PERCEIVED ALZHEIMER'S DISEASE THREAT AS A PREDICTOR OF BEHAVIOR CHANGE TO LOWER DISEASE RISK: THE GRAY MATTERS STUDY

by

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ABSTRACT

Perceived Alzheimer's Disease Threat as a Predictor of

Behavior Change to Lower Disease Risk:

The Gray Matters Study

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Alzheimer's disease is a growing public health concern with the current number afflicted of 5 million in the US expected to triple by 2050. Since there is currently no cure or preventive pharmacological treatment, AD prevention research is now recognized as an important enterprise, with a goal to identify modifiable lifestyle factors that can reduce AD risk or delay its onset. Among these, increased physical activity, healthier food choices, more cognitive stimulation, better sleep quality, stress management, and social engagement have been identified as reasonable targets for behavioral intervention. A smartphone application-based behavioral intervention targeting these six behavioral domains was recently developed and a six-month randomized controlled trial was conducted, both to determine feasibility and compliance with technology usage and to test its efficacy. This study, titled the Gray Matters Study, was conducted in Cache

County, Utah, enrolling a sample of 146 middle-aged participants (aged 40 to 64 years) randomized to treatment or control condition. Under the Health Belief Model, individuals who perceive a greater susceptibility to a particular health condition are hypothesized to be more likely to engage in more positive behaviors to reduce disease risk. Following this model, perceived threat of AD (operationalized by fear of AD, family history of AD, and metacognitive concerns) was examined for prediction of behavioral change over the six-month Gray Matters intervention period in these same six behavioral domains. Persons with a moderate level of fear of AD made significantly greater improvements in physical activity than those with low or high levels of fear. Family history was not a significant predictor of health-related behavioral change. However, persons with a moderate level of metacognitive concerns made significantly greater improvements in both physical activity and food quality than those with low or high levels of concerns. This is the first study to examine these psychological constructs related to AD risk and the extent to which they predict health-related behavior change. Future studies should extend the length of follow-up to at least one full year, include a more diverse sample of participants to expand generalizability, and build upon these findings to personalize supportive behavioral change interventions in order to be sensitive to these psychological factors.

(141 pages)

PUBLIC ABSTRACT

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Christine J. Clark

Alzheimer's disease is a growing public health concern with an estimated five million Americans currently afflicted. That number is projected to triple by 2050 as the baby boomer generation approaches age 65, the most common age where people begin to show symptoms of cognitive decline stemming from changes in the brain related to Alzheimer's. Since there is currently no cure or preventive pharmacological treatment, AD prevention research is now recognized as an important enterprise. Modifiable lifestyle factors that can reduce AD risk or delay its onset have been identified as reasonable targets for behavioral intervention, including increased physical activity, healthier food choices, more cognitive stimulation, better sleep quality, stress management, and social engagement.

Accordingly, the current investigation examined important psychological constructs related to perceived AD risk and the extent to which they predict health-related behavior change. Data were used from the Gray Matters Study, a smartphone application-based behavioral intervention targeting these six behavioral domains that was recently conducted in Cache County, Utah, following 146 middle-aged adults over six

months. A better understanding of the impact of these psychological factors will help future interventions become more effective.

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Watching a loved one die from Alzheimer's disease can be terrifying. In my case it ignited a resolve to learn everything I could about how to reduce the probability of that happening to me or anyone else in my family. Dr. Maria Norton gave me the opportunity of a lifetime to work with her, even though I was 59 years old at the beginning of this endeavor and had limited background in scientific research. I offer my sincere and heartfelt thanks for her persistence, enthusiasm, and endlessly patient mentoring that carried me through to the final page. Special thanks to my committee members, Drs. Beth Fauth, JoAnn Tschanz, Julie Gast, Kathy Piercy, and Travis Dorsch, for their assistance in developing and refining this project. Finally, I am indebted to my children for their encouragement and my husband for his unwavering support.

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CHAPTER I

INTRODUCTION

Alzheimer's Disease as a Public Health Crisis

The number of Americans age 65 and older is growing at a rate that is unprecedented (Vincent, 2010). As the population of the U.S. ages, Alzheimer's disease (AD), the most common cause of cognitive impairment and dementia in older adults, is projected to reach 16 million by the year 2050 ("2015 Alzheimer's Disease Facts and Figures," 2015).

The financial and social costs of AD are staggering. When the financial burden of unpaid care provided by informal caregivers is included, dementia care costs are estimated at more than $200 billion in the United States annually, forcing Medicare and Medicaid to cover increasingly larger portions of an individual's long-term care (Daviglus et al., 2010). In 2014, average Medicaid payments per person for Medicare beneficiaries with AD and other dementias were 19 times greater than payments for individuals without AD, making AD one of the costliest chronic diseases in America ("2015 Alzheimer's Disease Facts and Figures," 2015).

AD is perhaps even more costly in terms of its human impact. The long-term debilitating effects of dementia can cause a heavy financial and emotional strain on patients and their families and friends, eliciting stress, loss of relationships, and heavy burdens of daily care. Many studies have documented these issues and have found them to be cross-cultural and of global concern (Ivey et al., 2013; Ngandu, Mangialasche, &

Kivipelto, 2014; Rodríguez-Gómez, Palacio-Lacambra, Palasí, Ruiz-Laza, & Boada-Rovira, 2014).

Since there is currently no cure or preventive pharmacological treatment, one focus of AD research has expanded to include AD prevention through adoption of healthy lifestyle behaviors (Rodríguez-Gómez et al., 2014). A great deal of research is now dedicated to finding effective strategies for AD risk reduction by targeting individuals before the onset of observable clinical symptoms (Barnett, Bahar-Fuchs, Cherbuin, Herath, & Anstey, 2015).

Maintaining cognitive health throughout the lifecourse has been a subject of increasing concern, not only within members of the population designated as older adults, but also among health services personnel, political entities, and the research community (Hughes & Ganguli, 2009). With public campaigns such as "The Healthy Brain Initiative: A National Public Health Road Map to Maintaining Cognitive Health," to bring healthy aging into the spotlight, the importance of primary prevention research to meet these goals has been firmly established (Anderson & Egge, 2014).

In 2011, the National Institute on Aging (NIA) and the Alzheimer's Association (AA) collaborated to produce new AD diagnostic guidelines that featured two main additions to the previous recommendations in use by researchers since 1984 (McKhann et al., 2011). First, AD was conceptualized as occurring in three stages, beginning with a preclinical phase that could last more than 20 years before the onset of clinical symptoms. Second, the panel suggested using measureable biomarkers (such as levels of beta-amyloid and tau in cerebrospinal fluid and blood) as indicators of absent or likely AD neuropathology, or as indicators of higher risk for developing the disease.

This recommendation highlights the unusual nature of AD diagnosis in relation to other diseases such as cancer. Diagnostic protocol for cancer typically involves the detection of pathological changes that signal disease onset. It becomes problematic to use this protocol for dementia, however, given the fact that pathological changes in the brain may not cause observable clinical symptoms for decades, a mechanism that is not well understood (Solomon, Kivipelto, & Soininen, 2013). Thus, there has been a major shift in emphasis from prevention of pathological disease to primary prevention of cognitive impairment beginning in midlife (Hughes & Ganguli, 2009; Latimer, 2011; Solomon et al., 2013). Recent epidemiological studies have identified associations between AD and modifiable risk factors linked to late-life dementia.

In 2010, the U.S. National Institutes of Health published an independent state-of-the-science report, reviewing 250 observational studies and randomized controlled trials (RCTs) for evidence related to risk factors for AD and cognitive decline (Daviglus et al., 2010). Although the report highlighted many limitations of the original studies in terms of heterogeneous research designs and methodology, several potentially modifiable factors were identified as being associated with increased risk of cognitive decline (Barnes & Yaffe, 2011). These included diabetes mellitus, smoking, depression, poor cognitive stimulation, lack of physical activity, and unhealthy diet.

Since that time many researchers have taken up the challenge by the NIH to address the critical need for large-scale population-based studies and RCTs that will explore how best to promote healthy lifestyles that may reduce AD risk (Daviglus et al., 2010). Since the original NIH report in 2010, stress management and sleep quality have been added to the NIH list of risk factors (Arab & Sabbagh, 2010; Barnard et al., 2014;

Buscemi, Steglitz, & Spring, 2012). Multidomain preventive interventions targeting several risk factors simultaneously are now believed to be the most effective research design for this new focus (Anstey, Bahar-Fuchs, Herath, Rebok, & Cherbuin, 2013; Rodríguez-Gómez et al., 2014).

The RCT is an experimental design yielding the strongest internal validity for detecting effectiveness of an intervention. There are three RCTs that have begun in Europe featuring this optimal multidomain design (Anstey et al., 2013; Kivipelto et al., 2013). All of these interventions have focused on older adults or middle-aged persons at higher risk for AD. Specifically, the Finnish Geriatric Intervention Study to Prevent Cognitive Impairment and Disability (FINGER), Multidomain Alzheimer prevention study (MAPT), and Prevention of Dementia by Intensive Vascular Care (preDIVA) are three large RCTs that have explored AD prevention. FINGER has been studying 1260 community dwellers between 60-77 years of age with a double blind, parallel-group design. MAPT is based in France and has been working with 1680 participants, 70 years of age or older who have subjective memory complaints. The preDIVA study originates in the Netherlands and has had a multisite, cluster randomized study design featuring 3700 subjects between 70-78 years of age. All three studies have included healthy lifestyle components such as nutritional guidance and physical exercise advice with primary outcomes determined by a change in cognitive function.

While much of the emphasis of these recent multidomain interventions has been focused on either nurse-led intensive vascular care (preDIVA) or nutritional and exercise counseling, little is known about underlying psychological factors that may predict behavior change in similar circumstances, such as a perceived threat of AD. For

purposes of the current research, perceived AD threat has been defined as fear of AD, family history of AD, and metacognitive concerns. These variables have been operationalized this way in an attempt to describe different types of experiences a person might have in relation to AD. While the literature specifically linking these variables to behavior change in the context of AD is currently missing, there is much that is known about how perceived risk of disease affects health behaviors in other realms such as cancer and cardiovascular disease (Borreani et al., 2014).

The purpose of this study is to examine the extent to which perceived threat of AD in middle-aged adults is associated with subsequent behavioral changes in a range of health-related behavioral domains. Data from a recent lifestyle behavioral intervention RCT conducted in northern Utah were used for this study.

CHAPTER II

LITERATURE REVIEW

This chapter will examine empirical and theoretical research that will serve as a framework to better understand how perceived risk of Alzheimer's disease (AD) predicts health behavior change. A large body of literature on AD prevention research, health behavior change, and perceived AD risk provides a basis for the present study.

Alzheimer's Disease as a Public Health Crisis

It is estimated there are currently 5.3 million Americans who live with late-onset or sporadic AD and that every 67 seconds another person is diagnosed ("2015 Alzheimer's disease facts and figures," 2015). AD is the most common cause of dementia and is believed to account for 60-80% of the symptomatology associated with cognitive decline in late life, including one of the most feared symptoms: an inability to form new memories resulting in a loss of identity (Daviglus et al., 2010).

Advances in medicine and medical technology have brought about a significant increase in average life expectancy in the United States, now approaching 80 years according to a recent government report (Arias, 2014). Americans are surviving into their 80s, 90s, and beyond in increasing and unprecedented numbers. However, because advanced age is the most salient predictor of AD, one-third of all persons 65 and older who die in a given year have been diagnosed with AD or another type of dementia and one in nine older Americans currently have the disease ("2015 Alzheimer's disease facts and figures," 2015).

Improved living conditions have reduced mortality rates from infectious diseases but chronic conditions due to neurodegenerative processes have surfaced to become the new epidemics of the 21st century. In 2014 the United States Centers for Disease Control and Prevention released a report assessing recent progress in meeting high-priority national health objectives (Johnson, Hayes, Brown, Hoo, & Ethier, 2014). Researchers found that age-adjusted mortality rates had declined among eight of the ten leading causes of death, including breast cancer, prostate cancer, heart disease, stroke, and HIV. Only deaths attributable to AD and suicide have increased (Johnson et al., 2014).

Prevalence of AD is expected to triple over the next 40 years, with worldwide incidence increasing to over 100 million and U.S. projections around 15 million (Barnes & Yaffe, 2011). In the United States and other countries worldwide, this is partly driven by the demographics of the Baby Boomer generation who are approaching age 65, an age category at which late onset AD has been defined. Baby Boomers comprise an unusually large segment of the population and as they grow older, demographers are predicting a "silver tsunami," referring to the complex and expensive health conditions that often afflict adults as they age (Comlossy & Walden, 2013). Politicians and health care workers are preparing for the onslaught of needs from this birth cohort as they make demands on a healthcare system that is already under maximum stress. When the first wave of Baby Boomers reaches age 85 in 2031, statistical analyses predict that more than 3 million people age 85 and older will have AD. That figure could reach as high as 7 million by 2050 ("2015 Alzheimer's disease facts and figures," 2015). Thus, AD is widely considered to be a public health crisis and there is increasing urgency to find ways to reduce AD incidence.

Factors Related to AD Prevention Research

Because there is currently no cure for AD, much discussion has recently been focused on the topic of preventive measures to reduce AD risk. In this review, several trends of interest to the proposed study have been evaluated (i.e., papers concerning new guidelines and recommendations for AD diagnosis, studies exploring AD risk factors, and those involving recent AD prevention research trials).

Recent Changes in AD Diagnostic Criteria

The literature shows two main trends in researchers' discussions as they have explored different factors relating to AD prevention research. Specifically, these are the revised AD diagnostic indicators and the importance of defining different levels of prevention outcomes.

Updated AD diagnosis criteria and guidelines. In 2011, the National Institute on Aging (NIA) and the Alzheimer's Association (AA) proposed a new set of criteria to help researchers and clinicians diagnose Alzheimer's and related dementias (McKhann et al., 2011). These recommendations were intended to update the diagnostic criteria that had been in place since 1984 (McKhann et al., 1984). Shortly thereafter, another workgroup sponsored by the NIA and AA produced a different set of recommendations for pathologists to use when exploring evidence of physiological changes in the brain (Hyman et al., 2012). The differences between the updated recommendations and the previous criteria illustrate the progress that has been made in the ability to understand neuropathological changes in the brain and their association with cognitive function.

Three decades ago, AD was defined by a clinical manifestation of memory impairment, considered to be the main feature of AD, and the diagnosis was made after all other possibilities had been ruled out (McKhann et al., 1984). The new criteria and guidelines feature two important changes. First and most importantly in terms of its effect on current AD prevention research, is the identification of three stages of AD, defined as preclinical AD, mild cognitive impairment (MCI) due to AD, and fulminant dementia that includes a significant decline in a person's functional abilities (McKhann et al., 2011). The initial stage is manifested before symptoms such as memory loss become observable, and suggest the importance of prevention efforts.

The second change is the recommendation that researchers include biomarker tests such as genetic, neuroimaging, and cerebrospinal fluid markers, to add an *in vivo* aspect to AD diagnosis instead of relying on postmortem guidelines (Hyman et al., 2012). In a review article from the 9th Key Symposium of the Royal Swedish Academy of Sciences held in Stockholm in December 2012, Solomon and colleagues (2012) discussed the shift towards preclinical stages of AD and the impact of diagnostic reliability on preventive research strategies. Their conclusion was that future studies should be focused specifically on AD and cognitive impairment rather than as a secondary add-on to studies exploring diseases with similar pathologies. They also maintained that preventive research should be tailored to different groups at risk of dementia and that the groups should be defined according to age, vascular, metabolic and/or lifestyle profiles, using various biological markers and evidence of cognitive status (Solomon et al., 2014).

Many other researchers agree with this assessment and have produced papers to this effect. A recent study noted that the new guidelines highlight the long prodromal phase of AD (up to 20 years), opening up new possibilities for early intervention (Imtiaz, Tolppanen, Kivipelto, & Soininen, 2014). Some researchers have even suggested that brain health and adopting a healthy lifestyle should start in utero and continue throughout the entire lifespan (Barnett, Hachinski, & Blackwell, 2013). In a state-of-the-science conference statement, Daviglus and colleagues (2010) declared that large-scale population-based studies and RCTs are critically needed to investigate strategies that can maintain cognitive health in a large-scale population. Also needed are studies to verify AD protective factors that may delay onset or slow cognitive decline in persons with a pathological AD trajectory, foreshadowing the recently defined stages of AD (Daviglus et al., 2010).

Levels of prevention: Primary, secondary, tertiary. As AD diagnostic criteria have expanded, questions have also been raised about how prevention levels should be defined (Solomon et al., 2014). Unlike tertiary prevention which is focused on ways to slow clinical progression after onset, or secondary levels of prevention that seek to detect the disease at an early stage after neurodegeneration has begun, primary prevention for dementia centers around reducing an individual's risk of disease before any evidence of cognitive decline has manifested. This is accomplished either by encouraging the initiation and maintenance of a healthy lifestyle or by eliminating potential causes of AD (Han & Han, 2014).

In a review article that details the history of drug development for treatment of AD over the last thirty years, Schneider and colleagues (2014) explained that there is a

more than 95% failure rate in this effort and currently no pharmacological treatment exists that will slow or stop the disease (Schneider et al., 2014). With the new conceptual framework of AD as a process that begins decades before the onset of clinical symptoms, the focus has changed to include prevention campaigns as a *complement* to finding a cure. Now it makes sense to discuss the possibility of primary prevention in cognitively normal individuals who have no clinical evidence of the plaques and tangles that were discovered by Alois Alzheimer over one hundred years ago (Rodríguez-Gómez et al., 2014).

Part of the difficulty in designing prevention research, however, stems from the lack of understanding about the time lapse between pathological evidence in the brain and clinical manifestations of the disease. Up to 30% of subjects who were cognitively normal while alive have been found consistently to have a pathological profile that would qualify for an AD diagnosis (Vemuri et al., 2011). Accordingly, the new consensus among researchers is that it may be more relevant to focus on preventing cognitive impairment than preventing pathological changes in the brain when in some instances those changes have little relationship with cognitive dysfunction (Daviglus et al., 2010; Solomon et al., 2014; Vemuri et al., 2011). Treatment should also target cognitively intact individuals (Meng et al., 2014). Therefore, primary prevention of AD has become a research priority.

Risk Factors for Late-Onset Alzheimer's Disease

Alzheimer's disease is now recognized as a many-faceted disease that is complicated by interrelated genetic and environmental factors (Hughes & Ganguli, 2009).

There are many studies in support of a number of proposed risk and protective factors related to cognitive decline. This review will focus specifically on cardiovascular, genetic, and lifestyle factors related to risk of AD or cognitive decline.

Cardiovascular. The highly correlated relationship between cardiovascular risk factors and cognitive decline has led to the saying, 'What's good for the heart is good for the brain' (Clerici, 2014; Hughes & Ganguli, 2009). For example, Whitmer and colleagues (2005) found that hypertension, high cholesterol, and diabetes at midlife, (defined as between 45 and 65), were each associated with a 20 to 40% increase in risk of dementia. Fully adjusted Cox proportional hazards model were HR 1.24, 95% CI 1.04 to 1.48 for hypertension, HR 1.42, 95% CI 1.22 to 1.66 for high cholesterol, and HR 1.46, 95% CI 1.19 to 1.79 for diabetes (Whitmer, Sidney, Selby, Johnston, & Yaffe, 2005). In a review article with the aim to determine which of those factors imposes the greatest risk, it was found that at midlife (defined as age 45-64), the risk of dementia was highest for hypertension, accounting for up to 30% of cases of late-life dementia. Later in life (defined as age < 65), type 2 diabetes carried the highest risk (Kloppenborg, van den Berg, Kappelle, & Biessels, 2008). In the FINMONICA study (Kivipelto et al., 2005), midlife high systolic blood pressure (BP) nearly doubled risk of late life AD while in the Honolulu-Asia Aging Study (HAAS) of Japanese-American men (Launer et al., 2000), high diastolic BP increased the risk of AD by four times, results that have led many community-based interventions to use BP as an indicator of AD risk (Clerici, 2014). Anti-hypertensive treatments seem to reduce the risk of progression from MCI to AD in a recent observational study conducted with 837 subjects (Li et al., 2011).

Another vascular factor, cerebrovascular accident or stroke, is also linked to higher dementia risk. The midlife (mean age at baseline of 55.6) risk for stroke in a British cohort as measured by the Framingham stroke risk profile (which includes age, systolic blood pressure, treatment for hypertension, diabetes, smoking, and prior cardiovascular disease) resulted in a 6% increased risk of dementia 10 years later (Kaffashian et al., 2013). In summary, many longitudinal studies have identified midlife cardiovascular risk factors that can increase the risk of cognitive decline/dementia in late life (de la Monte & Tong, 2014; Imtiaz et al., 2014).

