to accurately recall specific tasks they were able or unable to do within a specific period of time. Also, the terms used in subjective measures can be confusing to participants, which can lead to over or underestimating true values. For example, in a question asking the participant to recall the number of days they engaged in vigorous activity within the past week, one participant may differ from another participant in their interpretation of what the term “vigorous” means. Some may consider vigorous activity to be walking up a flight of stairs while others may see running a marathon as vigorous activity. Examples of subjective measures of function include the Late Life Function and Disability Instrument (LL-FDI) (Jette, et al., 2002) and the Activities of Daily Living Scale (ADLs) (Katz et al., 1963).

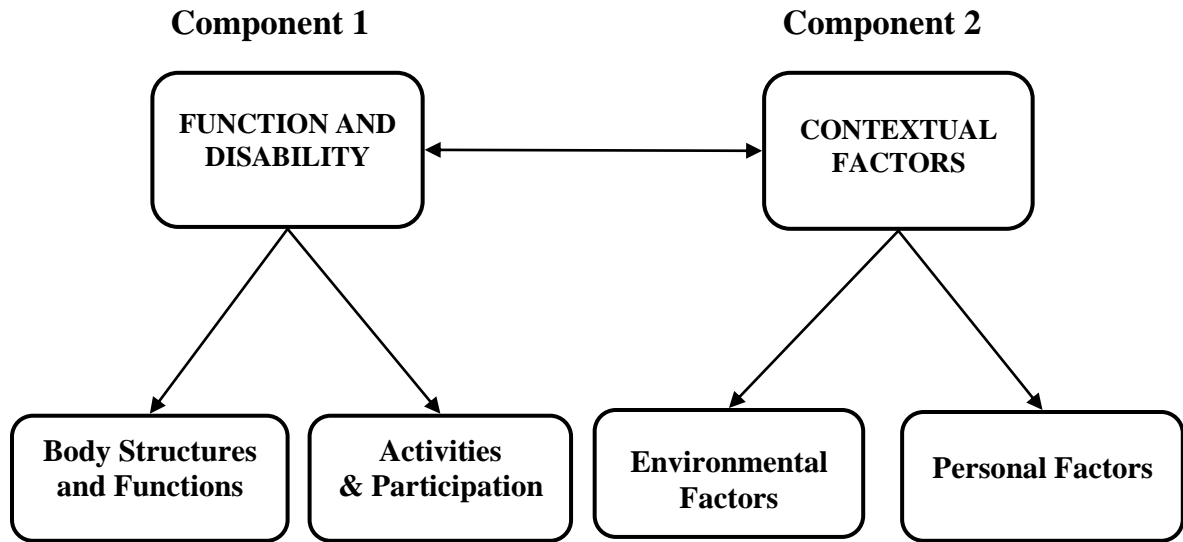
Objective measures of function quantitatively assess the ability of an individual to function at the physical level. Objective measures of function commonly used with older adults include the 400 meter walk test (Simonsick, et al., 2008) and the Short Physical Performance Battery (SPPB) (Guralnik, et al., 1994). These measures are able to provide information about specific physical abilities (i.e., walking speed or balance) performed in a clinical or research setting, but lack the ability to provide information about how a person functions in their real-world environment.

Physical activity is a fundamental component of health and its relationship with physical function has been demonstrated in the older adult population (Buman, et al., 2010; Taylor et al., 2004). Thus, accelerometers, pedometers and heart rate monitors have been used to assess physical function in older adults (Morie, et al., 2010; Webber & Porter, 2009). Accelerometers can be used to measure free-living physical activity behavior and the volume (step counts), intensity (activity counts), and duration of



physical activity can be measured across multiple days. But accelerometers are not capable of providing information about where this activity is taking place. Because function is defined as the interaction of a person within their environment, a true measure of function must be capable of measuring both the person and person's environment. To our knowledge, there are no objective functional measures capable of measuring the person-environment interaction. Evaluating a person's real-world function through the incorporation of physical activity and the environment would provide researchers with a more accurate measure of function.

The World Health Organization's (WHO) International Classification of Functioning, Health, and Disability Model (ICF) encompasses the factors associated with function (Figure 1) and provides the framework for understanding and measuring function in the proposed research. The ICF model is composed of two components. Component 1 includes function and disability at the level of the person (i.e. body structures and function along with activities and participation) and Component 2 includes contextual factors that consist of environmental factors and personal factors (World Health Organization, 2001). As previously mentioned, the major limitation in using current measures of function is that they only address Component 1 within the ICF model. Even though the ICF model acknowledges the importance of contextual factors (i.e., environmental factors and personal factors), current functional measures do not include these factors as part of the assessment of function.



**Figure 1. The World Health Organization's International Classification of Functioning, Health, and Disability Model, 2001.**

The essential factor that is not being measured in functional research is the environment. Through the use of geospatial technologies (i.e., different technologies that are all related to mapping features on the surface of the earth), researchers have the means to measure the environment allowing an assessment of a person's interaction within their environment (Herrmann & Ragan, 2008). The use of geospatial technologies, including Global Positioning System (GPS) and Geographic Information Systems (GIS) software to objectively measure the environment, appear to be useful in a variety of populations. GPS and GIS have been used to identify locations other than home where physical activity occurs (Troped et al., 2010), assess where children are physically active after school (Wheeler et al., 2010) or monitor sport-related movements (Edgecomb & Norton, 2006). In older adults, the combination of GPS and GIS have been used in a variety of settings, for example, to assess transport-related physical activity (Oliver et al., 2010), transportation and mobility patterns (Webber & Porter, 2009), and to assess the ability of older adults to stop at red lights (West, et al., 2010). A limited number of

studies have begun to measure environmental factors along with physical activity information to see where physical activity occurs (Troped et al., 2010). Measuring the environment using GPS and GIS in combination with measuring physical activity data will provide a more comprehensive measure of function compared to the currently available functional outcome measures used with older adults.

Acknowledging and measuring the influence of the environment on function is an important next step in functional outcome measure research in older adults. “Functional-living” is a term used to describe this interaction between a person and their environment. A recently developed functional-living measure, the Movement and Activity in Physical Space score (MAPS) (Herrmann, et al., 2011) objectively assesses function through the use of time-locked physical activity data and geospatial data. Physical activity is objectively measured using accelerometers which record step counts and activity counts (i.e., vertical accelerations) in 60 second epochs. Geospatial data is collected used GPS receivers and GIS software to automatically record latitude, longitude, altitude, along with speed, trip time, and trip distance of locations (i.e., places other than home that last 10 minutes or more). Using physical activity data and geospatial data, researchers can quantify how much physical activity occurs and where it occurs in the individual’s real-world environment. A MAPS intensity score ( $MAPS_I$ ) is created using activity counts specific to all locations other than home whereas a MAPS volume score ( $MAPS_V$ ) represents the step counts corresponding to locations other than home. MAPS scores reflect the duration, volume (i.e. step counts) and intensity (i.e. accelerations) of physical activity obtained in different locations during the day (excluding home). Below is the basic MAPS formula:

$$MAPS = \sum_{L=1}^n \left( \frac{Activity}{Minutes} \right)$$

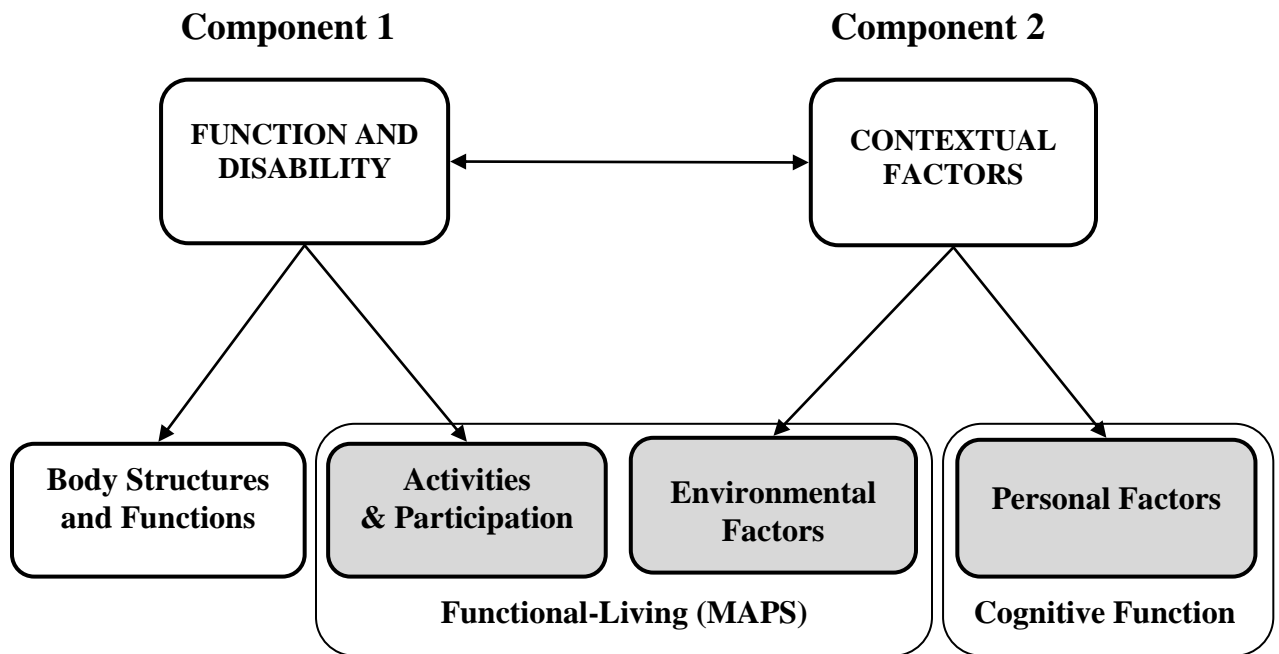
Within the MAPS formula, “L” represents locations other than home, “Activity” is a measure of physical activity counts (for the MAPS<sub>L</sub> score) or step counts (for the MAPS<sub>V</sub> score), and “Minutes” pertain to the number of minutes spent at specific locations lasting 10 minutes or more. According to MAPS, an older adult with high functional-living will have engaged in more physical activity (measured as physical activity counts and step counts) at locations away from home and an older adult with low functional-living will have engaged in less physical activity at fewer locations other than home.

MAPS has been used in post-surgical knee patients (Herrmann, et al., 2011) to assess functional improvements following knee surgery, in individuals with Multiple Sclerosis (MS) (Snook et al., 2011), and in a recent pilot study of older adults (Morand, Suckau, & Snook, 2011) to determine initial evidence of construct validity. The pilot study provided initial construct validity by taking the physical aspects of function into account (i.e., physical activity and the environment) but has not looked at other contextual components within the ICF model including personal factors. An example of a personal factor is cognitive function.

There is a well established relationship between cognitive function and physical activity in older adults. Different aspects of physical activity including exercise training, types of physical activity, and physical function have all been examined in relation to cognitive function. Cognitive function (i.e., speed, visuospatial, controlled processing, and executive control) was improved after aerobic exercise training in older adults

(Colcombe & Kramer, 2003). Physical function (e.g., grip strength, walking speed) in relation to cognitive function has shown that performance on physical function tasks indicate the risk for impairments in cognitive function (Schneider & Lichtenberg, 2008).

Other than the cognitive function and physical activity relationship, the ICF model provides a framework for the association of cognitive function (i.e., a personal factor) and functional-living (Figure 2). Physical activity makes up part of what functional-living is measuring; therefore, cognitive function should have a relationship with functional-living.



**Figure 2. Relationship between functional-living and cognitive function within the ICF model.**

The proposed study aimed to provide more construct validity evidence for MAPS in older adults by looking at other constructs of function that are found within the ICF model (i.e., personal factors). Cognitive function and functional-living were predicted

have an association based on the ICF model and the known relationship between cognitive function and physical activity.

### Significance

In the older adult population, it is essential for health care providers and researchers to evaluate function using a measure that captures the person-environment interaction. Current measures of function are limited in their ability to measure function because they are only assessing function at the level of the person (i.e., physical function or physical activity) without measuring the person's environment. MAPS measures the person-environment interaction by identifying the duration, frequency, and location where physical activity is performed.

In this proposal, the relationship between cognitive function and functional-living (i.e., MAPS), physical function and functional-living, and physical activity and functional-living were examined to provide further validity evidence for MAPS as a functional-living measure in older adults. In the future, MAPS may be used by clinicians, researchers, and other health professionals to evaluate the interaction an older adult has with their environment. The ability to assess the person-environment interaction is essential for determining functional decline in older adults and making decisions about an older adult's ability to live independently.

### Purpose

The purpose of the study was to provide further evidence of construct validity for MAPS as a functional-living measure in older adults and to determine the number of days

of data collection required to obtain reliable ( $ICC \geq .7$ ) MAPS scores. Providing evidence of construct validity was examined by a) measuring cognitive function and functional-living and b) measuring physical function and physical activity in a sample of older adults. Participants completed five measures of cognitive function [Delis-Kaplan Executive Functioning System (D-KEFS)-Verbal Fluency, Hopkins Verbal Learning Test- Revised (HVLT), Symbol Search, Paper Folding Test, and a visual reaction time test] and then wore an accelerometer and GPS receiver for 5 days. The accelerometer and GPS data were processed and MAPS scores were calculated. The correlations among the cognitive measures scores and the MAPS scores were examined. Cognitive function and functional-living are related to each other based on the ICF model and research evidence of a strong relationship between physical activity and cognitive function. If the measures of cognitive function and MAPS are associated with one another, further evidence of construct validity will be provided for MAPS as a functional-living measure in older adults. Participants also completed a physical function task (Timed Up and Go) and a physical activity questionnaire (International Physical Activity Questionnaire). The correlations among the physical function scores and MAPS scores along with the correlations among the physical activity scores and MAPS scores were examined. If the measures of physical function and physical activity are associated with one another, further evidence of construct validity will be provided for MAPS as a functional-living measure in older adults.

## Specific Aims and Hypotheses

### Specific Aim 1

Provide further evidence of construct validity for MAPS, a functional-living measure in older adults. Older adult participants completed 5 measures of cognitive function and wore an accelerometer and GPS receiver for 5 days. Correlations among the cognitive scores and MAPS scores were examined. The ICF model and previous physical activity and cognitive function research indicate that cognition and functional-living are related. If the MAPS and cognitive function scores are correlated, construct validity evidence will be provided for MAPS. Participants also completed a physical function task and physical activity questionnaire. If the MAPS scores and scores from the physical function task and physical activity questionnaire are correlated, construct validity evidence will be provided for MAPS.

### Hypothesis 1a

Construct validity evidence for the MAPS scores will be shown. Scores from four of the cognitive function measures (i.e. D-KEFS-Verbal Fluency test, HVLIT, Symbol Search, and Paper Folding Test) and MAPS will have moderate positive correlations. The visual reaction time test and MAPS will have a moderate negative correlation.

### Hypothesis 1b

Construct validity evidence for the MAPS scores will be shown. The score from the physical function measure (i.e., Timed Up and Go) and MAPS scores will have a moderate negative correlation. The score from the physical activity measure (i.e.,



International Physical Activity Questionnaire) and MAPS scores will have a low positive correlation.

### Specific Aim 2

Determine what combination of 3 days (i.e., 2 weekdays and 1 weekend day or 1 weekday and 2 weekend days) are needed to obtain reliable MAPS scores in older adults. The proposed study had participants wear the activity monitors for five days to examine what combination of weekend and week days are needed to provide reliable MAPS scores.

### Hypothesis 2

Three days of accelerometer and GPS data will provide MAPS scores with acceptable reliability ( $ICC \geq .7$ ) using any combination of weekdays and weekend days.

## CHAPTER 2

### LITERATURE REVIEW

#### The Increasing Population of Older Adults

By the year 2050, it is projected that the population of older adults, aged 65 and older, will more than double from over 40 million to over 85 million, making up 20% of the total U.S. population (U.S. Bureau of the Census, 2008). The number of centenarians, older adults aged 100 years and older, in the U.S. will increase six fold from about 79,000 to over 600,000 by the year 2050 (U.S. Bureau of the Census, 2008). This exponential rise in the number of older adults compared to the rest of the U.S. population is primarily due to the aging baby boomer population who are expected to live into their 80s, 90s, and 100s (Whitbourne & Whitbourne, 2011). With older adults experiencing longer life spans and the increased number of baby boomers entering old age, health care spending in the U.S. is projected to increase by 25% in the next twenty years (Centers for Disease Control and Prevention, 2004). Encouraging older adults to adopt healthier behaviors (e.g., participating in regular physical activity), will help reduce the risk for chronic health conditions, help lower health care costs, and increase the likelihood of living independently in old age.

Aging is an inevitable part of life. As we age, we face a series of physiological changes (e.g., decreased strength due to loss of muscle tissue) and cognitive changes (e.g., memory problems) which can be age-related or non-age related (Whitbourne & Whitbourne, 2011). These changes can increase the risk of falling or augment existing health conditions (e.g., arthritis), ultimately impacting overall quality of life. The risk for

many common diseases in old age (e.g., diabetes, heart disease) can be reduced through regular participation in physical activity (Nelson, et al., 2007).

### Physical Activity Definition and Recommendations for Older Adults

Physical activity is defined as bodily movement that is produced by skeletal muscles that results in energy expenditure (Casperson, Powell, & Christenson, 1985). The terms physical activity and exercise are related concepts and are frequently used interchangeably. However, exercise refers to planned, structured, and repetitive movement (i.e. planned physical activity) to improve or maintain one or more components of physical fitness (Chodzko-Zajko, et al., 2009).

The American College of Sports Medicine (ACSM) established the current physical activity recommendations for older adults. The current recommendations include 30 minutes of moderate-intensity aerobic activity on five days each week (150 minutes per week) or a minimum of 20 minutes of vigorous-intensity aerobic activity on three days each week for health benefits (Nelson, et al., 2007). Engaging in 8-10 strength training exercises in major muscle groups on two nonconsecutive days during the week can aid in offsetting the loss in muscle mass and strength associated with normal aging. At least 10 minutes of flexibility exercises two days a week is recommended and preferably performed on all days that aerobic or muscle-strengthening activity is performed (Nelson, et al., 2007). Balance exercises, such as Tai Chi, are also recommended two or more days each week for 10 minutes for frequent fallers or individuals with mobility problems to improve muscular strength and overall balance (Nelson, et al., 2007; Taylor-Piliae, 2006). If older adults are unable to engage in a

minimum of 150 minutes of moderate intensity aerobic activity per week due to chronic conditions (e.g. cardiovascular disease), they are encouraged to be as physically active as their body allows. Based on the data from the 2007 Behavioral Risk Factor Surveillance System (BRFSS) report, only 39.3% of older adults aged 65 and older met the recommended physical activity guidelines and 32.7% of older adults participated in no leisure-time physical activity (LTPA) (Centers for Disease Control and Prevention, 2007). Common leisure time physical activity for older adults includes walking, dancing, gardening, swimming, and other low impact activities (Salvador, Florindo, & Costa, 2009; World Health Organization, 2011).

If ACSM recommendations are followed, older adults can improve their fitness, improve management of existing diseases and further reduce their risk for premature chronic health conditions and mortality related to physical inactivity (Nelson, et al., 2007). Muscle strengthening exercises are particularly important because higher levels of musculoskeletal fitness have been shown to enhance the capacity to meet the demands of everyday life and allow a person to maintain functional independence for a greater period of time (Warburton, Nicol, & Bredin, 2006).

### Function In Older Adults

#### Function Definition

According to the World Health Organization (WHO), function is defined as all body functions, activities, and participation and their interaction with environmental factors (World Health Organization, 2001). The WHO uses a disablement model called the International Classification of Functioning, Health, and Disability (ICF) model that

views human function and functional decreases as the product of the dynamic interaction between health conditions (e.g. diseases, aging, disorders, injury) and contextual factors (e.g. the human-built, social, or attitudinal environment) (World Health Organization, 2001). The ICF model will be discussed in further detail later in the proposal. For now, understanding the definition of function as the person-environment interaction will be important for discussing the measures currently being used in research and clinical settings to assess function in older adults.

### Functional Measures Used in Older Adults

In older adults, it is common to measure function through the assessment of physical abilities and physical activity using subjective or objective measures.

#### Subjective Functional Measures

Subjective measures of function include self-report questionnaires which are frequently used in large-scale studies due to the ease of administration and low cost. Self-report questionnaires allow researchers to gain more insight into behaviors of older adults than would be possible to study in the laboratory setting and can be administered over the phone, on the Web, or in person (Whitbourne & Whitbourne, 2011). Due to their convenience, subjective measures of function are often used in older adults to obtain some insight into their self-perceived behaviors (e.g., ability to dress themselves, amount of physical activity engaged in within the past week, confidence level walking up a flight of stairs).

The Late Life Function and Disability Instrument (LLFDI) (Jette, et al., 2002) was designed to assess and be responsive to meaningful changes in function and disability and ask questions about social roles, mobility, personal maintenance, home life and other life tasks. Two functional outcome measures, Activities of Daily Living Scale (ADLs) (Katz et al., 1963) and Instrumental Activities of Daily Living (IADLs) (Lawton & Brody, 1969), require older adults to recall their ability to complete specific everyday tasks. ADLs refer to activities that are essential for self-care such as bathing, dressing, or feeding whereas IADLs refer to activities that are necessary to adapt independently to the environment such as shopping, using transportation, or housekeeping. Physical activity, one factor among others that influence function, is sometimes used as a functional outcome measure. Physical activity measures such as the International Physical Activity Questionnaire Short Form (IPAQ) (Craig, et al., 2003) require individuals to recall frequency and duration of vigorous-intensity physical activity, moderate-intensity physical activity, walking, and sitting (Heesch et al., 2010).

While there are some conveniences to using subjective measures, it is well-known that they may be influenced by fluctuations in health status and mood, depression, anxiety, or cognitive ability (Murphy, 2009). Other problems include the occurrence of social desirability bias (over-reporting good behavior) (Morie, et al., 2010), dependence on recall (Banda, et al., 2010), and problems reporting time spent in light or moderate physical activity (Washburn, 2000). All of the errors associated with subjective measures can lead to overestimating actual duration and intensity of activities (Troiano, Berrigan, Dodd, Masse, Tilert, & McDowell, 2007), ultimately leading to erroneous conclusions.

*Above all, the most apparent flaw in the currently available subjective functional measures is their inability to measure the environment where activity occurs.*

### Objective Functional Measures

Objective measurement typically involves the use of functional performance tasks to quantitatively assess functional ability. Other than functional assessments, activity monitors such as accelerometers and pedometers are commonly used as objective measures of function in older adults due to their ease of use and portability (Morie, et al., 2010; Buman, et al., 2010).

