# EFFECTS OF ONLINE SOCIAL NETWORKING ON THE COGNITIVE, SOCIAL, AND EMOTIONAL HEALTH OF OLDER ADULTS

by

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**TABLE OF CONTENTS**

## TABLE OF CONTENTS -- *Continued*

## LIST OF FIGURES

## LIST OF TABLES

**ABSTRACT**

Research suggests older adults who remain socially active and cognitively engaged have better cognitive function than older adults who are socially isolated and disengaged. Using an online social networking website, like Facebook.com, may require simultaneous cognitive and social engagement, thus yielding improvements in both domains. This study aimed to examine the efficacy of learning and using Facebook as an intervention to maintain or enhance cognitive function in older adults.

Results from a small pilot study with 7 older adults suggested there may be positive effects on executive functions and memory following learning and using Facebook. Therefore, a larger and more well-controlled examination of the intervention was completed. Participants were 41 older adults (12 male), with a mean age of 79.4 and 16.5 mean years of education. Participants were assigned to learn how to use Facebook (n = 14) or an online diary website (active control, n = 13), or they were placed on a waitlist (no treatment control, n = 14). Participants assigned to learn a website attended three 2-hour classes over the course of one week and then used the website at home daily for the next 7 weeks. Participants assigned to the waitlist received no contact for 8 weeks. All participants completed a series of neuropsychological tests and questionnaires on social and lifestyle factors before and after this 8-week period.

Results showed that all participants were able to learn and use Facebook or an online diary website over an 8-week period. In addition, the Facebook group showed a significant increase in updating performance at post-test compared to no significant change in the control groups. Other composite measures of executive function, memory, and social support showed no differential improvement in the Facebook group across the 8-week interval. Thus, learning and using an online social networking site appeared to provide specific benefits for executive functions associated with working memory in a group of healthy older adults. This may reflect the particular cognitive demands associated with online social networking and/or the benefits of social engagement more generally.

# CHAPTER 1: INTRODUCTION

Adults over the age of 65 are one of the fastest growing and most vulnerable populations in the United States today. In 2012, people over the age of 65 represented 13.7% of the population (U.S. Census Bureau, 2013), a percentage that is expected to increase as baby boomers move into this age range. As economic difficulties are mounting and government benefits to older adults are threatened, a significant burden is placed on older people to maintain jobs, live independently, provide caregiving services for family members, and remain productive members of society well into advanced age. Finding ways to facilitate productive and independent living among older people is thus an important goal to which psychological science can contribute.

Preservation of cognitive functions is an important factor in supporting the skills needed to maintain full participation in the workplace and in society as a whole (Ritchie, Artero, & Touchon, 2001), as well as for maintaining overall quality of life as we age. It is well established that healthy aging is generally characterized by declines in cognition including certain aspects of memory, executive function, and information processing speed (Lezak, Howieson, & Loring, 2004).

There are, however, individual differences in the ability of older adults to maintain their cognitive abilities. While some individuals are able to maintain optimal levels of cognitive function over their lifetime, others may experience age-related cognitive changes within the normal range, and still others may develop neurodegenerative diseases that lead to significant impairments in cognitive function (Daffner, 2010). Thus, it is increasingly important to understand why and how some individuals demonstrate “successful cognitive aging” and others do not. We can use this information to help intervene on processes that may be inefficient or impaired in some older adults to allow them to continue functioning at their optimal level.

There have been many approaches to this problem thus far in the literature including studies that focused on cognitive, physical, social, and emotional health factors, as well as interventions that combined multiple domains in an attempt to maximize outcomes. The aim of the present study was to explore the possibility that a novel intervention that increased social interaction and cognitive activity might provide cognitive benefits for older adults. Specifically, we examined the efficacy of online social networking, using Facebook.com, as an intervention that might not only increase social engagement but also improve or maintain cognitive function in healthy older adults.