Genetic. There are two main genetic factors that are thought to be related to AD. One is a rare genetic mutation in any of three genes known as early onset AD (Solomon et al., 2013). These mutations involve the gene for the amyloid precursor protein and the genes for the presenilin 1 and presenlin 2 proteins. Inheriting any of these genetic mutations is highly determinant that an individual will develop AD, usually before age 65 and sometimes as early as age 30. Only about 5% or less of AD cases are of this type where a gene brings on the disease with that degree of certainty (Combarros, 2014). The vast majority of individuals with AD have late-onset AD, otherwise referred to as "sporadic" AD, occurring at age 65 or later. The allele 4 of the apolipoprotein E (APOE) gene on chromosome 19 has been identified as a major risk factor (Daviglus et al., 2010).

Genetic factors play an important role, with the Ɛ4 allele at the APOE polymorphic locus being the strongest genetic marker identified to date for sporadic AD (Ridge, Mukherjee, Crane, & Kauwe, 2013). It is estimated that common genetic variants known today account for roughly 30% of variance in risk for AD (Ridge et al.,

2013), implying that a substantial portion of risk may be the result of modifiable environmental or lifestyle factors as described below.

Lifestyle. Recent research in AD prevention provides recommendations in dietary and lifestyle factors associated with AD (Barnard et al., 2014; Rodríguez-Gómez et al., 2014). The modifiable part of AD pathology also includes risk factors such as education, including participating in stimulating cognitive activities, physical activity, dietary factors, social interactions, sleep quality, and stress management (Arab & Sabbagh, 2010; Yaffe, Hoang, Byers, Barnes, & Friedl, 2014).

Higher levels of education have been found to be associated with a delay in the onset of AD by about seven years (Amieva et al., 2014) with the mechanism thought to be related to a concept called "cognitive reserve," a theory that suggests individuals with higher cognitive reserve have a greater capacity to weather preclinical pathological changes in the brain associated with AD than those with low cognitive reserve (Vemuri et al., 2011). In a meta-analysis of studies examining whether cognitive reserve could be increased through participation in cognitively stimulating activities, results showed evidence that education, occupation, and leisure or mentally stimulating activities added to cognitive reserve as a protective factor against dementia (Harrison et al., 2015).

Regular exercise has been associated with a 32% reduction in risk for dementia in persons 65 years and older (Larson et al., 2006) while a recent cohort study of 19,458 community-dwelling individuals revealed higher midlife fitness levels were associated with a 36% lower hazards of developing dementia later in life (Defina et al., 2013). Another study using the Swedish Twin Registry found that exercise at midlife may

reduce the odds of AD in older adulthood by 50%, recommending exercise interventions for midlife populations at risk of AD (Andel et al., 2008).

Dietary patterns have been found in multiple studies to have an association with AD risk. Researchers have found that individuals who adhere to a Mediterranean-type diet appear to be 40% less likely to develop AD (Scarmeas et al., 2009). Other guidelines include replacing meats and dairy products with vegetables, legumes, fruits, and whole grains as primary dietary staples (Barnard et al., 2014). Many studies concur that adherence to a Mediterranean diet or other dietary pattern rich in fruits and vegetables have a protective effect against dementia (Hughes, 2008; Hughes & Ganguli, 2009; Knopman, 2009). The MIND diet, which is a hybrid between the Mediterranean diet and the Dietary Approaches to Stop Hypertension (DASH) diet has also been shown to reduce incidence of AD (Morris et al., 2015).

Social engagement refers to an "enriched environment" (Crowe, Andel, Pedersen, Johansson, & Gatz, 2003). In this regard, the ability to network with other individuals in a positive sense, promoting cognitively enriching and challenging relationships, is believed to be protective for cognitive decline (Ellwardt, Van Tilburg, & Aartsen, 2015). Being socially engaged in a group setting seemed to have a significant and sustained positive effect on subsequent cognitive function in a large-scale panel study of 3,413 participants age 50 years and older (Haslam, Cruwys, & Haslam, 2014), and higher reported social support has been positively associated with cognitive function in middle-aged adults (Seeman et al., 2011; Zuelsdorff et al., 2013).

Insomnia is a common complaint among adults and it is well known that a lack of sleep can impair cognitive performance (Benedict et al., 2015). Sleep quality and sleep

quantity have been studied recently as a predictor of AD. A study using formal polysomnography to eliminate the validity issues connected with self-report found that subjects with poor sleep had a 5.6-fold increased risk of Abeta accumulation levels in the brain which may predict future onset of AD (Segal, 2013). A review of recently published studies reported that decrements in slow-wave sleep may decrease the clearance of Abeta from the brain and hypoxemia characteristic of sleep-disordered breathing increases Abeta production. These are indicators that poor sleep is a risk factor for cognitive decline and AD (Spira, Chen-Edinboro, Wu, & Yaffe, 2014).

Psychological stress is associated with numerous diseases including depression, hypertension, cardiovascular disease, cognitive decline and AD (Galla, O'Reilly, Kitil, Smalley, & Black, 2015). Experimental studies have examined potential mechanisms linking stress and AD, finding that exposure to stress is associated with production and accumulation of Abeta and tau protein which are known to be the neuropathological hallmarks of AD (Swerdlow, Burns, & Khan, 2014). Alternate biological mechanisms to explain the association between stress and AD involve neuroinflammation, another factor observed in AD-related pathological changes in the brain (Galla et al., 2015; Sultana & Butterfield, 2010; Wang et al., 2014).

In animal studies, psychological stressors were observed to cause hippocampal and cortical cell deaths (Zhao, Xu, Xu, & Young, 2007) and reduced neurogenesis of cells in the denate gyrus of the hippocampus (Herbert et al., 2006). Human studies have shown that prolonged exposure of older, non-demented individuals to stress is associated with decreased performance on memory tasks (Peavy et al., 2007) and hippocampal atrophy (MacLullich et al., 2005). In summary, a thorough understanding of evidence-

based factors associated with reducing AD risk is important to effectively structure multidomain lifestyle behavior interventions.

Prevention trials for Alzheimer's Disease

As explained in the NIA 2010 State-of-the-Science report, previous single domain RCTs aiming to prevent AD have produced inconclusive results with much methodological heterogeneity (Plassman, Williams, Jr., Burke, Holsinger, & Benjamin, 2010). Because AD has a multifactorial etiology and a number of modifiable factors associated with risk, conducting RCTs with multidomain interventions was also recommended (Daviglus et al., 2010). To date, several primary prevention trials with multidomain designs have been conducted in Europe and the United States. These trials include the Finnish Geriatric Intervention Study to Prevent Cognitive Impairment and Disability (FINGER), the Multidomain Alzheimer Prevention Study (MAPT), Prevention of Dementia by Intensive Vascular Care (PreDIVA), and the Body Brain Life Program (BBLP).

The FINGER study is a multicenter, randomized, controlled trial (RCT) with 1,260 individuals aged 60-77 who scored high on dementia risk factors that included hypertension, high cholesterol, and obesity (Kivipelto et al., 2013). The two-year multidomain intervention consisted of nutritional guidance, exercise, cognitive training, social activity, and management of metabolic and vascular risk factors through scheduled sessions with health coaches. Participant study diaries were an important component of the trial. The primary outcome was cognitive performance as measured by the modified Neuropsychological Test Battery assessing executive function, Stroop test, and Trail

Making Test. Main secondary outcomes were dementia, disability, depressive symptoms, vascular risk factors and outcomes, quality of life, and neuroimaging measures. The intervention was recently completed and preliminary findings suggest that a multidomain intervention could improve or maintain cognitive functioning in a population of at-risk older people. The intervention group also reported exercising more and eating more fish and vegetables than controls, improving quality of life that promises sustainability. Researchers will conduct a follow-up study in five years (Ngandu et al., 2015).

The MAPT study is a three-year RCT, also with a multicenter design, led by Bruno Vellas of the University Hospital Center in Toulouse, France. MAPT encouraged modification of lifestyle factors in addition to offering omega-3 fatty acid to prevent cognitive decline in people at risk. It enrolled 1,680 subjects (mean age 75.3 years) through 13 memory clinics. The participants were randomized into one of the following four groups: omega 3 alone, multidomain intervention alone, omega 3 plus multidomain intervention, or placebo. The intervention involved weekly or monthly counseling and in-session activities with experts in nutritional, exercise, and cognitive domains. Participants tracked their compliance with study protocols in a personal journal (Gillette-Guyonnet et al., 2009). The primary endpoint was a change in memory function at 3 years as assessed by the Free and Cued Selective Reminding test. Results are pending (Vellas et al., 2014).

The PreDIVA study is a cluster-randomized trial with the aim to determine whether the incidence of sporadic AD and cognitive decline can be reduced by intensive nurse-led treatment of vascular risk factors. Half of the participants received standard care from general practitioners and the other half saw a nurse for intense monitoring and

treatment if indicated. This included treatment of hypertension, hypercholesterolemia, and diabetes as well as behavior change coaching in weight loss, smoking cessation, and physical activity. The study enrolled 3,534 older individuals ages 70-78 at 26 primary health care centers in the Netherlands. Participants were seen in a clinic setting every four months for six years (Richard et al., 2009). Data collection concluded in the spring of 2015. Analysis of data for the primary outcome measure is pending with results expected in 2016 (Ligthart, Richard, van Gool, & Moll van Charante, 2012).

The Brain Body Life (BBL) project is a 12-week, single-blind RCT online AD risk-reduction intervention conducted in Australia with the aim of assessing the effectiveness of online health interventions in changing behavior, including alcohol use and smoking. One of the study goals was to explore the potential of online interventions that could provide large-scale implementation at a sustainable cost when compared to traditional nurse or other health care professionals in face-to-face (FF) delivery systems. The ability to customize intervention protocols through this medium was also a specific aim. Participants were 176 cognitively healthy adults (ages 50-60) who met at least three of the following AD risk factors: educational level of high-school or less, sedentary lifestyle, overweight or obese body mass index (BMI), low consumption of fish, low cognitive or social engagement, or a history of diabetes, hypertension, high cholesterol, mild to moderate traumatic brain injury, smoking, or depression. These participants were then randomly assigned to either a treatment group receiving seven online modules (dementia literacy, risk factor education, engagement in physical, social, and cognitive lifestyles, nutrition, and health monitoring), online modules plus face-to-face (FF) interaction with small group meetings, or an active control group receiving weekly email

links to relevant health information (Anstey et al., 2013a). The study also created a methodology for a self-report Alzheimer's Disease Risk Index called the Australian National University Alzheimer's Disease Risk Index (ANU-ADRI), reported as an AD risk assessment tool (Anstey, Cherbuin, & Herath, 2013b). Results found cognitive activity ($p = 0.03$) and fish intake ($p = 0.002$) both increased at six months from baseline levels. The ANU-ADRI risk score was significantly improved with online + FF group z = -0.48, $p = < 0.001$ and online only group z = -0.28, $p = 0.004$, compared to control group, due to increased protective factors (Anstey et al., 2015).

In summary, much can be learned through multidomain interventions. However, nearly all of these studies focus on older adults or, as in the case with the BBL study, on middle-aged individuals with at least three known risk factors for AD. More multidomain interventions are needed that target a healthy midlife population in order to provide recommendations designed to prevent cognitive decline and offer assistance with compliance and maintenance of improved lifestyle behaviors (Imtiaz et al., 2014).

Technology Use in Intervention Research

Encouraging individuals to change multiple domains of their lifestyle has inherent challenges, however, and employing a variety of intervention modalities may improve the odds of successful implementation. A new format for health behavior change interventions that reports positive results is an online delivery system (Anstey et al., 2013a). Other forms of information delivery and feedback loops include text messaging (Gold, Lim, Hellard, Hocking, & Keogh, 2010), health and fitness apps for cell phones and tablets (Lister, West, Cannon, Sax, & Brodegard, 2014) and video games for home

consoles (Lyons & Hatkevich, 2013). Internet- or technologically-delivered interventions are likely to increase in importance because they have the potential to reach a much wider group of individuals within a population than is currently possible using costly face-to-face interactions with clinical personnel. These innovative approaches also allow customization opportunities that can tailor an intervention protocol to an individual participant's needs (Cugelman, 2013). When combined with elements of traditional interventions that involve clinical settings, the possibility of creating effective strategies to reduce risk of chronic diseases such as AD is likely to be increased (Cugelman, 2013).

Factors Related to Health Behavior Change

Behavioral interventions in the context of health may achieve very little if not conducted with careful consideration as to what motivates individuals to modify lifestyle behaviors that may be quite resistant to change. These challenges are exacerbated when multiple lifestyle behaviors are targeted (Lippke, Nigg, & Maddock, 2012). Studies have found that risk behaviors can cluster within individuals (King et al., 2015), with clustering defined as co-occurring behaviors that are known risk factors for certain diseases. Recent studies have also shown that interventions are more likely to affect behavior change when multiple risk behaviors are addressed, most commonly smoking, unhealthy diet, physical inactivity, and alcohol misuse (Prochaska, Nigg, Spring, Velicer, & Prochaska, 2010). In an attempt to identify which components were successful facets of interventions for multiple health behavior change in adults at high risk for cancer, a meta-analysis was conducted that found most of the 10 interventions reviewed had successfully changed at least two health behaviors, diet and exercise, using in-person

interviews (Green, Hayman, & Cooley, 2015). An RCT conducted in the UK with the aim of changing lifestyle behaviors for 478 patients recently diagnosed with type 2 diabetes concluded that the facilitator-led and individually customized intervention did improve self-reported lifestyle change objectives relative to diet and exercise (Griffin et al., 2014). Intention to change and co-occurrence of four key lifestyle behaviors (specifically, inadequate fruit and vegetable consumption, excessive dietary fat, excessive sugary beverages, and inadequate physical activity in comparison to public health recommendations) were studied in an Australian cohort (n = 105) with results indicating that the majority of participants (66%) were willing to target only two risk behaviors, with the most popular pairings of behaviors focused on inadequate fruit/vegetable intake and excessive dietary fat (Cook, O'Leary, Chey, Bauman, & Allman-Farinelli, 2013). Individuals with better cognitive and physical functioning and higher SES were found to have a stronger preference for AD prevention (Chung, Mehta, Shumway, Alvidrez, & Perez-Stable, 2009). Factors such as these need to be considered when structuring multidomain interventions targeting reduction of AD risk-related lifestyle changes.

Factors Related to Perceived Alzheimer's Disease Risk

The proposed research will use a construct called "perceived AD threat" to explore behavioral change in an AD prevention study conducted in northern Utah. Perceived AD threat is defined as a general category for different types of experiences a person may have that might cause a sense of vulnerability to getting the disease, whether through direct caregiving, observations of family members or others who have the disease from a less hands-on perspective, concerns from hearing or reading about AD

through social media, or worries about one's own cognition. A literature search revealed several recent studies about these experiences and the psychosocial responses they engender. Accordingly, this section will summarize what is known about the following as they relate to perceived AD threat: Fear of AD, family history of AD, and metacognitive concerns.

Fear of Alzheimer's Disease

In 1996, Cutler and Hodgson examined the relationships between self-evaluations of memory and individuals' concerns about developing AD in 50 adult children (ages 40-60) with a living parent with a diagnosis of probable AD or other dementia (Cutler & Hodgson, 1996). Their findings reported that negative memory appraisals were strongly associated with fear of AD and led to a construct they labeled "anticipatory dementia" that they felt would prove valuable for future studies. Since that time, anticipatory dementia has been the subject of many studies, with results indicating that perceived AD risk is a prominent predictor of this phenomenon (Page, 2013). Studies in China (Zeng et al., 2015), France (Cantegreil-Kallen & Pin, 2012) and Korea (Moon, Kim, Choi, Oh, & Han, 2014) have replicated U.S. results, highlighting the negative image of AD in societies worldwide and the subsequent impact on negative aging stereotypes (Suhr & Kinkela, 2007). In various studies, fear of AD was predicted by exposure to the disease, also called "dementia encounters" (Kessler, Bowen, Baer, Froelich, & Wahl, 2012; Page, 2013), anxiety about aging in terms of becoming a burden and having poor health (Thompson, 2014), and subjective memory concerns (Kinzer & Suhr, 2015). What has not yet been studied concerning anticipatory dementia is whether the fear of getting AD

would be a motivating factor for an individual to initiate and sustain recommended lifestyle behavioral changes to reduce AD risk.

Family History of AD

When individuals correlate a family history of AD with its genetic risk component, it is not surprising that they frequently become concerned about their own risk for getting the disease. In a qualitative study of 40 patients with familial hypercholesterolemia, results indicated that a person's sense of vulnerability to the disease was correlated to their understanding of their genetic and inherited risk (Frich, Ose, Malterud, & Fugelli, 2006). Similarly, having a family history of AD is correlated strongly with perceived AD threat (Cutler & Hodgson, 1996); however, in a study exploring social and cognitive explanations for fear of AD, it was found that personal experience with AD had a strong effect on AD threat, whether a genetic risk was perceived or not, although individuals with a known family history of AD were more affected by negative aging stereotypes than those without a family history of AD (Suhr & Kinkela, 2007).

In the case of AD prevention, the desire to avoid developing AD if at all possible may be a powerful motivator. Such a desire can stem from many personal experiences but perhaps none as impactful as seeing a loved one with whom genetic factors are shared suffer the decline of his or her mental capacities through AD. This potential driver of perceived AD risk, (i.e., exposure to loved one(s) with AD and/or an awareness of genetic vulnerability to the disease), has been understudied, particularly as a motivator for behavioral change to reduce AD risk.

Metacognitive Concerns Relative to Alzheimer's Disease

Subjective memory complaints are common in an elderly population and many clinicians use instruments such as the MMSE to objectively evaluate whether or not there is a correlation between self-evaluation and actual cognitive performance. However, research indicates that memory complaints are usually not related to actual indicators of cognitive decline (Kinzer & Suhr, 2015; Ponds, Boxtel, & Jolles, 2000). In a longitudinal analysis over 11 years of middle-aged persons ages 40-60, worries about cognitive functioning and getting AD predicted poorer health outcomes regardless of whether the participant had a parental history of AD (Cutler & Hodgson, 2014). Of concern to many researchers is that the fear of AD may *cause* worse cognitive performance (e.g., due to testing anxiety), resulting in inaccuracies or "noise" in the cognitive assessment that is conducted in a clinical setting (French, 2009; Suhr & Kinkela, 2007). What is not known is whether metacognitive concerns would motivate individuals to change their behavior to reduce AD risk.

Conceptual Framework

The Health Belief Model (HBM) of behavior change was the theoretical foundation for the current study (Rosenstock, 1974). This model was developed in the 1950s by social psychologists at the U.S. Public Health Service to explore the failure of tuberculosis screening campaigns and has been widely used to explain and predict health-related behaviors (Janz & Becker, 1984). The HBM includes the following constructs

that predict engagement in health-related behaviors: perceived severity, perceived susceptibility, perceived benefits, perceived barriers, and cues to action. More recently, the model has been expanded to include modifying variables (Joseph, Burke, Tuason, Barker, & Pasick, 2009), cues to action through mass media (Bauman et al., 2003), and self-efficacy (Rosenstock, Strecher, & Becker, 1988). For purposes of this study, the literature pertaining to perceived severity and susceptibility, perceived benefits and barriers of preventive behavior, modifying variables, and cues to action will be explored. Self-efficacy and related constructs will also be addressed

.

Perceived Severity/Susceptibility (Threat) of Health Condition

Perceived severity addresses a person's belief about the seriousness or harshness of a disease in terms of the life complications the health condition could create. Perceived susceptibility refers to an individual's subjective perception of their risk of developing the disease, and includes a wide range of possible responses from no risk to a sense of extreme vulnerability (McClenahan, Shevlin, Adamson, Bennett, & O'Neill, 2007). The perceived threat construct of the HBM is created by combining perceived severity and susceptibility (Strecher, Champion, & Rosenstock, 1997) and this became an overall theoretical construct that guided the present study's exploration of perceived threat of risk for developing AD.

Perceived Benefits/Barriers of Preventive Health Behavior

This construct encompasses a person's belief regarding the value or usefulness of a new behavior in decreasing the risk of developing a disease. It also affects how an

individual ascertains the negative qualities or costs of adopting the preventive health behavior (Joseph et al., 2009). In order for a new lifestyle behavior to be assimilated, a person needs to believe the benefits of the new behavior outweigh the consequences of continuing the old behavior. He or she also needs to have overcome any perception that the preventive health behavior is expensive, painful, or tedious in order for the new behavior to be incorporated (McClenahan et al., 2007).