In older adults, the Short Physical Performance Battery (SPPB) (Guralnik, et al., 1994) is a commonly used measure of physical function. The SPPB includes assessments of standing balance, a timed 8 foot walk at casual pace, and a timed test of five repetitions of rising from a chair and sitting down. The Timed Up and Go (TUG) (Posiadlo & Richardson, 1991) measures the amount of time it takes an individual to rise from an arm chair, walk 3 meters, turn, walk back, and sit down again and is a good measure for quantifying functional mobility in older adults (Posiadlo & Richardson, 1991). The 400-meter walk test, also called the Long Distance Corridor Walk (LDCW) (Simonsick, et al., 2008), is able to predict functional limitations in older adults who reported no walking difficulty prior to testing.

Other than functional performance tasks, activity monitors (e.g., pedometers and accelerometers) are also used to objectively measure function. Pedometers are a non-invasive, inexpensive tool used to objectively quantify step counts and have been used in older adults due to their ease of use (Parker, Strath, & Swartz, 2008). The use of

pedometers in older adults has shown that higher physical activity levels were associated with reductions in physical impairments and overall well-being (Weinstock, et al., 2011).

Accelerometers measure the duration (i.e., physical activity data collected in 60 second epochs), intensity (i.e. activity counts), and volume (i.e., step counts) of physical activity and can record accelerations that occur in the vertical and horizontal planes.

Accelerometers have been used to assess physical activity levels of older adults based on the number of activity counts measured (e.g., sedentary, low-light physical activity, high-light physical activity, and moderate-vigorous physical activity) (Buman, et al., 2010).

The downfall of using accelerometers is their inability to measure stationary activity (e.g. stationary cycling) and upper body movement due to its typical placement on the body (e.g. at the hip). Accelerometers are water resistant (i.e. maintain their function in light rain showers) but are unable to measure underwater activity such as swimming or showering. When using accelerometers in older adults, problems with memory and recall may affect compliance of wearing monitoring devices over a series of days (Murphy, 2009). Physical activity data do not provide complete information about a person's functional abilities because only intensity and duration of movement without any contextual information is reported.

The objective functional measures described measure a few aspects of function such as physical performance, functional mobility, and physical activity; however, the length of time an older adult can hold a one-legged stand, for example, says nothing about their ability to walk on an icy surface during the winter or ability to walk up a flight of stairs without handrails. In other words, environmental information is not being

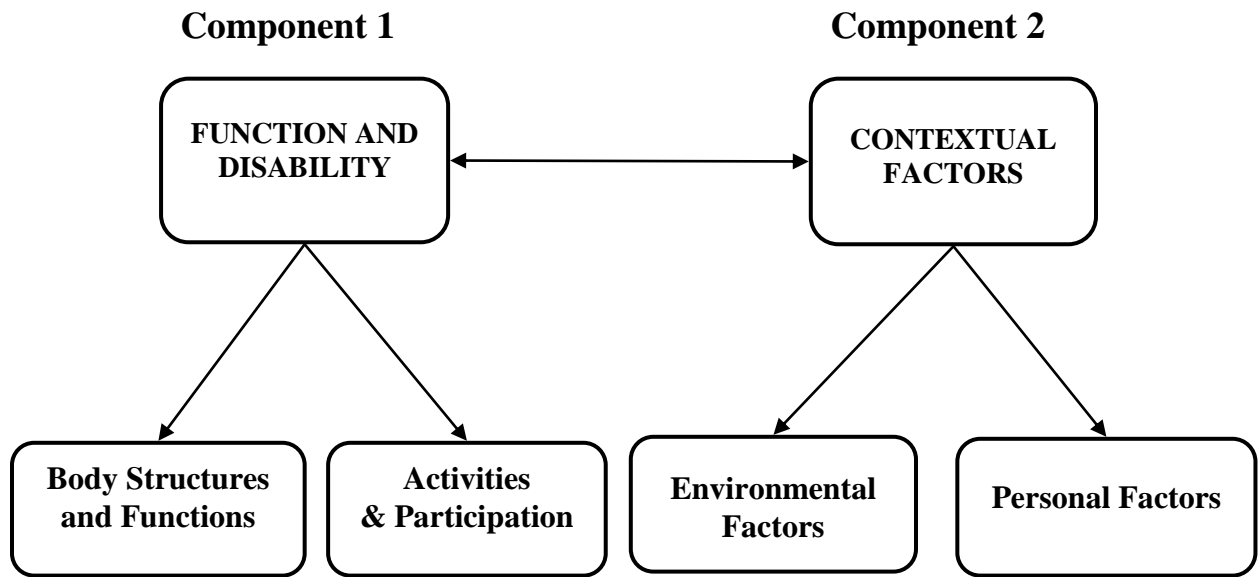


provided. *A significant weakness of the currently available objective measures of function is that they are not measuring information from the environment.*

#### World Health Organization's International Classification of Functioning Model

The ICF model developed by the WHO (2001) is a conceptual framework that is used internationally by physicians, athletic trainers, researchers, and other health professionals to help discuss the process of disablement in clinical outcomes assessment (Jette, 2006). Many disablement models have been created since the 1960s but the ICF model has been chosen to guide the framework of the proposed study because it is the most widely used disablement model and incorporates the factors that make up functional-living.

The ICF model (Figure 3) acknowledges the importance of including environmental factors and personal factors as having a significant impact on an individual's level of function due to the fact that both factors influence how people live and conduct their lives (World Health Organization, 2001). As opposed to previous disablement models, which only addressed function at the level of the person and their role in society, the ICF model has an environmental category that broadens the function definition (Jette, 2006).



**Figure 3. The World Health Organization’s International Classification of Functioning, Health, and Disability Model (ICF), 2001.**

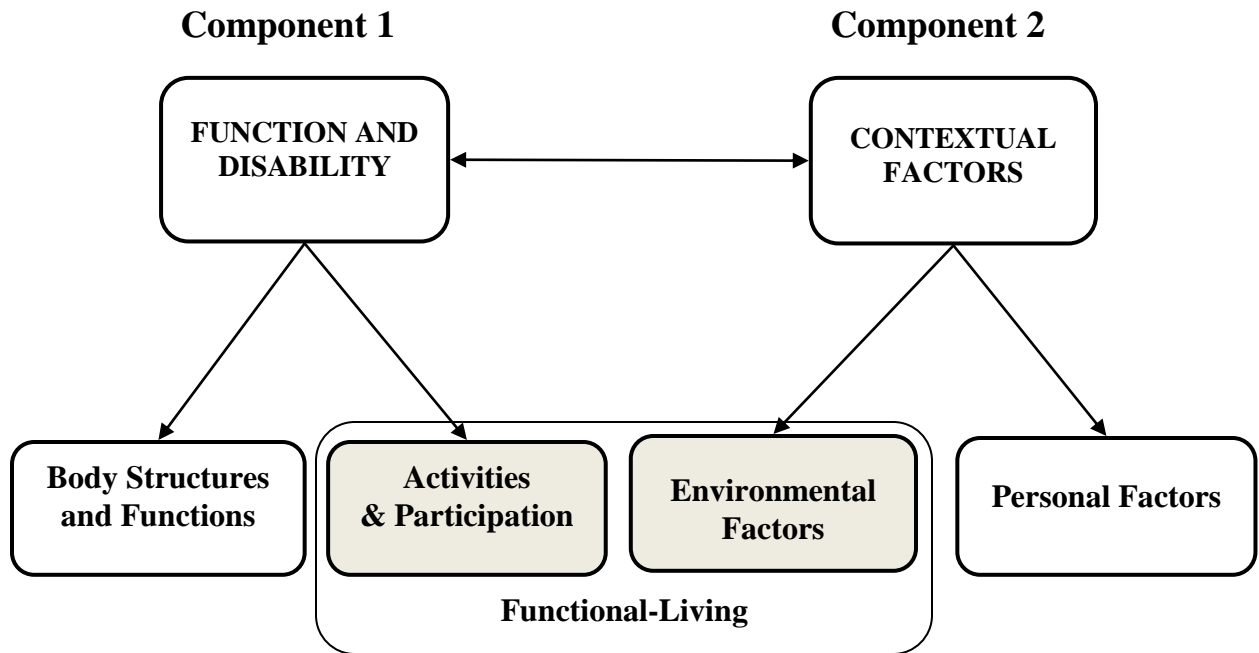
#### Components of ICF Model

The ICF model consists of two components: 1) Function and Disability and 2) Contextual Factors (Figure 3). Component 1, Function and Disability, attempts to account for functions at the level of the body, individual, and society by addressing *body functions and structures* (i.e. mental and physical aspects of health and all anatomical parts) along with *activity and participation* (i.e. structural and functional impairment on what a person can do within their environment) (Snyder, Parsons, McLeod, Bay, Michener, & Sauers, 2008; World Health Organization, 2001). An impairment is a significant deviation or loss in body function or structure (Jette, 2006). *Activity* is the execution of a task or action (e.g. walking, dancing, playing) whereas *participation* is the involvement in a life situation (e.g. going out to eat with friends, walking). Component 2, Contextual Factors, aims to account for the effect of the environment and personal factors on the overall level of functioning. Contextual factors include *environmental factors* (i.e.

physical, social, and attitudinal environments in which people conduct their lives) and *personal factors* (i.e. age, cognitive function, coping styles, social background, education, and past experiences) (World Health Organization, 2001). Environmental and personal factors influence function and disability.

### Functional-living

The term “functional-living” is defined as the interaction between a person and their real-world environment. The ICF model can be used as a framework to conceptualize the elements of functional-living (i.e., activities & participation and environmental factors). A person’s activities (e.g., walking, cleaning, shopping) and participation (e.g., going out to eat, biking to town) are demonstrated within Component 1 of the ICF model. The influences drawn from the environment (e.g., proximity of recreational centers, sidewalks in neighborhood) are demonstrated within Component 2 of the ICF model. By integrating activities and participation along with environmental factors, functional-living can be demonstrated within the ICF model as seen in Figure 4.



**Figure 4. Functional-living demonstrated within the ICF Model of 2001.**

### Objective Measures of Environmental Factors

Geospatial technologies, such as the Global Positioning System (GPS) and Geographic Information Systems (GIS), offer the means to measure the physical environment (Herrmann & Ragan, 2008).

### GPS

The GPS is a worldwide satellite based radio-navigation system developed by the United States Department of Defense to accurately track the latitude and longitude of a receiver's location through space and time (Federal Aviation Administration, 2010). Originally it was only used for military purposes but now is available to the public. The GPS is composed of three major divisions. The Space Division is composed of 24 satellites that orbit the earth twice daily, Control Segment is composed of five monitoring

stations and four ground antennas that track the satellite locations, and the User Equipment Division consists of a commercially available GPS receiver (Herrmann & Ragan, 2008). The GPS receiver must acquire three satellites as reference points to accurately triangulate a 2-D position (latitude and longitude) or four satellites to obtain a 3-D position (latitude, longitude, and altitude). Commercial receivers have 12 or more parallel channels that continuously track and update receiver position information for accuracy of less than three meters. Differential Global Positioning System (dGPS) uses stationary receivers in known locations to reduce error. Differential techniques are sometimes applied in order to improve the accuracy of GPS position data by recording GPS position information at a known point so that differential corrections can be computed (Chen, Moan, & Verhoeven, 2009).

The use of GPS and GPS receivers provide researchers with locations within the real-world environment. GPS receivers have been used in adults to identify locations other than home where physical activity occurs (i.e., built-environment including green space, street connectivity, land use mix, etc.) (Troped et al., 2010), assess where children are physically active after school (Wheeler et al., 2010), and for monitoring player movements and distance in sports (Edgecomb & Norton, 2006). Specifically in older adults, the use of GPS receivers is still relatively new but have been used, for example, to identify transportation and mobility patterns (Webber & Porter, 2009) and assess the ability of older adults to stop at red lights (West, et al., 2010).

## GIS

GIS integrates hardware, software, and data for capturing, managing, analyzing, and displaying all forms of geographically referenced information (Environmental Systems Research Institute, 2011). GIS allows us to view, understand, question, interpret, and visualize data in many ways that reveal relationships, patterns, and trends in the form of maps, globes, reports, and charts. GIS applications such as Google Earth integrate various types of geospatial information to provide analysis and improved visuals and understanding. This can allow researchers to critically appraise the space the person used, the amount of distance traveled, and more importantly the types of locations the person visited.

GIS is useful when evaluating differences in geographical access within populations, understanding health care utilization, and exploring how health care delivery can be improved (McLafferty, 2003). GIS has been useful in other health research to identify communities in need of primary care services (Dulin, et al., 2010), quantify potential health effects of air pollution in an urban population (Mindell & Barrowcliffe, 2005), or assess the impact of traffic exposure on adult asthma prevalence and symptoms (Lindgren, Bjork, & Jakobsson, 2010).

### Combining GPS, GIS, and accelerometers

Researchers are increasingly using the combination of physical activity data with GPS and GIS (i.e., environmental information) to identify duration and frequency of activities at specific locations or examine the locations where individuals are physically active. For example, GPS, GIS, and accelerometers have been used to assess transport-

related physical activity within a built environment but make no indication of how functional an individual is based on the amount of physical activity that occurs at specific locations (Oliver, Badland, Mavoa, Duncan, & Duncan, 2010; Troped, Wilson, Matthews, Cromley, & Melly, 2010). The use of GPS, GIS, and accelerometers are addressing more aspects of function (i.e., environmental factors); however, they are not quantifying the person-environment interaction. Research using GPS and GIS to assess an individual's function based on their activities within their real-world environment is warranted in the future. ***A real-world measure of function is needed to address the current deficits in functional research. A functional-living measure will attend to these deficits by measuring a person's interaction with their environment.***

#### MAPS: A New Functional-living Measure

The Movement and Activity in Physical Space (MAPS) score, a recently developed functional-living measure, reflects the person-environment interaction by identifying the duration, intensity, and volume of physical activity and where the physical activity is performed. MAPS addresses the current deficits in functional measurement by measuring the environment. The person-environment interaction is measured by combining physical activity data (i.e., activity counts and step counts from an accelerometer) and environmental information using geospatial technologies (Global Positioning Systems and Geographic Information Systems). The strength of using MAPS as a functional-living measure is its ability to objectively capture the person-environment interaction. As demonstrated in Figure 2, functional-living is captured within Components 1 and 2 of the ICF model.

## Components of MAPS

### Physical Activity

ActiGraph GT1M accelerometers are used as an objective measure of physical activity. The accelerometer records steps counts and activity counts. Step counts are the number of steps measured in a 60-second period. Activity counts are a summation of accelerations measured during a 60-second period. Physical activity data are downloaded using ActiGraph software and stored in a computer database.

### GPS

For our purposes in MAPS, a GPS receiver is used to record latitude, longitude, and altitude, along with speed, trip time, and trip distance. The receivers capture environmental factors (i.e., coordinates of locations traveled to other than home, length of trip, time arriving and departing from locations) that impact how an individual functions in the real-world.

### GIS

For our purposes in MAPS, GIS software is used to process the geospatial information from the GPS receivers. Information recorded in GPS receivers will be assessed using GIS and a Google Earth application to help researchers verify the identification of locations traveled to while wearing the accelerometer and the time, duration, and speed of the travel.



## MAPS Formula

The person-environment interaction is quantified using geospatial and accelerometer data to create a MAPS<sub>I</sub> and a MAPS<sub>V</sub> score. A MAPS intensity score (MAPS<sub>I</sub>) reflects the amount of activity counts (i.e., accelerations) specific to all locations other than home whereas a MAPS volume score (MAPS<sub>V</sub>) reflects the step counts corresponding to locations other than home. Within the MAPS formula, “Activity” is a measure of physical activity counts (for the MAPS<sub>I</sub> score) or step counts (for the MAPS<sub>V</sub> score) and “Minutes” pertain to the number of minutes spent at specific locations, “L”, for more than 10 minutes. Ten minutes was chosen following pilot testing to reduce confusion and misclassifying of locations due to long stoplights, drive-thrus, traffic congestion, etc. (Herrmann, et al., 2011). The amount of activity is divided by the amount of time spent at the specific location, and the information from all locations visited in one day is summed to create the corresponding MAPS<sub>I</sub> score (for activity counts) and MAPS<sub>V</sub> score (for step counts). The basic formula for MAPS is:

$$MAPS = \sum_{L=1}^n \left( \frac{Activity}{Minutes} \right)$$

### Interpretation of MAPS scores

The combination of accelerometers and GPS receivers along with GIS software allows time-locked accelerometer data to be linked to specific locations obtained from the GPS providing quantitative information on the amount of physical activity completed at specific locations outside of home. MAPS scores are weighted so that more activity in a

smaller period of time at single locations will cause MAPS scores to be greater. The increase in MAPS<sub>v</sub> score can be influenced, for example, by a greater amount of physical activity during a shorter period of time (e.g., 8000 step counts completed during 80 minutes at the gym vs. 8000 step counts recorded during the 8 hours an individual is at work). Also, unlike the current measures of function in older adults that yield a small range of possible scores (e.g., range for the SPPB is 0-12), MAPS scores are continuous data. This allows MAPS to detect larger functional differences between individuals, track functional decline in a more precise manner, and decreases the likelihood of seeing a floor or ceiling effect.

### Use of MAPS in Clinical Populations

#### Post-Surgical Knee Patients

In the development of MAPS (Herrmann, et al., 2011), a group consisting of 9 post-surgical knee patients and 9 controls ( $25.6 \pm 9.8$  years) was used to examine initial validity evidence and reliability evidence of MAPS scores. Participants wore an accelerometer and GPS receiver for three days and kept a travel log. Correlational analyses were used for MAPS scores with several outcome measures to determine if MAPS is a valid measure of measure of function. The Knee Injury and Osteoarthritis Outcome Score (KOOS) (a standardized knee outcomes survey that consists of 42 items) was an outcome measure used to compare to MAPS. The KOOS includes five subscales measuring pain, symptoms, function in daily living (ADLs), function in sport and recreation, and knee-related quality of life (QOL). The purpose of measuring function using this outcome measure is to examine the construct validity (i.e., whether the MAPS

scores are correlated with the theorized construct of function as measured by the KOOS) of MAPS as a functional measure. Pearson  $r$  correlations were used to examine the association between MAPS scores and the study measures. Moderate correlations ( $r = 0.51 - 0.58$ ;  $p < 0.05$ ) were found and supported convergent validity (i.e., a type of construct validity examining the degree to which a test measures a hypothetical construct by using multiple indicators of the construct of interest). Additional construct validity was established using the known-group difference method, with significant differences in MAPS scores found between the group of post-surgical knee patients and the control group. In rehabilitation settings, MAPS allows researchers to detect a patient's change in function in their environment (i.e., ability to commute to work, engage in their normal activities before the injury occurred, etc.) after having gone through surgery, something previous functional measures in rehabilitation could not do. This study also provided evidence that the MAPS scores are reliable and a minimum of three days of recording is necessary to obtain acceptable reliability (i.e.,  $>.70$ ).

### Multiple Sclerosis (MS)

Initial validity evidence for MAPS scores has also been established in a group of 19 individuals ( $n = 16$  females,  $47.1 \pm 10.6$  years of age) with MS (Snook et al., 2011). Study measures used to establish initial validity evidence included questionnaires assessing function, symptoms, and physical activity. The Late Life Function and Disability Instrument (LL-FDI) consists of three subscales of upper body, lower body, and advanced lower body function. A symptom inventory consisting of 100 items was used to assess the participant's MS-related symptoms. Physical activity was measured

used the Godin Leisure-Time Exercise Questionnaire (GLTEQ). Participants wore an accelerometer and GPS receiver for five days.

Correlations were used to examine the relationship among the MAPS scores and the measures of function, symptoms, and physical activity (weekly exercise). The MAPS<sub>I</sub> and MAPS<sub>V</sub> scores had moderate to strong correlations with function ( $r = .54; .66$ ), symptoms ( $r = -.46; -.51$ ), and exercise ( $r = .70; .87$ ), respectively. Initial construct validity of the MAPS scores is supported based on the strength and direction of the correlations with the function, symptoms, and exercise outcome measures.

A case comparison was completed (Snook et al., 2010) from initial data in the study and found a greater percent difference between MAPS<sub>I</sub> and MAPS<sub>V</sub> scores of two females with MS who were similar in age, years with MS, and type of MS (relapsing-remitting). Percent differences between MAPS<sub>I</sub> and MAPS<sub>V</sub> scores were 77.6% and 87.2%, respectively whereas the percent differences between the 9-Hole Peg Test, 25 Foot Timed Walk Test, and Paced Auditory Serial Addition Task were a mere 1.6%, 28.7%, and 24.2%. The larger percent differences speak to the ability of MAPS to discriminate between functional levels. Small changes in function could be detected using MAPS scores, whereas the other measures of function are not sensitive enough to capture these changes.

### Older Adults

A pilot study examined the initial validity of MAPS in a group of community-dwelling older adults (Morand, Suckau, & Snook, 2011). Participants ( $n = 14$ ) were 6 men and 8 women with a mean age of  $68.4 \pm 6.8$  years (range = 60 - 81). To validate the

MAPS scores, Pearson *r* correlations were used to examine the relationship between commonly used subjective and objective measures of function used in older adults. The International Physical Activity Questionnaire (IPAQ) (Craig, et al., 2003) was used to examine self-reported physical function using physical activity behavior assessment. The IPAQ requires participants to recall the amount of days per week and average minutes spent per day participating in vigorous activity, moderate activity, walking, and sitting. A subjective measure of physical function, the Patient Reported Outcomes Measurement and Information Systems (PROMIS) Physical Function Computer Adapted Test (PF-CAT), was also used. The SPPB was used as an objective physical function measure. Participants wore an accelerometer and GPS receiver for 3 days and kept a travel log.

The mean and standard deviation of MAPS<sub>I</sub> and MAPS<sub>V</sub> scores were 1574.8±2562.7 and 57.9± 8.2, respectively. Correlations were used to examine the relationship among the MAPS scores and the IPAQ, PF-CAT, and SPPB. The MAPS<sub>I</sub> and MAPS<sub>V</sub> scores had a significant moderate-high, positive correlation with the PF-CAT ( $r = .74, .74$ ) indicating that MAPS is measuring function. No statistically significant correlations were observed between MAPS<sub>I</sub> and MAPS<sub>V</sub> scores with the SPPB ( $r = .42, .43$ ) and IPAQ ( $r = .43, .44$ ). This finding suggests that MAPS may be measuring a different type of function than that measured by the SPPB. The non-significant relationships between the MAPS scores and the SPPB and IPAQ could be a result of the small sample size of the study. The environment, an essential factor of function, is not measured using the SPPB or IPAQ. The moderate correlation between MAPS and the SPPB could be explained by the fact that MAPS and the SPPB are both measuring physical function; however, MAPS is measuring an additional component of function, the environment. The

moderate correlation between MAPS and the IPAQ could be explained by the fact the MAPS and the IPAQ are both assessing physical activity which is one aspect of what MAPS is measuring. MAPS is reflecting something more than physical activity alone (i.e., the environment). In addition to examining initial construct validity, the pilot study examined the number of days required to obtain reliable MAPS scores after three days of wearing the activity monitors using intra-class correlations (ICC). The reliability for MAPS scores based on three weekdays was .90 and .88, for MAPS<sub>I</sub> and MAPS<sub>V</sub> scores, respectively. It is not clear if functional-living is the same on the weekends. Further research is needed to examine if older adult's functional-living patterns are different enough on weekend days to impact the reliability of MAPS scores.