# CHAPTER 2: BACKGROUND

## 2.1 Cognitive aging

Healthy cognitive aging has been characterized by declines in some areas, including episodic memory, executive functions, and information processing speed, but relative preservation, or even improvements, in other areas, including semantic knowledge and autobiographical memory (Park et al., 2002; Lezak et al., 2004). Several theories have been proposed to explain the nature of these age-related cognitive changes. Salthouse (1996) proposed the speed of processing theory, which states that declines in processing speed have a cascading effect that reduces information processing capabilities, leading to the cognitive declines seen in normal aging. The inhibition theory of aging from Hasher and Zacks (1988) proposed that deficits in the ability to inhibit peripheral or task-irrelevant information leads to age-related cognitive changes. Craik and Byrd (1982) theorized that reductions in working memory and attentional resources are driving age-related declines in cognitive function. More recent studies have shown that there may be multiple processes influencing age-related cognitive changes, and that there are also substantial individual differences.

This more complex picture is reflected by neuroimaging research that found evidence that older adults who performed as well as younger adults on specific cognitive tasks were engaging additional areas of the brain (Cabeza, 2002). For example, studies of working memory found that high-performing older adults showed bilateral activation in the prefrontal cortex, while those older adults with poorer performance had only unilateral activation in the prefrontal cortex (Cabeza et al., 2004; Grady et al., 1998; Reuter-Lorenz et al., 2000). However, it is unknown whether this additional activation captured by fMRI is due to neuronal changes, behavioral strategies, or both. Behaviorally, research has similarly demonstrated that on some age-sensitive cognitive tasks such as source memory and prospective memory, only a subset of older adults are impaired while others perform as well as younger adults (Glisky & Kong, 2008; McFarland & Glisky, 2009). Therefore, on both the behavioral and neurobiological level, there appears to be great variability within the realm of healthy cognitive aging.

### 2.2 Plasticity and cognitive reserve

These individual differences in how people approach and engage the brain during different cognitive tasks in aging suggests that some older adults may be able to compensate for age-related changes and perform as well as younger adults while others may not (Cabeza et al., 2002). Additionally, postmortem studies have found that some older adults with significant pathology in the brain were asymptomatic while alive (Katzman et al., 1988). That is, some older adults performed within normal limits on tests of cognitive function while harboring Alzheimer’s plaques at autopsy.

In order to explain this finding Stern proposed that there were individual differences in brain and cognitive reserve (Stern, 2002). Brain reserve refers to individual differences in protective physical features of the brain that determine how the brain copes with age-related changes or pathology. Cognitive reserve refers to individual differences in the strategies that people use to perform tasks even in the face of specific brain pathology. Work from Stern and others described certain lifestyle factors that may build cognitive reserve including education, occupation, pre-morbid IQ, and mental activities (see Valenzuela & Sachdev, 2005 for review). Importantly, these factors do not appear to be fixed over the lifetime. In fact, research has shown that estimated IQ at age 53 was influenced by childhood cognitive function and educational attainment, and also by adult occupation, suggesting that cognitive reserve can change over the course of the lifespan (Richards & Sacker, 2003).

This dynamic influence of experience that is reflected in cognitive performance as well as neurobiological markers such as structural and functional differences in the brain is consistent with literature on neural plasticity. Research in both humans and animals has demonstrated robustly that the brain retains plasticity throughout life (see Burke & Barnes, 2006 for review) and that changes to both structure and function can occur with different lifestyle changes (see Stern, 2009 for review). Animal research has demonstrated cortical reorganization following the disruption or lesion of neural circuits such that other areas of the brain were able to absorb responsibility for the damaged functions (Jenkins & Merzenich, 1987). In humans, this phenomenon is observed in stroke patients who may have severe deficits following injury that are recoverable with extensive therapy