Modifying Variables

The four major constructs of perception from the HBM are modified by various sociodemographic variables such as sex, race, socioeconomic status, educational level, and access to insurance. These variables are thought to influence and regulate individuals' assessments of health risk and subsequent preventive health behaviors (Joseph et al., 2009).

Cues to Action

Cues to action are described as triggers or instigators, whether events, people, or things, that incentivize individuals to modify their behavior. This construct may take different forms such as mass media campaigns, newspaper articles, advice from trusted sources, or reminders from a health care provider (Strecher et al., 1997).

Social Cognitive Theory

Bandura's Social Cognitive Theory was used for its perspective on expectancies and self-efficacy (Bandura, 2012). In 1988, Bandura's theory of self-efficacy and elements of his Social Cognitive Theory were added to the Health Belief Model in an

attempt to better explain individual differences in health-related behaviors (Rosenstock et al., 1988). This has implications for AD prevention research because Rosenstock and others who have developed and applied the original model recognized that self-efficacy is a critical factor to explain a person's ability to effect change in behavioral outcomes. A growing body of literature now supports the importance of self-efficacy in the initiation and maintenance of health behavior change (Jaccard, 1975; Janz & Becker, 1984; Joseph et al., 2009). Building on these constructs, it is hypothesized that individual differences in perceived AD threat may be related to a person's (1) perceived susceptibility and severity of being at risk for AD, (2) understanding about the consequences of getting AD, (3) recognition of methods for how to reduce AD risk, and (4) self-efficacy to be able to change lifestyle behavioral patterns.

Research Questions

To investigate the role of perceived AD risk on healthy behavior change in middle-aged adults, the association of three psychological constructs with outcomes on six behavioral measures was examined in a sample of individuals participating in an AD prevention study. The research questions were:

1. *Does a fear of developing AD predict making healthy lifestyle changes associated with AD risk reduction?* (Each research question will be addressed separately for six behavioral domains: exercise, nutrition, cognitive stimulation, social engagement, stress management and sleep quality). Based on the literature, it was expected that fear

of developing AD would be a significant predictor of making healthy lifestyle changes in at least some of the six behavioral domains.

2. *Does a strong family history of AD predict making healthy lifestyle changes associated with AD risk reduction?* Based on the literature it was hypothesized that having a high number of first-order relatives would be a significant predictor of making healthy lifestyle changes in order to minimize personal risk of getting AD.

3. *Do metacognitive concerns about one's memory predict making healthy lifestyle changes associated with AD risk reduction?* Based on a literature review it was hypothesized that metacognitive concerns would predict healthy lifestyle changes in an effort to reduce AD risk.

4. *What additional factors, if any, affect the associations between these three psychological constructs pertaining to perceived AD risk as examined in Questions 1-3?* Relevant factors identified from the literature review included gender, age, and overall health. The robustness of the findings for Research Questions 1-3 were examined, after adjusting for gender, age, and overall health. Technological resources that function as cues to action were also explored.

CHAPTER III

METHODS

Data for this dissertation project were taken from a pilot study titled "*Gray Matters*: Lifestyles to Lower Alzheimer's Disease Risk Health Education Randomized Trial." *Gray Matters* (GM) was a pilot study conducted in Cache County, Utah with Dr. Maria Norton as Principal Investigator, Christine Clark as Study Coordinator, and a multidisciplinary team of researchers from Utah State University that included experts in dietetics and nutrition, psychology, physical education, human development, and health education. Another team of researchers from the Computer Science Department at the University of Ulster in Northern Ireland assisted with the technological components of the intervention (Norton et al., 2015). The following sections will outline participant characteristics, data collection procedures, and assessment methods relevant to this investigation.

Gray Matters Lifestyle Behavior Change Alzheimer's Disease Prevention Study

The GM study was a multidomain randomized controlled trial (RCT) designed to promote positive changes in lifestyle behaviors within six domains: physical activity, food choices, cognitive stimulation, social engagement, stress management, and sleep quality. The intervention featured a smartphone application (app) that was specially designed to distribute daily evidence-based facts and suggestions to the 146 participants in midlife aged 39-64 years (Hartin et al., 2014). GM was based on a randomized, controlled research design with 2/3 of the sample placed into treatment and 1/3 into

control group. An unusual component of this study was to encourage the treatment group participants to rank order the six domains in terms of their personal priority list for making behavioral changes over the next six months. The focus of this intervention was to develop highly innovative methods of disseminating educational material about brain and vascular heath associated with AD risk reduction to a midlife population, to be compared to a group of control subjects who were encouraged to live their lives as they normally would. Treatment group participants interacted daily with the app and were able to track and report their behavior across the six domains. Feedback was given in the form of rating systems and graphs designed to promote accountability and encourage behavior change. The intervention was delivered over a six-month period beginning in April 2014 with posttest data collection commencing in October 2014. The last participant posttest data collection occurred in early December 2014.

Overview of Participant Selection

Recruitment strategies included posters that were placed throughout Cache County, Utah, as well as the utilization of various list serves for email marketing through Utah State University in Logan, Utah. Flyers were distributed at health fairs and the public health department and presentations were made by study organizers at various community functions. An article about the study was also featured in the local newspaper. All publicity materials contained a website address that linked to a survey containing eligibility requirements which included the following: (1) age between 40 and 64 years, (2) body mass index no higher than 41, (3) possession of a smartphone or tablet (iOS or Android), (4) fluency in the English language, (5) residence in Cache County,

and (6) not having any of the following exclusionary medical conditions: pregnancy, dementia, unmanaged diabetes, or untreated major depression. The eligibility survey also contained a health screening questionnaire, a request for demographical information, and questions related to family history of AD and availability for lab appointments and clinic visits. To achieve 80% statistical power in order to detect a medium effect size (Cohen's d = 0.50) 144 participants were needed at a 2:1 treatment:control ratio. The first 146 persons who met eligibility criteria were enrolled in the study. After randomization, the assignments were 104 participants in the treatment group and 42 participants in the control group, resulting in a final statistical power of 78%. The rationale for this approximate 2:1 ratio of treatment to control was to enhance statistical power in order to facilitate domain-level analyses, given the 'cafeteria style' of intervention components in which participants may choose to engage, relative to their prioritized behavioral domains. In cases where a married participant and his or her spouse were enrolled in the study, both were placed in the same group to avoid possible contamination of the control group. See Appendix A for a flow diagram of GM data collection procedures.

Intervention Program

The central goal of the GM intervention was to provide evidence-based educational materials, coupled with innovative technology and supportive activities that would enable participants to make healthy lifestyle changes in a variety of domains. Six behavioral domains associated with AD risk were presented: physical activity, healthy food choices, social engagement, cognitive stimulation, stress management, and sleep quality.

Activity Monitor

Through a generous donation by Nike Corporation, each participant was given a Nike FuelBand, with treatment group distribution at study outset and control group poststudy. The Nike Fuelband uses proprietary metrics, called "Nike Fuelpoints," not identical to actual real-time measurement of steps or calories. However, the device did serve as a reminder to engage in physical activity -- providing "cues to action"-- and it gave participants a baseline measure for subsequent changes in activity over time.

Booster Events

Study organizers arranged for 39 classes or "booster events," throughout the six-month intervention period. These classes featured experts in various fields related to good health who presented materials, provided demonstrations, and allowed hands-on participation in different genres such as yoga, painting, creativity, healthy cooking techniques, and relationship enrichment. Arrangements were made at local gyms for free or low cost rates for Gray Matters' participants. Presentations were intended to educate participants about resources available in the community and reinforce any commitments made by subjects towards a healthier lifestyle in their chosen domain. These booster events were an effort to increase self-efficacy for behavior change via provision of an experiential component to the intervention. See Appendix B for a list of booster events held as part of GM intervention protocol.

Smartphone Application

As a featured component of the Gray Matters study, a custom smartphone

application (hereafter, "app") was created specifically for use by treatment group participants. Control group members were also given access to the app poststudy. This technology was developed in collaboration with Utah State University and the Smart Environments Research Group (SERG) at the Ulster University. The app requested daily behavioral data entry from each participant and was designed to cause minimal burden in this regard through use of a slider bar instead of individual numerical posts. This required less than 2 minutes to complete each day. Users could slide the button left or right to indicate achievement levels and were able to do so on a continuous basis throughout the day until a daily cutoff point at midnight. Co-investigators at Ulster University compiled the daily information from their servers and reset the data collection software to zero so that daily data collection could continue throughout the intervention period of mid-April to mid-October 2014. A total of 12 questions were answered by each participant every day to generate a diary of behavioral outcomes. These questions were linked to the six targeted behavioral domains and included surveys such as consumption of fruits and vegetables and time spent in doing "novel mental exercises." Information describing the link between a behavioral domain and cognitive health was disseminated through the smartphone app in the form of a daily "fact" based on evidence from the AD/lifestyle literature. The fact was coupled with a concrete behavioral suggestion. The delivery on a daily basis of a specific piece of knowledge and a daily suggestion of an attainable behavior were incorporated into the intervention design to increase a sense of self-efficacy for healthy lifestyle change, with these reminders also providing another "cue to action" for users of the app. A copy of the list of questions and examples of these facts are included in Appendix C.

Educational Component

A "kick-off" event was held for treatment group participants where a presentation was made via talks and posters that included information on AD risk reduction through lifestyle behavioral change. A copy of talks given at this event and an example of information on posters are included in Appendix D.

Personal Coach

A team of 28 students was trained in motivational interviewing techniques by Dr. Dave Robinson, Director of the Marriage and Family Therapy clinical program at Utah State University. The students were instructed to communicate by email or text messages with their assigned participants and provide support and encouragement towards the goal of behavior change. A record of each interaction with participants was kept by the student coaches and entered into a Google Doc, which was routinely reviewed by study personnel, to provide answers to coaches' and participants' questions.

Study Website

A website was created at http://usugraymattersstudy.weebly.com and provided information about (a) risk and protective factors for AD, (b) behavioral goals for each of the six domains, (c) links to other educational materials, (d) contact information and biosketches of study personnel, and (e) information on how to download the smartphone app. Participants were encouraged to check the website often for updated information.

Social Engagement Workbook

A workbook focused on improving social engagement skills was prepared by Dr. Elizabeth Fauth, a *GM* co-investigator, featuring weekly goals and pathways based on validated social support interventions (Crowe et al., 2003). The workbook also provided space for journal entries so the participant could track his/her progress in this domain. An example of the social engagement workbook is included in Appendix D.

Procedures

The Center for Human Nutrition Studies (CHNS) on the Innovation Campus of Utah State University was the central location for all interactions with treatment group participants other than certain booster event activities. This included laboratory visits and cognitive testing appointments. Trained personnel employed by CHNS performed all blood draws and clinical measurements (height, weight, blood pressure and palm scan for carotenoids) at both pre and posttest lab appointments. A group of specially trained students performed the cognitive examinations taken from the National Institutes of Health (NIH) Toolbox: Picture Vocabulary, Flanker Inhibitory Control and Attention Test, List Sorting Working Memory Test, and Oral Symbol Digit Test for both pre and posttest evaluations (Weintraub et al., 2013). Global cognitive ability was assessed with the Montreal Cognitive Assessment (Nasreddine et al., 2005), episodic memory was assessed with the Rey Auditory Verbal Learning Test (Strauss, Sherman, & Spreen, 2006), and verbal fluency with the Controlled Oral Word Association Test (Patterson, 2011). Once labwork and cognitive tests were completed, participants were given a series of online surveys for feedback about various study endpoints such as food intake,

stress management, and readiness for change. After a thorough explanation of the necessity for a control group comparison, control group subjects were told to continue with their lives as they normally would and encouraged to make no attempts to change health-related behavior. Assurances were given that control group participants would receive all treatment group components at the end of the six months.

The Institutional Review Board (IRB) at USU approved this research and in-person explanations of IRB protocol were given to every participant as part of an initial work-up evaluation at the CHNS clinic. At that time, written informed consent was collected from all participants before study data were collected.

Selection Criteria

The analyses conducted for the current study examined participant data collected in two ways. First, data were collected through daily responses on the GM smartphone app over the course of 27 weeks. The second data collection source was through surveys administered at baseline, midstudy, and posttest. Surveys relevant to the current study will be described below. Missing data were handled through the use of linear mixed modeling which provides a more flexible approach when handling data that may vary across several points in time for different individuals (Shek & Ma, 2011).

Independent Variables

Fear of Alzheimer's Disease

Fear of AD was developed for this study and determined from a series of questions asked in a midstudy survey about various aspects of participants' emotional

responses to loved ones who experienced AD. The responses were based on a Likert scale from 1-5 and queried participants about their memory loss concerns, fears of developing AD, and motivation to reduce AD risk. These scores were summed (Cronbach's alpha 0.851) and then recoded into tertiles (described as "high," "moderate," or "low") instead of the original continuous variable because a significant improvement was not anticipated in the outcome for a 1-unit increase in the fear of AD score. Other measures for similar constructs were considered for use in this study, including the fear of AD scale (French, Floyd, Wilkins, & Osato, 2012) and the anticipatory dementia scale, or Memory Assessment Index (Hodgson & Cutler, 1997). However, these scales included open-ended components and factors related to individual anxiety traits that were not measured in the present study. Accordingly, new measures were developed to better describe the psychological constructs defined by the independent variables. See Appendix E for the survey questions and Table 1 for an explanation of how this variable was derived.

Family History of AD

Family history of AD was determined by creating a dichotomous variable if the participant endorsed even one family member as having been affected by Alzheimer's disease or other form of dementia. First-degree relatives including mother, father, maternal and paternal grandparents, and aunts, uncles, and siblings were considered as "family" with the rationale that a person's perceived AD risk could be affected by his or her experience with any one of those individuals who are genetically linked and is diagnosed with AD. A second cumulative family history "load" was computed by

Table 1

Independent Variables (All Subjects, n = 137)

Variable	Min(Max)	M(*SD)*	Source	Response
Fear of AD (continuous)	4(15)	11.6(2.48)	Gray Matters midstudy survey questions 7, 13, and 14 of Q48; also Q49, Q50 (See Appendix E)	Scores on the 5 questions (each scored from 1-5) were summed, for possible range of 5-25 points[a]
Fear of AD in (tertiles)	1(3)	1.9(.810)	Recoded fear of AD variable into 3 tertiles based on a frequency distribution of scores	Fear of AD recoded into: high fear (13 - high) moderate fear (2 -11) low fear (low - 10)
Total family history of AD/dementia (continuous)	1(8)	1.6(1.36)	Q11 on the GM pretest survey (See Appendix E)	Total family history was represented by a summative score with 2 pts for each sibling and for each parent and 1 pt for each grandparent who had AD/dementia.
Total family history of AD in (tertiles)	1(3)	2.04(.671)	Recoded total family history of AD variable into 3 tertiles based on a frequency distribution of scores	Family history recoded into: high family hx (3 - high) moderate family hx (1-2) low family hx (0)
Metacognitive concerns (continuous)	8(29)	22.5(2.63)	The Metacognitive concerns variable used the 7 sub-questions on Q23 of the GM pretest (See Appendix E)	Scores on the 7 questions (each scored from 1-5) were summed, for possible range of 7-35 points
Metacognitive concerns in (tertiles)	1(3)	2.06(.811)	Recoded the Metacognitive concerns variable into 3 tertiles based on a frequency distribution of scores	Metacognitive concerns recoded into: high concerns (24 - hi) moderate concerns (22-23) low concerns" (8 - 21)

[a]Total scores were computed by summing non-missing responses resulting in a min of 4.

summing the number of familial categories endorsed for a positive dementia history, with two points given for each sibling and parent and one point for each grandparent who were known to have AD/dementia. Because the survey did not ask for actual number of

affected relatives within each category, this cumulative family history "load" variable reflected the number of familial categories endorsed, rather than the number of affected relatives. Nevertheless, it facilitated the option of examining a dose-response pattern, where greater behavioral changes would be predicted for higher levels of family history "load." Family history values were measured at each of three points in time but only the baseline values were used in the analyses for this project. See Appendix E for the survey questions and Table 1 for an explanation of how this variable was derived.

Metacognitive Concerns

Participants completed a 7-item questionnaire to measure metacognition ratings that was validated in a 2010 study using data from the Cache County Study (Buckley, Norton, Deberard, Welsh-Bohmer, & Tschanz, 2010). Cronbach alpha was calculated at 0.75 for the Cache County study. This questionnaire had been adapted from other published instruments assessing cognitive and functional status (Gilewski, Zelinski, & Schaie, 1992; Jorm & Jacomb, 1989). Three of the questions assess functional changes within the past 3 years and four questions assess cognitive changes during that time. Each participant's scores on the seven survey questions were summed. The baseline value of this metacognitive measure (a continuous variable) was recoded into tertiles. See Appendix E for the survey questions and Table 1 for an explanation of how this variable was derived.

Assessment of Covariates

During data analysis, several covariates were added to statistical models examining the relationship between the three psychological constructs and the six

behavioral outcomes. This was done in order to ascertain robustness of these findings to covariate adjustments, including age, gender, and overall health. There were two reasons for the inclusion of these covariates. First, since a number of studies have controlled for the effects of demographic and health-related factors, the above variables were selected to ensure consistency with previous research. Second, these covariates are known to have a significant potential to confound relationships between the independent variables and the outcomes. They were therefore examined in exploratory and statistical analyses. The overall health variable had a min (max) of 1 (3) with M (SD) of 1.76 (0.612).

Dependent Variables

Daily Behavioral Reports from Smartphone App

All six dependent variables were measured by daily participant self-report on the smartphone app. These data were restricted to just the treatment group because only these subjects were given the smartphone app (n = 101). This constituted my primary analyses. For each behavioral domain, 28 daily values (corresponding to 4 weeks of daily responses) were averaged to generate "monthly" values for longitudinal statistical analysis. Survey questions from the smartphone app are listed in Appendix C and inquire about behavioral achievement over the past 24-hour period, with a varying number of questions per behavioral domain. See Appendix E for survey questions and Table 2 for an explanation of how these variables were derived.

Survey Reports of Selected Behavioral Domains via Online Survey (Pretest, Midstudy, Posttest)

For secondary analyses, I utilized data available through online surveys that

measure the physical activity, social engagement and food choices domains. For these analyses, the entire sample (treatment and control subjects) was included.

Table 2

Dependent Variables, App Data (Treatment Group Subjects Only, n = 101

Variable	Min(Max)	M(SD)	Source	Response
Physical activity	0(90.6)	45.3(21.37)	Two questions on the smart phone app: one asking for number of minutes of moderate and one asking for number of minutes of vigorous activity over the last 24 hours (See Appendix E)	Daily values were summed, then averaged across 28 days (4 weeks) into "monthly" values
Social engagement	0(6.96)	4.38(1.49)	One question on the smart phone app: How would you rate your social engagement in the last 24 hours?	Daily responses were averaged across 28 days (4 weeks) into "monthly" values
Diet quality	10.8(69.3)	35.09(13.6)	Three questions on the smart phone app asking for number of cups of fruits/vegetables, ounces of whole grains and servings of nuts, seeds or legumes in the last 24 hours (See Table C1 in Appendix C)	Daily values were standardized into ounces, summed, then averaged across 28 days (4 weeks) into "monthly" values .
Sleep quality	0(5)	3.16(1.19)	One question on the smart phone app: How would you rate your sleep promotion efforts over the past 24 hours?	Daily responses were averaged across 28 days (4 weeks) into "monthly" values

(Table Continues)

Variable	Min(Max)	M(SD)	Source	Response
Cognitive stimulation	0(197.8)	85.9(1.19)	Two questions on the smart phone app asking for number of minutes spent doing "novel" and/or "cognitively stimulating" activities in the last 24 hours (See Table C1 in Appendix C)	Daily values were summed, then averaged across 28 days (4 weeks) into "monthly" values
Stress management	0(9.8)	4.42(2.43)	One question on the smart phone app: How much effort have you put into decreasing your stress over the past 24 hours?	Daily responses were averaged across 28 days (4 weeks) into "monthly" values

Physical activity was measured with two online survey questions that asked respondents for the number of minutes spent in vigorous physical activity with a separate question for number of minutes spent in moderate activity. Definitions for "vigorous" and "moderate" intensity activities were provided, and taken from the Center for Disease Control and Prevention guidelines: 150 minutes (2 hours and 30 minutes) of moderate-intensity activity per week and 75 minutes (1 hour and 15 minutes) per week of vigorous-intensity activity. Respondents were then allowed to enter "minutes per day" or "minutes per week" for both intensity levels of activity (whichever was easier for them to recall) and if minutes per day was reported, it was multiplied by 7, so that this variable was measured in units of minutes per week.