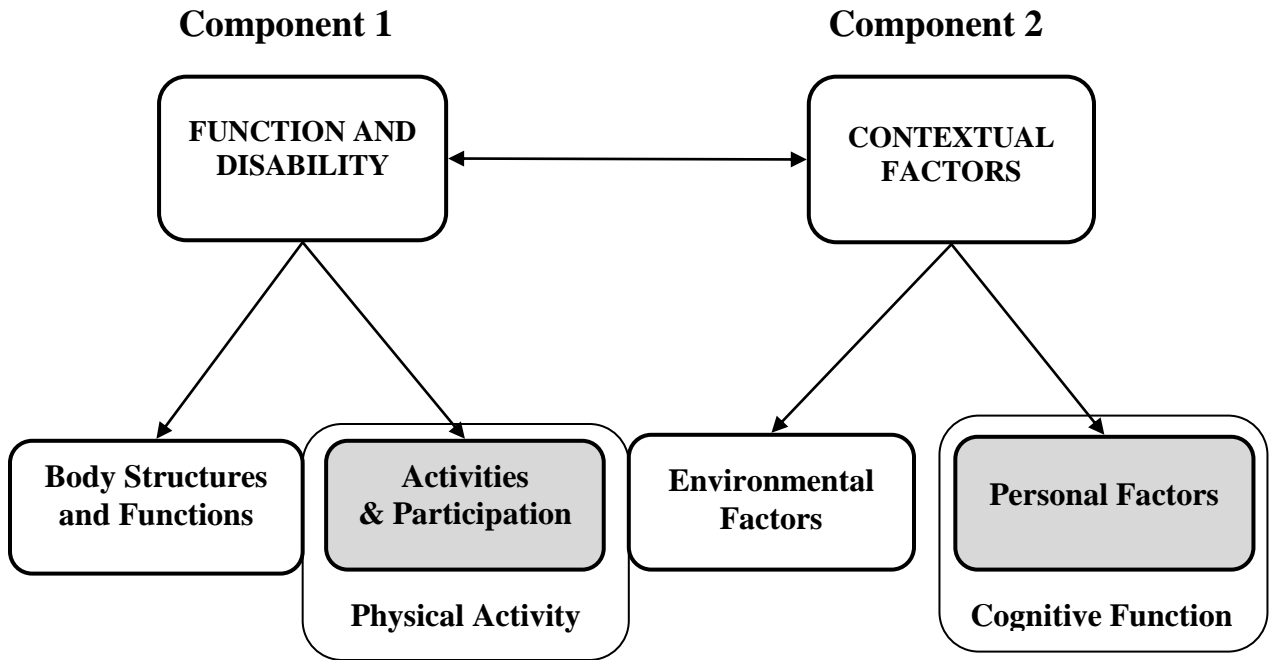
While the pilot study partially established initial construct validity evidence in older adults, the study sample was small (i.e. 14 participants). As a result, further validity evidence needs to be established using a larger sample size. The pilot study has taken the physical aspects of function into account (i.e., physical activity and the environment) but has not examined other contextual components within the ICF model including personal factors. *Additional components within the ICF model can be used as a means of establishing further construct validity for MAPS as measure of functional-living in older adults.*

### Cognitive Function

#### Cognitive Function and the ICF Model

Cognitive function generally refers to a broad range of largely invisible activities such as information processing, attention, and memory (Whitbourne & Whitbourne,

2011). As seen in Figure 5, cognitive function fits into the ICF model as a personal factor within Component 2 (Contextual Factors).



**Figure 5. Physical Activity and Cognitive Function relationship within the ICF model.**

### Cognitive Function and Physical Activity

The ICF model provides a framework for understanding how cognitive function (a personal factor) and physical activity (activities and participation) are related to one another (Figure 5). There is substantial research examining the impact of physical activity on cognitive function. In regards to physical activity and exercise, some of the major cognitive functions that have been measured include memory, attention, perception, vigilance, problem solving, reaction time, movement time, and digit symbol substitution (Chodzko-Zajko, 2006).

Cognitive function has a well-established relationship with physical activity including exercise training (i.e. interventions examining change or status of cognitive function) and types of physical activity (e.g. walking, tai-chi, biking). Physical function (i.e. the ability to perform at the level of the person) is a variable that influences physical activity and has also been shown to be associated with cognitive function.

### Exercise Training

A recent meta-analysis of exercise studies on older adults examined the effect of aerobic exercise training on speed, visuospatial, controlled processing, and executive control (Colcombe & Kramer, 2003). It was found that aerobic exercise training improved cognitive performance, particularly on tasks that assess executive functions (i.e., planning, inhibition, and scheduling of mental procedures) (Colcombe & Kramer, 2003). Executive functions, along with other cognitive constructs, will be discussed later in the literature review. In addition to this finding, resistance training alone and in combination with aerobic exercise training improved executive function (Colcombe & Kramer, 2003). Following Colcombe and Kramer's study, an exercise training study was conducted in a group of older adults to examine the effect of aerobic exercise training over a 10 month period using similar tasks to measure the same four-group categorization (i.e., speed, visuospatial, controlled processing, and executive control) (Smiley-Owen et al., 2008). Results demonstrated that aerobic exercise in older adults can have a beneficial effect on the performance of timed tasks (i.e., Stroop Color Word Interference) that rely heavily on executive control.



### Types of Physical Activity

Individuals engaging in more daytime walking, the most popular form of physical activity in older adults, have demonstrated less cognitive impairment (Barnes et al., 2008). It has also been suggested that physical activities requiring large cognitive demands (e.g., activities requiring intense mental focus such as Tai Chi) may have a higher “cognitive load”. In other words, engaging in physical activities that are mentally and physically challenging have been shown to be more beneficial to cognitive functioning than repetitive, cyclic activities such as walking or biking where the brain is not being stressed as much (Spirduso, 2006).

### Physical Function

In examining the relationship between physical function and cognitive performance in older adults, weaker grip strength, slower walking speeds, and increased time to perform chair stand tasks (i.e., going from a sitting to standing position) were all associated with greater cognitive impairment (Auyeung et al., 2008). Studies have shown that older adults with cognitive impairment demonstrate poorer performance on subjective physical function tasks (i.e., ADL and IADL measures) compared to cognitively intact older adults (Burton et al., 2009). It has also been shown that older adults with minimal cognitive impairment are at higher risk for future incident loss of ADL and IADL abilities possibly because of the progression of cognitive impairment or acute illness such as stroke (Dodge et al., 2005; Ishizaki et al., 2006). Using an observed measure of ADL and IADL tasks, a study found that cognitive performance (as measured by four Delis-Kaplan Executive Function System subtests) was related to ADL and IADL

performance, with the Trail Making Test (TMT) being the best predictor of daily physical functioning (Mitchell & Miller, 2008). Other measures of physical function such as the SPPB were found to be associated with measures of cognitive function (i.e., TMT, Controlled Oral Word Association, Animal Naming), particularly executive functioning (Schneider & Lichtenberg, 2008). Better performance on the 4 Meter Walk test and TUG were found to be associated with greater cognitive impairment compared to cognitively healthy older adults suggesting that walking speed could potentially be used to screen people at risk for cognitive impairment (Eggermont, et al., 2010).

### Cognitive Function and MAPS

Previously in the proposal it was noted that physical activity is an essential aspect of what MAPS measures. Based on the strong evidence of the relationship cognitive function has with physical activity, it is possible to say that a relationship should exist between cognitive function and the combination of physical activity and environmental factors (i.e., MAPS).

### Onset of Cognitive Decline

Numerous cross-sectional and longitudinal studies have disagreed on when cognitive decline, or a decrease in normal cognitive function, begins (Salthouse, 2009). Typically, studies show a negative relationship with age, implying that normal aging results in a decline of cognitive function, with little or to no drop occurring before the age of 55 (Salthouse, 2009). Regardless of when or if an older adult shows signs of cognitive decline, a great deal of variability exists in regards to changes in age-related cognitive

function due to genetics and environmental influences (Finkel & Reynolds, 2010) . In regards to genetics, the presence of an allele called apoe e4 in older adults in combination with atherosclerosis, peripheral vascular disease, or diabetes mellitus were at substantially higher risk of cognitive decline than those without the apoe e4 allele (Haan et al., 1999). Other contributors to cognitive decline include the independent influence of low education supporting the notion that more highly developed memory may provide some protection against cognitive decline (Chodosh, Reuben, & Albert, 2002). A recent cross-sectional study examined the density of cortical gray (i.e., any accumulation of cell bodies and neuropile in the brain and spinal cord) and white matter (i.e., primarily myelinated axons of the brain) in a sample of adults ranging from 55 to 79 years of age (Colcombe, et al., 2003). Those with greater cardiovascular fitness level were less likely to suffer from decreased density of gray and white matter. This suggests that fitness levels may moderate the trajectory of age-related tissue loss significantly.

### Changes in Cognitive Function

There are many constructs of cognitive function (e.g., working memory, executive function, speed of processing) responsible for everyday living. Age-related changes in cognitive function can interfere with daily routines and are not uniform across the whole brain or across older individuals (Glisky, 2007). For example, some aspects of memory hold up well with age while others show significant declines (Glisky, 2007). Although differences in cognitive function are present in older adults, some of the differences can be attributable to the type of study being conducted. It is difficult to interpret differences in cognitive function between age groups in cross-sectional studies due to the effect of

cohort differences (Salthouse, 2009). Cohorts are groups of individuals born within a distinct period of time that share a common characteristic (e.g., age), such as the baby boomer generation (Whitbourne & Whitbourne, 2011). Influences from historical events, economic changes, and other experiences that cohorts share are often referred to as “generational effects” and may account for the cross-sectional age differences found in some cognitive variables (Salthouse, 2009).

### Constructs of Cognitive Function

The constructs to be discussed (i.e., executive function, working memory, speed of processing, spatial visualization) work to help us with everyday activities such as interpreting information (e.g., using a map to find a location), making decisions (e.g., dressing properly for the weather), or remembering important information (e.g., taking regular medications). While it is not a cognitive construct, reaction time plays a role in the speed of many cognitive processes. Reaction time is the time it takes for an individual to respond to a stimulus and is also helpful in carrying out everyday activities (e.g., responding to dangerous drivers on the road before getting into an accident). It is logical to believe that having healthy cognitive function may impact the extent to which older adults function in their environment.

#### Executive Function

Executive control is a multi-component construct that consists of a range of different processes that are involved in the planning, organization, coordination, implementation, and evaluation of many of our non-routine activities (Glisky, 2007).

Executive functioning controls the contents of the conscious mind using working memory (i.e. goal-directed behavior) (Blanchard-Fields, 2010). An older adult with high executive functioning has the ability to complete complex behavioral procedures such as regularly taking medications or handling finances. Common clinical tests of executive function have been shown to predict physical functioning such as dressing oneself or climbing stairs (Bell-McGinty et al., 2002).

### Working Memory

Working memory provides the ability to complete tasks that require simultaneous passive storage and maintenance as well as active speed of information processing (e.g., mentally completing math equations and identifying answers orally) (Bopp & Verhaeghen, 2009). Older adults can typically hold about  $7 \pm 2$  digits in mind as long as the digits are being rehearsed (Glisky, 2007). The time-sensitive storing of information in an ordered series has implication for complex motor and behavioral actions (Anderson, 2008). In older adults, many deficits in working memory can be seen in well-known experiences of “almost knowing” or the “tip of the tongue” (TOT) phenomenon where an individual has difficulty verbally recalling information stored in their memory (Berry et al., 2010).

### Processing Speed

Processing speed refers to the time needed to process a stimulus, prepare a response, and deliver the response. The ability to process information and respond quickly is particularly important to older adults in everyday situations such as driving a

car. Processing complex information quickly, such as yielding to oncoming traffic when making a left hand turn, is particularly difficult for many older adults and puts them at higher risk for a car accident (Whitbourne & Whitbourne, 2011). An older adult experiencing slowed information processing may take longer to complete everyday tasks whereas older adults with faster processing speeds may be more functional in their environment (e.g., more likely to drive a car safely or live independently). Older adults taking part in processing speed training can not only improve their processing speed, but can also improve everyday activities (e.g. finding and reading the directions on a medicine container, counting out change from a group of coins) (Edwards et al., 2005). Improvements in these types of everyday activities may speak to the impact of processing speed on an individual's function. For example, the frequency of shopping trips taken away from their house may be minimized because the older adult feels unsafe processing complex traffic information. As a result, the older adult may take precaution by taking one car trip to complete all weekly errands in one day, ultimately lowering their interaction with the environment.

### Spatial Visualization

Spatial abilities can be divided up into three subcategories including spatial visualization, spatial relations, and visuo-spatial processing speed. Spatial visualization is a particularly important aspect of cognitive function because it allows individuals to integrate and manipulate information over time and space. Spatial visualization has been found to have a stronger association with executive function (i.e., fundamental construct responsible for our planning, organizing, implementing activities) than the other two

aspects of spatial abilities (i.e., spatial relations and visuo-spatial processing speed), highlighting its usefulness in everyday function (Miyake et al., 2001). Spatial visualization is a cognitive construct that varies widely among individuals due to influences from direct experience, learning from visual media, and an individual's sense of direction (Wolbers & Hegarty, 2010). Specific tests commonly used to measure spatial visualization in older adults include the Paper Folding Test (Ekstrom et al., 1976) and the Space Relations Test (Bennet et al., 1972).

### Reaction Time

Reaction time is the time it takes an individual to react to a stimulus. Simple reaction time tests involve one possible response and will take a shorter time to react compared to choice reaction time tests which involve several possible responses and take longer to determine which response to carry out. Older adults can improve their reaction time by increasing their physical activity as seen in a group of sedentary older adults who showed improvements in both simple and choice reaction time tests after a three-month aerobic fitness training program (Renaud et al., 2010). Maintaining a high level of aerobic fitness into old age has been shown to be associated with better response preparation in simple and choice reaction time tasks (Renaud et al., 2010).

### Measures of Cognitive Function

The following commonly used measures of cognitive function assess a variety of constructs (i.e., executive function, working memory, speed of processing, spatial visualization) including reaction time, and will be used in the proposed research:

### Delis-Kaplan Executive Function System - Verbal Fluency Test

The Delis–Kaplan Executive Function System (DKEFS) consists of nine subtests of **executive functioning** (Delis, Edith, & Kramer, 2001). DKEFS subtests [e.g., DKEFS Verbal Fluency (DKEFS-VF)] can be administered as a stand-alone test or as a group of tests (Swanson, 2005). DKEFS-VF consists of three sections and measures the ability to generate words fluently in a phonemic format (letter fluency), from over-learned concepts (category fluency), and simultaneously shifting between over-learned concepts (category switching) (Swanson, 2005). All DKEFS subtests have been used in 8-89 year old individuals (Delis, Edith, & Kramer, 2001).

### Hopkins Verbal Learning Test- Revised

The Hopkins Verbal Learning Test-Revised (HVLT) (Benedict et al., 1998) measures **working memory** and has been used to independently predict everyday physical functioning, problem-solving, and psychomotor speed (Gross et al., 2010). The HVLT is a 12-item list learning test in which individuals are presented three learning and recall trials followed by a delayed recall and 24 item recognition test (Grande et al., 2010). Four outcome variables are produced including: learning across trials (HVLT learning), the number of items recalled after the delay (HVLT delayed recall), the percentage of delayed recall items relative to the maximum items learned (HVLT retention percent), and the number of recognition items correctly identified (HVLT Recognition) (Grande et al., 2010).



### Symbol Search test

The Symbol Search test is a subtest of the Wechsler Adult Intelligence Scale, fourth edition (WAIS-IV) (Wechsler, 2008a) and measures **processing speed**. Symbol Search is one of ten core subtests of the WAIS-IV and is part of the Processing Speed Index (one of four indexes). The 60-item subtest requires the individual to select a response among other distractions that correctly matches a target symbol within a designated period of time. The single outcome variable for the Symbol Search is processing speed which is scored by taking the total correct and subtracting the total incorrect. Symbol Search has been validated in individuals aged 16-90 years old (Wechsler, 2008b).

### Paper Folding Test

The Paper Folding Test (Ekstrom et al., 1976) is a measure of **spatial visualization** where successive drawings of folded paper are presented and the participant must determine what the paper would look like if it were unfolded from a series of options. The single outcome variable for the Paper Folding Test is spatial visualization and is measured by the individual's ability to identify as many correct "unfolded" images as possible out of the 20 drawings. In older adults, the Paper Folding Test has been used to discriminate between pass/fail older drivers (Mathias & Lucas, 2009), aid in the design of small mobile devices (e.g., cell phone) (Ziefle, 2010), and to look at the association between throwing accuracy and spatial visualization (Jardine & Martin, 1983). It has also been used to assess spatial visualization performance in a

longitudinal study of older adults looking at the association between increasing age and cognitive performance (Salthouse, 2010).

### Visual Reaction Time test

The Visual Reaction test (Cognitive Fun, 2009) is a measure of **reaction time** administered on a computer where the participant is required to hit the space bar as fast as possible when a large green dot appears on the computer screen. Reaction time is essential to many of the cognitive measures used in the literature because lower reaction time would result in better scores for all cognitive measures discussed. Several computer-based reaction time tasks have been created using software technologies or publicly available tests of reaction time including the simple reaction time task to be used in the proposed study. Decline in performance of simple and choice reaction time tasks was shown to be associated with higher risk of mortality over a seven year follow up (Shipley et al., 2007).

### Summary

Older adults are not only living longer but the number of older adults living in the U.S. is exponentially increasing due to the aging baby boomer generation. Many factors play a role in function; however, the current functional measures used in the literature are limited in what they can measure (e.g., physical function, physical activity). Research in the fields of health and physical activity, among older adults, have measured the environment to look at modes of physical activity or transport-related physical activity through the use of GPS, GIS software, and self-report measures of the environment.

However, the research has failed to assess function by measuring physical activity in combination with measuring the environment to quantify the person-environment interaction. In other words, there are no measures of functional-living.

MAPS makes up for the deficits in current functional measures by objectively capturing the person-environment interaction to obtain a quantitative score. MAPS identifies the duration, frequency, and location where physical activity is performed. Both physical activity (i.e., activities and participation) and the environment (i.e., environmental factors) are known to influence function as seen in the ICF model. MAPS has been applied in knee patients, in individuals with MS, and in a pilot study of older adults but because this is a new measure of functional-living, additional validation is needed to include other components of the ICF model.

The ICF model demonstrates that cognitive function (i.e., a personal factor) and functional-living as measured by MAPS (i.e., activities and participation combined with environmental factors) will have a relationship. Cognitive function also has a very well-known relationship with physical activity (which is half of what functional-living measures) in older adults. Exploring the relationship between cognitive function and functional-living through the use of correlational analyses will potentially provide further construct validity for MAPS.

### Specific Aims

#### Specific Aim 1

The first specific aim of the proposed study was to provide further construct validity for MAPS, a functional-living measure in older adults by looking at cognitive

function. Several measures of cognitive function were used including the D-KEFS-Verbal Fluency test, HVLT, Symbol Search, Paper Folding Test, and a visual reaction time test to determine if there was an association between cognitive function and functional-living as measured by MAPS. Pearson  $r$  correlations were used to examine the association between the scores on the cognitive function measures and MAPS scores. Participants also completed a physical function task and physical activity questionnaire. If the MAPS scores and scores from the physical function task and physical activity questionnaire are correlated, construct validity evidence will be provided for MAPS. Pearson  $r$  correlations were used to establish the association between scores on the physical function task and MAPS scores along with scores on the physical activity questionnaire and MAPS scores.

### Specific Aim 2

The second specific aim of the proposed study was to determine if the reliability of MAPS scores is impacted (i.e., reduced) if weekend days are measured in addition to a weekday. The proposed study had participants wear the activity monitors for five days to examine what combination of weekend and week days are needed to provide reliable MAPS scores because data was collected primarily from weekdays in the older adult pilot study.

## **CHAPTER 3**

### **METHODOLOGY**

#### Participants

A total of 30 community-dwelling older adults, aged over 60 years were enrolled in the study. Participation was open to individuals from any ethnic group or race and consisted of roughly 50% males and 50% females. The older adults participating in the study had good physical and mental health status with minimal functional limitations. Criteria required to participate in the study included 1) men and women aged 60+ years, 2) ambulatory without the use of aid (i.e., cane, wheelchair, scooter), 3) free from any diseases or conditions that may affect walking ability (e.g., stroke, diabetes), and 4) able to complete the Telephone Interview for Cognitive Status (TICS) (Brandt, Spencer, & Folstein, 1988) at time of screening.

#### Sample Size Estimate

Due to the lack of funding for this study, a large sample size is not feasible. However, the sample size used ( $n = 30$ ) reflected the minimum sample size typically associated with normally distributed data. The central limit theorem states regardless of the distribution of the parent population (i.e., normal, j-shaped, u-shaped), as a series of sample means taken from the parent population gets larger, this sampling distribution will approximate the normal distribution (Brase & Brase, 2009). A sample size of 30 is typically considered the size required to reasonably expect the data to be normally distributed (Brase & Brase, 2009).

## Recruitment

### Location

Recruitment took place within the surrounding towns of Amherst, MA such as Hadley, Northampton, Sunderland, and Belchertown and one participant resided in central Massachusetts. Study flyers (see Appendix E) were posted at grocery stores, banks, bus stops, town halls, coffee shops, senior centers, and other local businesses. Recruitment ads (see Appendix E) were placed in senior center newsletters (e.g., BANGS Community Senior Center) and in local newspapers. Past participants who expressed interest in future studies through the Physical Activity and Behavior Lab at UMass Amherst were also contacted for potential recruitment.

### Screening

Participants interested in the study called or emailed the Physical Activity and Behavior Lab at UMass Amherst. A lab researcher screened potential participants over the phone to confirm interest in the study (see Appendix B for screening script) after describing the study in full detail (i.e., purpose, testing sessions, compensation, and confidentiality). The researcher checked to see if inclusion criteria were met by asking about date of birth (to verify age), asking if they were currently mobile without using a mobility aid (e.g., cane, crutch, wheelchair) and asking if they were free of any impairments that may affect mobility (e.g., diabetes, stroke). A questionnaire asking about readiness to participate in physical activity and a questionnaire asking about health conditions that may affect walking (e.g., stroke, diabetes) were used to assess health status and ensure that participants met the inclusion criteria. A cognitive screening test

was used to exclude any older adults that may have existing cognitive impairments that may have interfered with their ability to remember to wear the accelerometer, take the GPS when they left their residence, or filled out the travel log. If all inclusion criteria were met, the researcher collected the participant's contact information (i.e., mailing address, phone numbers, e-mail address) and set up a time for the first of two testing sessions.