(Ramanathan, Conner, & Tuszynski, 2006). While stroke patients typically have much more extensive and focal damage compared to neural degeneration from the aging process, the neural plasticity shown in stroke patients suggests humans can change their brain functioning even in older age. However, stroke patients engage in extensive and rigorous therapy in order to make these gains. There is evidence from work in non-patients that with extensive and sustained experience, the environment can effect changes in neural structures. For example, McGuire and colleagues determined that London taxi drivers with many years of experience had larger hippocampi compared to bus drivers that drove the same route every day, suggesting that the extensive spatial maps built over long periods of driving a cab to novel locations each day had spurred neurogenesis in the hippocampus (Maguire et al., 2000; Maguire, Woollett, & Spiers, 2006). It remains unclear what types, duration, and frequency of enrichment activities are most beneficial for older adults and at what time in life (Wang, Xu, & Pei, 2012). Cognitive reserve may be more robust if developed earlier in life; however studies continue to demonstrate that the brain retains plasticity into older age. In fact, cognitive activity in late life is related to slower rates of cognitive decline independent of the extent of various neuropathologies (Wilson et al., 2013).

Therefore it is important to understand why and how older adults can engage these additional brain regions and maintain or improve cognitive performance. Evidence shows that physical, cognitive, and social enrichment have positive effects on the brain function of older adults (Kramer, Bherer, Colcombe, Dong, & Greenough, 2004), suggesting promising avenues for intervention.

## 2.3 Cognitive interventions

Research has attempted to capitalize upon the capacity for plasticity in the aging brain by developing and studying interventions that may improve cognitive function. This area of study has focused on using what we know about factors that promote cognitive reserve and plasticity, including cognitive engagement or education, physical activity, and social contact, in order to improve or maintain areas of cognitive function that are affected by the aging process (Hertzog, Kramer, Wilson, & Lindenberger, 2008). There are two different approaches to rehabilitation in general: “recovery,” which attempts to restore the affected function to its pre-morbid state, and “compensation,” which attempts to use intact functions to compensate for the affected function (Glisky & Glisky, 2008). In more recent literature on cognitive interventions and brain training, Park, Gutchess, Meade, & Stine-Morrow (2007) define two approaches: “traditional,” which attempts to train a specific function directly, and “nontraditional,” which attempts to train a specific function indirectly either through compensatory cognitive strategies or lifestyle changes that provide general intellectual stimulation or by affecting a biological mechanism that may lead to a general boost to cognitive function.

## 2.4 Cognitive engagement or strategy

Current literature includes reports of several interventions that have focused on training specific cognitive functions that decline with age, such as episodic memory, executive functions, and processing speed (see Lustig, Shah, Seidler, & Reuter-Lorenz, 2009 for review). The ACTIVE trial, the country's largest study of cognitive training, examined the effects of three different types of direct training in a large sample of older adults (Ball et al., 2002; Willis et al., 2006). A total of 2,802 healthy older adults over the age of 65 were randomized to one of four groups: memory training, problem solving training, processing speed training, or no training control. Participants received 60-75 minute training sessions twice a week over a period of 5 weeks. Improvements in cognitive function were shown in the processing speed and problem solving group and, to a lesser extent, the memory group, although these effects were specific to the abilities trained. Improvements were maintained over a period of 5 years, especially in those participants that received booster training. Results of this landmark study suggest that deficits in cognitive function are trainable and the brain remains plastic into old age.

Since results of the ACTIVE study were first published over ten years ago, many researchers have examined other means of cognitive engagement in aging ranging from a computerized cognitive exercise program (Smith et al., 2009) to a traditional Thai board game called "Ska" (Panphunpho, Thavichachart, & Kritpet, 2013). Results of cognitive intervention studies have been mixed, however, with few reports of generalization of the benefits to everyday life or even to other related cognitive tasks that were not specifically trained (Owen et al., 2010).