Social engagement behavior was measured with two questions in the online survey, as follows: "Please indicate your level of participation in social, political, or community groups or clubs (for example, Rotary Club, Sons/Daughters of Utah Pioneers,

Veterans of Foreign Wars, Audubon Society, Hiking club, Bicycling club, Book club, etc.)" and "Please indicate how often you spend time with family or friends, in addition to the participation in community groups or clubs you reported on in the previous question." Response options included: every day or nearly every day, several times a week but less than daily, several times a month, several times a year, and once a year or less.

To measure diet quality in the GM study, a food frequency questionnaire was used that queries 134 food categories and asks about consumption, from which a Dietary Approaches to Stop Hypertension (DASH) score was computed, with higher score implying greater adherence. This DASH score is a more comprehensive picture of dietary pattern than the limited three questions that were included on the smartphone app. An explanation of how the dependent variables from survey data were measured is found in Table 3.

Statistical Analyses

Exploratory Analyses

Before computing advanced statistical analyses, the data were screened using initial descriptive analyses to expose any outliers or data entry errors. Cronbach alpha coefficients were calculated on the metacognition questionnaire and the fear of AD items to provide an estimate of internal consistency for these two scales. One-way analyses of variance were computed on continuous variables and chi-square tests were computed on categorical variables to determine bivariate associations and possible confounding between key covariates and the perceived threat of AD construct. T-tests and chi-square

Table 3

Dependent Variables from Online Survey (All Subjects, n = 146)

Variable	Min(Max)	M(*SD)*	Source	Response
Physical activity Total min/wk	0(7.5)	5.19(1.36)	Two questions on the GM pretest, mid-study and posttest surveys: one asking for number of minutes of moderate and one asking for number of minutes of vigorous activity over the last 24 hours (See Appendix E)	Scores for moderate and vigorous physical activity were summed at each point in time.
DASH Adherance diet quality score	27(63)	47.2(7.08)	Food frequency questionnaire with 134 food categories, collected at pretest and posttest; converted into a diet adherence score for the Dietary Approaches to Stop Hypertension (DASH)	Scores from food categories of interest (fruit, vegetables, low-fat dairy, grains, sodium, added sugar and meats) were divided by the recommended amount according to the American Heart Assn .
Social engagement	2(9)	5.58(1.52)	Q15 and Q16 on the GM pretest, mid-study and posttest surveys (See Appendix E)	Scores from both questions were summed at each point in time.

tests were then run to determine whether or not the randomization process yielded treatment and control groups which did not differ significantly over time in a given behavioral domain, as a function of one of the perceived threat of AD variables. Finally, descriptive statistics were computed on a range of demographic variables to describe the sample of participants in this convenience sample.

Research questions were then addressed in a series of linear mixed models by first adding a term for "time" measured as number of months (4-week periods) from pretest. The next step in model-building was to add a term for time**2 to test for whether or not the pattern of change over time was curvilinear. If the time**2 term was significant, it

was retained in all future models or removed in all future models if nonsignificant. Next, one of the three exposure variables ("perceived threat of AD") was added to the model, along with its interaction with time (and interaction with time**2 if it was retained in the model). In each case, the determination of statistical significance of the newly added terms to the model was determined by computing the difference between the -2 Log Likelihood statistic of the "nested models" (e.g., a model with time only is "nested" within a larger model with time and time**2), and comparing this difference to a statistical probability from the chi-square distribution to determine whether or not the added variable(s) are significant. I then added the covariates of interest—age, gender, and overall health to determine robustness of the model to these adjustments. I also added a treatment group variable in each of the models that used survey data to control for any variability in the behavior change that was due to group assignment.

Treatment and Control Groups

The decision was made to include both treatment and control groups in the analysis of the survey data for three reasons. First, this maximized the sample size and increased the generalizability of the results. Second, by controlling for the treatment group in the linear mixed model, the psychological effects of the independent variables over time became the key focus, following the intent behind the research questions. Third, some members of the control group chose to engage in behavioral change in spite of study protocol instructions to refrain from making such changes. This could be a function of their perceived AD risk as identified by the independent variable constructs.

Linear Mixed Models

In order to capture developmental changes over time and be able to address both intra and interindividual differences in the growth parameters with greater precision, linear mixed models (LMM) were computed. LMM models take into account the within-subject dependence of observations due to repeated measures, and allows the testing of fixed effects (independent variables) for their effect on the outcome measure overall, and also for their effect on the rate of change over time in the outcome.

The first LMM model focused on the variation within individuals over time, estimating the average within-person initial status at baseline and rate of change over time. No predictors were included in this model and a determination was made whether the growth curve was linear or curvilinear by first testing a model with only the time effect, then a model with time and time^2 to ascertain incremental improvement in model fit. In the next model, one of the three exposure variables, corresponding to RQs 1, 2, and 3, was each examined for its effect on rate of change over time, with a separate set of models for each exposure variable, examining the trajectory of behavioral change for each behavioral outcome variable separately.

Unless otherwise noted, whenever the -2LL test for nested models revealed a significant improvement in model fit, there was a corresponding significance in the Type III omnibus test for the effect of exposure on rate of behavioral change over time. Whenever the omnibus effect of exposure*time is significant, single-degree-of-freedom contrasts are also reported (parameter estimates and *p*-values), to address the effects of the predictor on rate of change in the behavior. However, if the omnibus test is non-significant, reporting ends with the omnibus *p*-value of exposure*time. Similarly, if the

exposure*time^2 interaction is significant, single degree of freedom contrasts are also reported to address the effects of the predictor on acceleration of change in the behavior, otherwise reporting ends with the omnibus *p*-value of exposure*time^2. When the exposure*time (and/or exposure*time^2) effect is non-significant, covariate effects are not discussed, as these have relevance only in the determination of robustness of initially observed exposure effects, before covariates were included in the model.

As each step in model building progressed, to select the model with the better fit, a chi-square test was computed by subtracting -2 LL statistics between "nested models" (where a smaller model including only a subset of variables included in a larger model is said to be "nested" within the larger model). This chi-square test has degrees of freedom equal to the difference in number of parameters in the two models. This statistical test must be significant before the interpretation of the significance of the single-degree-of-freedom parameter estimates (Singer & Willett, 2003). The maximum likelihood (ML) method was used when the focus was on the fixed and random effects and the restricted maximum likelihood (REML) method was used to compare models differing by covariance structure (Shek & Ma, 2011). When parameter estimates are significant, results of -2LL comparison chi-square tests are reported.

CHAPTER IV

RESULTS

This chapter begins with a description of the overall data analysis procedures which pertain to all statistical analyses reported herein. The remainder of this chapter is organized into two major sections, the first reports analyses of behavioral change data from the smartphone app, collected from treatment group participants only (from which all six behavioral domains are available). The second major section reports on a parallel set of analyses of behavioral change from online surveys, collected from the entire sample (treatment and control subjects, from which only three of the six behavioral domains are available). Each of these two major sections begins with a description of sample characteristics, including participants' demographic information and baseline health profile. The results of exploratory analyses are provided next, followed by linear mixed models that address research questions, for each of the behavioral outcomes. Significant covariates are also discussed in the corresponding sections for each research question.

Statistical Reporting Overview

As detailed in the account of the analytic approach used throughout the current study that is described in chapter three, the numbers that are reported in the tables are the final LMM results, and not each individual model.

Behavioral Change from Smartphone App Data Reported by Treatment Group

Demographic Profile, Treatment and Control Group Participants

The comparison between the demographic information of the 104 participants randomly assigned to the treatment group and the 42 participants randomly assigned to the control group is shown in Table 4 and Table 5. Two treatment group participants dropped out of the study shortly after enrollment. This matches a frequency count of GM identifiers connected with the app data which found 102 unique users of the GM app, signifying two participants who did not install the app on their smartphones (the two who dropped out). One participant only recorded one week of data leaving 101 participants who actively recorded their personal behavioral data into the GM smartphone app. All participants who provided more than one week of data on the app are included in the linear mixed models since their data can contribute to parameter estimates of intercept and slope. Via the app, the average participant submitted 7.3 +/- 3.2 behavioral logs/day (n = 122,719; Hartin et al., 2014). This number is out of 12 total possible questions with which the user was prompted daily.

Treatment (T) and control groups (C) did not differ at baseline in terms of demographic profile (Refer to Table 6 for a representation of these data). Of the 104 participants randomized into the treatment group at baseline, 68 (65.4%) were female while 29 (69%) of the participants randomized into the control group were female and nearly all in both groups (T = 98%; C = 97.1%) were Caucasian. At baseline, treatment group participants ranged in age from 40 to 64 years with a mean (*SD*) of 54.55(6.73).

Table 4

Comparison of 104 Treatment and 42 Control Group Participants at Baseline: Categorical Variables

Categorical variables	Treatment group N (%)		Control group N (%)		Chi-square test (*p*-value)	
Gender: Male	36	(34.6%)	13	(31.0%)	0.180	(.671)
Gender: Female	68	(65.4%)	29	(69.0%)		
Education: HS/GED	1	(1.0%)	1	(2.9%)	1.564	(.668)
Edu: Some college/trade	19	(18.6%)	4	(11.4%)		
Edu: College grad/ B.S, B.A.	42	(41.2%)	16	(45.7%)		
Edu: graduate/prof. degree	40	(39.2%)	14	(40.0%)		
Overall health - fair	8	(7.8%)	5	(14.3%)	1.397	(.497)
good	60	(58.8%)	18	(51.4%)		
excellent	34	(33.3%)	12	(34.3%)		
Ethnicity: Non-Hispanic White	99	(98%)	34	(97.1%)	.093	(.761)
Ethnicity: Hispanic	2	(2.0%)	1	(2.9%)		
Marital status: married	89	(86.4%)	31	(79.5%)	9.021	(.061)
Marital status: widowed	1	(1.0%)	0	(0.0%)		
Marital status: divorced	7	(6.8%)	7	(17.9%)		
Marital status: never married	6	(5.8%)	0	(0.0%)		
Income: less than $45K	6	(8.0%)	6	(11.5%)	4.349	(.361)
Income: $45K - $55K	14	(13.9%)	3	(8.6%)		
Income: $55K - $75K	16	(15.8%)	9	(25.7%)		
Income: greater than $75K	63	(62.4%)	19	(54.3%)		
Withdrew from study	2	(1.9%)	3	(7.1%)	2.465	(.116)

Table 5

Comparison of 104 Treatment and 42 Control Group Participants at Baseline: Continuous Variables

Continuous variables	Treatment group mean (SD)	Control group Mean (SD)	Independent samples *t* test (*p*-value)
Age	54.55 (6.7)	52.93 (7.30)	-1.28 (.20)
No. of relatives with dementia	1.12 (.99)	1.09 (1.03)	-.16 (.87)

Control group participants ranged in age from 40 to 64 years with the mean (*SD*) of 52.9(7.3) years. Most of the treatment group participants had incomes over $45,000 annually (92.1%) and held college degrees (80.4%). Similarly, 88.6% of the control group had incomes over $45,000 and the majority also held college degrees (85.7%), with 40% holding an advanced degree and only 2.9% holding less than a college degree. The majority of treatment group were married (86.4%) with only 14 participants reporting single status (1.0% widowed, 6.8% divorced, 5.8% never married). Control group participants were nearly all married (79.5%) with 18% describing themselves as single through divorce. Participants rated their baseline overall health profile as follows: Treatment group = 8 (7.8%) described themselves with fair health, 60 (58.8%) with good health and 34 (33.3%) with excellent health. Control group = 5 (14.3%) described themselves with fair health, 18 (51.4%) with good health and 12 (34.3%) with excellent health.

Exploratory Findings on the Six Dependent Variables

Physical activity. The physical activity frequency distribution showed a mean of 45 (21.37) minutes per day, indicating a normal distribution of scores based on the Center

Table 6

Baseline Demographic Summary of 146 Gray Matters Study Participants

Variable	*N* (%)	*N* (%)	*N* (%)	*N* (%)
Gender	Female 97 (66%)	Male 49 (34%)	---	---
Ethnicity	Hispanic 1 (0.6%)	Non-Hispanic White 136 (93.2%)	---	---
Marital status	Married 121 (82.9%)	Widowed 1 (0.6%)	Divorced 12 (8.2%)	Never married 6 (4.1%)
Religious affiliation	Catholic/Protestant 12 (8.2%)	LDS (Mormon) 90 (61.6%)	Jewish, Eastern, or Other 18 (12.3%)	Atheistic or Agnostic 20 (13.7%)
Education	High school 2 (1.2%)	Some college/trade 23 (16.0%)	College B.S./B.A. graduate 59 (40.4%)	Graduate/professional 54 (37.0%)
Income	< $45K 12 (8.2%)	$45-55K 17 (11.6%)	$55-75K 26 (17.8%)	> $75K 82 (56.2%)
Family history of dementia	None 36 (24.7%)	Mother **or** Father 55 (37.7%) Mother **and** Father 7 (4.8%)	Maternal GP **or** Paternal GP 51 (34.9%) Maternal GP **and** Paternal GP 5 (3.4%)	Aunt, uncle, sibling 34 (23.3%)

for Disease Control and Prevention (CDC) recommendations for PA, specifically, 150 minutes of moderate-intensity activity per week or 75 minutes of vigorous-intensity activity per week. No transformation was computed prior to statistical modeling, given the normal distribution.

Diet quality. The baseline frequency distribution of DASH diet adherence scores showed a mean of 35.09 (13.57), indicating sufficient variability to facilitate a study of

change as a function of the exposure variable. No transformation was computed prior to statistical modeling, given the normal distribution.

Social engagement. The social engagement response also showed a near-normal frequency distribution with a mean of 4.38 (1.49). No transformation was computed prior to statistical modeling as the distribution did not deviate substantially from a normal distribution.

Sleep quality. The sleep promotion behavioral response also showed a near-normal frequency distribution with a mean of 3.16 (1.194). No transformation was computed prior to statistical modeling, given that the distribution did not deviate substantially from a normal distribution.

Cognitive stimulation. The cognitive stimulation behavioral response also showed a near-normal frequency distribution with mean 85.95 (42.55). No transformation was computed prior to statistical modeling due to the normal distribution.

Stress management. The stress management response also showed a near-normal frequency distribution with mean 4.42 (2.45). No transformation was computed prior to statistical modeling considering the normal distribution.

Research Question #1: Fear of Developing AD and its Effect on Behavioral Change as Captured by the Smartphone App in Treatment Group Participants

Exploratory Findings on the Fear of Developing AD Independent Variable

The mean fear of AD score at baseline for the entire sample (N = 146) was 11.60 (2.48). The fear of AD composite variable contained scores that ranged from 4 to 15 with the tertiles ranging from 13 to 15 (high to very high fear), 11 and 12 (moderate to high

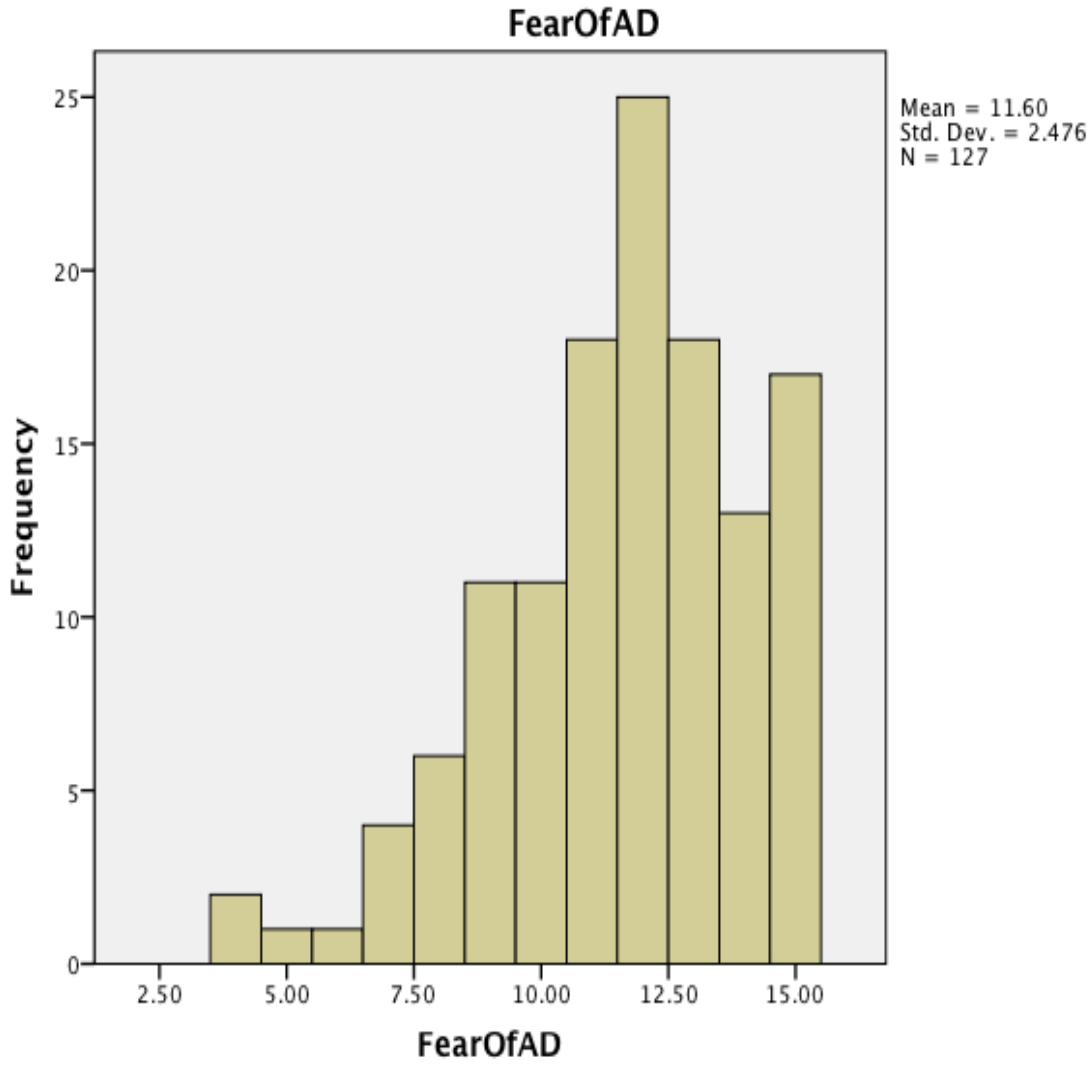

Figure 1. Histogram showing baseline fear of AD scores.

fear) and 4 through 10 (no fear to moderate fear). See Figure 1 for histogram of baseline survey scores, Table 7 for Fear of AD summed variable frequency table, and Table 8 for a fear of AD frequency table for the variable recoded into tertiles.

Table 7

Fear of AD Scores Frequency Table

Fear of AD		Frequency	Percent	Valid percent	Cumulative percent
Valid	4.00	2	1.4	1.6	1.6
	5.00	1	.7	.8	2.4
	6.00	1	.7	.8	3.1
	7.00	4	2.7	3.1	6.3
	8.00	6	4.1	4.7	11.0
	9.00	11	7.5	8.7	19.7
	10.00	11	7.5	8.7	28.3
	11.00	18	12.3	14.2	42.5
	12.00	25	17.1	19.7	62.2
	13.00	18	12.3	14.2	76.4
	14.00	13	8.9	10.2	86.6
	15.00	17	11.6	13.4	100.0
	Total	127	87.0	100.0	
Missing	System	19	13.0		
Total		146	100.0		

Table 8

Fear of AD Tertiles Frequency Table

Fear of AD		Frequency	Percent	Valid percent	Cumulative percent
Valid	1.00	48	32.9	37.8	37.8
	2.00	43	29.5	33.9	71.7
	3.00	36	24.7	28.3	100.0
	Total	127	87.0	100.0	
Missing	System	19	13.0		
Total		146	100.0		

Linear Mixed Model Results for Research Question 1

Physical activity. A linear mixed model with time as the sole predictor was nonsignificant for the time effect (ß = 1.06, p = .224). When time^2 was added to the model and the –2LL values were compared, time^2 did not significantly improve the model (ß = -.259, p = .066). Time^2 was therefore dropped from the remaining models. After adding the fear of AD*time interaction to the model, the omnibus test was significant (p = .002). Individual contrasts revealed that, compared to the low fear subgroup, the high fear subgroup made nonsignificant progress in terms of their physical activity over time (ß = .057, p = .928), whereas the moderate fear subgroup showed a significant increase in PA that was 2 min/day, on average, higher than the PA increase observed in the low fear subgroup (ß = 1.970, p = .002).