### Instruments

Study instruments are provided in Appendix C.

#### Screening Instruments

At the time of the phone screening, a researcher verbally administered the Telephone Interview for Cognitive Status (TICS) (Brandt, Spencer, & Folstein, 1988). TICS is comprised of 11-items with a maximum score of 41. The participant was required to answer a series of questions aimed to distinguish between individuals with cognitive impairment (score of 30 or lower) and those without cognitive impairment (score of 31 or greater). The researcher verbally administered the Physical Activity Readiness Questionnaire (PAR-Q)(Thomas, Reading, & Shepard, 1992) and a health history questionnaire over the phone.

#### Physical Function Measure

The Timed Up and Go (TUG) (Posiadlo & Richardson, 1991) is an objective measure of function and mobility in older adults. The test required participants to rise

from a chair with arms, walk 3 meters at a comfortable and safe pace, walk back to the chair, and sit down. The TUG is associated with measures of balance, gait speed, and physical function which are all abilities older adults need to use in their everyday lives (Posiadlo & Richardson, 1991). The TUG score is the time it takes for the individual to stand from an armed chair, walk 3 meters, walk back to the chair, and sit back down. As determined from physical function measures originally used to examine the validity of the TUG test, most participants who scored a 20 or less (i.e., the time it takes the participant to complete the TUG) generally indicated older adults who were independently mobile and can do activities such as go outside or climb stairs. Older adults with a score of greater than 30 tended to need assistance from others for many mobility tasks (Posiadlo & Richardson, 1991). Higher scores indicated more functional mobility impairment and lower scores indicated better functional mobility. The TUG was used over other physical function measures because it involved a quick administration and no special equipment or training was required. In the proposed study, the TUG was used to assess the relationship between physical function and functional-living to provide further construct validity for MAPS as a functional-living measure in older adults.

### Cognitive Function Measures

#### Delis-Kaplan Executive Function System – Verbal Fluency Test

The verbal fluency subtest of the Delis-Kaplan Executive Function System test (DKEFS - VF) (Delis, Edith, & Kramer, 2001) required participants to verbally generate a series of words beginning with the letters F, A, and S within a period of 60 seconds per letter. The DKEFS - VF consisted of three sections and measured the ability to generate



words fluently in a phonemic format (letter fluency), from over-learned concepts (category fluency), and simultaneously shifting between over-learned concepts (category switching). Correct responses for words beginning with F, A, and S were summed to obtain a total correct raw score. Higher scores on the DKEFS - VF represented higher executive functioning. The DKEFS - VF has been validated in ages 8-89 (Delis, Edith, & Kramer, 2001) and has been used in older adults to detect subtle cognitive differences in individuals at-risk for Alzheimer's disease (Houston et al. 2005). It took approximately 5 minutes to administer the DKEFS - VF.

#### Hopkins Verbal Learning Test- Revised

The Hopkins Verbal learning Test- Revised (HVLТ) (Benedict et al., 1998) was a memory task where a 12-item list learning test was presented to the participant and then three learning and recall trials were given followed by a Delayed Recall Trial 20-25 minutes later. The last trial is called the Delayed Recognition Trial and was administered immediately after the Delayed Recall trial, and used a 24-item recognition task using some of the same words from the original list, but required the participant to respond "yes" or "no if the word was presented in the original list (Grande et al., 2010). All words were related to four-legged animals (i.e., lion, horse, tiger, cow), precious stones (i.e., emerald, sapphire, opal, pearl), and human dwellings (i.e., tent, hotel, cave, hut). The HVLТ produced four outcomes: learning across trials, the number of items recalled after the delay, the percentage of delayed recall items relative to the maximum items learned, and the number of recognition items correctly identified. Raw scores were obtained from the total number of recalled items from the first three trials and the fourth trial alone (i.e.,

delayed recall). The retention percentage was calculated using the number of recalled items in the fourth trial divided by the higher score of trails 2 and 3, multiplied by 100. Lastly, the Recognition Discrimination Index was the total number of true positives minus the total number of false-positives from the Delayed Recognition Trial. Higher scores represented better verbal memory. Performance on the HVLT was significantly affected by age and gender suggesting that as age increases in older adults, performance goes down (i.e., lower scores) (Vanderploeg et al., 2000). The first half of the test took approximately 5 minutes to administer and the second half was administered 20 minutes later and took approximately 5 minutes to administer.

#### Symbol Search test

The Symbol Search test is a subtest of the Wechsler Adult Intelligence Scale, fourth edition (WAIS-IV) (Wechsler, 2008a). In this test of **processing speed**, participants were presented with 6 pages of symbols presented in rows. Two symbols (i.e., targets) were presented on the left side of each row and the right side contained five other symbols (i.e., distracters). Participants were given 120 seconds to mark a line through the correct distractor that matched one of the targets on the left for all trials. Some lines contained distractor symbols that did not match either target and in this case, participants were asked to mark a line through the “NO” option at the end of the row. The idea was to complete the most trials correctly as fast as possible. The number of correct, incorrect, and incomplete responses were recorded for each of the 6 pages and then totaled. The score for the participant was the number of total correct responses minus the number of total incorrect responses with a maximum possible score of 60. Any scores

less than or equal to 0 were recorded as 0. Higher scores denoted better processing speed. The test took approximately 5 minutes to administer.

### Paper Folding Task

The Paper Folding Test (Ekstrom et al., 1976) measures **spatial visualization** and consisted of 20 images of a piece of paper folded up with a punched out hole through the folded piece of paper. The participant was required to imagine unfolding the piece of paper and choose the response that correctly matched what the piece of paper would look like, as quickly as possible. The total score for the Paper Folding test was the amount of items the participant answered correctly out of 20. Higher scores represented better spatial visualization. The test took approximately 5 minutes to administer.

### Visual Reaction Time test

The **reaction time** test (Cognitive Fun, 2009) is a simple choice reaction task that was conducted on a computer from an online website where participants were asked to hit the space bar when a large green dot appeared on the screen. A total of 5 trials were administered. The results yielded an average time it took for the participant to hit the space bar for all 5 trials. The score for the participant was the average time to react to each of the 5 stimuli with lower scores representing better reaction times. The test took approximately 2 minutes to administer.

## Physical Activity Measures

### International Physical Activity Questionnaire short-form

The International Physical Activity Questionnaire short-form (IPAQ) (Craig, et al., 2003) contains 6 items that measure the frequency (number of days) and duration (amount of time) of vigorous activities, moderate activities and walking during a 7-day period. Total MET-minutes per week was calculated by first multiplying the frequency and the duration for each level of activity and then multiplying this value by the MET value associated with the vigorous (8.0 METs), moderate (4.0 METs), and walking (3.3 METs) activity. These values were then summed to get a continuous measure of physical activity. The test-retest reliability ( $r$ ) of the IPAQ has been examined in older men and women and was found to be more consistent for walking ( $r =$  men; women,  $r = .76; .75$ ) and sitting ( $r = .76; .77$ ) activities, implying older adults are better able to recall walking and sitting activities than moderate or vigorous activities (Kolbe-Alexander et al., 2006).

### Actigraph GT1M Accelerometer

An ActiGraph GT1M accelerometer was used as an objective measure of physical activity (ActiGraph, LLC; Fort Walton Beach, FL, USA). The GT1M is 1.5 in. x 1.44 in. x 0.70 in. and light weight (1.5 ounces). Accelerometers are small, non-invasive devices that are clipped on a belt or waistband in front of the non-dominant hip. The accelerometer measures and stores physical activity information in predetermined epoch lengths (i.e., 60 seconds for the proposed study). The step counts represented a quantitative measure of activity over time. Accelerometer data were downloaded using

ActiGraph v.5.0 software, saved as an .agd file and then converted to an excel file for use in MAPS data processing.

## Geospatial Data

Environmental information was obtained from GPS and GIS.

### Global Positioning Systems

Location information (i.e., places participants traveled to other than home) was obtained using a LandAirSea TracKing Global Positioning Systems (GPS) receiver (Land Air Sea Systems, Woodstock, IL). The unit is 3.01 in. x 1.95 in. x 1.40 in., lightweight, and automatically stores up 100 hours of data. It is capable of running on two AA batteries and enters sleep mode (after 2 minutes of no movement) to conserve energy. Participants were asked to leave the GPS receiver in the car or clipped to their car keys in order to maximize battery life. The GPS receiver was used to automatically record latitude (X), longitude (Y), and altitude (Z) coordinates, measure speed, trip time, and trip distance. The data was stored on the device and then downloaded at a later time (i.e., we did not capture real-time location information on the participants). The receiver has 16 parallel channels that continuously track and use up to 16 satellites to compute and update position information for accuracy of < 3 meters.

## Geographic Information Systems

Geographic Information Systems (GIS) software was used to process the geospatial information from the GPS receivers. GIS works with Google Earth to create images of where the participant traveled while wearing the accelerometer.

## Travel Log

A travel log provided self-reported information about locations in which the participant traveled to while wearing the activity monitors. It is used in addition to the objective environmental information provided by the geospatial technologies (GPS and GIS). Participants were asked to complete a travel log to record the locations they traveled to (e.g., mall, grocery store, friend's home), the duration in time spent at that location (e.g. 9:10am-10:43am), and the activity type (e.g. walking, shopping, exercising). Travel log information was an additional source to the geospatial information to help confirm specific times (to the nearest minute) an individual left their house and began driving, for example. Recorded activities from the travel log also provided researchers with qualitative physical activity information that accelerometers are unable to measure (e.g., water activities such as swimming).

## Functional-living Measure

The Movement and Activity in Physical Space (MAPS) score identifies the duration, volume, intensity, and location (i.e. physical activity space) where physical activity is performed. Physical activity data obtained from the accelerometers combined

with the environmental information from the GPS receivers and GIS software were used to determine the amount of physical activity completed at specific locations. Unique to MAPS, researchers use the physical activity and geospatial data to draw conclusions as to when participants left home, arrived at locations, left locations, etc. to the nearest minute. Physical activity counts and step counts at each location other than home were summed to be used in the MAPS formula. A MAPS intensity score (MAPS<sub>I</sub>) was created using activity counts specific to all locations other than home whereas a MAPS volume score (MAPS<sub>V</sub>) represented the step counts corresponding to locations other than home. The basic formula for MAPS is:

$$MAPS = \sum_{L=1}^n \left( \frac{Activity}{Minutes} \right)$$

Within this formula, L represents a location that the participant went to, other than home. “Activity” refers to activity counts in the MAPS<sub>I</sub> score and step counts in the MAPS<sub>V</sub> score. The strength of using MAPS as a functional-living measure in older adults is its ability to objectively capture the person-environment interaction.

MAPS is a valid measure of functional-living in post-surgical knee patients (Herrmann, et al., 2011) and individuals with MS (Snook et al., 2010). A small pilot study of MAPS in older adults has provided initial validity evidence for MAPS in this population (Morand, Suckau, & Snook, 2011).

### Procedure- Testing Session 1

The study took place over the course of two testing sessions, approximately one week apart. The first testing session took place in the Physical Activity and Behavior Lab (located in Totman Building on the UMass campus). The second testing session took place in the lab or at the participant's home. The first testing session lasted approximately 1 hour.

### Informed Consent Document

During the first testing session, participants read the informed consent document (see Appendix A) that contained all details of the study including risks, benefits, compensation, and the lab's contact information. If the participant agreed to participate, they signed and dated one copy and the second copy was taken home.

### Data Collection

All demographic information was collected using paper and pencil.

### Cognitive Function Measures

The researcher administered the HVLТ first because there was a 20 minute delay between the first and second half of the HVLТ. The researcher administered the Symbol Search test, Paper Folding Test, and visual reaction time test during the 20 minute delay of the HVLТ. Once the HVLТ was completed, the D-KEFS Verbal Fluency test was administered. When needed, participants were allowed a brief resting period between measures. The five measures took approximately 30-40 minutes.



### Physical Function Test

The researcher administered the TUG test. Going over instructions with the participant and administering the TUG took approximately 2 minutes.

### Distribution of Activity Monitors and Travel Log

The accelerometer and GPS receiver were distributed to the participant. The researcher explained the purpose of each device, demonstrating how to wear the accelerometer, and answered any questions the participant had. Participants were asked to wear the accelerometer for 5 days during waking hours and to clip the GPS receiver to their car keys, purse, or other object that travels with them when they leave their house. Participants were given an instruction sheet (see Appendix C) to take home with them along with contact information for the participant to call or email the lab with questions at any point during the study. Participants were asked if they would like a reminder call in the morning to wear the activity monitors on each of the five days of data collection. The travel log was also distributed and explained.

The researcher answered any additional questions the participant had at the time. At the end of session 1, the participant and researcher scheduled a time to meet approximately one week later.

### Procedure- Testing Session 2

The second testing session took place approximately one week later in the Physical Activity and Behavior Lab or at the participant's home. The second testing session lasted approximately 20 minutes.

### Activity Monitor Retrieval

The accelerometer and GPS receiver were collected from the participant. The researcher checked that there was 10 hours of accelerometer data for each of the 5 days along with 5 days of data in the activity report obtained from the GPS receiver. The travel log was checked over to clarify any unclear information (e.g., illegible handwriting, missing date). If data from either or both activity monitors were insufficient, the participant was asked to re-wear the devices and keep a travel log so that five days of complete data were obtained for all participants.

### Physical Activity Questionnaire

Participants filled out the IPAQ while the researcher checked over the activity monitor data.

### Compensation

Participants were given a total of \$15 for completing all components of the study (\$10 for the initial visit and \$5 upon completion of the study). Participants who completed the study received a check for \$15 approximately 4-6 weeks after the compensation paperwork was submitted.

## Data Processing

### Accelerometer Data Download

Accelerometer data were downloaded using ActiGraph software in the form of an .agd file. The .agd file was converted to a .dat file and the .dat file was then converted into an .xls file to be opened using Microsoft Excel.

### GPS Data Download

All data downloaded from the GPS receiver were inputted into the GIS software to be analyzed. An activity report was saved for each participant along with the raw data to be used when MAPS data processing was completed (Figure 6).

Departed	Driving Time	Arrived	Location Arrived	Distance (Miles)	Stopped Time
09:08:30am	29m:19s	09:37:49am	<a href="#">450 Memorial Dr, Chicopee, MA 01020, USA</a>	19.0	1h:14m:15s
10:52:04am	10m:11s	11:02:15am	<a href="#">38-90 Pittroff Ave, South Hadley, MA 01075, USA</a>	4.8	26m:44s
11:28:59am	15m:25s	11:44:24am	<a href="#">450 Memorial Dr, Chicopee, MA 01020, USA</a>	4.3	53m:38s
12:38:02pm	08m:54s	12:46:56pm	<a href="#">450 Memorial Dr, Chicopee, MA 01020, USA</a>	2.1	1h:06m:53s
01:53:49pm	1h:17m:16s	03:11:05pm	<a href="#">403-431 Watertown St, Newton, MA 02458, USA</a>	81.0	31m:48s
03:42:53pm	1h:42m:48s	05:25:41pm	<a href="#">450 Memorial Dr, Chicopee, MA 01020, USA</a>	82.3	1h:11m:27s
06:37:08pm	15m:29s	06:52:37pm	<a href="#">25 Park Pl, Ludlow, MA 01056, USA</a>	5.9	41m:07s
07:33:44pm	06m:53s	07:40:37pm	<a href="#">76-102 Winsor St, Ludlow, MA 01056, USA</a>	0.3	41m:52s

**Figure 6. Example of GPS Activity Report for one day.**

### MAPS Data Processing

Two researchers worked simultaneously to complete MAPS data processing with one researcher who processed the environmental information using GIS software and Google Earth while the other researcher examined the accelerometer data in Microsoft Excel (see Appendix D for the data processing form). The activity report and travel diary were used to determine the exact time the person left their home, the time they arrived at

a different location, and the time they left that location. The activity counts (for the MAPS<sub>I</sub> score) and step counts (for the MAPS<sub>V</sub> score) that occurred between the arrival and departure times of locations were summed. This value was divided by the number of minutes at that location. This was completed for all locations and summed to create a MAPS<sub>I</sub> and MAPS<sub>V</sub> score for that day. This process was completed for each of the five days of data collection. Differences between MAPS<sub>I</sub> and MAPS<sub>V</sub> scores across the five days of data collection were examined to identify any changes between how individuals are functioning during weekdays compared to the weekend.

SPSS. Demographic variables and scores from the cognitive measures, TUG test, IPAQ, and MAPS were entered into SPSS 17.0.

### Statistical Analyses

Descriptive statistics (e.g., mean, standard deviation, range) were analyzed in SPSS for all the study outcome variables.

### Specific Aim 1

Pearson Product-Moment Correlation Coefficients ( $r$ ) were used to assess the relationship between cognitive function scores and MAPS<sub>I</sub> and MAPS<sub>V</sub> scores, the relationship between the physical activity score and MAPS<sub>I</sub> and MAPS<sub>V</sub> scores, and the relationship between the physical function score and MAPS<sub>I</sub> and MAPS<sub>V</sub> scores. Higher cognitive function was expected to be associated with higher functional-living scores as measured by MAPS. It was predicted that the relationship between cognitive function and MAPS would provide further evidence of construct validity for MAPS as a

functional-living outcome measure in older adults. Higher physical activity and physical function was expected to be associated with higher functional-living scores as measured by MAPS. It was predicted that the relationship between physical activity and MAPS, and physical function and MAPS, would provide further construct validity for MAPS as a functional-living measure in older adults.

### Specific Aim 2

Intra-class correlation coefficients (ICC) were used to address the second specific aim of the proposed study, determining how many total weekday and weekend days are needed to obtain reliable (acceptable reliability  $> .7$ ) MAPS scores.

## CHAPTER 4

### RESULTS

Results for Hypothesis #1 and Hypothesis #2 of the study will be provided in this section of the thesis including demographic information of the participants, results from all statistical analyses performed, and addressing results of the specific aims. A total of 30 older adults participated in the study. All participants completed a demographic questionnaire and 5 measures of cognitive function, performed a physical function task, wore an accelerometer and GPS receiver for 5 days, and filled out a physical activity questionnaire.

#### Participant Characteristics

Demographic information for all 30 participants is provided in Table 1. Participants were between the ages of 61 – 89 with a mean age of 72.6 ( $\pm$  7.0) years. In this sample of predominately Caucasian participants, more than half of the participants were married. A little over 60% were retired with the remaining older adults working part-time or full time positions such as a piano teacher, night auditor, professor, writer, etc. All participants in the study graduated from high school with more than half completing a degree in higher education and earning an annual household income of over \$40,000 a year.

**Table 1. Participant Demographic Information (n = 30)**

Demographic Variable		Number	%
<b>Sex</b>	Male	11	36.7
	Female	19	63.3
<b>Age</b>	60-64	2	6.7
	65-69	9	30.0
	70-74	10	33.3
	75-79	2	6.7
	80-84	5	16.7
	85-89	2	6.7
<b>Marital Status</b>	Married	18	60.0
	Single	7	23.3
	Divorced/Separated	1	3.3
	Widow/Widower	4	13.3
<b>Occupation</b>	Retired	19	63.3
	Employed	10	33.3
	Unemployed	1	3.3
<b>Race</b>	American Indian	0	0
	Asian	1	3.3
	Black or African American		
	American	0	0
	Native Hawaiian or Other Pacific Islander	0	0
	Caucasian	29	96.7
	Latino/a	0	0
	Other	0	0

<b>Education</b>	1-3 Years of College	5	16.7
	College/University		
	Graduate	7	23.3
	Masters Degree	14	46.7
	PhD or Equivalent	4	13.3
<b>Annual Income</b>	\$5,001-10,000	3	10.0
	\$10,001-15,000	2	6.7
	\$15,001-20,000	1	3.3
	\$20,001-25,000	0	0
	\$25,001-30,000	0	0
	\$30,001-40,000	1	3.3
	\$40,001 or greater	20	74.1
	Missing Data	3	10.0

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#### Descriptive Statistics: Cognitive Function Measures

The descriptive statistics for all cognitive function and MAPS scores are provided in Table 2. All of the scores had acceptable levels of skewness and kurtosis (less than  $\pm 2$ ) indicating the scores were normally distributed.



**Table 2. Descriptive Statistics for the Total Scores of Cognitive Measures and MAPS**

Measure	N	<i>M</i>	<i>SD</i>	Range	Skewness	Kurtosis
MAPS <sub>I</sub>	30	1894.63	1494.19	124.39 - 5886.81	1.17	.43
MAPS <sub>V</sub>	30	66.54	54.40	4.58 - 243.16	1.8	3.8
HVLT-Recall	30	26.63	6.29	11 - 35	-.91	.12
HVLT-Delay	30	8.90	2.68	3 - 12	-.95	-.11
HVLT-Retention (%)	30	84.70	16.23	42.90 - 109.10	-.85	-.06
HVLT-Discrimination	30	10.43	1.61	7 - 12	-.72	-.45
DKEFS-VF	30	48.87	16.97	17 - 83	.32	-.56
SS	30	29.20	6.73	15 - 41	-.21	-.38
PFT	30	1.45	4.90	(-7) - 9.50	.02	-.96
RT (s)	30	322.20	65.81	221.80 - 509.40	1.02	1.00

Note: MAPS<sub>I</sub> = Movement and Activity in Physical Space Intensity score, MAPS<sub>V</sub> = Movement and Activity in Physical Space Volume score, HVLT = Hopkins Verbal Learning Test, DKEFS-VF = Delis-Kaplan Executive Function System- Verbal Fluency, SS = Symbol Search, PFT = Paper Folding Test, RT = Reaction Time

Hypothesis # 1 Results: Providing Construct Validity for MAPS

Hypothesis 1a

Construct validity evidence for the MAPS scores will be shown. Scores from four of the cognitive function measures (i.e. D-KEFS-Verbal Fluency test, Hopkins Verbal Learning Test, Symbol Search, and Paper Folding Test) and MAPS will have moderate positive correlations. The visual reaction time test and MAPS will have a moderate negative correlation.

### Correlational Analyses

Correlational analyses were used to examine the relationships between functional-living as measured by MAPS, and cognitive function as measured by the five tests of cognitive function, each measuring a different cognitive domain. Specifically, Pearson  $r$  correlations were calculated among the total MAPS scores (i.e., MAPS<sub>I</sub> and MAPS<sub>V</sub>) and cognitive function measures (HVLT and its subscales, DKEFS-VF, SS, PFT, and RT) and are reported in Table 3. A correlation coefficient of .40 or lower was considered low strength, between .40 – .60 was considered moderate, and greater than .60 was considered high. The matrix containing the correlations among all the measures is provided in Table 4.