However, some recent studies have shown evidence for generalizability to cognitive tasks beyond those that were trained. Wolinsky, Vander Weg, Howren, Jones, & Dotson (2013) demonstrated effectiveness of a visual speed of processing training program implemented both at home and in the office. Middle-age (50-64) and older (65+) adults assigned to the treatment group had gains in both visual processing, but also Trails A, Trails B, Symbol Digit Modalities Test, and Stroop Word, demonstrating a generalizability of the training to other speeded neuropsychological tests. Another recent study demonstrated older adults improved performance on a specially designed multi-tasking video game called Neuroracer, along with improved attention and working memory performance (Anguera et al., 2013). Neuroracer is a video game that requires the user to drive a car along a twisted, hilly road with a joy stick while simultaneously monitoring for certain signs that appear on the screen and making a button press only to one type of sign. Healthy older adults were randomly assigned to train on the multi-tasking game, a single task control (either only driving the car or only monitoring for signs), or a no-contact control group. Participants in the multi-tasking training group made significant gains on performance on the Neuroracer game such that they were able to perform as well as healthy untrained 20 year olds. Importantly, these effects generalized to other tasks of attention and working memory. They also found that older adults assigned to the multi-tasking group had greater midline theta EEG signal, which is related to concentration and attention. This research presents both neural and behavioral evidence that attention and working memory remain plastic and trainable into old age, as well as support for generalizability of cognitive training. Additionally, it suggests that attention and working memory are viable targets for intervention for healthy older adults.

### 2.5 Physical activity

It has been well established that physical fitness is related to better cognitive performance in advanced age. There is robust evidence supporting improvements in cognitive function, specifically processing speed and executive functions, following cardiovascular exercise programs (see Kramer & Erickson, 2007; Hayes, Hayes, Cadden, & Verfaellie, 2013 for review). Furthermore, research has shown that physical fitness is related to changes in the morphology and function of the hippocampus, specifically cell proliferation in the dentate gyrus (Erickson et al., 2011). Interestingly, despite the documented improvements in hippocampal integrity related to exercise, cardiovascular fitness interventions do not tend to find robust changes in memory performance following intervention, although Erickson and colleagues have shown increases in spatial memory following an aerobic exercise program (Erickson et al., 2011).

More recent research suggests that other forms of exercise, including resistance exercises and stretching, may also improve neuropsychological outcome measures. Although a newer area with less rigorous research support, a few studies have shown that older adults who participate in Tai Chi show improvements in cognitive function (see Blake & Hawley, 2012 for review). Similar effects were not observed for older adults who participated in a yoga intervention, although quality of life and physical fitness improved (Oken et al., 2006). Research on the influence of physical fitness presents further evidence of the plasticity of the human brain even in advanced age.

### 2.6 Social connection

Correlational research demonstrates that various aspects of social engagement are related to cognitive function as well. In general, older adults who are more socially engaged are not only happier, but also have better health outcomes and cognitive function (Cohen & Janicki-Deverts, 2009; Conroy, Golden, Jeffares, O'Neill, & McGee, 2010; Holt-Lunstad, Smith, & Layton, 2010; Bassuk, Glass, & Berkman, 1999; Berkman & Glass, 2000; Krueger et al., 2009; Obisesan & Gillum, 2009; Seeman, Lusignolo, Albert, & Berkman, 2001; Seeman et al., 2010). Results of these studies reveal that older adults with better social health tend to have higher general cognition as reflected by overall scores on the Short Portable Mental Status Questionnaire (Obisesan & Gillum, 2009), the Abbreviated Mental Test (Conroy et al., 2010), a brief telephone test of cognitive function (Seeman et al., 2001), and a composite of 19 different neuropsychological tests (Kreuger et al., 2009).

There are, however, several different aspects to our social life including social network size, social support, social activities/social integration, and subjective loneliness, which may be differentially related to cognitive function. Cohen (2004) describes social support as resources provided by others that increase our ability to cope, while social integration is the participation in a wide variety of social relationships and activities. While some studies have shown that larger social networks are associated with less cognitive decline (Unger, McAvay, Bruce, Berkman, & Seeman, 1999; Holtzman et al., 2004; Zunzunegui, Alvarado, Del Ser, & Otero, 2003), other research argues that social network size is not critical for cognitive function abilities in aging (Glei et al., 2005; Green, Rebok, & Lyketsos, 2008; Krueger et al., 2009). A large epidemiologic study found evidence that, rather than social network size, social integration and engagement with members of that social network were related to better cognitive function in older adults (Seeman et al., 2001). Based on these results, Seeman and colleagues argued that having many social contacts provides no benefit if you never actually engage with those contacts. Participation in social activities was shown to be associated with lower risk of cognitive decline and better cognitive performance (Zunzunequi et al., 2003; Glei et al., 2005; Lövdén, Ghisletta, & Lindenberger, 2005). Additionally, recent research suggests a biological underpinning for this relationship. Higher social engagement was associated with larger total brain and gray matter volumes, especially in the temporal and occipital lobes, although it was not related to white matter volumes (James, Wilson, Barnes, & Bennett, 2011). However, the majority of these studies are correlational and thus do not reflect causal relations.