In the final model with all covariates included, the effect of fear of AD on PA was robust, with parameter estimates and p-values virtually unchanged (see Table 9). For each one year of increased age, subjects reported 0.7 additional minutes of physical activity per day, on average (ß = .715, p = .006). In terms of baseline overall health, subjects in the fair/poor health subgroup reported 16 fewer minutes of physical activity, on average, than subjects in the excellent health subgroup (ß = -16.358, p = .018), whereas the moderate and excellent health subgroups did not differ in PA (ß = -1.335, p = .729). The -2LL results were highly significant with each successive model, with the final model including the fear of AD predictor, linear time and the fear*time interaction and covariates. A table with the results of all final models for the fear of AD independent variable can be found in Table 9 with a trajectory plot created in R in Figure 2.

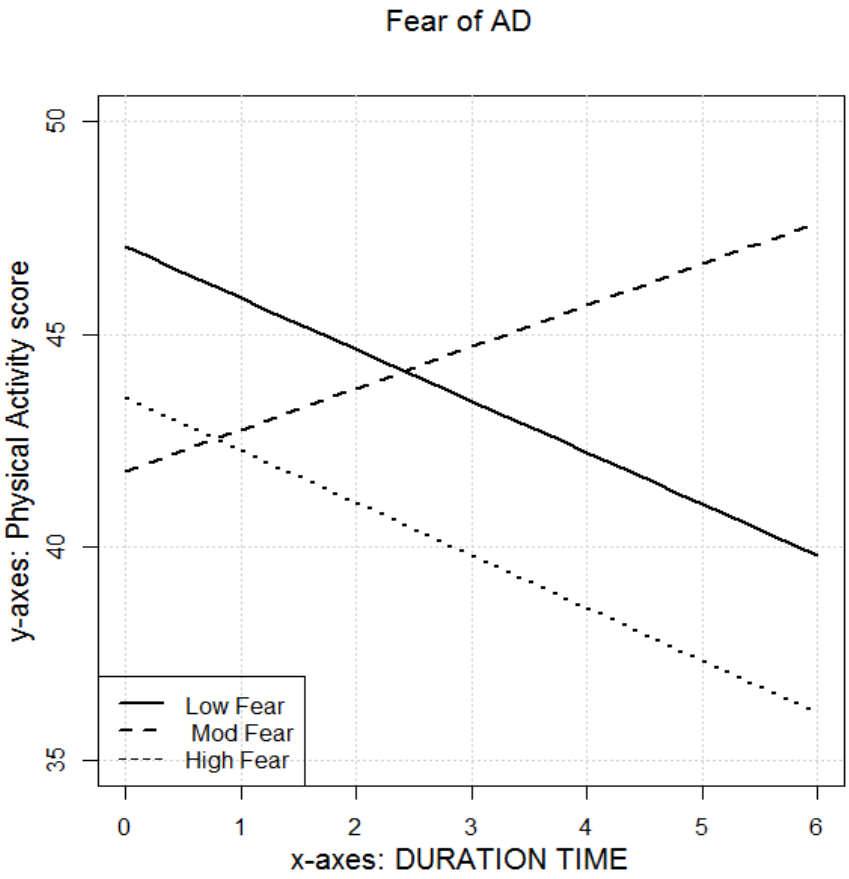

Figure 2. Fear of AD and physical activity trajectory plot.

Food choices. The initial linear mixed model containing terms for time (ß = -.109, p = .861) and time^2 (ß = .003, p = .971) was nonsignificant for both predictors. The fear of AD*time interaction was also nonsignificant (p = .196) and the addition of covariates did not improve the model which remained virtually unchanged.

Social engagement. A linear mixed model for this variable indicated the change over time to be highly significant (ß = .083 p = .001) and time remained significant when the nonlinear time^2 term was added (month: ß = .142, p = .026; month2: ß = -.009

p = .323). However, the -2LL likelihood value (p = 1.00) was in agreement that time^2 was not significant. Therefore, time^2 was not carried into subsequent models (ß = .009, p = .323). The fear of AD*time interaction was nonsignificant (p = .526). The final model remained unchanged with the addition of covariates.

Sleep quality. Linear mixed models showed significant change over time (ß = .054 p = .006) that held constant with the addition of time^2 to the model (ß = .112 p = .046). Time^2 was dropped from the model as it was nonsignificant (ß = -.008, p = .265). The fear of AD*time interaction was nonsignificant (p = .961). The addition of covariates did not change the results.

Cognitive stimulation. Linear mixed models were highly significant at both time (ß = 10.22, p = .001) and time^2 (ß = -.085, p = .001) revealing an increase in the number of minutes participants engaged in cognitively stimulating activities of 5 min/day for every month on average across the six months of the study. The fear of AD*time interaction was nonsignificant (p = .451). The addition of covariates did not change the model.

Stress management. Linear mixed models were highly significant for time (ß = .250 p = .001). Testing for a nonlinear trajectory by including a term for time^2 was also highly significant (time: ß = .623, p = .001; time^2: ß = -.057 p = .001). -2LL test p-value for adding time^2 to the model was .001. Time^2 was therefore retained in the succeeding models. The stress management*time interaction was not significant (p = .083) although it indicates a trend, after the adjustment for the entire set of covariates, the effect remained the same.

Table 9

Linear Mixed Models with Fear of AD as Predictor of Behavioral Change over Time in Each of Six Behavioral Domains, as Reported on Gray Matters Smartphone Application

Fear of AD	Time (months since baseline)	$Time^2$	Fear of AD*Time (Omnibus)	Fear of AD*$Time^2$ (Omnibus)	Male gender	Age	Overall health
Physical activity	0.078 (-0.497)	0.066 (-0.260)	0.001		0.542	0.009 (0.796)	0.043
Contrast 1			0.966 (-0.027)[a]				0.016 (-16.241)[c]
Contrast 2			0.001 (2.182)[b]				0.770 (-1.101)[d]
Food choices	0.701 (-0.088)	0.971 (0.003)	0.126		0.905	0.268	0.048
Contrast 1							0.015 (-13.309)[c]
Contrast 2							0.233 (-3.647)[d]
Social engagement	0.001 (0.084)	0.323 (-0.009)	0.594		0.006 (-0.705)	0.022 (0.043)	0.173
Contrast 1							
Contrast 2							
Sleep quality	0.046 (0.112)	0.265 (-0.008)	0.987		0.928	0.158	0.870
Contrast 1							
Contrast 2							
Cognitive stimulation	0.001 (4.704)	0.001 (-0.846)	0.451	0.333	0.295	0.055	0.668
Contrast 1							
Contrast 2							
Stress management	0.001 (0.623)	0.001 (-0.057)	0.083	0.191	0.289	0.097	0.589
Contrast 1							
Contrast 2							

Note. Each cell provides the p-value for the given effect. Fear of AD (FAD)*$Time^2$ is only included in models for behavioral domains where the $Time^2$ term was significant. Additionally, standardized regression coefficients (in parentheses) are reported for all terms involving Time and $Time^2$, and for all remaining terms only if the omnibus test was significant.

[a]FAD Contrast 1: high FAD compared to low FAD; [b]FAD Contrast 2: moderate FAD compared to low FAD;
[c]Overall Health (OH) Contrast 1: high OH compared to low OH; [d]OH Contrast 2: moderate OH compared to low OH

Research Question #2: Family History of AD and its Effect on Behavioral Change as Captured by the Smartphone App in Treatment Group Participants

Exploratory Findings on the Family History of AD Independent Variable

The mean of the family history of AD composite score variable was 1.61 (1.36). The family history of AD composite variable contained scores that ranged from 0 to 8 with the tertiles ranging from 3 to 8 (high family history), 1 and 2 (moderate levels of family history) and 0 (no family history). See Figure 3 for a histogram of baseline survey scores, Table 10 for a family history of AD composite variable frequency table, and Table 11 for a family history of AD frequency table for the variable recoded into tertiles.

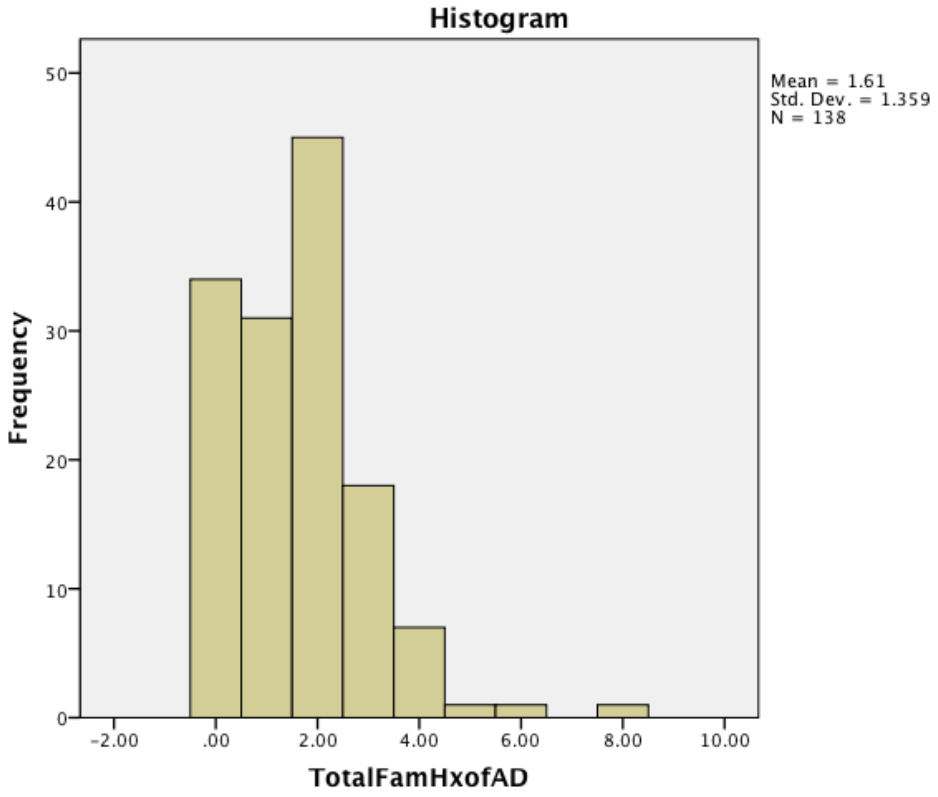

Figure 3. Histogram of baseline scores for total family history of AD.

Table 10

Family History of AD Frequency Table

Family History of AD		Frequency	Percent	Valid percent	Cumulative percent
Valid	.00	34	23.3	24.6	24.6
	1.00	31	21.2	22.5	47.1
	2.00	45	30.8	32.6	79.7
	3.00	18	12.3	13.0	92.8
	4.00	7	4.8	5.1	97.8
	5.00	1	.7	.7	98.6
	6.00	1	.7	.7	99.3
	8.00	1	.7	.7	100.0
	Total	138	94.5	100.0	
Missing	System	8	5.5		
Total		146	100.0		

Table 11

Family History of AD Tertiles Frequency Table

Family History in Tertiles		Frequency	Percent	Valid percent	Cumulative percent
Valid	3+pts of famhx	28	19.2	20.3	20.3
	1-2 pts of famhx	76	52.1	55.1	75.4
	0 pts of famhx	34	23.3	24.6	100.0
	Total	138	94.5	100.0	
Missing	System	8	5.5		
Total		146	100.0		

Linear Mixed Model Results on Research Question #2

Physical activity. The family history*time interaction was not significantly associated with the rate of change in participants' PA levels (p = .945). The model was virtually unchanged when all covariates were included. A table with the results of all final models for the family history of AD independent variable and the six dependent variables can be found in Table 12.

Food choices. The family history of AD*time interaction was not significantly associated with the rate of change in participants' healthy food choices over time (p = .726). The addition of covariates did not significantly change the model.

Social engagement. The family history of AD*time interaction was nonsignificant (p = .415). The addition of covariates did not significantly change the model.

Sleep quality. A family history of AD was not significantly related to the change over time in implementing sleep promotion efforts (p = .847). Adding all covariates does not change the final model. The addition of covariates did not change the final model.

Cognitive stimulation. A family history of AD was not significantly related to the change over time in adopting more cognitively stimulating behaviors (p = .684). Adding all covariates does not change the final model.

Stress management. When added to the initial model, the family history of AD*time interaction was not significantly associated with change over time in the stress management behavioral domain (p = .470). Covariates did not change the model.

Table 12

Linear Mixed Models with Family History of AD as Predictor of Behavioral Change over Time in Each of Six Behavioral Domains, as Reported on Gray Matters Smartphone Application

Family history of AD	Time (months since baseline)	Time^2	Family history of AD*Time (omnibus)	Family history of AD*Time^2 (omnibus)	Male gender	Age	Overall health
Physical activity	0. 078 (-0.479)	0.066 (-0.260)	0.652		0.466	0.008 (0.655)	0.013
Contrast 1							0.004 (-17.911)[a]
Contrast 2							0.747 (-1.112)[b]
Food choices	0.701 (-0.088)	0.971 (0.003)	0.712		0.754	0.230	0.111
Contrast 1							
Contrast 2							
Social engagement	0.001 (0.084)	0.323 (-0.009)	0.451		0.005 (-0.680)	0.103	0.230
Contrast 1							
Contrast 2							
Sleep quality	0.006 (0.054)	0.265 (-0.008)	0.860		0.703	0.384	0.672
Contrast 1							
Contrast 2							
Cognitive stimulation	0.001 (4.704)	0.001 (-0.846)	0.658	0.395	0.261	0.049 (1.089)	0.651
Contrast 1							
Contrast 2							
Stress management	0.001 (0.250)	0.001 (-0.057)	0.643	0.539	0.153	0.079	0.669
Contrast 1							
Contrast 2							

Note. Each cell provides the p-value for the given effect. Family History of AD*Time^2 is only included in models for behavioral domains where the Time^2 term was significant. Additionally, standardized regression coefficients (in parentheses) are reported for all terms involving Time and Time^2, and for all remaining terms only if the omnibus test was significant.

[a]Overall Health (OH) Contrast 1: high OH compared to low OH; [b]OH Contrast 2: moderate OH compared to low OH

Research Question #3: Metacognitive Concerns and its Effect on Behavioral Change as Captured by the Smartphone App in Treatment Group Participants

Exploratory Findings on the Metacognitive Concerns Independent Variable

The mean of the metacognitive variable was 22.48 (2.64). The metacognitive ranging from 24 to 29 (moderate to high metacognitive concerns), 22 and 23 (moderate levels of metacognitive concerns) and 8 to 21 (low to moderate metacognitive concerns). See Figure 4 for a histogram of baseline metacognitive scores, Table 13 for a family history of AD composite variable frequency table, and Table 14 for a family history of AD frequency table for the variable recoded into tertiles.

Linear Mixed Model Results for Research Question #3

Physical activity. The metacognitive concerns*time interaction in this linear mixed model showed a significant effect (p = .012) which remained constant even after the addition of covariates. Metacognitive concerns*time^2 was nonsignificant. The individual parameters revealed a counterintuitive result with the high metacog compared to low metacog contrast showing a decrease in physical activity change over time (ß = -1.406, p = .055). Covariates were added separately to the model and the omnibus p-value was virtually unchanged with the individual effects remaining constant. The final model was robust to adjustment. -2LL were highly significant for each successive model with the test for nested models having chi-square = 15.06 df = 4, and p = .005. A table with the results of all final models for the family history of AD independent variable and the six dependent variables can be found in Table 15, a trajectory plot for metacognitive

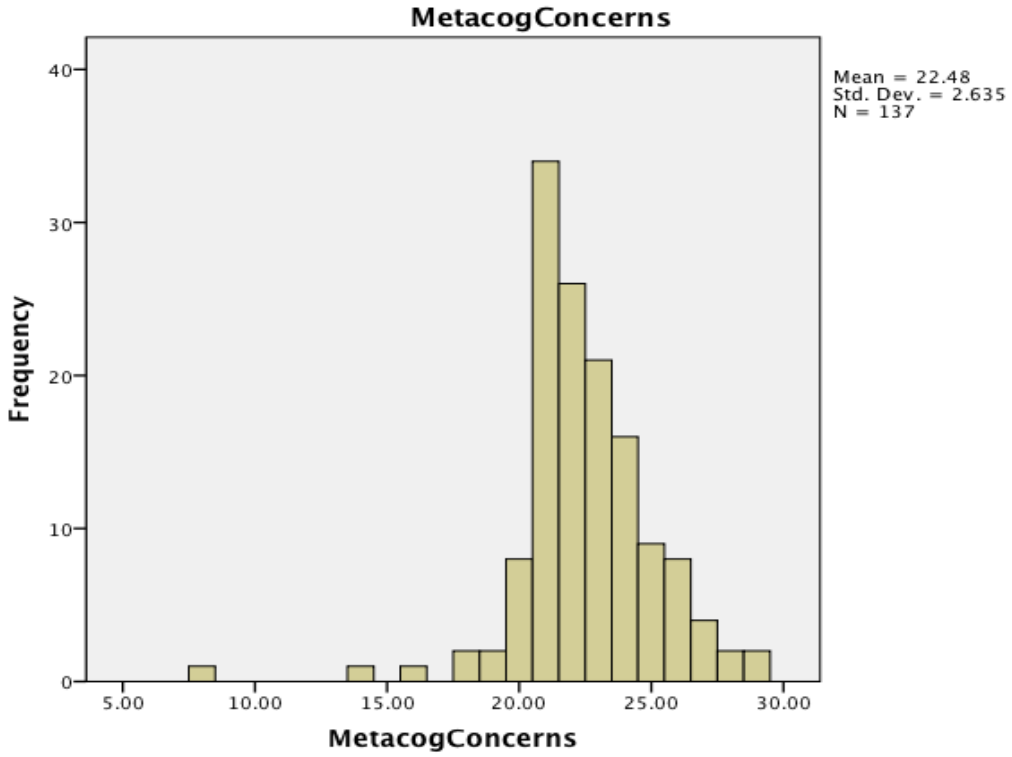

Figure 4. Baseline scores for metacognitive concerns.

concerns and physical activity created in R in Figure 5, and a trajectory plot for metacognitive concerns and diet quality in Figure 6.

Food choices. When the predictor variable was added to the model and interacted with time, a significant result on the omnibus test ($p = .030$) was observed. The results of single-degree-of-freedom contrasts indicated that participants who have a moderate concern for their metacognitive status (as compared to those with low concern) were improving their diet quality over time (ß = .960, $p = .059$). On average this was associated with one ounce per day greater intake of the healthy foods recommended in

Table 13

Metacognitive Concerns Scores Frequency Table

METACOG		Frequency	Percent	Valid percent	Cumulative percent
Valid	8.00	1	.7	.7	.7
	14.00	1	.7	.7	1.5
	16.00	1	.7	.7	2.2
	18.00	2	1.4	1.5	3.6
	19.00	2	1.4	1.5	5.1
	20.00	8	5.5	5.8	10.9
	21.00	34	23.3	24.8	35.8
	22.00	26	17.8	19.0	54.7
	23.00	21	14.4	15.3	70.1
	24.00	16	11.0	11.7	81.8
	25.00	9	6.2	6.6	88.3
	26.00	8	5.5	5.8	94.2
	27.00	4	2.7	2.9	97.1
	28.00	2	1.4	1.5	98.5
	29.00	2	1.4	1.5	100.0
	Total	137	93.8	100.0	
Missing	System	9	6.2		
total		146	100.0		

Table 14

Metacognitive Concerns Tertiles Frequency Table

METACOG TERTILE		Frequency	Percent	Valid percent	Cumulative percent
Valid	1.00	41	28.1	29.9	29.9
	2.00	47	32.2	34.3	64.2
	3.00	49	33.6	35.8	100.0
	Total	137	93.8	100.0	
Missing	System	9	6.2		
Total		146	100.0		

Table 15

Linear Mixed Models with Metacognitive Concerns as Predictor of Behavioral Change over Time in Each of Six Behavioral Domains, as Reported on Gray Matters Smartphone Application

Metacognitive concerns	Time (months since baseline)	$Time^2$	Metacognitive concerns*Time (omnibus)	Metacognitive concerns*$Time^2$ (omnibus)	Male gender	Age	Overall health
Physical activity	0. 078 (-0.479)	0.066 (-0.260)	0.012		0.473	0.008 (2.414)	0.016
Contrast 1			0.055 (-1.406)[a]				0.005 (-17.744)[c]
Contrast 2			0.168 (0.850)[b]				0.722 (-1.252)[d]
Food choices	0.701 (-0.088)	0.971 (0.003)	0.030		0.895	0.234	0.145
Contrast 1			0.340 (-0.566)[a]				
Contrast 2			0.059 (0.960)[b]				
Social engagement	0.001 (0.084)	0.323 (-0.009)	0.881		0.001 (-0.766)	0.102	0.384
Contrast 1							
Contrast 2							
Sleep quality	0.006 (0.054)	0.265 (-0.008)	0.226		0.724	0.373	0.879
Contrast 1							
Contrast 2							
Cognitive stimulation	0.001 (4.704)	0.001 (-0.846)	0.482	0.458	0.431	0.151	0.904
Contrast 1							
Contrast 2							
Stress management	0.001 (0.250)	0.001 (-0.057)	0.028	0.020	0.189	0.077	0.750
Contrast 1			0.123 (-0.392)[a]	0.212 (0.044)[a]			
Contrast 2			0.166 (0.302)[b]	0.074 (-0.054)[b]			

Note. Each cell provides the p-value for the given effect. Metacognitive Concerns (MC)*$Time^2$ is only included in models for behavioral domains where the $Time^2$ term was significant. Additionally, standardized regression coefficients (in parentheses) are reported for all terms involving Time and $Time^2$, and for all remaining terms only if the omnibus test was significant.