**Table 3. Pearson  $r$  Correlations between Cognitive Tests and MAPS Scores**

Cognitive Measure	Cognitive Domain	MAPS <sub>I</sub>	p-value	MAPS <sub>V</sub>	p-value
1a. HVLT-Recall	Working Memory	.15	.42	.06	.74
1b. HVLT-Delay	Working Memory	.11	.56	.01	.96
1c. HVLT-Retention	Working Memory	.06	.77	-.02	.94
1d. HVLT-Discrimination	Working Memory	.11	.57	.04	.83
2. DKEFS Verbal Fluency	Executive Function	-.05	.78	.08	.66
3. Symbol Search	Processing Speed	.46*	.01	.39*	.03
4. Paper Folding Test	Spatial Visualization	.42*	.02	.39*	.03
5. Reaction Time	Reaction Time	-.30	.11	-.31	.10

Note: MAPS<sub>I</sub> = Movement and Activity in Physical Space Intensity score, MAPS<sub>V</sub> = Movement and Activity in Physical Space Volume score, HVLT = Hopkins Verbal Learning Test, DKEFS = Delis-Kaplan Executive Function System.

Out of the five cognitive domains measured, significant, positive correlations were reported between MAPS scores and two cognitive function measures. Correlation coefficients of  $r = .46$  ( $p = .01$ ) and  $r = .39$  ( $p = .03$ ) were observed between the SS and MAPS<sub>I</sub> and MAPS<sub>V</sub> scores, respectively. Correlation coefficients of  $r = .42$  ( $p = .02$ ) and  $r = .39$  ( $p = .03$ ) were found between the PFT and MAPS<sub>I</sub> and MAPS<sub>V</sub> scores, respectively. The scores of the remaining cognitive function measures were not significantly correlated with MAPS scores. These correlation coefficients ranged from  $r = -.05$  to  $r = -.30$  for MAPS<sub>I</sub> scores and  $r = .01$  to  $r = -.31$  for MAPS<sub>V</sub> scores.

**Table 4. Pearson  $r$  Correlations among the Total Scores of MAPS and Cognitive Measures**

	1	2	3	4	5	6	7	8	9	10
1. MAPS <sub>I</sub>	-----									
2. MAPS <sub>V</sub>	.93**	-----								
3. HVLТ-Recall	.15	.06	-----							
4. HVLТ-Delay	.11	.01	.89**	----						
5. HVLТ-Retention	.06	-.02	.62**	.89**	-----					
6. HVLТ-Discrimination	.11	.04	.74**	.82**	.70**	-----				
7. DKEFS-VF	-.05	.08	-.01	-.13	-.13	-.05	-----			
8. SS	.46*	.39*	.40*	.31	.13	.23	-.01	-----		
9. PFT	.42*	.39*	.29	.22	.14	.18	-.09	.56**	----	
10. RT	-.30	-.31	-.30	-.31	-.25	-.23	-.12	-.22	-.10	----

Note: \*\* =  $p < .01$

\* =  $p < .05$

MAPS<sub>I</sub> = Movement and Activity in Physical Space Intensity score, MAPS<sub>V</sub> = Movement and Activity in Physical Space Volume score, HVLТ = Hopkins Verbal Learning Test, DKEFS-VF = Delis-Kaplan Executive Function System- Verbal Fluency, SS = Symbol Search, PFT = Paper Folding Test, RT = Reaction Time

## Additional Analyses

Because significant correlations were observed among the scores of the cognitive measure, additional analyses, partial correlations, were performed to determine if the observed covariance of the scores impact the significant bivariate correlations of the PFT and SS with MAPS scores. Partial correlations among MAPS scores and cognitive scores were conducted first controlling for age (Table 5), then controlling for years of education (Table 6), and finally age and years of education combined (Table 7). When controlling for age, the only significant association observed was between the MAPS<sub>I</sub> score and SS and this partial correlation coefficient ( $pr = .38, p = .04$ ) was lower than the bivariate coefficient ( $r = .46, p = .01$ ). When controlling for education, significant partial correlations were observed for both the MAPS<sub>I</sub> score with the PFT ( $pr = .46, p = .01$ ) and SS ( $pr = .49, p = .01$ ) and the MAPS<sub>V</sub> scores with PFT ( $pr = .41, p = .03$ ) and SS ( $pr = .41, p = .03$ ) and these coefficients were of the same or greater strength compared to the bivariate coefficients (i.e.,  $r = .39 - .46$ ).

**Table 5. Partial Correlations among the Total Scores of MAPS and Cognitive Measures Controlling for Age**

	1	2	3	4	5	6	7	8	9	10
1. MAPS <sub>I</sub>	-----									
2. MAPS <sub>V</sub>	.92**	-----								
3. HVLT-Recall	-.01	-.12	-----							
4. HVLT-Delay	-.05	-.17	.86**	----						
5. HVLT-Retention	-.08	-.15	.54**	.87**	-----					
6. HVLT-Discrimination	.03	-.04	.73**	.83**	.67**	-----				
7. DKEFS-VF	.05	.20	.18	.04	-.00	-.05	-----			
8. SS	.38*	.31	.25	.14	-.04	.13	.15	-----		
9. PFT	.34	.32	.14	.07	-.00	.10	-.03	.49**	----	
10. RT	-.23	-.24	-.19	-.20	-.16	-.17	-.23	-.11	-.00	----

Note: \*\* =  $p < .01$

\* =  $p < .05$

MAPS<sub>I</sub> = Movement and Activity in Physical Space Intensity score, MAPS<sub>V</sub> = Movement and Activity in Physical Space Volume score, HVLT = Hopkins Verbal Learning Test, DKEFS-VF = Delis-Kaplan Executive Function System- Verbal Fluency, SS = Symbol Search, PFT = Paper Folding Test, RT = Reaction Time

**Table 6. Partial Correlations among the Total Scores of MAPS and Cognitive Measures Controlling for Years of Education**

	1	2	3	4	5	6	7	8	9	10
1. MAPS <sub>I</sub>	-----									
2. MAPS <sub>V</sub>	.93**	-----								
3. HVLT-Recall	.16	.07	-----							
4. HVLT-Delay	.11	.01	.89**	----						
5. HVLT-Retention	.05	-.02	.63**	.89**	-----					
6. HVLT-Discrimination	.11	.04	.75**	.82**	.70**	-----				
7. DKEFS-VF	-.02	.10	-.03	-.13	-.13	-.05	-----			
8. SS	.49**	.41*	.40*	.32	.14	.23	-.07	-----		
9. PFT	.46*	.41*	.29	.23	.15	.19	-.19	.54**	----	
10. RT	-.32	-.31	-.30	-.31	-.26	-.23	-.08	-.20	-.07	----

Note: \*\* =  $p < .01$

\* =  $p < .05$

MAPS<sub>I</sub> = Movement and Activity in Physical Space Intensity score, MAPS<sub>V</sub> = Movement and Activity in Physical Space Volume score, HVLT = Hopkins Verbal Learning Test, DKEFS-VF = Delis-Kaplan Executive Function System- Verbal Fluency, SS = Symbol Search, PFT = Paper Folding Test, RT = Reaction Time

**Table 7. Partial Correlations among the Total Scores of MAPS and Cognitive Measures Controlling for Age and Years of Education**

	1	2	3	4	5	6	7	8	9	10
1. MAPS <sub>I</sub>	-----									
2. MAPS <sub>V</sub>	.92**	-----								
3. HVLT-Recall	.00	-.12	-----							
4. HVLT-Delay	-.05	-.17	.86**	----						
5. HVLT-Retention	-.08	-.15	.54**	.88**	-----					
6. HVLT-Discrimination	.03	-.04	.73**	.83**	.67**	-----				
7. DKEFS-VF	.08	.21	.16	.02	-.01	.04	-----			
8. SS	.42*	.32	.23	.13	-.05	.13	.08	-----		
9. PFT	.39*	.33	.11	.05	-.01	.10	-.07	.45**	----	
10. RT	-.25	-.24	-.18	-.19	-.16	-.16	-.12	-.07	-.06	----

Note: \*\* =  $p < .01$

\* =  $p < .05$

MAPS<sub>I</sub> = Movement and Activity in Physical Space Intensity score, MAPS<sub>V</sub> = Movement and Activity in Physical Space Volume score, HVLT = Hopkins Verbal Learning Test, DKEFS-VF = Delis-Kaplan Executive Function System- Verbal Fluency, SS = Symbol Search, PFT = Paper Folding Test, RT = Reaction Time

### Hypothesis 1b

Construct validity evidence for the MAPS scores will be shown. Scores from the physical function measure (Timed Up and Go) will have moderate negative correlations with MAPS scores. Scores from the physical activity measure (International Physical Activity Questionnaire) will have moderate positive correlations with MAPS scores.

The Timed Up and GO (TUG) was used to assess the physical function level of the sample and the International Physical Activity Questionnaire (IPAQ) was used to assess the physical activity level of the sample. The descriptive statistics for the TUG and

IPAQ are reported in Table 8. The data set for the TUG and IPAQ were positively skewed, suggesting the scores may not have been normally distributed, which led to a further investigation of outliers (See Outlier Analysis below).

**Table 8. Descriptive Statistics for the Total Scores of IPAQ and TUG ( $n = 30$ )**

Measure	$n$	$M$	$SD$	Range	Skewness	Kurtosis
TUG (s)	30	10.72	2.78	7.31-22	2.39	8.53
IPAQ (MET - min/wk)	30	5387.82	7151.35	66-35,808	3.04	11.20

Note: IPAQ = International Physical Activity Questionnaire, TUG = Timed Up and Go

### Correlational Analyses

The Pearson  $r$  correlations ( $n = 30$ ) for the TUG, IPAQ, and MAPS scores are reported in Table 9. The TUG was found to have a significant negative, moderate correlation with the MAPS<sub>I</sub> score. The correlation between the TUG and MAPS<sub>V</sub> score neared significance. In other words, better performance on the physical function test, as measured by the TUG, was associated with better functional-living, as measured by MAPS. The IPAQ was found to have non-significant correlations with both MAPS scores.



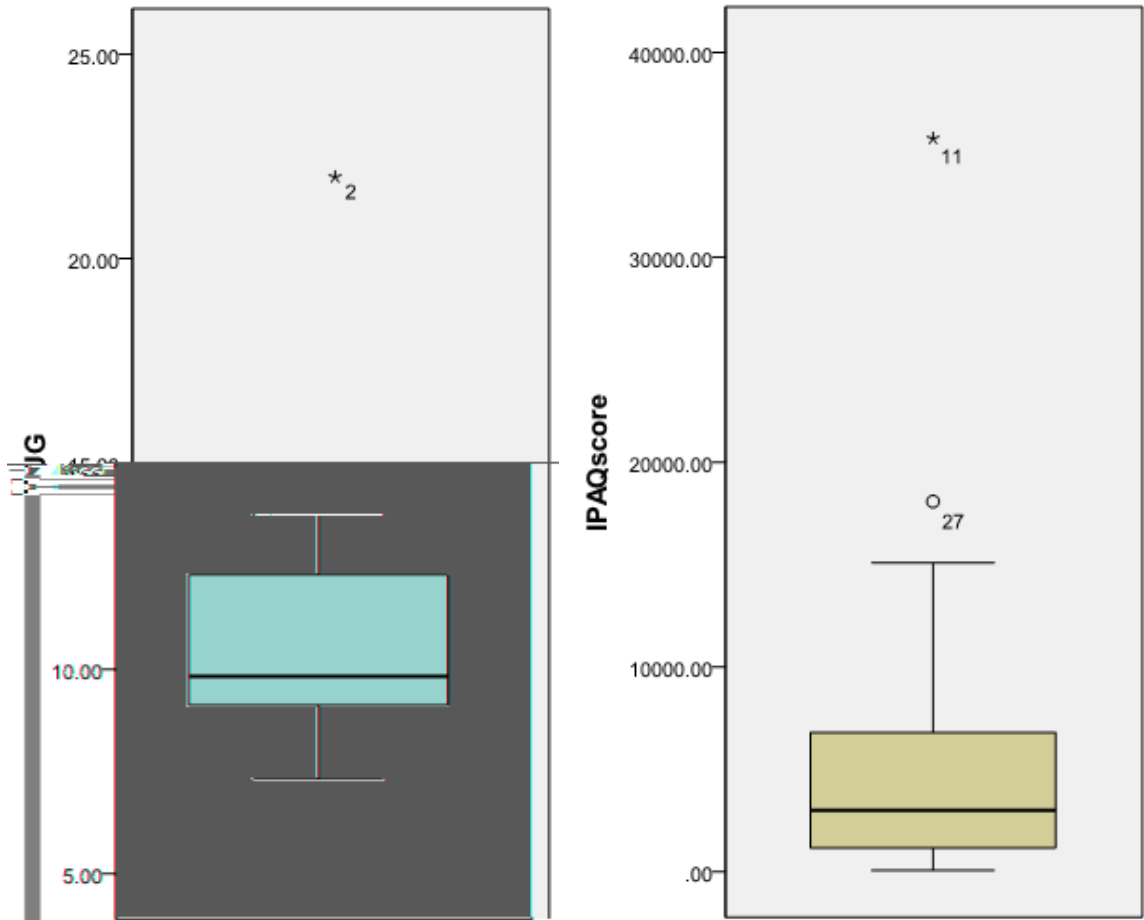
**Table 9. Pearson  $r$  Correlations between Scores of TUG and IPAQ Measures and MAPS.**

Measure	MAPS <sub>I</sub>	p-value	MAPS <sub>V</sub>	p-value
TUG (s)	-.48**	.01	-.35	.06
IPAQ (MET – min/wk)	-.05	.78	-.05	.79

Note: MAPS<sub>I</sub> = Movement and Activity in Physical Space Intensity score, MAPS<sub>V</sub> = Movement and Activity in Physical Space Volume score, TUG = Timed Up and Go, IPAQ = International Physical Activity Questionnaire

### Outlier Analysis

Box and whisker plots were used to examine the distribution of scores for the TUG and IPAQ and showed that there was one outlier impacting the skewness and kurtosis of the TUG and two outliers for the IPAQ (Figure 7). These three outliers were removed from the sample of 30 participants and descriptive statistics were examined. The resulting skewness and kurtosis for the TUG and IPAQ fell within the acceptable levels of skewness and kurtosis (Table 10), indicating that removing the scores from the outliers resulted in normally distributed scores for both measures. Pearson  $r$  correlations were then examined for this  $N = 27$  sample to determine if the correlations among the scores changed after removing the outliers. The strengths of the correlations showed minimal changes and the significance of the correlations between the TUG, IPAQ, and MAPS scores did not change.



**Figure 7. Outliers displayed in box and whisker plots for the Timed Up and Go (TUG) and International Physical Activity Questionnaire (IPAQ).**

**Table 10. Descriptive Statistics for the Scores of IPAQ and TUG, n = 27**

Measure	<i>n</i>	<i>M</i>	<i>SD</i>	Range	Skewness	Kurtosis
TUG (s)	27	10.28	1.85	7.31-13.78	.50	-.83
IPAQ (MET - min/wk)	27	3972.43	3500.75	66-15090	1.41	2.44

Note: IPAQ = International Physical Activity Questionnaire, TUG = Timed Up and Go

## Hypothesis 2 Results: Reliability of MAPS scores on Weekdays and Weekend Days

### Hypothesis 2

Three days of accelerometer and GPS data will provide MAPS scores with acceptable reliability ( $ICC \geq .7$ ) using any combination of weekdays and weekend days. The original validation study of MAPS found that a minimum of three days of wear time was necessary for reliable  $MAPS_I$  and  $MAPS_V$  scores (i.e.,  $> .70$ ) (Herrmann, et al., 2011). In the current study, participants wore the activity monitors for 5 days (3 weekdays and 2 weekend days) in order to observe the 3 day reliability among various combinations of weekdays and weekend days.

When organizing the reliability data, each of the five days of wear time for all participants were labeled as either Weekday 1, Weekday 2, Weekday 3, Weekend 1, or Weekend 2. To examine the reliability of MAPS scores using all possible 3-day combinations (i.e., 3 weekdays, 2 weekdays and 1 weekend day, or 1 weekday and 2 weekend days), intra-class correlations (ICC) were used.

In looking at the 3-day combinations using weekdays and weekend days, it was found that wearing the monitors during any three days during the week (i.e., Monday-Friday) yielded a reliability of .82 and .84 for  $MAPS_I$  and  $MAPS_V$  scores (Table 11), respectively. Similarly, it was found that using any 2 weekdays and 1 weekend day, or, 2 weekend days and any 1 weekday also provided acceptable MAPS scores ranging from  $ICC = .71$  to  $.80$  and  $ICC = .75$  to  $.83$  for  $MAPS_I$  and  $MAPS_V$  scores, respectively.

<b>Table 11. MAPS<sub>I</sub> and MAPS<sub>V</sub> 3-Day Reliability</b>		MAPS <sub>I</sub> ICC	MAPS <sub>V</sub> ICC
3 Weekdays	Weekday 1, Weekday 2, Weekday 3	.82	.84
2 Weekdays and 1 Weekend day	Weekday 1, Weekday 2, Weekend 1	.73	.79
	Weekday 2, Weekday 3, Weekend 1	.76	.75
	Weekday 1, Weekday 3, Weekend 1	.72	.77
	Weekday 1, Weekday 2, Weekend 2	.76	.83
	Weekday 2, Weekday 3, Weekend 2	.79	.81
	Weekday 1, Weekday 3, Weekend 2	.71	.75
1 Weekday, 2 Weekend days	Weekday 1, Weekend 1, Weekend 2	.71	.77
	Weekday 2, Weekend 1, Weekend 2	.80	.77
	Weekday 3, Weekend 1, Weekend 2	.74	.78

Regardless of whether the monitors were worn on 3 weekdays, 2 weekdays and 1 weekend day, or 1 weekday and 2 weekend days, any 3-day combination of wear time within a 7-day week yielded reliable MAPS scores in this older adult sample.

## CHAPTER 5

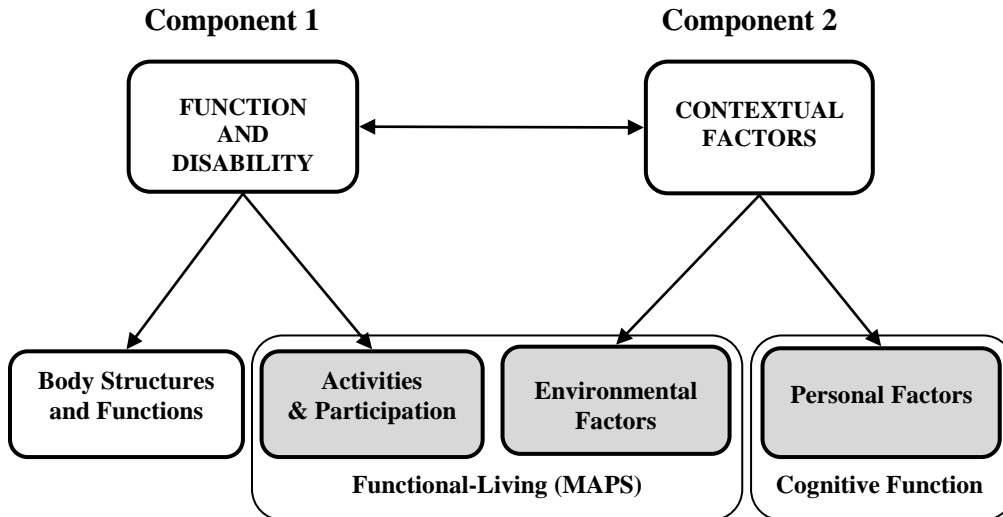
### DISCUSSION

In the chapter to follow, a brief summary of the theoretical basis for Hypothesis 1 is provided, followed by a discussion of the results for Hypothesis 1 and 2, limitations of the study, future directions, and study conclusions.

When looking at our grandparents, our great-grandparents, and other important older adults in our life, we often wonder what factors contributed to their functional ability, both positive and negative. Function is the interaction of an individual with their environment. In other words, function is to what extent a person is out in the real-world participating in any form of movement or physical activity. Currently, to measure function, researchers focus primarily on the physical aspect of function by assessing physical function (e.g., Short Physical Performance Battery) or physical activity levels of an individual. An essential element of the function definition, the environment, is not being assessed through these conventional assessments of function. For example, measuring the time it takes a person to walk 6 meters does not speak to the ability of that individual to walk around a grocery store or maneuver on uneven sidewalks in a real-world setting. There is a need to measure function in a way that incorporates the person-environment interaction. Until recently, a comprehensive measure of function incorporating the person-environment interaction did not exist.

The Movement and Activity in Physical Activity (MAPS) is a newly-developed measure of function-living that assesses the person-environment interaction by using time-locked physical activity and geospatial data. The Activities and Participation and Environmental component of the ICF model represent the person-environment interaction

(Figure 8). Accelerometer data (physical activity) provides Activities and Participation information and the geospatial data (GPS and GIS) provides Environmental Factors information. The combination of these two data sources results in quantifiable measures of functional-living, the MAPS scores.



**Figure 8. Functional-living and Cognitive Function represented within the World Health Organization’s International Classification of Functioning and Disability (ICF) Model, 2001.**

According to the ICF model, there are other factors impacting function (e.g., personal factors). Cognitive function is a personal factor that would be expected to have an association with functional-living based on the relationships among the factors of the ICF model (Figure 8). To date, minimal research examining the relationship between cognitive function and the person-environment interaction exists. However, cognitive function and physical activity levels have an established relationship in the literature showing higher levels of physical activity are associated with better cognitive function (Barne et al., 2008). Although MAPS is not a measure of physical activity, physical activity data are included in the calculations of the MAPS scores. Therefore, cognitive

function and functional-living, quantified as MAPS scores, would be expected to be positively associated with one another.

The purpose of this study was to 1) provide further evidence of construct validity for MAPS as a functional-living measure in older adults by examining the relationships between a) MAPS scores with scores from five measures of cognitive function and b) MAPS scores with measures of physical function and physical activity and 2) to determine the number and combination of weekend and week days required to obtain reliable ( $ICC \geq .7$ ) MAPS scores.

### Hypothesis #1 Discussion

#### Hypothesis 1a

Construct validity evidence for the MAPS scores will be shown. Scores from four of the cognitive function measures (i.e. D-KEFS-Verbal Fluency test, HVLT, Symbol Search, and Paper Folding Test) and MAPS will have moderate positive correlations. The visual reaction time and MAPS scores will have a moderate negative correlation.