Studies examining the direct effects of social support, social networks, and social integration on health and cognition have also produced mixed findings. The MacArthur Studies of Successful Aging, which followed 1,189 older adults longitudinally, demonstrated that individuals with greater emotional support had higher levels of cognitive function at baseline and 7.5 years later (Seeman et al., 2001), a relationship observed correlationally in several other studies (Gow, Pattie, Whiteman, Whalley, & Deary, 2007; Zunzunegui et al., 2003; Glei et al., 2005; Krueger et al., 2009). Another longitudinal study found that social integration and family connections were positively associated with cognitive function in older adults over time (Beland, Zunzunegui, Alvarado, Otero, & del Ser, 2005).

A recent review of interventions targeting social isolation and loneliness in older adults revealed that some, but not all, studies showed improvement in at least one outcome domain—social, psychological, or physical health, although the specific results varied (Dickens, Richards, Greaves, & Campbell, 2011). However, none of the studies included in this review examined changes in cognition as a result of the intervention.

Despite the correlational and longitudinal relationships between social engagement and cognitive function, there are few studies that attempted to directly manipulate social variables with an aim to improve cognitive function in older adults. Pitkala, Routasalo, Kautianinen, Sintonen, & Tilvis (2011) examined the effects of increasing social interaction and friendships by facilitating social groups among older adults. They assigned 235 healthy adults age 75 or older to either a social intervention or a no treatment group. Participants in the social intervention participated in facilitated group discussions along with one of the following activities based on their interests: 1) therapeutic writing, 2) group exercise, or 3) art. After three months, participants in the social groups improved performance on the Alzheimer's Disease Assessment Scale-cognitive subscale (ADAS-cog) compared to no treatment controls. While this study demonstrates the possible effects of social interaction on cognitive function in older adults, the addition of different activities to the social groups makes it difficult to disentangle the effects of the increased social interaction from the effects of the additional physical and cognitive activities associated with the groups.

Although there are very few studies that directly examine the cognitive benefits of social interaction in older adults, there is evidence that social interactions, even brief encounters, can boost cognitive performance in younger adults. A study from Ybarra and colleagues (2008) found that just 10 minutes of social interaction improved performance on measures of processing speed and working memory in college students.

In addition, although there have been some studies demonstrating relations among social variables, cognitive function and physical health in older adults, there have been few studies examining the causal factors underlying these relations (Cohen, 2004).

### 2.7 Multi-modal interventions

Although some findings suggest a link between social variables and cognitive function in older adults, few studies have directly examined the impact of social interventions on cognitive aging. There are some multimodal interventions, however, that have reported positive effects on social and cognitive variables. For example, the Experience Corps is a program that enlists older adults as volunteers in elementary school classrooms. This program is described as an intervention that simultaneously targets cognitive, social, and physical functions in an attempt to maximize benefits in all three functional domains. Participants in the Experience Corps intervention reported increased physical activity and strength, a greater number of social contacts on which they could rely, and better executive function and memory performance after 4 to 8 months compared to a no-treatment control group (Fried et al., 2004; Carlson et al., 2008, 2009). More specifically, this intervention demonstrated increases in performance on Trails B and delayed memory of the Rey-Osterrieth complex figure test, especially among those participants lower on executive function at baseline (Carlson et al., 2008). The researchers for the Experience Corps study also examined a subset of experimental participants' brain activation using fMRI before and after the intervention.  This study demonstrated increased activation in the prefrontal cortex during a flanker task in the intervention group, demonstrating some evidence that the intervention resulted in functional brain changes (Carlson et al., 2009).  These results show that the intervention improved each of the targeted domains (physical, cognitive, and social).