[a]MC Contrast 1: high MC compared to low MC; [b]MC Contrast 2: moderate MC compared to low MC;
[c]Overall Health (OH) Contrast 1: high OH compared to low OH; [d]OH Contrast 2: moderate OH compared to low OH

the study. The addition of covariates did not alter this effect which remained robust. -2LL were highly significant for each successive model with the test for nested models having chi-square = 75.30 df = 8, and $p = .001$.

Social engagement. Concerns about metacognitive function were not related to change in social engagement behaviors over time. The metacognitive concerns*time interaction was nonsignificant ($p = .876$). The addition of covariates did not change the model.

Sleep quality. The metacognitive concerns*time interaction, when added to the time and time^2 linear mixed model, was not significantly related to sleep promotion behavioral change over time ($p = .225$). The addition of covariates did not change the model.

Cognitive stimulation. Linear mixed models adding the metacognitive concerns*time interaction were not significantly associated with efforts to change cognitively stimulating behaviors ($p = .484$). The final model included all three covariates.

Stress management. Linear mixed models tested the pattern of behaviors to reduce stress as a function of metacognitive concerns and revealed a significant association with the metacognitive concerns*time interaction ($p = .028$). The -2LL was not significant, however, with the test for nested models having chi-square = 5.84 df -4, and $p = .212$ so no further results are reported. The addition of gender, age, and overall health status to the model did not alter these effects.

Behavioral Change from Online Survey Data Reported by Full Sample

Demographic Profile, All Participants

Of the 146 participants enrolled in the GM study at baseline, 97 (66%) of the sample was comprised of females and nearly all 136 (93.2%) self-identified as White/Caucasian. Participants ranged in age from 40 to 64 years with the mean (*SD*) of 54.6 (6.9) years. Most of the participants had incomes over $45,000 annually (92.1%) and the majority also held college degrees (77.4%), with 37% also holding an advanced or professional degree and only 1.2% with less than a college degree. Participants reported marital status as follows: married (82.9%), widowed (0.6%), divorced (24%).

Exploratory Findings on the Three Dependent Variables

Physical activity. The physical activity variable from the baseline survey data had a mean (SD) of 5.19 (1.36). This distribution was positively skewed and was transformed using the natural log transformation, resulting in a normal distribution. See Figure 7 for a histogram.

DASH diet adherence score. Baseline mean scores were 5.19 (1.36). No transformation was computed prior to statistical modeling, given the normal distribution. A frequency histogram of DASH scores is presented in Figure 8.

Social engagement. Mean scores were 5.58 (1.52). No transformation was computed prior to statistical modeling, given the normal distribution. See Figure 9 for frequency histogram.

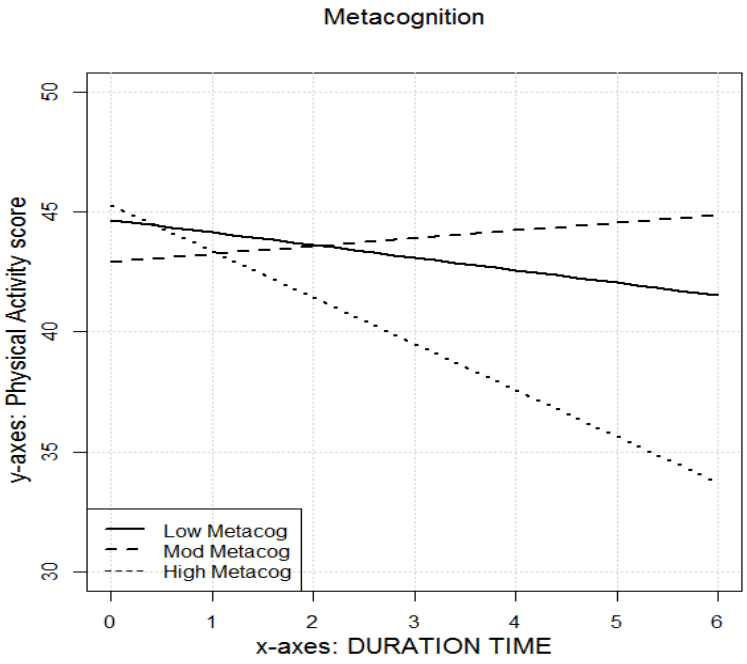

Figure 5. Metacognitve concerns and physical activity trajectory plot created in R.

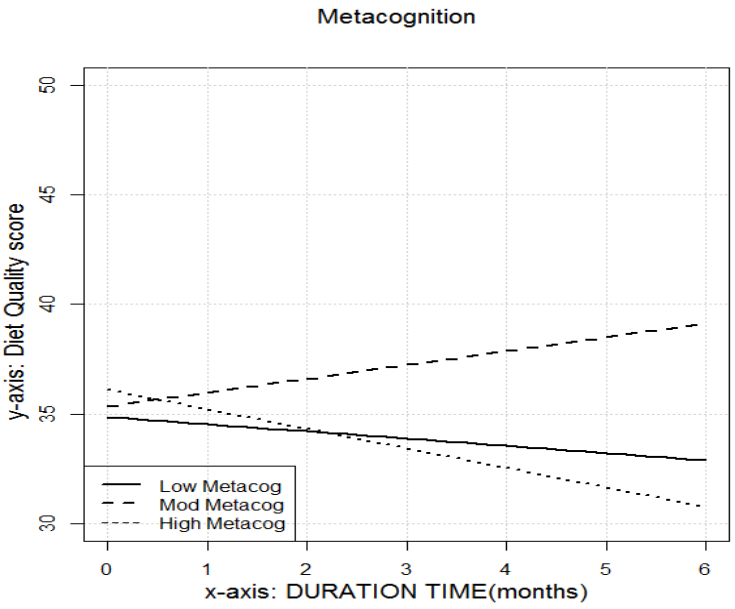

Figure 6. Metacognitive concerns and diet quality trajectory plot created in R.

Research Question #1: Fear of Developing AD and its Effect on Behavioral Change as Captured by Online Surveys in the Entire Sample (Treatment and Control Groups)

Linear Mixed Model Results for Research Question 1

Physical activity. A linear mixed model with time as the sole predictor was

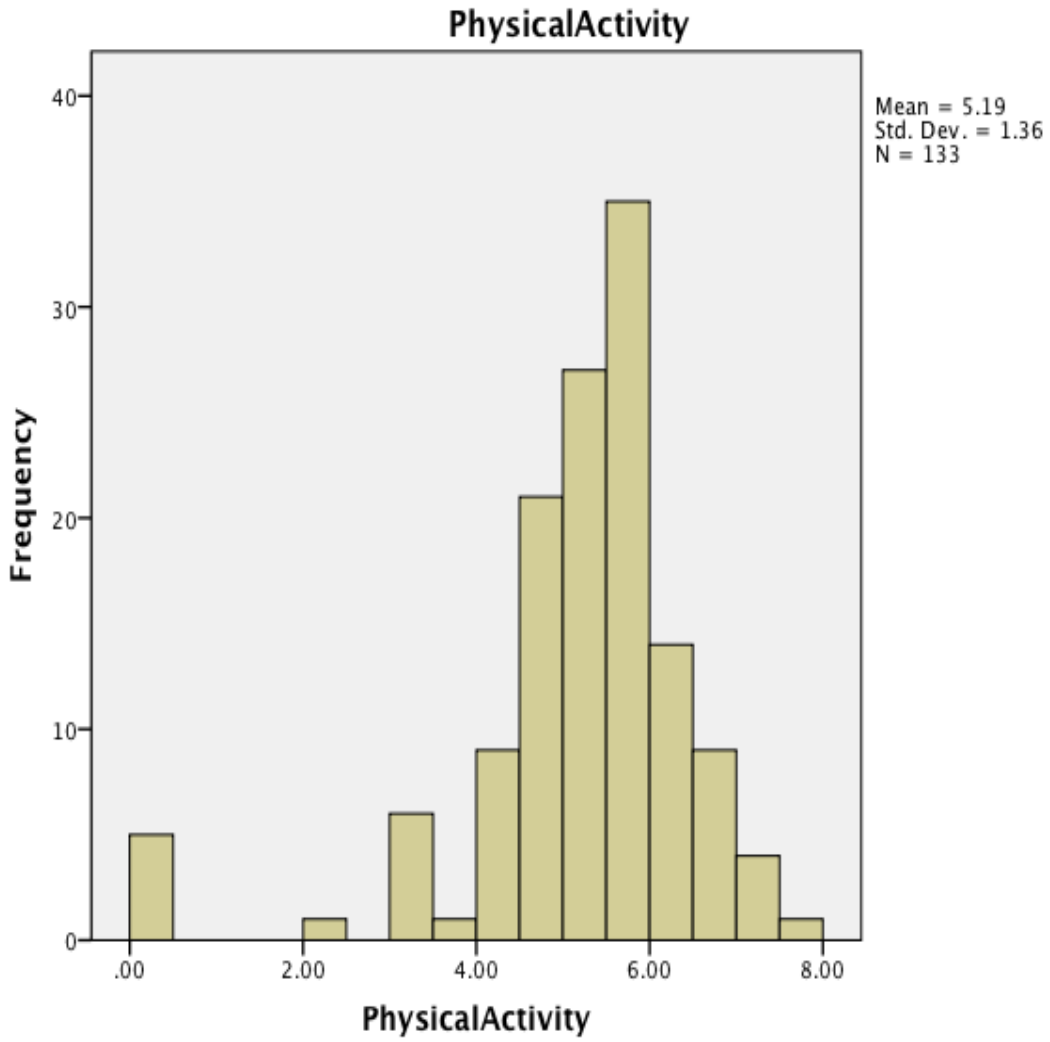

Figure 7. Natural log transformed physical activity scores.

significant for the time effect (ß = .032, p = .006). The fear of AD*time interaction was nonsignificant in terms of showing an increase in physical activity (p =.940). Addition of covariates did not change the final model. A table with the results of all final models for the fear of AD independent variable and the three dependent variables can be found in Table 16.

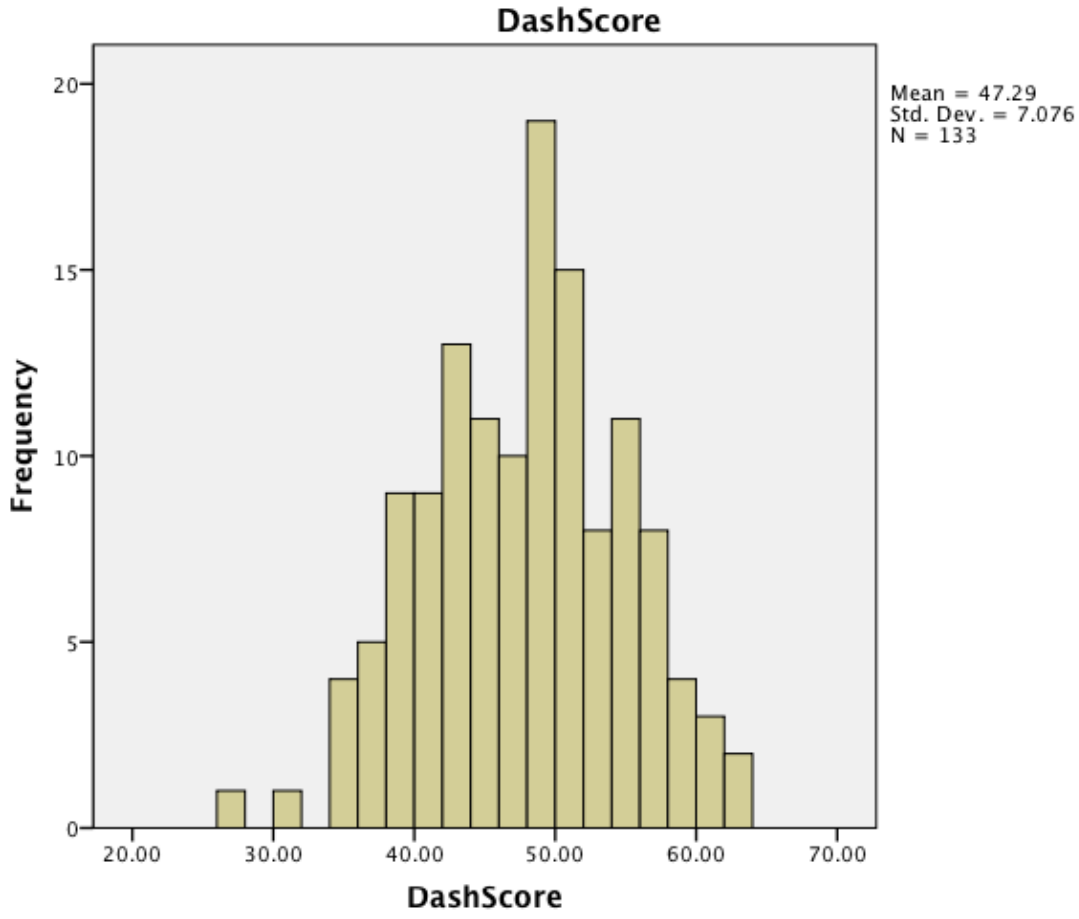

Figure 8. Baseline frequency of DASH diet adherence scores.

Diet quality. A linear mixed model with time as the sole predictor was significant for the time effect (ß = .510 p = .001). A linear mixed model with the fear of AD*time interaction was nonsignificant in terms of showing an increase in making healthy food choices (p = .611). Addition of covariates did not change the final model.

Social engagement. A linear mixed model with time as the sole predictor was

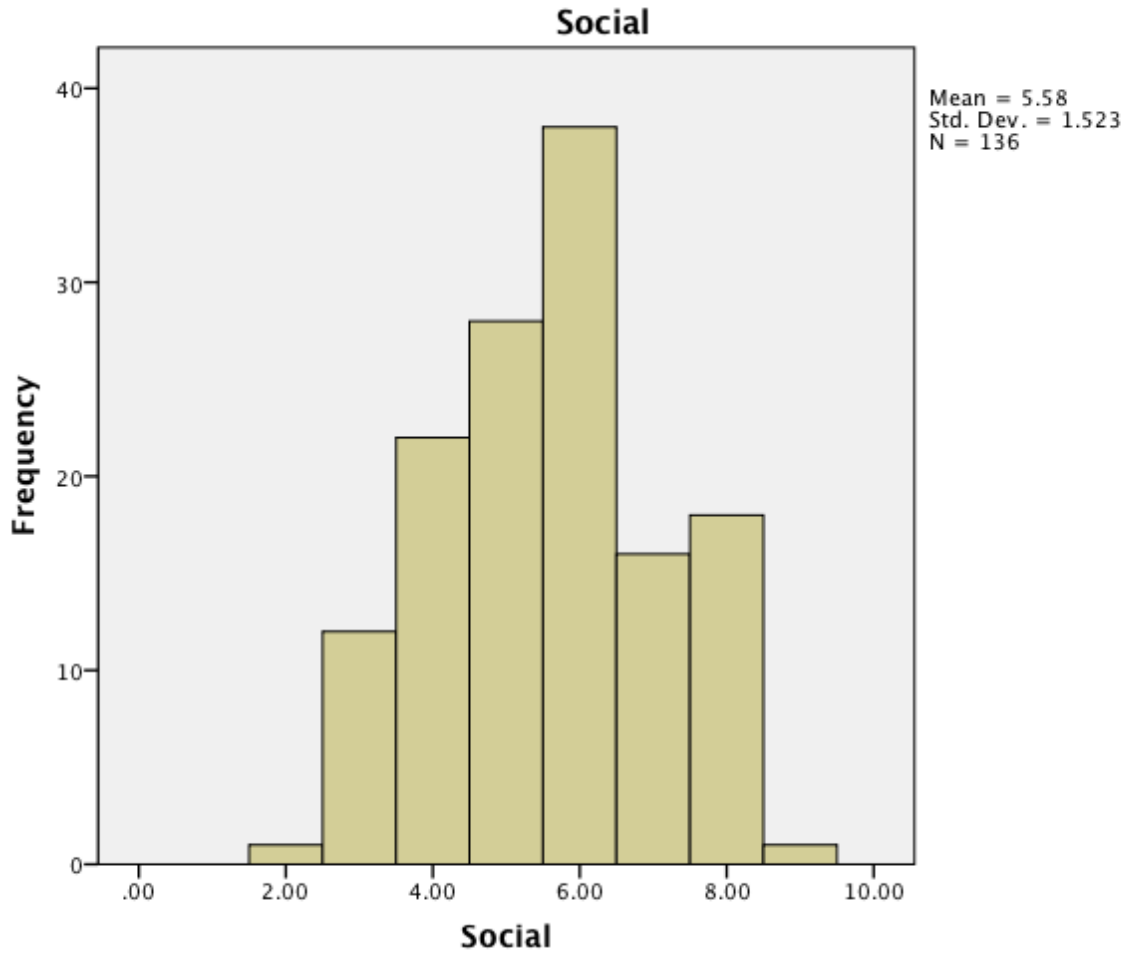

Figure 9. Baseline social engagement scores using full sample survey data.

Table 16

Linear Mixed Models with Fear of AD as Predictor of Behavioral Change over Time in Each of Three Behavioral Domains, as Reported on Gray Matters Survey Data

Fear of AD	Time (months since baseline)	Fear of AD*Time (Omnibus)	Treatment group	Male gender	Age	Overall health
Physical activity	0.143 (0.033)	0.808	0.016	0.747	0.864	0.001
Contrast 1						0.001 (1.154)[a]
Contrast 2						0.003 (0.640)[b]
Food choices	0.001 (0.480)	0.611	0.302	0.121	0.003 (0.177)	0.001
Contrast 1						0.001 (9.159)[a]
Contrast 2						0.001 (5.409)[b]
Social engagement	0.054 (-0.041)	0.267	0.316	0.172	0.494	0.079
Contrast 1						
Contrast 2						

Note. Each cell provides the p-value for the given effect. Additionally, standardized regression coefficients (in parentheses) are reported for all terms involving Time and for all remaining terms only if the omnibus test was significant.

[a]Overall Health (OH) Contrast 1: high OH compared to low OH; [b]OH Contrast 2: moderate OH compared to low OH

nonsignificant for the time effect (ß = -.041, p = .054). The fear of AD*time interaction was nonsignificant in terms of showing an increase in social engagement (p = .267). Addition of covariates did not change the final model.

Research Question #2: Family History of AD and its Effect on Behavioral Change as Captured by Online Surveys in the Entire Sample (Treatment and Control Groups)

Linear Mixed Model Results for RQ2

Physical activity. A linear mixed model interacting family history of AD with time was nonsignificant in terms of showing an increase in physical activity (p = .809). Addition of covariates did not change the final model. A table with the results of all final models for the family history of AD variable and the dependent variables is found in Table 17.

Diet quality. A linear mixed model using the continuous DASH scores interacted with time showed a trend towards significance in the omnibus (p = .056) with one-half point higher adherence to the improved diet per month in the group with high family history of AD (ß = .534, p = .026) compared to those with lower family history of AD (ß = .109, p = .581). Those in the group with moderate family history of AD did not differ from the low family history group on diet quality change over time. Addition of covariates did not change the final model.

Social engagement. A linear mixed model interacting family history of AD with time was nonsignificant in terms of showing an increase in social engagement (p = .786). Addition of covariates did not change the final model.

Table 17

Linear Mixed Models with Family History of AD as Predictor of Behavioral Change over Time in Each of Three Behavioral Domains, as Reported on Gray Matters Survey Data

Family history of AD	Time (months since baseline)	Family history of AD*Time (omnibus)	Treatment group	Male gender	Age	Overall health
Physical activity	0.143 (0.033)	0.809	0.075	0.286	0.633	0.001
Contrast 1						0.001 (1.260)[a]
Contrast 2						0.001 (0.802)[b]
Food choices	0.001 (0.480)	0.056	0.713	0.904	0.037 (0.162)	0.002
Contrast 1						0.004 (5.593)[a]
Contrast 2						0.234 (2.175)[b]
Social engagement	0.054 (-0.041)	0.786	0.421	0.169	0.951	0.004
Contrast 1						0.005 (-1.098)[a]
Contrast 2						0.204 (-0.472)[b]

Note. Each cell provides the p-value for the given effect. Additionally, standardized regression coefficients (in parentheses) are reported for all terms involving Time and for all remaining terms only if the omnibus test was significant.