Hypothesis 1a was partially supported by the study results. Scores from two of the five cognitive measures, the Paper Folding Test (PFT) and Symbol Search (SS), were significantly associated with  $MAPS_I$  and  $MAPS_V$  scores. The remaining cognitive function tests including the Hopkins Verbal Learning Test (HVLT), Delis Kaplan Executive Functioning System-Verbal Fluency Test (DKEFS-VF), and Reaction Time (RT) did not have significant correlations with either  $MAPS_I$  or  $MAPS_V$  scores.

## Cognitive Scores Correlated with MAPS Scores

### Paper Folding Test

The Paper Folding Test (PFT) (Ekstrom et al., 1976) is a cognitive function measure that assesses spatial visualization, the ability to integrate and manipulate information over time and space. The ability to integrate or manipulate information over time and space is essential when navigating the environment (e.g., navigating a grocery store, following road detours, or driving to the doctor's office or bank). Supporting Hypothesis 1a, the Paper Folding Test (PFT) was significantly associated with MAPS<sub>I</sub> scores ( $r = .42, p = .02$ ) and MAPS<sub>V</sub> scores ( $r = .39, p = .03$ ). The correlation suggests that a greater ability to manipulate spatial information was associated with better functional-living (i.e., more movement and physical activity done at locations other than home).

The existence of a modest relationship between spatial visualization and real-world function reflects previous older adult research examining the impact of spatial visualization on driving. A recent meta-analysis (Mathias & Lucas, 2009) examining predictors of unsafe driving in older adults reviewed twenty-one articles that utilized fifty different cognitive tests assessing different cognitive domains.. The meta-analysis showed that the PFT had the fourth highest average Cohen's  $d$  effect size ( $d = 0.93$ ) for the difference in scores between the older adult drivers who passed and those who failed an on-road driving test, indicating that better visualization is associated with driving performance. Another study was conducted assessing cognitive predictors of vehicle crash problems in older adults and found that scores from several spatial visualization



measures (i.e., Trail Making Test, Block Design, and Rey-Ostereith test) were predictors for more frequent vehicle crash problems (Ball, 1993). Older adults who performed poorly on spatial visualization tasks were unable to navigate their environment, whereas performing well on the PFT spoke to their success in navigating their environment. Older adults with better spatial visualization may be more likely to leave home and go out into their environment, indicating better functional-living.

### Symbol Search

Symbol Search (SS) (Wechsler, 2008a) is a measure of processing speed, referring to the time needed to process a stimulus, prepare a response, and deliver the response. The test requires participants to look at two target symbols on the left of the page. On the right, there was a row of five symbols along with a “NO” option. The participant was asked to make a slash through the symbol that matched one of the target symbols, or, if neither target symbol had a match, a slash would be made through the “NO” option (i.e., denoting that no match was made). In support of Hypothesis 1a, the scores for SS were significantly correlated with MAPS<sub>I</sub> scores ( $r = .46, p = .01$ ) and MAPS<sub>V</sub> scores ( $r = .39, p = .03$ ). The correlation suggests that faster processing speed is associated with better functional-living.

The results found in this study are congruent with the literature demonstrating the importance of processing speed among older adults. Scores from other speed of processing tasks such as the Trail Making Test have been shown to discriminate between frail and non-frail older adults (Langlois, 2012). Older adults with an increased likelihood of falling or obtaining an injury due to their frail state may have reduced levels of

functional-living (e.g., purposely not leave their home as often to maintain their safety). Another study emphasized the importance of processing speed in older adult populations by investigating the role of several cognitive abilities and street-crossing ability of young (aged 20-30), younger-old (aged 61-71), and older-old participants (aged 72-83) (Dommes, 2011). The study found that processing speed scores, along with visual-attention abilities, played the most important role in explaining the variance of incorrect street-crossing decisions (e.g., focusing attention on irrelevant information leading to untimely decisions increasing the risk of an injury or death). The findings may speak to the ability of an older adult to safely walk around in their environment where cars and/or cross-walks are present. These studies are consistent with the findings of the current study highlighting the importance of processing speed in everyday activities.

### Cognitive Scores Not Correlated with MAPS Scores

#### Hopkins Verbal Learning Test

The Hopkins Verbal Learning Test (HVLT) (Benedict et al., 1998) assesses working memory and contains four subscales including Recall, Delay, Retention, and Discrimination. Contrary to Hypothesis 1a, all four subscales were not associated with MAPS<sub>I</sub> and MAPS<sub>V</sub> scores, respectively, including Recall ( $r = .15$ ,  $r = .06$ ), Delay ( $r = .11$ ,  $r = .01$ ), Retention ( $r = .06$ ,  $r = -.02$ ), and Discrimination ( $r = .11$ ,  $r = .04$ ). As would be expected, the subscales within HVLT had strong correlations among each other.

Working memory is used for temporary storage and manipulation of remembered information. Information held by the working memory guides behaviors that are not

brought on by external cues or prompts such as the executing the activities of your daily routine (Goldman-Rakic, 1996). In the HVLT, a list of 12 words (i.e., name of a precious stone, dwelling, or animal) was read to the participant. The participant was required to verbally recall as many words as they could remember in any order immediately after the tester read the list of words. The same list of words was repeated again for a total of three trials. The number of words recalled from the first three trials made up the HVLT Recall score. Roughly twenty minutes later, and without being read the list of words, the participant was asked to verbally recall as many words as they could remember from the original list. The number of words recalled from this trial formed the HVLT Delay score. The HVLT Delay score divided by the higher score from Trials 2 and 3, multiplied by 100, made up the HVLT Retention score. Lastly, the tester read a list of 24 words. Half the words were from the original list and the other half were words similar in category meant to distract or confuse the participant. After each word was read, the participant was required to say “Yes” if they believed the word read aloud was from the original list or “No” if they believed the word was new. The HVLT Discrimination score was formed by taking the number of true positives from this 24-word list and subtracting the number of false positives.

In regards to the HVLT, reading a list of words to an individual and asking them to either verbally recall the words immediately, recite the words after a delay in time, or decipher between the original list of words and a new set of words may not be an ability required for functioning in the real-world. Perhaps using a working memory task that incorporated words that an individual would use on a daily basis may be of greater relevance to everyday routines versus using a list of words containing animals, precious

stones, and dwelling categories. It may be that this particular measure of working memory was simply not a good choice for the current study due to the irrelevance of the terms used in the word list with everyday living.

#### Delis-Kaplan Executive Functioning System- Verbal Fluency

The subscale assessing verbal fluency within the Delis-Kaplan Executive Functioning System (DKEFS-VF) (Delis, Edith, & Kramer, 2001) differed from Hypothesis 1a. The DKEFS-VF score was not significantly associated with either MAPS<sub>I</sub> scores ( $r = -.05, p = .78$ ) or MAPS<sub>V</sub> scores ( $r = .08, p = .66$ ).

Verbal fluency, or the ability to generate words, is only one aspect of executive function, which includes cognitive processes (e.g., such as planning, organization, coordination, implementation, and evaluation) required for many non-routine daily activities. The nine subscales assessing executive function of the DKEFS are designed to be used individually or as a battery. The subscales include the Trailing Making Test, Verbal Fluency, Design Fluency, Color-Word Interference Test, Sorting Test, Twenty Questions Test, Word Context, Tower Test, and the Proverbs Test (Swanson, 2005).

One of the limitations to using the DKEFS system is that only one subscale (i.e., verbal fluency) was used. It is possible that using more subscales would have provided a better assessment of executive function. A limitation to using the DKEFS-VF subscale may be that verbal fluency has little to do with our ability to move around in our environment. The ability to generate words in a specific period of time may be important in a social setting when conversing with other individuals, for example, but having good communication or performing well on a verbal generation task, like the DKEFS-VF, may

not be a vital aspect of how much an individual interacts with their environment. In a typical errand run, for example, individuals are driving, shopping, paying, making decisions, carrying loads, and other non-verbal activities.

In this study, solely using verbal fluency as a depiction of executive function as a whole may have provided a narrow view of what executive function represents, explaining low, non-significant correlations with MAPS scores. Using the entire battery of subscales to measure executive function may have resulted in a stronger correlation between executive functioning and functional-living.

#### Reaction Time

Reaction time (RT), the amount of time it takes an individual to react to a stimulus, was measured using an online test (<http://cognitivefun.net/>) (Cognitive Fun, 2009). The RT test consisted of five trials requiring the participants to hit the space bar on a keyboard as fast as possible when a large green dot was presented on the computer screen at random. The correlations between the RT score with MAPS<sub>I</sub> scores ( $r = -.34, p = .07$ ) and MAPS<sub>V</sub> scores ( $r = -.34, p = .07$ ) neared significance. The negative direction of the correlation implies that slower reaction time may be associated with reduced levels of functional-living scores.

The scores for the RT measure and MAPS were both nearing significance. The lack of a significant correlation between these scores may be due in part to the number of participants enrolled in the study. Using a larger sample size may have increased power resulting in a significant correlation. A significant correlation would potentially have been seen between reaction time and functional-living, provided a larger sample size was

used, because there is evidence in the literature to support the relationship between reaction time and physical activity (i.e., a component of functional-living as measured by MAPS). Research has shown that increased amounts of physical activity achieved through fitness training (i.e., self-paced walking program occurring over 10 months) resulted in better performance on reaction time measures (Rooks et al., 1997). This research is consistent with the idea that higher levels of functional-living (i.e., participating in more physical activity in the real-world) are associated with better reaction time performance.

There were several limitations to using the online RT test. While the RT test was chosen for this study because it was easily accessible (i.e., online and free to the public) and did not require administration training, it was a test that did not provide any information about validity and reliability. A PubMed literature search found no articles that included online tests from the Cognitive Fun website. Without any validity, reliability, or normative data information on the RT measure used, it is difficult to interpret the scores of the RT in the sample studied. Another limitation of using this particular reaction time test is the number of trials required to obtain a score. Commonly used, validated RT tests use many more trials than the five used by this test. For example, the Eriksen Flanker test which uses 20 trials (Eriksen, 1974) and a similar computerized RT test which uses 30 trials (Schneider, 2002). In the future, using a better measure of reaction time will likely provide evidence of a significant positive association between reaction time and functional-living.

### Additional Analyses

The planned bivariate correlations for hypothesis 1a revealed that some of the cognitive measures had strong correlations with each other (e.g., the PFT and SS). This covariance suggested that the correlation coefficients among measures could be inflated. A series of partial correlations were conducted to examine the impact of the covariance on the results. The first partial correlation analysis controlled for age, the second controlled for education and the third controlled for age and education. Although the participants had varying ages from 61 – 89, the majority of participants were between 70-74 years of age. The education level of participants spanned from high school degree to doctoral/post-graduate degrees. Additionally, some of the participants were either current or recently retired university professors.

The partial correlations controlling for age and for both age and education resulted in slightly weaker associations among the PFT and SS with the MAPS<sub>I</sub> and MAPS<sub>V</sub> scores compared to the bivariate correlations. Controlling for education only resulted in slightly stronger associations among the PFT and SS with the MAPS<sub>I</sub> and MAP<sub>V</sub> scores and all of these remained significant. Because the study focused on measures of cognitive function and education level is closely associated with cognitive ability, the partial correlation analysis controlling for education only provides the most relevant results for the study. These results are consistent with the bivariate correlation results previously discussed.

### Confounding Variables

According to the ICF model, there are a number of factors that play a role in everyday function including functioning at the level of the body, physical activity, environmental factors, and personal factors. MAPS is the first functional outcome measure to incorporate physical activity and environmental components to assess functional-living. Using the ICF model, it is reasonable to hypothesize that cognitive function, a personal factor, is related to MAPS scores. There are many other personal factors (e.g., depression, self-efficacy, motivation, etc.) that may be associated with functional-living that were not assessed in this study. Keeping in mind that there are many other factors that impact function, it is logical to assume there were confounding variables potentially influencing the correlations seen between MAPS scores and cognitive function scores.

Social Cognitive Theory (SCT) is a model of the interactions between personal (e.g., depression), behavioral (e.g., going to the gym each day), and environmental factors (e.g., proximity to fitness centers), all influencing one another to impact health-related behaviors (Bandura, 1989). These three factors influence each other bi-directionally (i.e., reciprocal determinism), where behavior is influenced by environmental factors or personal factors. The components of what MAPS assesses (i.e., physical activity and the environment) are represented using SCT, under the behavioral and environmental factors. The third factor within SCT, personal factors, is not measured by MAPS but the model of SCT depicts that personal factors influence behavioral and environmental factors. MAPS combines behavioral and environmental information to provide contextual information of a person's everyday function. Personal factors influencing contextual information may



include mental disorders, personality, or motivation. For example, the literature has shown that older adults often experience a fear of falling due to poor self-assessed physical health, cognitive health, balance and gait abnormalities, and other factors, all which contribute to the ability of an individual to participate in physical activity (e.g., walking around a grocery store) (Baumgartner, 1997). These factors may lead to self-imposed limitations on physical activity, in the end interacting less with one's environment. A fear of falling (i.e., personal factor) can influence the confidence of an older adult to safely walk around in their pharmacy, bookstore, neighborhood, etc. Another individual may be depressed and may take less frequent trips outside of their home due to low energy and low interest which is typically associated with depression (Sanderson, 2007). Both scenarios may result in the individual staying home more frequently and not interacting with their environment. Depression, speech impairments, falls self-efficacy, mood, and other personal variables were not measured in this study. The results for Hypothesis 1a may have been influenced by personal factors that were not measured in the study. Measuring personal variables in future studies may help identify variables mediating the relationship between cognitive function and functional-living, as measured by MAPS.

#### Hypothesis 1a Summary

The findings from the current study modestly provide further evidence of construct validity for MAPS scores. As stated in Hypothesis 1a, construct validity would be provided for MAPS if a correlation was found between functional-living, as measured by MAPS, and cognitive function, as measured by five cognitive measures each assessing

a different cognitive domain. Hypothesis 1a was partially supported by significant associations between MAPS scores and two of the five cognitive function measures including the Paper Folding Test assessing spatial visualization and Symbol Search assessing processing speed. Both measures assessed a cognitive domain that is expected to help an individual function in the real-world (i.e., spatial visualization to help navigate in one's environment and processing speed to help an individual safely and effectively execute physical activity behaviors such as driving).

#### Hypothesis 1b

Construct validity evidence for the MAPS scores will be shown. The score from the physical function measure (i.e., Timed Up and Go) and MAPS scores will have a moderate negative correlation. The score from the physical activity measure (i.e., International Physical Activity Questionnaire) and MAPS scores will have a low positive correlation.

The physical function measure, Timed Up and Go (TUG), was found to be significantly correlated with MAPS<sub>I</sub> scores whereas the MAPS<sub>V</sub> scores and TUG scores were nearing significance. The physical activity measure, the International Physical Activity Questionnaire (IPAQ), was not significantly correlated with MAPS scores.

#### Correlation between MAPS Scores and Timed Up and Go

The Timed Up and Go (TUG) (Posiadlo & Richardson, 1991) measured lower-extremity physical function by assessing the time it took an individual to stand up from a

seated position, walk three meters, turn around, walk back to the chair, and sit down again. Participants were instructed to walk at their everyday pace (i.e., the pace one uses to walk around a neighborhood, grocery store, etc.). Higher scores indicated slower walking speeds and lower physical function, and lower scores indicated faster walking speeds and higher physical function. For the sample of 30 older adults used in the study, the average time it took participants to complete the TUG was 10.7 ( $\pm$  2.8) seconds with the range of walking speeds varying from 7.3 seconds to 22.0 seconds. Based on existing TUG research, the results of the current study suggest that the participants should be able to walk without aid and not need assistance with daily activities such as showering, getting up and down from a chair, going out alone, climbing stairs, etc. (Posiadlo & Richardson, 1991).

A significant negative, moderate correlation was found between the TUG scores and MAPS<sub>I</sub> scores ( $r = -.48, p = .01$ ), indicating that better physical function (i.e., lower TUG scores) was associated with better functional-living (i.e., higher MAPS scores). The correlation between the TUG scores and MAPS<sub>V</sub> scores was nearing significance ( $r = -.35, p = .06$ ) and would likely have been significant provided a larger sample size was used in the study.

The correlation found between the TUG scores and MAPS<sub>I</sub> scores was expected. The TUG score relied heavily on the average walking speed of the individual and one of the components the MAPS intensity score (i.e., MAPS<sub>I</sub>) relied on is the intensity of the physical activity. The faster the average walking speed is, the harder the intensity of the step will be (i.e., the impact on heel strike of the walking stride). The study results may also be explained by examining what the TUG and MAPS are measuring. The TUG

measures the individual's ability to stand from a seated position, participate in walking, and includes the movement of turning around while standing. These are all movements that are required from an individual during their daily routine (e.g., getting out of a car, turning around after selecting books at a library or groceries at the market) and may speak to the ability of the individual to move around, or "up and go" in their environment (i.e., physical activity).

The correlation found between the TUG scores and MAPS<sub>V</sub> scores would have most likely been significant had a larger sample size been used in the study. However, it makes sense that the correlations between the TUG and MAPS<sub>V</sub> scores were lower than the correlation between the TUG and MAPS<sub>I</sub> scores. While the TUG and MAPS<sub>I</sub> scores each contain a variable that are associated with one another (i.e., walking speed and walking intensity) helping to explain the significant relationship between them, the TUG and MAPS<sub>V</sub> scores do not. MAPS<sub>V</sub> scores represent the MAPS volume score which is impacted by step count. In the TUG, an individual's speed of walking is what influences the score. Walking speed is not concurrent with step counts when using a fixed distance, such as the 6 meter round trip in the TUG.

The moderate correlation between MAPS<sub>I</sub> scores and the TUG scores provided evidence of construct validity supporting Hypothesis 1b. Overall, the TUG assesses physical function which has been known to be associated with physical activity, and physical activity is part of what MAPS assesses. Therefore, the TUG and MAPS scores should be associated with one another. Other than physical activity, MAPS is also assessing a contextual component, the environment, providing more information than physical activity or physical function alone. The results for the relationship between

physical function and functional-living, as measured by MAPS, provide further construct validity for MAPS through the evidence that MAPS is assessing physical activity, a shared component of the TUG and MAPS measures.

### Correlations between MAPS Scores and International Physical Activity

#### Questionnaire

The International Physical Activity Questionnaire (IPAQ) (Craig, et al., 2003) was used to assess the physical activity levels of the participants. The IPAQ requires participants to self-report how often they participate in vigorous and moderate activity along with walking and sitting time in an average week. The correlations between the IPAQ and MAPS<sub>I</sub> scores ( $r = -.05, p = .78$ ) and MAPS<sub>V</sub> scores ( $r = -.05, p = .79$ ) were not significant indicating that there was no association between the IPAQ scores and MAPS scores.

The correlation between the MAPS scores and IPAQ was expected to be low but significant. A significant correlation was expected because the IPAQ is measuring physical activity, and physical activity is one component of what MAPS is assessing. However, a low correlation was expected because MAPS measures an additional component, the environment, in addition to physical activity alone. A low correlation was also expected because the IPAQ is a subjective measure of physical activity whereas MAPS measures physical activity objectively. The terminology used in the IPAQ could be interpreted differently by different people. For example, in the question asking about moderate physical activity, an example of moderate activity was carrying light loads which for some people might be considered to be a vigorous activity. Another problem

with the subjective nature of the questionnaire included the misreporting (i.e., overestimation or underestimation) of time spent doing physical activity. Scores for the IPAQ ranged from 66 to 35,808 MET – minutes/week, further supporting this point. The maximum score reported (i.e., 35,808 MET – minutes/week) was self-reported from a participant who wrote down that they participated in 8-10 hours of vigorous activity during 6 days of the week, 1 hour of moderate activity every day of the week, and walked for 8 hours a day every day of the week. It is very likely that this individual overestimated the amount of time spent doing each of these activities, resulting in outlier data.

### Hypothesis #2 Discussion

#### Hypothesis 2

Three days of accelerometer and GPS data will provide MAPS scores with acceptable reliability ( $ICC \geq .7$ ) using any combination of weekdays and weekend days.

Hypothesis 2 was supported by the results of the study. The original validation study for MAPS involving a group of 9 post-surgical knee patients and 9 healthy matched controls ( $25.6 \pm 9.8$  years) showed that a minimum of three days of wear time was necessary for reliable MAPS scores (i.e.,  $>.70$ ) (Herrmann, et al., 2011). Identifying what combination of three days, using weekdays and weekend days, the monitors need to be worn to obtain reliable MAPS scores has not previously been examined. This study found that wearing the GPS and accelerometer during three weekdays, two weekdays and one weekend day, and one weekday and two weekend days all yielded an intra-class

correlation of  $>.70$ . The results indicate that three days of data collection in older adults would be expected to yield reliable estimates of  $MAPS_I$  and  $MAPS_V$  scores.

### Hypothesis 2 Summary

The results from the data collected in the study provided evidence that three days of accelerometer and GPS data among older adults will provide MAPS scores with acceptable reliability ( $ICC \geq .7$ ) using any combination of weekdays and weekend days. Previously, it was only shown that data from three days of wear time would provide reliable MAPS scores without providing information on what combination of days using weekend or week days provided MAPS scores with acceptable reliability. In the future, MAPS may be used in clinical settings, giving clinicians the ability to track changes in functional-living of older adults by instructing individuals to wear the activity monitors during three days out of the week at their convenience without needing to identify specific days to obtain reliable MAPS scores. For researchers interested in using MAPS in the future, the findings from Hypothesis 2 have increased the flexibility of the time frame for when data collection can occur. In other words, MAPS data can be collected during any three-day period within a week.

### Limitations

This study had several limitations including the size and demographic characteristics of the older adult sample, the cognitive function measures, and the inability of accelerometers to capture water-based physical activity.

## Study Sample

The sample size was chosen because there were no data available for conducting a power analysis to determine the appropriate sample size needed to examine the relationship between functional-living and cognitive function in older adults. To reflect the minimum sample size typically associated with normally distributed data, a sample size of 30 older adults was used for the study (Brase & Brase, 2009). While all of the cognitive function scores were normally distributed, it is possible that a sample of 30 participants did not provide adequate power for detecting associations between some of the cognitive measure scores and MAPS scores. The correlations between RT with both MAPS<sub>I</sub> and MAPS<sub>V</sub> scores, as well as the correlation between the TUG and MAPS<sub>V</sub> score, neared significance. We can speculate that faster processing speed, as measured by the RT measure, and physical function, as measured by the TUG, would be related to functional-living as measured by MAPS. As previously discussed in the discussion of the correlations between cognitive function measures and MAPS, there is evidence in the literature to support a relationship between faster processing speeds and physical activity, along with physical function and physical activity. Physical activity makes up one component of what MAPS measures. Therefore, with a slightly larger sample size, the correlation between MAPS<sub>I</sub> and MAPS<sub>V</sub> scores with the RT scores, and the MAPS<sub>V</sub> scores and TUG scores would likely be significant.