Noice, Noice, & Staines (2004) implemented a theater-training group with older adults and demonstrated modest effects on cognition.  In this study, 124 community-dwelling older adults participated in a theater arts group, a visual arts group (active control), or a no-treatment control group.  After 4 weeks, the theater group performed significantly better on measures of word recall and problem solving compared to both control groups.  Notably, the visual arts control group required participants to engage in discussions surrounding art lessons, in an attempt to balance the social engagement aspects of both active groups. However, the study did not report data on social variables, so the extent to which these may have been affected by the intervention, and potentially related to changes in cognition, is unknown. The authors argue that the theater exercises may cultivate creativity and cognitive flexibility, leading to improved cognitive performance.  In a similar vein, Senior Odyssey was a project developed by Stine-Morrow and colleagues to investigate the efficacy of involving older adults in an Odyssey of the Mind program.  Odyssey of the Mind is a program used with gifted children that assigns groups to solve complex group problems.  The results of the Senior Odyssey study suggest some improvements on problem solving ability compared to a no treatment control group (Stine-Morrow, Parisi, Morrow, Greene, & Park, 2007). Both of these studies found improvements on cognitive tasks that appear to be closely related to the hypothesized cognitive components of each intervention activity.

Although the aforementioned studies include some increases in physical activity, other studies have looked at multi-modal interventions with more substantial physical demands. Researchers have shown a positive effect on cognitive performance through a dance intervention, arguing it engages physical, as well as mental and social components (Kattenstroth, Kalisch, Holt, Tegenthoff, & Dinse, 2013). Some recent studies have attempted to combine physical exercise with cognitive training (Barnes et al., 2013; de Bruin, van Het Reve, & Murer, 2013; Shatil, 2013; Linde & Alfermann, in press). One such study demonstrated that cognitive training only, exercise only, and combined exercise and cognitive training groups each showed differential effects in older adults (Linde & Alfermann, in press). All three groups displayed improved concentration following intervention; however this effect was only maintained in the exercise group. The combined and cognitive groups had improvements in speed of processing immediately following intervention, however only the combined group maintained these benefits. In contrast, Barnes and colleagues (2013) found both combined, physical exercise only, and mental exercise only groups all showed significant improvement on global performance on a comprehensive neuropsychological battery compared to no treatment control group. However, they did not break down these findings based on different cognitive domains, and it is possible that the different intervention groups showed effects specific to individual cognitive domains. A study on exer-gaming attempted to engage older adults in simultaneous cognitive and aerobic training (Anderson-Hanley et al., 2012). This research investigated the cybercycle, a stationary bicycle that engages the rider in a virtual reality tour on a built in computer monitor. This study found that 3 months of cybercycling increased executive functioning abilities above and beyond traditional exercise.

These studies suggest that interventions that target more than one aspect of lifestyle engagement and cognitive reserve are promising. However, most of these interventions are available only to those older people who are able to leave their homes and thus excludes the most vulnerable groups who are home-bound or have limited mobility.

## 2.8 Technology

One possible option for older adults who face physical, financial, or mental challenges that prevent them from leaving their home regularly is to use resources already present in their home, such as their computer. The Internet can act as a gateway to different experiences including information-gathering and socializing. The advent of online social networking sites allows users to connect with others without leaving their homes and thus provides an avenue for older adults who are socially isolated to engage with other people. Furthermore, an online interaction environment may feel “safer” for older adults who are experiencing cognitive decline because conversations can occur at the individual’s own pace. In an online social networking interaction, individuals can carefully prepare and review their remarks before they are shared with others. On the other hand, offline communication occurs in real time and the normal pace of conversation may not allow individuals time to compensate and work through cognitive difficulties. Thus the online interaction interface may protect people from the risk and shame resulting from revealing their cognitive impairment during a social interaction. Little is yet known about the utility of online social networking sites for older adults, and no studies have examined the direct effects on older adults of learning and using Facebook on a regular basis. In fact, a recent review of all studies examining Facebook in social sciences research included only a few studies that examined older adult Facebook users (Wilson, Gosling, & Graham, 2012). These studies note that older adults use Facebook less and have fewer friends compared to younger adults (Wilson et al., 2012).