[a]Overall Health (OH) Contrast 1: high OH compared to low OH; [b]OH Contrast 2: moderate OH compared to low OH

Research Question #3: Metacognitive Concern and its Effect on Behavioral Change as Captured by Online Surveys in the Entire Sample (Treatment and Control Groups)

Linear Mixed Model Results on RQ3

Physical activity. A linear mixed model interacting metacognitive concerns with time was nonsignificant in terms of showing an increase in physical activity ($p = .675$). Addition of covariates did not change the final model. A table with the results of all final models for the metacognitive concerns independent variable and the three dependent variables can be found in Table 18.

Food choices. A linear mixed model interacting metacognitive concerns with time was nonsignificant in terms of showing an increase in making healthy food choices ($p = .800$). Addition of covariates did not change the final model.

Social engagement. A linear mixed model interacting metacognitive concerns with time was nonsignificant in terms of showing an increase in social engagement ($p = .374$). Addition of covariates did not change the final model.

Table 18

Linear Mixed Models with Metacognitive Concerns as Predictor of Behavioral Change over Time in Each of Three Behavioral Domains, as Reported on Gray Matters Survey Data

Metacognitive concerns	Time (months since baseline)	Metacognitive concerns*Time (omnibus)	Treatment group	Male gender	Age	Overall health
Physical activity	0.143 (0.033)	0.675	0.027	0.247	0.540	0.001
Contrast 1						0.001 (1.308)[a]
Contrast 2						0.001 (0.834)[b]
Food choices	0.001 (0.480)	0.800	0.937	0.923	0.022 (0.174)	0.005
Contrast 1						0.008 (5.112)[a]
Contrast 2						0.293 (1.900)[b]
Social engagement	0.054 (-0.041)	0.374	0.445	0.180	0.925	0.007
Contrast 1						0.009 (-1.027)[a]
Contrast 2						0.268 (-0.410)[b]

Note. Each cell provides the p-value for the given effect. Additionally, standardized regression coefficients (in parentheses) are reported for all terms involving Time and for all remaining terms only if the omnibus test was significant

[a]Overall Health (OH) Contrast 1: high OH compared to low OH; [b]OH Contrast 2: moderate OH compared to low OH

CHAPTER V

DISCUSSION

This pilot study with a group of midlife participants in Cache County, Utah explored the relationship between three psychological factors, specifically, fear of AD, family history of AD, and metacognitive concerns and their effect on six behavioral outcomes in an intervention focused on AD prevention. The following results were obtained: (a) a moderate fear of AD was associated with a significant increase in physical activity when compared to those with lower fear of AD; (b) an unexpected decline in physical activity was observed in participants with high metacognitive concerns when compared to those with low metacognitive concerns; (c) a positive trend was observed in those with moderate levels of metacognitive concerns compared to those with low concerns regarding diet quality. Each finding will be described in greater detail in the following discussion. Finally, strengths and limitations of the study as well as future directions for research will be addressed.

Fear of Alzheimer's Disease: Effect on Physical Activity

Over the course of the six-month *Gray Matters* study, participants in the moderate fear category reported increasing their physical activity levels by 2.186 minutes every day, on average, or 15 minutes of increased time in physical activity every week, or 60 minutes every month. This means that a moderate level of fear of AD was associated with an increase in physical activity of one hour per month, on average. A search of the literature contributed to the hypothesis that participants with the highest levels of

perceived AD risk would be more likely to engage in or increase their physical activity over time. For example, in a comprehensive meta-analysis, Tannenbaum and colleagues (2015) found that fear appeals, or persuasive messages focused on possible harmful outcomes that could occur if certain preventive measures are ignored, are highly effective at positively influencing attitudes, intentions, and behaviors, including in a public health context (Tannenbaum et al., 2015). A correlation between externally generated fear-based marketing messages and internally generated fear-based messages would seem likely. However, our results indicate that those with higher levels of fear of AD made changes in their physical activity over time that did not differ from those made by participants who had lower fear (ß = -.027 p = .966). Participants in this study were significantly more likely to increase their level of physical activity when they had a moderate fear of AD, compared to those with low fear (ß = 2.19 p = .001).

A possible explanation for this finding could be related to the social-cognitive theory of personality called locus of control, referring to the extent to which individuals believe they have power over events in their lives (Rotter, 1966). According to research on health locus of control by Wallston and colleagues (1976), the relationship between locus of control beliefs and health-care-related behaviors is very complex (Wallston, Wallston, Kaplan, & Maides, 1976). The general assumption is that individuals believe their health outcomes are either under the control of powerful others such as God (external beliefs) or the direct result of their own actions (internal beliefs). Study participants with high fear of AD might have included individuals with a high external locus of control who felt powerless to change their perceived AD trajectory.

Another possible explanation could be the increasing awareness by the general population of the debilitating symptomatology of AD through wider coverage by mass media and personal contact with the AD-impaired (Kessler et al., 2012). According to the Health Belief Model (HBM), health-related actions depend on the belief that following a particular health recommendation will be efficacious in reducing the perceived threat (Rosenstock et al., 1988). For participants experiencing increased age-related declines, a sense of helplessness that modifying health-related behaviors will actually reduce AD risk may stem from a lack of self-efficacy. They may have doubted their physical or cognitive capacity to make long-term modifications in physical activity or any other lifestyle domain. This is an area where the GM intervention adds greater understanding to the psychology behind health behavior change according to the HBM. In focus group interviews poststudy, participants reported feeling empowered by the information they had received about various health behaviors known to reduce AD risk and the cues to action represented by the smartphone app. They also indicated a determination to continue with the healthy lifestyle changes they had initiated and they had even formed support groups with others in the study who were likewise committed. It is possible that intervention components were effective in reducing participants' high levels of fear of AD to more moderate levels by targeting various key constructs of the HBM, specifically by increasing perceived benefits, decreasing perceived barriers, boosting self-efficacy and increasing social support to engage in health-promoting behaviors.

Multiple studies in the cancer literature suggest that a moderate degree of perceived threat of cancer as compared to a high degree is more likely to motivate cancer

screening behaviors (Hay, Buckley, & Ostroff, 2005). For those who had a moderate level of fear of AD, the tendency to do more physical activity could reflect the hope that making positive lifestyle changes could still lower their risk of getting the disease (Cutler & Hodgson, 2013). A moderate level of fear has been shown to be the optimal mechanism for engagement in health behaviors such as screening, but too little fear leads to denial or lack of attention to risk factors while too much fear may lead to avoidance (Janis & Feshbach, 1953), as in the current study, possibly avoidance of engagement in physical activity and other healthy lifestyle behaviors.

Studies also show a negative correlation between respondents who score high on indicators of concerns about cognitive functioning and fear of getting AD with actual physical and psychological well-being (Cutler & Hodgson, 2013, 2014). In this context, study participants may have been debilitated by high levels of fear with negative physical and psychological outcomes as a result. This would need further research to fully explicate, however, as the current study lacks data specifically on the extent to which participants felt that their fear of AD (at high levels) may have had a debilitating effect on motivation for behavioral change.

To date there is very little research that explores the relationship between persons who are concerned about their cognitive functioning and worried about developing AD and whether or not these psychological stressors predict engagement in preventive health measures, in spite of a call to action for such studies by the NIH in 2010 (Cutler & Hodgson, 2014; Daviglus et al., 2010). Results from the present study may contribute to enhanced understanding of these issues.

Metacognitive Concerns: Effect on Physical Activity and Food Choices

Of the three psychological factors hypothesized to be predictors of health behavior change that were investigated in the current study, metacognitive concerns has the most established trends in the literature (Cutler, 2015; VonDras, 2009), although still underexplored. Chung and colleagues (2009) found that both better cognitive test performance and better physical functioning are strong positive predictors of preferences for AD prevention, implying that people with moderate (as compared to high) levels of metacognitive concerns would be more likely to engage in AD prevention activities (Chung, Mehta, Shumway, Alvidrez, & Perez-Stable, 2009). In the current study, this hypothesis is supported by a statistically significant positive relationship in the effect of metacognitive concerns on healthy food choices. Participants consumed seven more ounces per week, on average, for each month of the study, but only if they had moderate metacognitive concerns. Those with high metacognitive concerns did not differ from the participants who had lower metacognitive concerns. This is again suggestive of a lack of self-efficacy or a high external locus of control in those with high levels of metacognitive concerns and dementia worry as described in the previous section.

According to Rosenstock and colleagues (1988), the Health Belief Model accounts for more individual variance in health-related behaviors when Bandura's self-efficacy theory is incorporated into the HBM to help explain "perceived barriers" to behavior change in terms of modifying lifelong habits such as eating and exercise (Rosenstock et al., 1988, p. 179). In other words, individuals must have an incentive to change, feel threatened by their current patterns of behavior, and believe that making

specific changes in lifestyle behaviors will have desired outcomes (as outlined by the HBM), but self-efficacy theory implies they must also feel competent to implement that change (Rosenstock et al., 1988). If people believe themselves to be affected by memory loss, they may also lack confidence in their ability to improve their cognition in the short term or prevent further memory loss in the future. Findings from the current study would support this hybrid HBM/self-efficacy hypothesis in that those with the highest levels of metacognitive concerns may have had very little confidence in their ability to improve their memory, accounting for the statistically significant parameter estimate showing an approximate 10-minute decline per month in physical activity compared with those with low metacognitive concerns. Another possibility is that the hypothesis was correct but the intervention may have been weak in targeting the lowering of concerns for participants who had expressed high levels of fear of getting AD and worries about their own cognition. One of the components of the intervention, booster events, was designed to generate a cue to action and increase self-efficacy beliefs. However, only a small percentage of treatment group participants attended, lessening their impact on positive behavior change and suggesting the need for alternative methods of engagement in future approaches, especially because booster events are not economically sustainable on a large scale. Virtual support communities designed for midlife populations have been explored with positive results (King et al., 2013).

Family History of Alzheimer's Disease

Although in other studies a family history of AD has been found to be a strong predictor of intentions to be tested for dementia and engage in other health promotion

activities (Cutler & Hodgson, 1996; Roberts, 2000), having a family history of AD was not related to behavior change in the current study. It could be that there are enough interindividual differences with regard to participants' psychological responses to their relatives with AD that the hypothesized fear-based impetus to change behavior wasn't realized. There is some support for this finding in the literature, which suggests that some people react with positive emotions towards people with dementia and others find fulfillment through their caregiving roles, rather than becoming fearful and internalizing dementia risk for themselves (Cohen, Werner, & Azaiza, 2009). This could indicate that a personal concern for developing AD through experience with family members who have the disease might have been overshadowed in our study by a majority of participants who had a more positive response. Unfortunately we lack objective data to know for certain each relative's AD diagnosis and have to rely on participants' self-reports of family history of AD which are frequently subject to potential bias. Further, a future study may reveal whether a positive family history of AD may impact behavior change only among those who either performed a caregiving role or were otherwise directly impacted by direct observations of loved ones' decline. While the current approach used a weighted aggregate measure of family history, it may also be informative to study the impact of parents-only with dementia instead of an aggregate variable using siblings or grandparents, or even to test the specific effect of the same sex parent who has dementia.

Strengths and Limitations

The large number of statistical tests that were run likely results in an inflated Type I error rate in these pilot study findings. However, it should also be noted that a fairly

consistent pattern was observed in the moderately concerned subgroups making the greatest behavioral changes. Such nonrandomness to the pattern of significant findings increases the likelihood that such findings are "real" and may be an indication of psychological forces at work as discussed herein. Ideally the measure for fear of AD would have been conducted at pretest as well as midstudy, however, it is assumed to not have varied significantly between pretest and the three-month midstudy timeframe. Because the sample was ethnically homogeneous, generalizability to multiple ethnic groups is possible though as yet unproven. This sample was highly educated with 77% holding an undergraduate or advanced degree, higher than average in terms of income, overwhelmingly white (98%), and selected in part because of their access to technological resources such as smartphones that may not be readily available to the entire US population. In spite of this, however, internal validity is increased by the absence of contextual variables that might otherwise confound results. Other strengths of this study include the RCT design, the many components to the intervention, the novel use of technology as an intervention delivery tool and outcome data collection system, the monitoring of six different domains, the real-world 'holistic' approach that grants full autonomy to each participant, allowing participants the autonomy to choose to work on a domain(s) of personal interest. The freedom to choose which domain is of interest has been shown to have positive benefits for participant engagement and sustainability in behavior change (Olanrewaju, Clare, Barnes, & Brayne, 2015). However, the disadvantage for this approach in the current study is that the effect of each independent variable on behavior change was tested for all domains, regardless of whether or not the subject had actually targeted a specific domain. This creates the need for a new type of

analysis in future research, perhaps a formula that would yield the average level of behavioral change success across the domains the individual was targeting.

Future Research

Several additional research questions should be investigated that are beyond the scope of this dissertation. These include data analytic issues, personal priorities, community influence, length of intervention, and mechanisms.

Data Analysis

In the current study, a ceiling effect was observed in some domains, especially in the area of physical activity, where it was determined that many subjects in the treatment group were already participating in a high level of physical activity at baseline and had little room for improvement. A future study using this data set could remove the top quartile of participants who were already exercising significantly beyond the CDC recommendations (and who, therefore, were unlikely to see any need for change in their physical activity and who, therefore, likely did not make increasing physical activity level a priority during the study period). Then, a reanalysis could be conducted to see if significant change is observed in the remaining 75% of the total sample, and if the perceived AD risk would have stronger predictive ability on physical activity change (and similarly for the other domains). Future studies should consider enrolling participants who have a higher cardiovascular risk, a lower physical activity level, and possibly also those with mild cognitive impairment (via objective screening test) or subjective memory complaints in order to reduce the likelihood of ceiling effects in the data.

Mechanisms for Perceived AD Threat and Behavior Change

Future research linked to the current study should develop mediation models using data collected at pretest, midstudy and posttest on measures of intrinsic motivation and readiness for change. This is important for several reasons. First, previous studies have shown that external incentives will motivate people to change their behavior on a short-term basis, but that intrinsic motivation is necessary to sustain behavior change over time (Seifert, Chapman, Hart, & Perez, 2012). Factors such as emotions and unconscious thoughts can interact to affect health behaviors in ways not addressed by the HBM. In addition, individuals may choose to either engage with or not participate in health-related behaviors for reasons unrelated to health. Finally, habitual health-related responses such as smoking may preclude conscious decision-making in terms of healthy behaviors, all of which points to the need for a better understanding of how perceived threat of AD affects behavior change in a health context.

Personal Priorities

A review of the literature showed an increased awareness of the importance of multicomponent AD risk-lowering interventions (King et al., 2015; Olanrewaju et al., 2015; Prochaska et al., 2012) as well as the need for allowing individuals to actively identify what they need in terms of health behavior improvement and what they are willing/able to do (Olanrewaju et al., 2015). In the GM pilot study, each treatment group participant was asked to self-prioritize the six behavioral domains. In the entire treatment group, the overall rank order of importance of these domains from most to least important was as follows: physical activity, cognitive stimulation, healthy food choices, stress

management, sleep quality, and social engagement. A future study could evaluate how much these prior experiences with AD (which may result in a sense of personal vulnerability to the disease) would predict behavior change in the *specific* domains that were more highly prioritized at the individual participant level. Future analyses of the current data should test whether greater behavioral change in each given behavioral domain occurred within the subset of participants who prioritized that domain and whether the independent variables might influence participants' level of intervention utilization.

Community Influence

Another question to be addressed by future research is whether we can find a way to profile and then target those participants who will be the most likely to engage, sustain, and benefit from an intervention to encourage the adoption and maintenance of healthy lifestyle behaviors at a community level. Resources should be directed to this subgroup initially since the odds are greater that significant lifestyle behavior change could be initiated and sustained in a more motivated population. Factors to consider could include personality traits (Candel & Merckelbach, 2003), other life stressors such as overall health (Tsai et al., 2010), and access to information about AD risk factors (French, 2009; Kessler et al., 2012). Some individuals may benefit from an information-only approach while others might need a more intensive level of engagement. Olanrewaju and colleagues (2015) suggest the establishment of a community facilitator who could direct people to the kinds of resources best suited for their individual needs.

Length of Intervention

Future research should also expand on this pilot study by lengthening the intervention time frame to at least one year, owing to seasonal variations in mood, comfort in outdoor activities due to weather, availability of fresh produce, and so forth. Richard and colleagues (2012) highlighted the need for RCTs or adaptive trials to have larger samples and longer follow-up periods (Richard et al., 2012). A successful behavior change program must find a way to be effective for each individual according to his or her psychological, economic, cultural, and logistical parameters. Only with enough time to create a highly customized approach to lifestyle modification will it be more likely to effect meaningful and sustainable change through educating, empowering, and encouraging each study participant over time. Expanding the sample of study participants to include individuals from diverse ethnic and socioeconomic backgrounds would be recommended to increase evidence of generalizability.

Conclusion

The results of this study, at least in the psychological domains related to perceived AD risk, could help to clarify what important factors need to be measured and tracked in order to reach those individuals who are more motivated as well as those who are not yet incentivized. Feedback and supports to assist these individuals to maintain healthy lifestyle choices will be important to future interventions. Moderating influences such as gender, age, marital status, SES, and social support networks should also be evaluated to assist in the identification of subgroups for whom an intervention such as GM will be most effective. Considering the tsunami of aging Baby Boomers who will soon be

reaching the age of greater susceptibility to AD, interventions that assist individuals and communities with making these changes are urgently needed.