The older adult sample in the study primarily resided in towns in and around Amherst, MA. Amherst is located in Hampshire County, which is a mix of rural and suburban areas with many hiking trails, bike paths, mountains, rivers, and other outdoor commodities that provide many opportunities for residents to be active in their



environment. Urban and inner city settings may not provide equivalent access to environments that encourage outdoor activities. urban and inner city settings may also pose environmental threats (e.g., crime, high traffic, less cross-walks) that aging older adults may perceive as unsafe and be a determining factor when they are making decisions about whether or not to walk in their environment (Wang, 2010). For example, one study showed that older adults engaged in more self-reported walking in their environment (i.e., outside of their home) if their environment was safer (i.e., less reported crime and more police surveillance). Because there are differences in rural and suburban environments versus inner city and urban environments, the MAPS scores of the older adult sample used in the study may not reflect the average MAPS scores of older adults who do not live in rural or suburban areas. MAPS scores may vary based on the residential setting in which an older adult resides.

### Cognitive Function Measures

Before addressing the limitations associated with the cognitive function measures used in the study, it is important to note that there is no existing literature in functional outcome measure research that has looked at the relationship between functional-living and cognitive function. The objective of selecting measures of cognitive function was to use several measures each assessing a different cognitive domain to represent an overall depiction of cognitive function. The five measures chosen were selected because of the relationship between that specific cognitive domain and physical activity which is part of what MAPS measures. Assessing all possible cognitive domains and their relationship with functional-living would be unrealistic due to the amount of testing involved in the

study, the burden that would be placed on the participants because of the length of the testing session, and funding. Some of the cognitive function measures used assessed domains that upon review may not have been the best choice (i.e., HVLТ and DKEFS-VF). For the HVLТ, it may be that this particular measure of working memory was simply not a good choice for the current study because the tasks involved in the HVLТ may not have anything to do with everyday functioning in a real-world setting. For the DKEFS-VF, the use of the verbal fluency subscale as a stand-alone measure may have provided a narrow view of executive function.

In choosing the best study measures, most researchers seek measures that are valid and reliable but also low-cost, easily accessible, require minimal testing time, and do not require any training to administer. The current study was not funded and a trained neuropsychologist was not available to administer the tests, making it necessary to select five measures of cognitive function that were free, easily accessible, did not take long to administer, and required minimal training to administer correctly. Although the cognitive function measures used in this study were valid and widely used in cognitive research, with the exception of the RT test, it would be beneficial to administer additional measures (e.g., the full DKEFS battery).

### Accelerometers

MAPS assesses the person-environment interaction by using time-locked physical activity data (i.e., accelerometers) and geospatial data (i.e., GPS receiver and GIS software). Accelerometers are commonly used because they objectively assess physical activity. However, accelerometers are not waterproof and therefore could not capture

when a participant was swimming or taking part in water activities. The inability to capture physical activity in water will result in lower MAPS scores because water-based physical activity is not included in the MAPS score associated with the location where the activity occurred.

### Future Directions

This was the first study to examine MAPS and cognitive function in older adults. To address the limitations of the current study, future studies should take several factors into consideration such using a larger sample size and better measures of reaction time and executive function. Because MAPS is a newly developed measure, there are many future directions for research.

The inclusion criteria for this study required individuals to be mobile without the use of aid. A study conducted in individuals with multiple sclerosis included some participants who used a walking aid (Snook et al., 2010). In the future, a study should include participants who use canes as a means of mobility. This will also open up the sample to participants with a wider range of walking abilities.

Future studies should investigate the relationship between functional-living, as measured by MAPS, and different residential settings. The study took place in western MA with the participants primarily residing in towns in and around Amherst, MA. In the future, it would be interesting to investigate the functional-living information provided by MAPS data and how it varies across different residential areas such as urban, inner city, rural, and suburban areas, because this has never been examined in the existing MAPS research.

Aside from the MAPS scores themselves, the accelerometer and GPS/GIS information obtained provides details about the interaction an individual has with their environment including total physical activity and step counts, total number of trips and types of trips (i.e., instrumental or discretionary) taken away from home and total amount of time spent at home, at locations other than home and while traveling. Variables like these could be used in clinical studies to identify changes in everyday routine such as how much time an individual spends outside their home after having surgery. In addition to MAPS scores, these variables (e.g., average number of leisurely trips taken, average of daily step counts) can be tracked over time to detect changes in a person's real-world functional level.

A future study may examine the differences in MAPS scores and additional MAPS variables (time, trips, etc.), across different living situations (e.g., assisted living facilities, live alone independently, live alone but has visiting nurse, lives with children, etc.). It would be worthwhile to examine the differences in MAPS scores, if any, based on who lives with the individual which may potentially speak to the effects of social support (i.e., personal factor) impacting function.

The current study collected data between the months of August 2011 and May 2012. For five days, each participant wore an accelerometer during waking hours brought a GPS receiver with them whenever leaving home. Despite the fact that data were only collected during one time point (i.e., cross-sectionally) per participant, it is interesting to note that the average MAPS scores were higher during the spring and summer months compared to the fall and winter months (Table 12).

**Table 12. Reported MAPS<sub>I</sub> and MAPS<sub>V</sub> Scores Across Seasons**

Measure	<i>n</i>	MAPS <sub>I</sub>	MAPS <sub>V</sub>
Summer	7	3148.66	98.84
Fall	11	1405.13	50.50
Winter	7	1619.81	55.81
Spring	5	2148.59	86.37

The time of year may have affected the participants' ability or willingness to leave their home, resulting in lower MAPS scores during the colder months (i.e., fall and winter) and higher scores during the warmer months (i.e., spring and summer). Assessing a person's interaction with their environment (i.e., how much physical activity they are doing outside of their home at the store, visiting a friend, running errands, etc.) during one time of year may have impacted their MAPS scores. Recruitment of participants was slow. Ten months were required to collect data from 30 participants stretching data collection over the four seasons. There were not enough data collected per season to run an analysis of variance to determine if a difference in MAPS score means exists across different seasons. In an ideal situation, data would be collected for all participants during one season. A study collecting data across multiple time points for each participant is needed in order to examine if and how seasonal changes may influence MAPS scores.

The cross-sectional data collection for this study is a necessary first step in the evaluation of new measures. Assessing functional-living over multiple time points will allow researchers examine increases (i.e. reflecting functional improvement) and/or decreases (i.e., reflecting a decline in function) in MAPS scores.

Aside from examining the direction of change in MAPS scores over time, the degree of change within MAPS scores over multiple time points will also provide important information to researchers in the future. MAPS scores have a very large range compared to current functional outcome measures. In the current study, MAPS<sub>I</sub> scores ranged from 124.39 to 5886.81 with a standard deviation of 1494.2 and MAPS<sub>V</sub> scores ranged from 4.58 to 243.16 with a standard deviation of 54.4. To point out how drastic the range of MAPS scores are in comparison with other functional outcome measures, the scores for the Short Physical Performance Battery (SPPB), for example, fell between 0.97 and 2.95 with a standard deviation of  $\pm 0.5$  in a pilot study assessing the validity of MAPS in older adults (Morand, Suckau, & Snook, 2011). In this example, the SPPB provides ordinal data that have rank order but not equal distance between intervals (i.e., the distance between a score of 1.0 and 2.0 on the SPPB may not be the same as the distance between 2.0 and 3.0). MAPS scores have an advantage over other functional outcome measures like the SPPB because MAPS scores are ratio data (i.e., scores have meaning order and unit and a score of 0 reflects the complete absence of functional-living). In other words, in MAPS scores, we can say that 200 is twice as much as 100 and the distance between a score of 50-100 is the same as the distance between 100-150. The much larger standard deviation and range in MAPS scores, compared to other functional outcome measures, present the scores on a much wider range (i.e., scores are more spread out) compared to other functional outcome measures, allowing for the detection of smaller changes in everyday function.

A clinical trial should be conducted to provide evidence that MAPS is sensitive to changes in functional decline compared to common measures of function. MAPS could

provide new information about the everyday aspects of living rather than the information provided by functional tests which currently do not provide information about environments outside of a lab setting. In the future, it is possible that MAPS could be a tool used by physicians to identify signs of functional decline. By identifying early signs of functional decline, physicians could utilize preventive measures when assessing functional-living over multiple time periods. For example, tracking older adults' MAPS scores over time could identify when small functional declines occur allowing physicians to prescribe early interventions (e.g., physical therapy) in order to help individuals' maintain their function and prevent further decline.

### Implications

The current study has taken a substantial step in the right direction for functional outcome measure research. Function is defined as the interaction an individual has with their environment. As of now, functional outcomes research is limited in its ability to measure function in the true sense of its definition because it is currently only measuring a single factor contributing to function such as physical function (e.g., Short Physical Performance Battery, Timed Up and Go) or physical activity (e.g., accelerometry, International Physical Activity Questionnaire). These physical function and physical activity assessments are neglecting to measure a key component of function, the environmental context.

Not only are the current functional outcome measures missing a key component, the environment, but the information provided does not necessarily reflect everyday functioning (e.g., the time it takes the individual to walk 6 meters does not speak to the

person's ability to walk up and down a hill, walk on an uneven surface, or walk on a slippery sidewalk). For example, rehabilitation patients care about whether or not they are living their everyday lives the same way they were prior to having surgery or being injured (i.e., leaving their home to visit friends, going back to work, picking up groceries, etc.). For the older adult population, quantifying the person-environment interaction is of importance to them because functional-living, assessed by MAPS scores, can show how well they are getting around in their environment to avoid being placed in an assisted living facility and ultimately, maintaining their independence. The information that MAPS provides is substantially more useful to the general public compared to current functional outcome measures because it provides a more well-rounded assessment of quantifying functional-living.

In the current study, the correlations found between functional-living, processing speed and visual spatial processing have provided further evidence of construct validity for MAPS. Strengthening this functional-living measure (i.e., MAPS), will be important in the future as MAPS may become an important tool to measure and track function-living (i.e., the person-environment interaction) in older adults and clinical populations.

### Conclusion

One thing that every person in the world shares with one another is the inevitable aging process. As we age, there are many physiological and psychological changes that occur, ultimately impacting our function. Many of these changes can increase the severity of existing health conditions, increase the risk of falling and losing independence, and increase the risk for many diseases (e.g., diabetes, heart disease) (Nelson, et al., 2007).



The current literature on functional assessment has focused on physical function and physical activity, providing no contextual information about where the physical activity occurs. Incorporating environmental information with physical activity information results in a better assessment of real-world function than currently used methods. The Movement and Activity in Physical Space (MAPS) score, captures this person-environment interaction by identifying the duration, frequency, and locations where physical activity occurs. The combination of accelerometer data and geospatial information sets MAPS apart from existing functional outcome measure because it provides the ability to assess how an individual interacts within their environment.

The main purpose of the current study was to provide further construct validity for the MAPS measure in older adults. While construct validity has been provided in previous MAPS studies (Herrmann, et al., 2011) (Morand, Suckau, & Snook, 2011) (Snook et al., 2011), there was an interest in examining other factors that impact function (i.e., cognitive function). Additional evidence of construct validity was provided for MAPS scores in older adults as evidenced by the modest significant relationships between MAPS scores with processing speed, spatial visualization, and TUG scores. The results of the study have provided additional evidence that MAPS is a measure of functional-living in older adults.

MAPS scores provide an opportunity to make a positive impact on health care. As stated previously, MAPS could potentially detect changes in functional decline earlier than existing methods, resulting in earlier interventions to maintain or improve their current functional state. Many clinical populations would benefit tremendously by MAPS because they all experience changes in their everyday function either due to aging,

symptoms of a disease, change in prescription medication, etc. MAPS has the potential capability to detect smaller changes in functional status due to continuous data provided by MAPS scores. Current methods indicate how well a person can walk a specified distance, for example, but the information provided is clinically-based and not necessarily reflective of an individual's function within the non-clinical environmental. People are concerned about their every day ability to function and MAPS is a functional measure capable of assessing this.

The second purpose of the study was to examine the reliability of wearing the activity monitors during combinations of three different days. Previously it was found that three days is required to obtain reliable MAPS scores but it was not specified as to which combination of days (i.e., weekend and week days) yield reliable scores. The results of the study provided evidence that any combination of three days in a seven-day week provide reliable MAPS scores.

MAPS is an important advancement in functional outcome measures because it incorporates the environmental component of the ICF model and provides contextual information about a person's function. MAPS is a methodological improvement in the way in which function is measured. The current study has contributed to MAPS research providing some additional evidence of construct validity for MAPS as a measure of functional-living in older adults and demonstrating that any combination of three weekdays or weekend days will provide reliable MAPS scores.

## APPENDICES

APPENDIX A  
INFORMED CONSENT DOCUMENT

**Informed Consent**  
**University of Massachusetts Amherst**

**Real-World Function of Older Adults**

**Introduction**

You are invited to participate in a research study conducted by Dr. Erin Snook and Ms. Andrea Morand of the Department of Kinesiology at the University of Massachusetts Amherst. The purpose of this study is to further validate a newly developed measure of functional-living (Movement and Activity in Physical Space [MAPS] score) in older adults. Using MAPS, we can measure “functional-living”, or how older adults function in their free-living environment. MAPS combines data about how much physical activity is done and where, providing an assessment of “real-world” function. Using several cognitive tasks, we will examine if a relationship exists between cognitive function and functional-living. You will visit the lab for the first of two testing sessions. On the first visit, you will be asked to complete a demographic questionnaire, five cognitive function tasks, a physical performance test, and then you will be given two small devices (accelerometer and GPS receiver) to be worn at the waist for five days. A travel log will be kept to record activities and travel outside of your residence. One week after the first visit, you will return to the lab (or we will come to your residence) and collect the GPS, accelerometer, and travel log. You will then complete one additional questionnaire. The data collected from these measures will be used to determine how well MAPS is measuring functional-living in older adults.

**Eligibility**

Your participation in this research is voluntary and you may withdraw from participation at any time. To participate in this study, you must (a) be 65+ years old, (b) ambulatory without aid and (c) free of any conditions that affect walking, and (d) have no cognitive impairments.

**Testing Procedures**

You will visit the Physical Activity and Behavior Lab for the first of two testing sessions. Approximately one week later, you will revisit the lab or a researcher will visit your residence for the second testing session.

**Visit 1: 1 hour**

At the beginning of Visit 1, a researcher will explain the study to you and answer any initial questions you may have. You will be asked to read this informed consent document and encouraged to ask any questions you have about it or the study. Upon agreeing to participate in the study, you will be asked to sign and date this document. A copy of this form will be given to you.

After completing the informed consent you will be asked to complete a few questionnaires. The questions ask for general information such as age, sex, occupation, and functional abilities. Next you will complete a series of five cognitive performance tasks to the best of your ability. Four out of five cognitive measures will be administered orally or using a pencil and paper and the other cognitive measure will be administered on the computer. For example, participants will be read aloud a series of words and they will be asked to recall as many as they can after the list of words is read.

Next we will ask you to complete a physical performance test, the Timed Up and Go (TUG), to measure your physical functioning. This test requires participants to rise from a seated position in an arm chair, walk 3 meters straight ahead, turn around, walk back 3 meters, and sit back down in the chair. A researcher will time you as you complete the task as quickly and safely as possible.

At the end of Visit 1, a researcher will distribute a physical activity monitor (accelerometer) and GPS unit attached. The accelerometer will provide information about your physical activity. The GPS unit will provide information about where you did the activity. The GPS unit can only store data. It is not a functional GPS capable of providing directions. The two monitors are small and lightweight, about the size of a pager, and do not inhibit movement. You will be asked to wear the monitors for 5 days from the time you wake-up until you go to bed (except when swimming or showering). You will also be given a travel log and asked to complete it each day you wear the monitors.

The researchers will make every effort to ensure that you are comfortable with the equipment and procedures. A clear explanation of all the study procedures and equipment will be given to you. If you have any questions, you should feel free to address them with the

researchers at any time. The researcher will demonstrate how to wear the devices. An instruction sheet will also be provided for you.

### **Visit 2: 20 minutes**

You will visit the Physical Activity and Behavior Lab or a researcher will visit you at your residence for the second session. You will be asked to return the two monitoring devices and the travel diary. The researcher will review the travel log with you to ensure it is complete. You will then be asked to complete a questionnaire that asks about physical activity. At the end of the second testing session, you will fill out a compensation form and W-9 form to be compensated for your participation.

### **Risks**

If you decide to participate in this study, you will have minimal risk of injury. There is no additional risk beyond that which occurs during your normal daily life. We are not asking you to change your regular daily activity in any way. The cognitive function tasks are challenging and you may experience some psychological discomfort, such as frustration, when performing the tests.

### **Benefits**

Participation in this study will provide no immediate benefits to you; however, the information obtained will help to determine how well MAPS is measuring functional-living in older adults. If a relationship is shown between functional-living, as measured by MAPS, and cognitive function, then we can say that MAPS is doing a good job at measuring functional-living in older adults. In the future, MAPS could be used to track functional decline, improve rehabilitation outcomes, and improve the efficacy of exercise programs in older adults.

### **Compensation**

Participants will receive \$5 for completing the first session, \$5 for wearing the devices, and \$5 for completing the second testing session.

### **Confidentiality**

The information obtained from this study will be treated as privileged and confidential. It will not be released except upon your written consent. No personal identifying information will be used in the

analysis or presentation of the data. Data will be stored on a password protected laboratory computer. All study data, demographic information, and screening materials will be kept in a locked file cabinet that is only accessible to study researchers.

### **Request for Further Information**

If you have any questions or concerns about being in this study you should contact Andrea Morand by phone or email (413-545-6007; REALWORLDfunction@gmail.com) or Dr. Erin Snook (413-545-6438; esnook@kin.umass.edu). You are encouraged to ask questions about the study. The investigators will attempt to answer all your questions to the best of their knowledge. The investigators fully intend to conduct the study with your best interest, safety, and comfort in mind. They have read and understand the *Assurance of Compliance with OHRP Regulations for Protection of Human Research Subjects*. This study has been approved through the internal review board of the School of Public Health and Health Sciences. If you would like to speak with someone not directly involved in the research study, you may contact the University of Massachusetts Amherst Human Research Protection Office (HRPO) via email (humansubjects@ora.umass.edu); telephone (413-545-3428); or mail (Office of Research Affairs, Research Administration Building, University of Massachusetts Amherst, 70 Butterfield Terrace, Amherst, MA 01003-9242).



**PLEASE READ THE FOLLOWING STATEMENT AND SIGN  
BELOW IF YOU AGREE**

I have had the chance to ask any questions I have about this study and my questions have been answered. I have read the information in this consent form and I voluntarily agree to be in the study. There are two copies of this form. I will keep one copy and return the other to the researchers.

\_\_\_\_\_  
Study Representative Name (print or type)

X \_\_\_\_\_      \_\_\_\_\_  
Participant Name (Print)                                      Date

X \_\_\_\_\_  
Participant Signature

APPENDIX B  
SCREENING SCRIPT AND QUESTIONS

## **Screening Script Real-World Function of Older Adults**

Hello. May I please speak to \_\_\_\_\_? My name is Andrea Morand and I'm from the Department of Kinesiology at the University of Massachusetts Amherst. You recently called/emailed us about the study looking at cognitive function and functional-living in older adults currently being conducted. I'm calling to give you information about the study and to see if you are interested in participating. Do you have some time for me to explain the study now, or is there a better time for me to call you?

The purpose of this new study is to help us better understand how well a newly developed measure assesses function-living called the Movement and Activity in Physical Space score (called MAPS for short) in older adults. MAPS measures how older adults function in their free-living environment by measuring physical activity within one's environment. The study will be completed over two sessions, approximately one week apart, with the first taking place in our lab and the second can take place at your residence or in the lab. We will first have you complete this Informed Consent Document which explains the study and provides information about how to contact us with any questions. Once you sign it, we will have you complete a demographic questionnaire asking about general information such as race, education, and income. When you have finished the questionnaire, we will have you complete five measures of cognitive function. The tasks will take approximately a half hour to complete and will test your cognitive abilities and include tasks such as pressing a key when a specified shape appears on the screen. Next we will do a brief functional test where you will rise from a chair, walk three meters, walk back, and sit back in a chair. At the end of the first session, we will give you two small monitoring devices, a GPS and an accelerometer, to wear for five days. These devices will be used to record the amount of physical activity you participate in at the various places where you travel. You will also be asked to keep a travel log which will be provided to you to keep track of the time and types of physical activity you do over five days. After one week, you will return to the lab or we can come to your residence for the second testing session to collect the GPS, accelerometer, and travel log. An additional questionnaire will be completed and you will be left with our contact information in case you have any questions in the future.

You will receive \$15 for completing both the testing sessions.

### **Confidentiality Policies**

- All paper documents will be kept confidential and only researchers in this lab have access to it.
- Your contact information will be stored in a secure, password protected database and it will not be shared with anyone outside of this study.
- Any data that is used for publication of study results will not have any personal identifying information.

Participant contributions to our project will help us strengthen the evidence that MAPS is measuring functional-living in older adults. This outcome measure could potentially be used as a way to track functional decline in older adults and improve rehabilitation techniques and exercise interventions to help improve function and quality of life in older adults.

Does this study sound like something you would be interested in doing?

Yes—Do Screening and get Contact Info

No – Thank you for your time

## Screening Questions

### Real-World Function of Older Adults

#### Participant Screening

#### Contact Information

Name: \_\_\_\_\_

Mailing Address: \_\_\_\_\_

\_\_\_\_\_

Home phone number: (\_\_\_\_) \_\_\_\_ - \_\_\_\_ OK to leave voicemail?    Y    N

Cell or work phone:    (\_\_\_\_) \_\_\_\_ - \_\_\_\_ OK to leave voicemail?    Y    N

Email address: \_\_\_\_\_

What is the best day/time to contact you? \_\_\_\_\_

How did you hear about the study? \_\_\_\_\_

**\*\*\*READ ALL CONTACT INFORMATION BACK TO THE PARTICIPANT TO BE SURE IT IS CORRECT\*\*\***

#### **START SCREENING TO DETERMINE IF PARTICIPANT CAN BE ENROLLED IN THE STUDY**

1. What is your date of birth? \_\_\_\_\_

2. Are you able to walk without aid?

Yes: Great

No: Ok. For the current study we are only enrolling participants that are able to walk without aid. However, it is likely that we will be expanding this

research in the future to include people that have walking impairments. Would it be okay for us to contact you with information about upcoming studies that you may qualify for? Thanks for your interest in our study.

3. Do you have any diseases or conditions that affect your walking ability (e.g., diabetes or stroke)?

No: Okay

Yes: For the current study we are only enrolling participants that do not have any conditions that might affect their walking ability. However, it is likely that we will be expanding this research in the future to include people that have walking impairments. Would it be okay for us to contact you with information about upcoming studies that you may qualify for? Thanks for your interest in our study.