Although little is known about online social networking use in older adults, research on computer use in general is mixed. It is estimated that approximately 40% of adults over age 65 have a computer in their home (Nielsen, 2009). A more recent study from the Pew Research Center found that 42% of adults over age 65 use social networking sites, up from just 13% in 2009 (Brenner & Smith, 2013). Contrary to popular stereotypes, research has found that most older adults have positive attitudes towards technology and find computers potentially beneficial (Mitzner et al., 2010). However, previous studies investigating the impact of training older adults to use computers and the internet found no significant positive results on various psychosocial measures (Kraut et al., 1998; White et al., 2002; Slegers, van Boxtel, & Jolles, 2008; Slegers, van Boxtel, & Jolles, 2009). Slegers and colleagues performed a large randomized controlled trial of computer use in older adults, which observed no beneficial effects of learning to use a computer on cognitive function or psychosocial well-being. However, when participants were followed over time, computer use was related to less decline in selective attention and memory, although effect sizes were small (Slegers, van Boxtel, & Jolles, 2012). A recent study found that older adults who regularly or occasionally played digital games had higher levels of well-being and lower levels of negative affect and depression compared with older adult non-gamers (Allaire et al., 2013).

Although research on online social networks, including Facebook, is lacking in older adult populations, there is a growing body of literature on Facebook use in younger adults, including effects on cognition and social functioning. A recent study found that adolescents that had used Facebook for longer than one year had higher working memory and verbal abilities compared with adolescents that had been using the site for less time (Alloway, Horton, & Alloway, 2012; Alloway & Alloway, 2012). These results were not found for experienced users of other websites, like YouTube.

However, there is also a growing body of literature that has documented deleterious effects of Facebook use. Kross and colleagues (2013) utilized experience-monitoring, a method which collects self report data in real time over mobile smart phones, in order to examine changes in subjective well-being and both Facebook and non-virtual social interaction. They found that Facebook use was related to decreases in subjective well-being, while face-to-face and telephone social interaction led to increases in subjective well-being. Other studies have shown negative relationships between academic achievement and Facebook use (Junco, 2011; Kirschner & Kirpinski, 2010); however it might depend upon how Facebook is used. Changing the way in which young people engage on Facebook may lead to meaningful changes. For example, a recent study from Deters and Mehl (2013) found that college students who were asked to increase the number of status updates they posted each day reported feeling less lonely and more socially connected compared to controls that continued to use Facebook as usual. These results were independent of how much feedback participants received from friends on their posts. Facebook updates may be more memorable as well, according to a study from Mickes and colleagues (2013), which showed that younger adults were able to remember status updates better than randomly selected sentences from a book or pictures of neutral faces.

It is unknown whether findings about Facebook use in younger adults will generalize to older adults who may have different motivations for engaging through social media. Additionally, if face-to-face interaction is no longer possible for an individual as a result of disability or other isolating factors, then it is possible Facebook may positively affect well-being. Furthermore, older adults may engage in different Facebook behaviors compared to younger adults, which may lead to different effects on psychological constructs.

Because lifestyle engagement appears to have the potential to improve cognitive function in older adults, it is possible that online social networking may provide a useful nontraditional, multi-modal cognitive intervention in this group. In the present study we investigated one of the most popular online social networks: Facebook.com. Facebook has approximately 1.11 billion unique users, and is one of the most popular social networking sites for those over age 65 (Brenner & Smith, 2013). Because of the large number of users on Facebook, there is the greatest potential for individuals to be able to find and connect with real-life friends and family members through this medium. Facebook, as well as online social networking in general, may capitalize upon the effects of both the cognitive engagement of learning a new skill and social engagement of interacting with others to provide an additive effect that will benefit cognition in older adults. Based on the results of a small pilot study, we hypothesized that using Facebook might provide benefits specifically for tasks of working memory, executive function, and processing speed and lead to increases in social support and decreases in loneliness.