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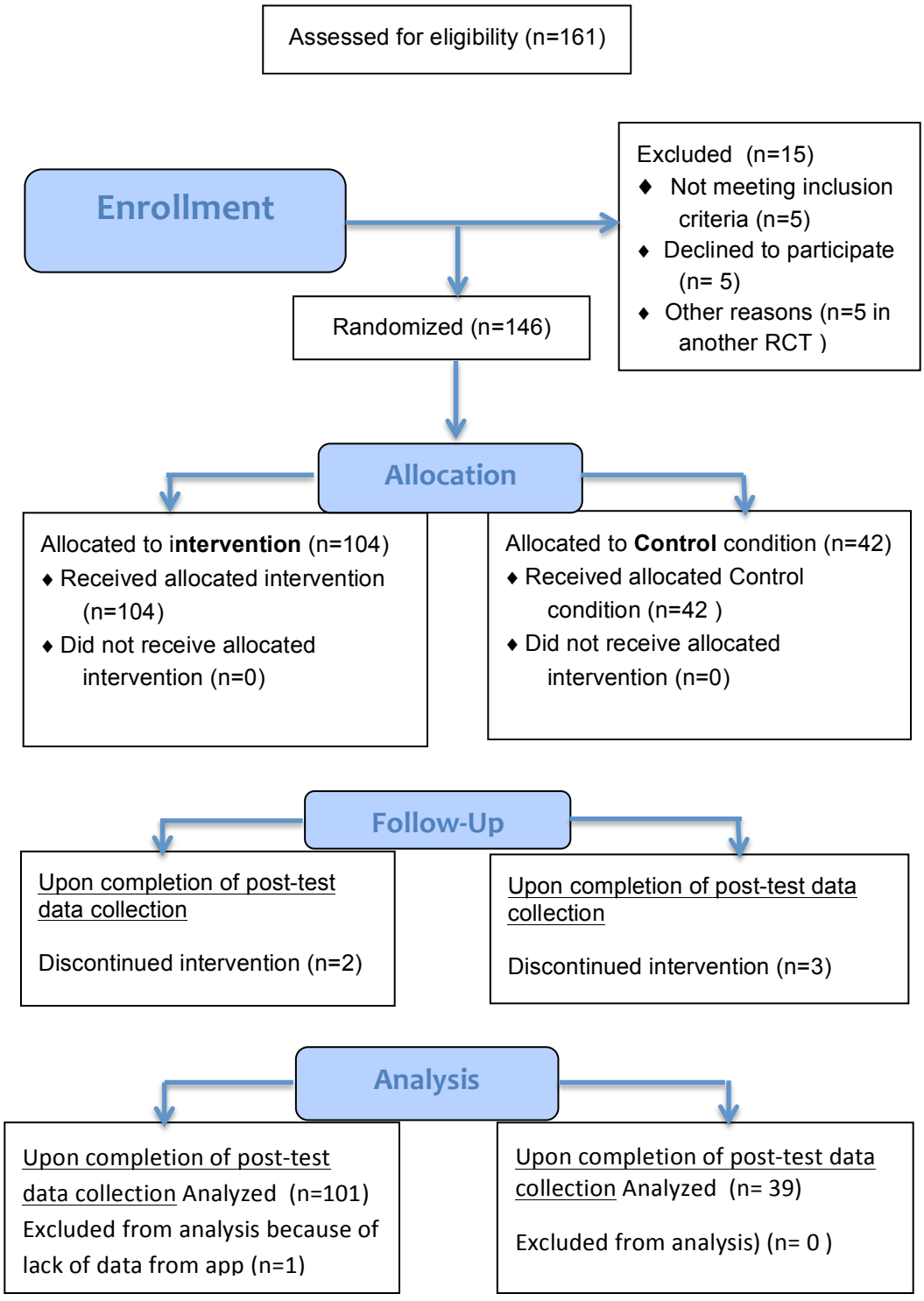
APPENDICES

Appendix A

Flow Diagram of Gray Matters Data Collection Procedures

GRAY MATTERS Data Collection Flow Diagram

ClinicalTrials.gov Identifier: NCT02290912



Appendix B

List of Booster Events in GM Intervention Protocol

Domain(s)	Booster event	Description
Cog. Stimulation	Brain challenge with painting	Local artist taught a class on painting and drawing in ways to challenge the brain, providing novel information processing
Cog. Stimulation	Tagalog Language	Introductory lesson on the Filipino language Tagalog
Cog. Stimulation	Mnemonics	Introductory lesson on use of mnemonics to improve one's memory
Cog. Stimulation	Choral singing	Lesson and rehearsal in choral singing, led by renowned former conductor of the Mormon Tabernacle Choir
Cog. Stimulation	"Alice Inside" documentary screening	Participants attended a screening of this documentary that won the Audience Award at the 2014 Sundance Film Festival, raising awareness of the importance of music in keeping us "alive" inside.
Cog. Stimulation	Guesstimation: The Art of Getting About the Right Answer	Physics professor provided a physics mini-class demonstrating atoms visually in scanning-tunneling microscope, and how the Drake equation can be used to estimate the probability of a wide range of phenomena (e.g. life on other planets)
Cog. Stimulation/Food choices	Cooking competition	Reality show-like format; participants created new food dishes using ingredients of from familiar to very unfamiliar, graded on: creativity, presentation, taste
Food choices	Legumes, Grains, Vegetables	Cooking classes preparing recipes with legumes, whole grains, green vegetables
Food choices	Grocery tour	Reading nutrition labels, psychology of food placement in stores, resources for healthy eating
Physical Activity	Fitness class	Orientation to local gym's services and classes
Physical Activity	Cross-fit class	Ten-visit complementary punch pass to local Cross-fit gym
Physical Activity	Kubex gym	6-week trial membership in gym that provides individual private cubicles with exercise machines, custom workout, tracked and modified by computer.
Physical Activity	Pilates	Intro class on Pilates
Physical Activity/Cog. Stimulation	Wildflower hike	Retired faculty native plants expert-led hike on a local trail for physical activity and learning how to identify wildflowers; preceded by mini-class on hydration for hiking and healthy trail snacks

(Table Continues)

Domain(s)	Booster event	Description
Physical Activity/Social Engagement	Alzheimer's Association-sponsored "Walk to End Alzheimer's"	Participants completed a 2-mile walk in a local park with fellow team members to raise awareness (local businesses sponsored each walker, as organized by study staff)
Sleep Quality/Stress Mgt.	Interior Design	Renowned local interior designer gave workshop on ways to design the home for better relaxation, lower stress level and more conducive to improved sleep quality
Social Engagement	Social Engagement	Orientation to study SE workbook, discussion
Stress Mgt.	Mindfulness	Learning to be in the moment and de-stress
Stress Mgt.	Relationship Enrichment	Learn more effective tools for communication in intimate relationships, to reduce relationship-related stress
Stress Mgt.	Effective time management	Lesson on strategies for improving organization in one's life for better time management and reduction of stress
Stress Mgt./ Sleep Quality	Yoga class	Introduction to yoga
Stress Mgt./Sleep Quality	Tibetan Singing Bowl	Learning to de-stress, wind down and appreciate simple things like breathing

Appendix C

List of Questions and Facts on the GM Smartphone App

Table C1- The questions presented to the user, showing their minimum, maximum and recommended values

Domain	Id	Question	Min.	Max.	Recommended	Type
Cognitive	1	How many minutes did you spend today doing "novel mental exercises"?	0	120	30 minutes	Objective
Cognitive	2	How many minutes did you spend today doing "cognitively stimulating activities"?	0	120	30 minutes	Objective
Food	3	How many cups of fruits and vegetables did you eat today?	0	10	5 cups	Objective
Food	4	How many ounces of whole grains did you eat today?	0	10	3 ounces	Objective
Food	5	How many servings of nuts, seeds, or legumes did you eat today?	0	5	1 serving	Objective
Physical	6	How many minutes of "moderate" physical activity did you do today?	0	60	30 minutes	Objective
Physical	7	How many minutes of "vigorous" physical activity did you do today?	0	60	20 minutes	Objective
Sleep	8	How would you rate your sleep promotion efforts over the past 24 hours?	0	5	5 (out of 5)	Subjective
Social	9	How would you rate your social engagement in the last 24 hours?	0	7	7 (out of 7)	Subjective
Stress	10	How much effort have you put into decreasing your stress over the past 24 hours?	0	10	10 (out of 10)	Subjective
Stress	11	On a scale of 1-10 how would you rate your stress level over the past 24 hours?	1	10	1 (out of 10)	Subjective
Wearable	12	How many Nike Fuelpoints did you earn today?	0	5000	2000 Fuelpoints	Objective

Table C 2. Examples of facts and suggestions from the smartphone app for each of the six health-related behavioral domains

Domain	Fact	Suggestion	Reference	Weblink
Food Choices	Eating foods with polyphenols can improve your memory.	Have some walnuts for a snack.	Féart C et al. Potential benefits of adherence to the Mediterranean diet on cognitive health. Proc Nutr Soc. 2013;72(1):140-52.	http://journals.cambridge.org.dist.lib.usu.edu/download.php?file
Physical Activity	Physical activity reduces risk of type-2 diabetes, an AD risk factor.	Strive to be lean and fit today!	Tortosa-Martinez, J., & Clow A., (2011). Does physical activity reduce risk for Alzheimer's disease through interaction with the stress neuroendocrine system. Stress: The International Journal On The Biology Of Stress. May 2012;15(3):243-261.	http://www.sciencedirect.com/science/article/pii/S0006899313013401
Cognitive Stimulation	People with less education are more likely to have AD.	Enroll in a class in a topic of interest that you know little about.	Ott A et al.(1995) Prevalence of Alzheimer's disease and vascular dementia: Association with education. The Rotterdam study. BMJ 310: 970–973. doi: 10.1093/carcin/22.2.233	http://www.ncbi.nlm.nih.gov/pmc/articles/PMC2549358/
Stress Manage-ment	Stress is linked to higher risk of AD.	Find ways to relax every day; meditate, warm baths, etc.	Johansson, L et al.(2010). Midlife psychological stress and risk of dementia: a 35-year longitudinal population study. Brain, 133(8), 2217-2224.	http://brain.oxfordjournals.org/content/133/8/2217.long
Sleep Quality	Fragmented sleep has been linked with a 22% increase in rate of cognitive decline.	Eliminate possible sleep interrupters, such as turning off telephone ringers, and avoiding liquid consumption near bedtime.	Lim, A et al. (2013). Sleep Fragmentation and the Risk of Incident Alzheimer's Disease and Cognitive Decline in Older Persons. Sleep, 36(7), 1027-1032. doi: 10.5665/sleep.2802	http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3669060/
Social Engage-ment	Having a strong social support network can help your cognition now and later.	Keep friends close & stress away for a sharper mind now and later.	Zuelsdorff, ML et al.(2013). Stressful events, social support, and cognitive function in middle-aged adults with a family history of Alzheimer's disease. Journal of aging & health, 25(6), 944-959. doi:10.1177/0898264313498416	http://www.ncbi.nlm.nih.gov/pubmed/23945762

Appendix D

GM Educational Components: Examples of Posters with Talks Presented at the GM Kick-off Event and an Example of the Social Engagement Workbook

Example of Educational Posters Presented at the GM Kickoff Meeting March 22, 2014

~Adopt a Cognitively Active Lifestyle~

Using a two-pronged approach:

1. Build up cognitive skills by engaging in "Cognitive Calisthenics." Try:

    a. Crossword puzzles, word games
    b. Sudoku puzzles
    c. Hands-on puzzles
    d. Computer activities
    e. Reasoning problems

2. Stimulate your brain in your leisure-time
    a. Take a class to learn new skills (build/repair a computer; interior design; landscaping)
    b. Learn to speak a new language
    c. Volunteer and meet new people and solve challenges
    d. Learn to play a musical instrument
    e. Join a stimulating club – Reading Club, Arts, Nature
    f. Watch and discuss a documentary

Novel activities will be more stimulating

~Watch for these Community Events~

April - Summer: MUSEUMS on Utah State University Campus
Art: http://artmuseum.usu.edu/
Anthropology: http://anthromuseum.usu.edu/

April – June: STOKES NATURE CENTER:
http://www.logannature.org/community_program_schedule.html
Workshops on survival, forests, astronomy, book binding, soap making, summer solstice art and others will stimulate your brains!

July 9 – Aug 9: Utah Festival Opera: http://www.utahfestival.org/
Sign up for Academy Classes to enhance your experience!

Educational Components from the Gray Matters Intervention Kickoff Meeting March 22, 2014

1. **"A disease unlike any other."** There are a host of health conditions and diseases one may develop in later life—high blood pressure, high cholesterol, Type II diabetes, heart disease, cancer, etc. Unlike all of these other conditions, Alzheimer's stands alone, for 2 major reasons:
    a. These other conditions have treatments that work, at least in some people, the condition is arrested, resolved, or at least held at bay "in remission" so that you can return to relatively normal life. Alzheimer's disease has no effective treatment and is irreversible.
    b. These other conditions rob you of vitality, energy, the ability to do many of the things you physically used to be able to do. Alzheimer's disease kills off brain cells until there is so much disintegration of the brain that basic functions are lost, and along with it, memories and personality. Alzheimer's is a disease you want to avoid at all costs!

2. **The "silver tsunami"**. Share AD stats, e.g. 5 million now, 15 million by 2050 in US alone. While the rate that people are dying from conditions like heart disease, cancer, and HIV has been dropping in recent years (since 2000), the trend for Alzheimer's is going in the other direction—getting worse, and FAST. In the absence of a cure, we must do all that we can to reduce the number of new cases, or the burden on society will be enormous. There will not only be inadequate financial resources, there may simply not be enough caregivers to take care of all the new Alzheimer's cases to come. DON'T BECOME ONE OF THEM.

3. **Legacies**
    a. Cache County Memory Study participants (and others of their generation) gave us the knowledge we have today about Alzheimer's disease and its risk and protective factors; they have left a legacy for their children—YOU in this audience
    b. With your involvement in this new study, YOU will leave a legacy for your children and grandchildren, by helping to test a health education program that puts Alzheimer's disease front and center, and teaches what modern science has discovered about how we can lower our risk

4. **Spare you and your children.** On a more personal level, by being involved in this study, and making lifestyle changes we are going to teach you about, you just might spare yourself from ever getting Alzheimer's, thereby also sparing your children of the heartache of losing you to this brain-robbing disease. So, do this for yourself (the "you" who you are today, and the "you" that you will become in 20-30 years). Do it for your children.

5. **Proactive, not passive.** Without a cure for Alzheimer's disease, what we are about to teach you, starting today, IS GOING TO PUT YOU IN THE DRIVER'S SEAT OF YOUR BRAIN'S VITALITY ON INTO OLD AGE. Your other option is just wishing and hoping that you don't develop this disease. Wit h what we now know about how lifestyle choices affect our risk for Alzheimer's, wishing and hoping is simply not an acceptable option.

6. **Go slowly.** Changing lifestyle habits takes time. Go easy at first. Baby steps, and then when you are confident you've got some areas nailed, you might try to change habits in another area. Successes, even small ones, can help build the confidence you need to keep it up!

7. **Ultimately, "It's up to you. "** You will get out of the study whatever you decide to put into it. Today you have the choice to become committed to making some healthy changes in your lifestyle.

Example of GM Social Engagement Workbook

START HERE!

Week 1: Goals and Pathways

Diagram your goals for the duration of the intervention (up to 8 months). Through this exercise you will define areas of your social network that you would like to improve. The *Goals and Pathways* activity is an essential starting point in this intervention process. We refer back to this diagram often in your workbook, so take the time now to really think about your goals.

Using the pages provided, write in the space at the top of the diagram to summarize your current social life and social network (relationships, activities, etc.).

Draw circles on the 8 month intervention timeline for where you would like to be in your social engagement. Write in your goals or things to improve.

Connect a path (a line) between where you are now, and where you want to be (the circles).

Include ideas along the pathway (boxes) for "*Action items*" – things you can do along the way to achieve those goals. See the example here, and then fill this out on the next page on your own.

Keep in mind your goals may change along the way – leave room for additions over the next few months. Halfway through you can revise the whole diagram, if needed. Also leave some space for additional action items. Throughout this intervention you will receive suggestions for action items you can add to your Goals and Pathways diagram.

Appendix E

Survey Questions Used to Create Independent and Dependent Variables

GM MIDSTUDY SURVEY QUESTIONS:

Q48 on the GM midstudy survey: People joined the Gray Matters study for a variety of reasons. For each of the reasons listed below, please check the response that most closely describes the extent to which you were motivated to join the study. (Likert answers coded 1-5. Strongly disagree, Disagree, Neither Agree nor Disagree, Agree, Strongly Agree)

- Answer #7: I was worried about my own memory loss.
- Answer #13: I am fearful that I may develop AD/dementia
- Answer #14: Seeing effects of AD/dementia on an afflicted loved one has been disturbing to me

Q49 on the GM midstudy survey: Prior to joining the study, I was worried about my risk for AD:

- not worried at all (1)
- mildly worried (2)
- somewhat worried (3)
- very worried (4)
- terrified (5)

Q50 on the GM midstudy survey: Prior to joining the study, I worried about getting AD:

- never (1)
- rarely (2)
- somewhat worried (3)
- often (4)
- all of the time (5)

Q51on the GM midstudy survey: Who do you know that has (or had before they died) AD or other form of dementia? Please check all that apply to you.

- Father (1)
- Mother (2)
- Sibling (3)
- Other relative (4)
- Other person not in my family but who feels like family to me (5)
- I know no one with AD or dementia in any of the above 5 categories (6)

Q11 on the GM pretest survey: Do you have any ancestors or relatives who have (or had, if deceased) Alzheimer's disease or other form of dementia? (please check all that apply)

- None that I know of (1)
- Mother (2)
- Father (3)
- One or both maternal grandparents (4)
- One or both paternal grandparents (5)
- One or more aunts/uncles (6)
- One or more aunts/uncles (6)

- One or more siblings (7)

Q8 on the GM pretest survey: What is your highest education level?

- Less than High School Graduate (1)
- High school graduate/GED (2)
- Some college/Trade School/Associate's Degree (3)
- College Graduate/ Bachelor's Degree (4)
- Graduate or Professional degree (5)

Q3 What is your age? _____ years

Q9 on the GM pretest survey: What is your annual household income (including all sources: earned income, investment income, retirement, etc)?

- Less than $35,000 (1)
- $35,000-$45,000 (2)
- $45,001- $55,000 (3)
- $55,001-$75,000 (4)
- More than $75,000 (5)

Q10 on the GM pretest survey: Are you currently providing care for a parent or other close relative with cognitive impairment or dementia?

- No, and I have never provided such care in the past (1)
- No, but I have provided such care in the past (2)
- Yes I currently provide such care, but this person does not live with me (3)
- Yes I currently provide such care, and this person lives with me (4)

Q15 on the GM pretest survey: Please indicate your level of participation in social, political, or community groups or clubs (for example, Rotary Club, Sons/Daughters of Utah Pioneers, Veterans of Foreign Wars, Audobon Society, Hiking club, Bicycling club, Book club, etc):

- every day or nearly every day (1)
- several times a week but less than daily (2)
- several times a month (3)
- several times a year (4)
- once a year or less (5)

Q16 on the GM pretest survey: Please indicate how often you spend time with family or friends, in addition to the participation in community groups or clubs you reported on in the previous question.

- ❍ every day or nearly every day (1)
- ❍ several times a week but less than daily (2)
- ❍ several times a month (3)
- ❍ several times a year (4)
- ❍ once a year or less (5)

Q23 on the GM pretest survey: The following questions are about how you feel your memory is doing. Try to remember what your memory was like 3 years ago and compare that to what it is like now. For each question in the table below, please indicate whether you've gotten much better, a bit better, have not had much change, have gotten a bit worse or much worse in that situation. (adapted from Gilewski, Zelinski, & Scaie, 1992; Jorm & Jacomb, 1989)

	Compared with 3 years ago, how are you at:							
	Much Better (1)	A Bit Better (2)	Not Much Change (3)	A Bit Worse (4)	Much Worse (5)	Refused (6)	Don't Know (7)	
Remembering recent events, appointments, or recalling where you put objects? (1)	❍	❍	❍	❍	❍	❍	❍	❍
Remembering the names and faces of friends and relatives? (2)	❍	❍	❍	❍	❍	❍	❍	❍
Keeping your train of thought or finding the right words in a conversation? (3)	❍	❍	❍	❍	❍	❍	❍	❍
Finding your way around familiar places? (4)	❍	❍	❍	❍	❍	❍	❍	❍
Operating gadgets, appliances, or machinery around the house? (5)	❍	❍	❍	❍	❍	❍	❍	❍
Keeping up with household chores, hobbies, and other interests? (6)	❍	❍	❍	❍	❍	❍	❍	❍
In general how is your memory now compared to the way it was 3 years ago? (7)	❍	❍	❍	❍	❍	❍	❍	❍

Q30 During the past month, how would you rate your sleep quality overall?

- ❍ Very Good (1)
- ❍ Fairly Good (2)
- ❍ Fairly Bad (3)
- ❍ Very Bad (4)

Q13 In a typical week, how many total minutes do you engage in "moderate intensity" physical activity (i.e., brisk walking, bicycling, vacuuming, gardening, or anything else that causes small increases in breathing or heart rate)?

(1)	Minutes per week or (1)	Minutes per day (1)

Q14 In a typical week, how many total minutes do you engage in "vigorous intensity" physical activity (i.e., running, aerobics, heavy yard work, or anything else that causes large increases in breathing or heart rate)?

(1)	Minutes per Week or (1)	Minutes per Day (2)

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Doctor of Philosophy, Family and Human Development. Utah State University. 2016

Master of Business Administration. Utah State University, Logan, Utah. 2010

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2015	Graduate Instructor, Ph.D. Candidate, Department of Family, Consumer, and Human Development, Utah State University, Logan, Utah.
2014	Study Coordinator for *Gray Matters*, a multidomain lifestyle intervention to reduce Alzheimer's disease risk, Utah State University, Logan, Utah.
2012-2013	Graduate Research Assistant, Ph.D. Candidate, Department of Family, Consumer, and Human Development, Utah State University, Logan, Utah.
2005-2009	Managing Director, Salt Lake Choral Artists and American Festival Chorus, Salt Lake City, Utah and Logan, Utah.
2003-2005	Graduate Assistant, Department of Music, University of Utah, SLC, Utah.

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Norton MC, Fauth E, **Clark CJ**, Hatch DJ, Greene D, Pfister R, Tschanz JT, Smith KR. Family member deaths in childhood and adulthood independently predict Alzheimer 's disease risk. The Cache County Study. *International Journal of Geriatric Psychiatry*. July 2015 [published online ahead of print].

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Hartin PJ, Cleland I, Nugent CD, McClean SI, **Clark C,** Tschanz JT, Norton MC. A Smartphone App to Deliver and Monitor Behavioral Change Interventions Aiming to Reduce Risk of Developing Alzheimer's Disease. Poster presentation at the Alzheimer's Association International Conference on Alzheimer's Disease, July 2015, Washington DC, USA.

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Clark CJ, Pfister R, Smith KR, Tschanz JT, Norton MC**.** Family member deaths in childhood and adulthood independently predict Alzheimer's disease risk. Poster presentation at the annual conference of the Gerontological Society of America, November 2013, New Orleans, LA.

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