TICS

PARQ

Health History Questionnaire

## Telephone Interview for Cognitive Status (TICS)

Directions:

1) Explain exam to participant, 2) Get address 3) Be sure distractions are minimal (e.g., no TV or radio on, remove pens and pencils from reach), 4) Be sure sources of orientation (e.g., newspapers, calendars) are not in subject's view, 5) Caregivers may offer reassurance, but not assistance, 6) Single repetitions permitted, except for items 5 and 8.

Instruction	Scoring Criteria	Score
1. "Please tell me your full name?"	1 pt. for first name, 1pt. for last name	_____ _____
2. "What is today's date?"	1 pt. each for month, date, year, day of week, and season. If incomplete, ask specifics (e.g., "What is the month?" "What season are we in?")	_____
3. "Where are you right now?"	1 pt. each for house number, street, city, state, zip code. If incomplete, ask specifics (e.g., "What street are you on right now?")	_____
4. "Count backwards from 20 to 1."	2 pts if completely correct on the first trial; 1 pt. if completely correct on second trial; 0 pts for anything else	_____
5. "I'm going to read you a list of ten words. Please listen carefully and try to remember them. When I am done, tell me as many words as you can, in any order. Ready? The words are: cabin, pipe, elephant, chest, silk, theatre, watch, whip, pillow, giant. Now tell me all the words you can remember."	1 pt. for each correct response. No penalty for repetitions or intrusions. *Only one trial allowed.	_____
6. "One hundred minus 7 equals what?" "And 7 from that?"...	Stop at 5 serial subtractions. 1 pt. for each correct subtraction. Do not inform the participant of incorrect responses, but allow subtractions to be made from his/her last response.	_____

	(Ans:93-86-79-72-65)	
7. “What do people usually use to cut paper?” “How many things are in a dozen?” “What do you call the prickly green plan that lives in the desert?” “What animal does wool come from?”	1 pt. for “scissors” or “shears” 1 pt. for “12” 1 pt. for “cactus” 1 pt. for “sheep” or “lamb”	_____ _____ _____ _____
8. “Say this: ‘No ifs, ands, or buts.’” “Say this: “Methodist Episcopal.””	1 pt. for each complete repetition on the first trial. *Repeat only if poorly presented.	_____ _____
9. “Who is the President of the United States right now?” “Who is the Vice-President?”	1 pt. for correct first and last name 1 pt. for correct first and last name (Ans: Barack Obama and Joe Biden)	_____ _____
10. “With your finger, tap 5 times on the part of the phone you speak into.”	2 pts. If 5 taps are heard; 1 pt. if subject taps more or less than 5 times	_____
11. “I’m going to give you a word and I want you to give me its opposites. For example, the opposite of hot is cold. What is the opposite of ‘west’?” “What is the opposite of ‘generous’?”	1 pt. for “east” 1 pt. for “selfish”, “greedy”, “stingy”, “tight”, “cheap”, “mean”, “meager”, “skimpy” or other good acronym	_____ _____
	TOTAL (out of 41)	_____

**Interpretation of scores:**

- Scores can range from 0 to 41.
- Individuals scoring a **31 or greater** are allowed to participate in the study.
- A score of **30 or less** denotes a **cognitively impaired** individual.

## Physical Activity Readiness Questionnaire (PAR-Q)

Please read the following questions carefully and answer each one honestly: check YES or NO.

**YES**   **NO**

- |                          |                          |  |
|--------------------------|--------------------------|--|
| <input type="checkbox"/> | <input type="checkbox"/> | 1. Has your doctor ever said that you have a heart condition <u>and</u> that you should only do physical activity recommended by a doctor? |
| <input type="checkbox"/> | <input type="checkbox"/> | 2. Do you feel pain in your chest when you do physical activity?   |
| <input type="checkbox"/> | <input type="checkbox"/> | 3. In the past month, have you had chest pain when you were not doing physical activity?   |
| <input type="checkbox"/> | <input type="checkbox"/> | 4. Do you lose your balance because of dizziness or do you ever lose consciousness?  |
| <input type="checkbox"/> | <input type="checkbox"/> | 5. Do you have a bone or joint problem that could be made worse by a change in your physical activity?                                     |
| <input type="checkbox"/> | <input type="checkbox"/> | 6. Is your doctor currently prescribing drugs (for example, water pills) for your blood pressure or heart condition?                       |
| <input type="checkbox"/> | <input type="checkbox"/> | 7. Do you know of <u>any other reason</u> why you should not do physical activity?   |

*PAR-Q (Thomas, Reading, & Shephard, 1992)*





## Family History

13. Has any **male** in your immediate family had a heart attack or sudden death before the age of 55?      Yes    No
14. Has any **female** in your immediate family had a heart attack or sudden death before the age of 65?      Yes    No
15. Do you have family history of heart disease?      Yes    No
16. Do you have family history of lung disease?      Yes    No
17. Do you have family history of diabetes?      Yes    No
18. Do you have family history of strokes?      Yes    No

## APPENDIX C

- i. DEMOGRAPHIC INFORMATION
- ii. TIMED UP AND GO (TUG)
- iii. PAPER FOLDING TEST
- iv. VISUAL REACTION TIME TEST
- v. INTERNATIONAL PHYSICAL ACTIVITY QUESTIONNAIRE (IPAQ) SHORT FORM
- vi. INSTRUCTIONS HOW TO WEAR ACTIVITY MONITORS
- vii. TRAVEL LOG EXAMPLE AND TEMPLATE
- viii. IMAGES OF ACTIVITY MONITORS (ACCELEROMETER AND GPS RECEIVER)

**i. DEMOGRAPHIC INFORMATION**

**Demographic Information**

Please complete the following information about yourself.

1. Gender (Circle one)      Female      Male

2. Marital Status (Circle one)

- Married
- Single
- Divorced/Separated
- Widow/Widower

3. Date of Birth \_\_\_\_\_

4. Occupation \_\_\_\_\_

5. Hours worked per week: \_\_\_\_\_ hours

6. Race (Circle one)

- American Indian
- Asian
- Black or African American
- Native Hawaiian or Other Pacific Islander
- Caucasian
- Latino/a
- Other: \_\_\_\_\_

7. Education (Circle highest level attained)

- Less than 7<sup>th</sup> grade
- 9<sup>th</sup> grade (Jr. High)
- Partial High School
- High School Graduate
- 1-3 years of College
- College/University Graduate
- Masters Degree

PhD or Equivalent

8. Annual Household Income (Circle one)

- Less than \$5,000
- \$5,001 – 10,000
- \$10,001 – 15,000
- \$15,001 – 20,000
- \$20,001 – 25,000
- \$25,001 – 30,000
- \$30,001 – 40,000
- \$40,001 or greater

*By answering a few questions regarding your current and past health, you will help us gain further insight into how your health impacts your current function.*

Please circle all that apply :

Arthritis

Cancer

Cardiovascular Disease

Coronary Heart Disease

COPD

Diabetes

Emphysema

Hearing Loss

Hypertension

Incontinence

Osteoporosis

Pulmonary Disease

Significant disorders of heart rhythm

Stroke

Vision Impairment

Functional Impairment of the Musculoskeletal system

## ii. THE TIMED UP AND GO

### Timed Up and Go (TUG) Test\*

1. Equipment: arm chair, tape measure, tape, stop watch.
2. Begin the test with the subject sitting correctly in a chair with arms, the subject's back should resting on the back of the chair. The chair should be stable and positioned such that it will not move when the subject moves from sitting to standing.
3. Place a piece of tape or other marker on the floor 3 meters away from the chair so that it is easily seen by the subject.
4. Instructions : "On the word GO you will stand up, walk to the line on the floor, turn around and walk back to the chair and sit down. Walk at your regular pace.
5. Start timing on the word "GO" and stop timing when the subject is seated again correctly in the chair with their back resting on the back of the chair.
6. The subject wears their regular footwear, may use any gait aid that they normally use during ambulation, but may not be assisted by another person. There is no time limit. They may stop and rest (but not sit down) if they need to.
7. Normal healthy elderly usually complete the task in ten seconds or less. Very frail or weak elderly with poor mobility may take 2 minutes or more.
8. The subject should be given a practice trial that is not timed before testing.
9. Results correlate with gait speed, balance, functional level, the ability to go out, and can follow change over time.
10. Interpretation :
  - < 10 seconds = normal
  - < 20 seconds = good mobility, can go out alone, mobile without a gait aid.
  - < 30 seconds = problems, cannot go outside alone, requires a gait aid.

A score of more than or equal to fourteen seconds has been shown to indicate high risk of falls.

\*Podsiadlo D, Richardson S. The Time "Up & Go": A Test of Basic Functional Mobility for Frail Elderly Persons. Journal of the American Geriatrics Society 1991; 39(2): 142-148



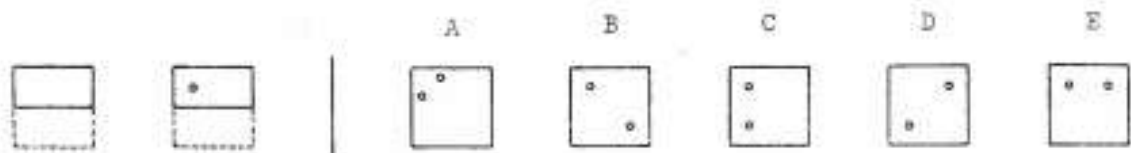
### iii. PAPER FOLDING TEST

Name / ID: \_\_\_\_\_

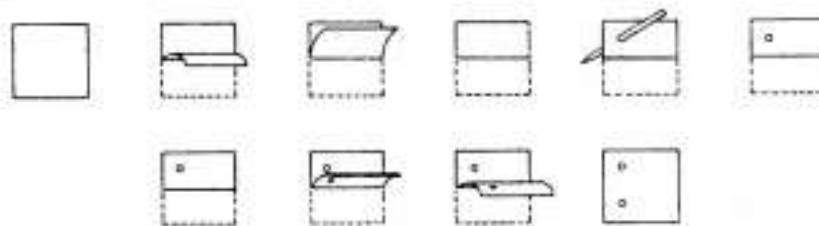
#### Paper Folding Test – VZ-2

In this test you are to imagine the folding and unfolding of pieces of paper. In each problem in the test there are some figures drawn at the left of a vertical line and there are others drawn at the right of the line. The figures at the left represent a square piece of paper being folded, and the last of these figures has one or two small circles drawn on it to show where the paper has been punched. Each hole is punched through all the thicknesses of paper at that point. One of the five figures at the right of the vertical line shows where the holes will be when the paper is completely unfolded. You are to decide which one of these figures is correct and draw an X through that figure.

Now try the sample problem below.  
(In this problem only one hole was punched in the folded paper.)



The correct answer to the sample problem above is C and so it should have been marked with an X. The figures below show how the paper was folded and why C is the correct answer.



In these problems all of the folds that are made are shown in the figures at the left of the line, and the paper is not turned or moved in any way except to make the folds shown in the figures. Remember, the correct answer is the figure that shows the positions of the holes when the paper is completely unfolded.

Your score on this test will be the number marked correctly minus a fraction of the number marked incorrectly. Therefore, it will not be to your advantage to guess unless you are able to eliminate one or more of the answer choices as wrong.

You will have 3 minutes for each of the two parts of this test. Each part has 1 page. When you have finished Part 1, STOP. Please do not go on to Part 2 until you are asked to do so.

DO NOT TURN THIS PAGE UNTIL ASKED TO DO SO.

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Part 1 (3 minutes)

					A	B	C	D	E
1.									
2.									
3.									
4.									
5.									
6.									
7.									
8.									
9.									
10.									

DO NOT GO ON TO THE NEXT PAGE UNTIL ASKED TO DO SO.

**STOP.**

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Part 1 (3 minutes)

		A	B	C	D	E
1.						
2.						
3.						
4.						
5.						
6.						
7.						
8.						
9.						
10.						

DO NOT GO BACK TO PART 1, AND  
DO NOT GO ON TO THE NEXT PAGE UNTIL ASKED TO DO SO.

**STOP.**

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#### iv. VISUAL REACTION TIME TEST

Website URL : <http://www.cognitivefun.net>

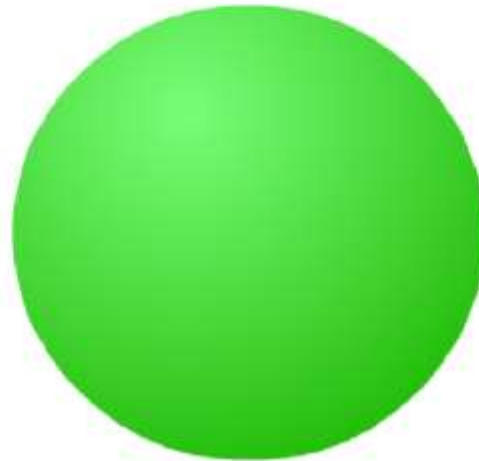


**cognitive fun!**  
Learn your mind. Play it too.

TESTS | STATS | DISCUSS | RESOUR

### Cognitive tests: Visual Reaction Time [go to stats]

Click on the green dot when it appears.



trial: 0  
(5 minimum)



Total trials: 5

Score= Average time from 5 trials

## v. INTERNATIONAL PHYSICAL ACTIVITY QUESTIONNAIRE SHORT FORM

### International Physical Activity Questionnaire Short Form (IPAQ)

We are interested in finding out about the kinds of physical activities that people do as part of their everyday lives. The questions will ask you about the time you spent being physically active in the **last 7 days**. Please answer each question even if you do not consider yourself to be an active person. Please think about the activities you do at work, as part of your house and yard work, to get from place to place, and in your spare time for recreation, exercise or sport.

---

Think about all the **vigorous** activities that you did in the **last 7 days**. **Vigorous** physical activities refer to activities that take hard physical effort and make you breathe much harder than normal. Think *only* about those physical activities that you did for at least 10 minutes at a time.

1. During the **last 7 days**, on how many days did you do **vigorous** physical activities like heavy lifting, digging, aerobics, or fast bicycling?

\_\_\_\_\_ **days per week**

No vigorous physical activities → **Skip to question 3**

2. How much time did you usually spend doing **vigorous** physical activities on one of those days?

\_\_\_\_\_ **hours per day**

\_\_\_\_\_ **minutes per day**

Don't know/Not sure

Think about all the **moderate** activities that you did in the **last 7 days**. **Moderate** activities refer to activities that take moderate physical effort and make you breathe somewhat harder than normal. Think *only* about those physical activities that you did for at least 10 minutes at a time.

3. During the **last 7 days**, on how many days did you do **moderate** physical activities like carrying light loads, bicycling at a regular pace, or doubles tennis? Do not include walking.

\_\_\_\_\_ **days per week**

No moderate physical activities → **Skip to question 5**

4. How much time did you usually spend doing **moderate** physical activities on one of those days?

\_\_\_\_\_ **hours per day**

\_\_\_\_\_ **minutes per day**

Don't know/Not sure

Think about the time you spent **walking** in the **last 7 days**. This includes at work and at home, walking to travel from place to place, and any other walking that you might do solely for recreation, sport, exercise, or leisure.

5. During the **last 7 days**, on how many days did you **walk** for at least 10 minutes at a time?

\_\_\_\_\_ **days per week**

No walking → **Skip to question 7**

6. How much time did you usually spend **walking** on one of those days?

\_\_\_\_\_ **hours per day**

\_\_\_\_\_ **minutes per day**

Don't know/Not sure

The last question is about the time you spent **sitting** on weekdays during the **last 7 days**. Include time spent at work, at home, while doing course work and during leisure time. This may include time spent sitting at a desk, visiting friends, reading, or sitting or lying down to watch television.

7. During the **last 7 days**, how much time did you spend **sitting** on a **week day**?

\_\_\_\_\_ **hours per day**

\_\_\_\_\_ **minutes per day**

Don't know/Not sure

## vi. INSTRUCTIONS FOR HOW TO WEAR ACTIVITY MONITORS

### HOW TO WEAR THE ACTIVITY MONITORS

#### Important Reminders:

1. When you get the activity monitors (accelerometer and GPS receiver), they will already be programmed to begin recording and the physical activity information will be saved on the devices.
2. Start wearing the accelerometer (red device) when you get out of bed each morning. Clip the accelerometer on to your pants/shorts at the front of your left hip bone (see picture below). You do not have to wear the accelerometer when you are showering and getting dressed.
3. Take the accelerometer off before going to bed each evening. Put it in a location that will help to remind you to put it on the next morning (e.g. the bathroom sink or nightstand).
4. Be cautious when using the restroom to be sure that the monitors do not fall off.
5. Wear the accelerometer when you exercise, but please remember to take it off before going swimming or showering. The devices are water resistant but NOT waterproof.
6. Bring the GPS receiver (black device in case) with you when you go on ALL trips. You do NOT need to attach the GPS to your body (e.g. clip it onto your car keys to ensure it is with you during trips away from home).
7. Complete the Travel Log every day. Please attempt to fill it out throughout the day as you make trips away from home.



GPS clipped to belt loop



GPS clipped to pants

**Please call the Physical Activity and Behavior Lab at (413)545-6007 or email at [REALWORLDfunction@gmail.com](mailto:REALWORLDfunction@gmail.com) if you have questions!**

**vii. TRAVEL LOG EXAMPLE AND TEMPLATE**

Travel/Activity Purpose Diary- EXAMPLE

Accelerometer **TIME ON:** 6 : 53 A.M.

<b>Date: 7/7/2010</b>	<b>Location/Place</b>	<b>Time at Location (minutes)</b>	<b>Type of activity</b>
<b>Location (#)</b>			
1	Home	12:00am- <u>7:26am</u>	Sleeping, Walking
2	Grocery Store	7:43am-8:16am	Grocery Shopping
3	Pharmacy	8:28am-8:40am	Walking
4	Home	9:05am-12:22pm	Sitting, Walking
5	Park	12:35pm-1:21pm	Walking the dog
6	Library	1:30pm-3:13pm	Sitting
7	Home	3:19pm-4:00pm	Sitting
8	YMCA	4:27pm-6:30pm	Exercising
9	Mall	7:02pm-8:26pm	Shopping
10	Home	8:55pm-11:59pm	Sitting

Accelerometer **TIME OFF:** 9 : 46 P.M.

Travel/Activity Purpose Diary

Accelerometer **TIME ON:** \_\_\_\_\_:\_\_\_\_\_ A.M.

<b>Date:</b>	<b>Location/Place</b>	<b>Time at Location (minutes)</b>	<b>Type of activity</b>
<b>Location (#)</b>			
1	Home	12:00am- _____	
2			
3			
4			
5			
6			
7			
8			
9			
10			

Accelerometer **TIME OFF:** \_\_\_\_\_:\_\_\_\_\_ P.M.



**viii. ACTIVITY MONITORS (ACCELEROMETER AND GPS RECEIVER)**

ActiGraph GT1M accelerometer (actual size):



GPS receiver (actual size):



(view from above)



(side view)

APPENDIX D

MAPS DATA PROCESSING FORM

# MAPS Data Form

Participant ID: \_\_\_\_\_

Day #: \_\_\_\_\_

Date:	Type of Place	Latitude (X)	Longitude (Y)	Time (minutes)	Physical Activity Count (Intensity)	Steps (Volume)	Travel Time (minutes)	
Location (#)								
1								
2								
3								
4								
5								
6								
7								
8								
9								
10								
11								
12								

TOTAL TIME (1440): \_\_\_\_\_

Total PA counts: \_\_\_\_\_

Total time at \_\_\_\_\_

locations:

Total PA \_\_\_\_\_

Total time at home: \_\_\_\_\_

locations:

Total PA home: \_\_\_\_\_

Total Travel Time: \_\_\_\_\_

Total Step counts: \_\_\_\_\_

Total Locations: \_\_\_\_\_

Total Steps \_\_\_\_\_

Instrumental Trips: \_\_\_\_\_

locations:

Total Steps home: \_\_\_\_\_

Discretionary Trips: \_\_\_\_\_

MAPS<sub>I</sub>: \_\_\_\_\_

MAPS<sub>V</sub>: \_\_\_\_\_

KEY:

**Total PA Counts** = PA count total from excel file

**Total PA locations** = sum of PA counts for all locations

**Total PA home** = sum of PA counts at home

**Total Step Counts** = Step count total from excel file

**Total Steps locations** = sum of step counts for all locations

**Total steps home** = sum of steps counts at home

**Total time at locations** = sum of time at all locations

**Total time at home** = sum of all time at home

**Total Travel time** = sum of all travel times

**Total Locations** = total trips away from home

**Instrumental trips** = number of trips with instrumental purpose (e.g., grocery store, work, doctor, dropping off/picking up child from school/practice etc.)

**Discretionary trips** = number of trips with discretionary purpose (e.g., shopping at mall, restaurant, walk, park, library, movies, etc.)

**MAPS<sub>I</sub>** = MAPS Intensity Score

**MAPS<sub>V</sub>** = MAPS Volume Score

**APPENDIX E**

**RECRUITMENT FLYER AND WEB ADVERTISEMENT**

# Are you 65 years or older?



Physical Activity and Behavior Lab  
Kinesiology Department- UMass Amherst

## Real-World Function in Older Adults

### Eligibility:

- Men or Women 65+ years old
- Ambulatory without aid
- Free of conditions that affect walking (i.e. stroke)



### Study Requirements:

- Two testing sessions
- Complete a few questionnaires, a brief walking test, several cognitive performance tasks and wear two small physical activity monitoring devices for five days

Participants will be paid \$15

For more information please contact  
Andrea Morand by phone (413-545-6007) or email  
([REALWORLDfunction@gmail.com](mailto:REALWORLDfunction@gmail.com))

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## Website Advertisement

### Real-World Function of Older Adults

Andrea Morand of the University of Massachusetts Amherst is conducting a study to examine the relationship between cognitive function and a newly developed measure of functional-living (Movement and Activity in Physical Space [MAPS] score). MAPS measures how older adults function in their real-world environment. Two testing sessions will take place at the Physical Activity and Behavior Lab (Totman Building) on the UMass Amherst campus. A packet of questionnaires, brief walking test and cognitive testing will be completed. Participants will wear two small monitoring devices for 5 days to measure individuals' movement within their real-world environment. A week later the second session will take place during which the activity monitors will be returned and a few questionnaires will be completed. Study participation is voluntary and all information is confidential. Eligible participants must be (1) men or women age 65 years or older, (2) ambulatory without aid, (3) free of any conditions that affect walking, and 4) capable of completing a brief cognitive task at time of screening.

Please contact Andrea Morand by email ([REALWORLDfunction@gmail.com](mailto:REALWORLDfunction@gmail.com)) or telephone (413-545-6007) for further information about participating in the study.



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