# CHAPTER 3: METHODS

## 3.1 Pilot study

All Facebook procedures were first piloted with a small group (n = 7) of community-dwelling older adults. Participants were 3 men and 4 women with a mean age of 78.5 (Range = 75-86) and 16.14 years of education (Range = 10-20). They attended six 2-hour classes over two weeks followed by six weeks of continued use at home. At the end of the Facebook training class all participants indicated that they learned more about how to use Facebook from class, 6 out of 7 participants said that they felt comfortable using Facebook at home, and 5 out of 7 felt confident using Facebook. All participants were able to log in and create micro-blogs during the home-based intervention period, although the extent with which participants utilized the service varied.

Participants received a short battery of neuropsychological tests and questionnaires on social activities and connections both before and after the intervention. Although results from the pilot study were mixed with respect to the social variables, they strongly suggested that Facebook may have positive effects on executive function and/or memory, and that further research was warranted. We therefore proceeded with a larger-scale study that included measures of executive function, working memory, episodic memory and processing speed, along with several measures of social support and loneliness, and we added appropriate control groups to determine the specificity of the effects and to rule out re-test effects.

### 3.2 Participants

Participants were recruited from two sites that were studied independently with the same procedures. One cohort was from a retirement community in Green Valley, Arizona called La Posada, and the other was from the greater Tucson, Arizona community. Both cohorts were recruited using the same flyers and listserv announcements that asked participants if they were interested in learning more about how to use Facebook or an online diary website. These recruitment materials stated that people would be participating in a study to learn more about “micro-blogging,” or “writing a few short statements and posting those thoughts online.” The materials stated that the aim of the study was to investigate whether micro-blogging was more beneficial if it was shared with others or if it was kept private. Recruitment materials were designed to be neutral in regards to our hypotheses about the potential benefits of learning and using Facebook.

Our goal was to recruit individuals who lived alone, so that we could observe people with a range of scores on the loneliness, social support, and social integration measures (see below), while attracting at least some individuals who were truly socially isolated. Eighty-five individuals responded to our recruitment materials and 43 met the following eligibility criteria: They (a) lived alone, (b) either did not have an account with any online social networking sites including

Facebook, MySpace, Eons, or used it once a month or less, (c) had a computer or tablet with internet access at home and an e-mail address, (d) were available to attend three 2-hour classes and use a website every day for seven weeks, (e) did not have a significant neurological, psychiatric, or medical condition that would affect cognitive function, (f) did not have a history of psychoactive substance abuse, and (g) had a score ≥ 26 on the Mini Mental Status Exam (MMSE). Of the 42 individuals who were not eligible, 48% (N = 20) were unable to make the time commitment, 38% (N = 16) already used an online social networking site regularly (greater than once per month), 9.5% (N = 4) had a significant medical condition that would affect cognitive function, and 4.5% (N = 2) did not live alone. In order to get sufficient participants from the La Posada retirement community, however, we relaxed the live-alone criterion and enrolled three couples.

All individuals provided written informed consent to participate in the study. Participants from each cohort were randomly assigned to the Facebook, Online Diary, or Waitlist group. The Facebook and Online Diary classes began one week apart. In order to accommodate participants' schedules, such as pre-existing doctor appointments or other commitments, some people were placed into a class based on their availability. The intent was to have 12 individuals in each group, but that distribution was not quite achieved. We were unable to recruit 72 eligible participants, and 2 individuals failed to complete the entire study. Both dropouts were due to changes in health; one occurred prior to group assignment and the other occurred after the Online Diary classes. Thus, there were a total of 41 participants (12 male) who completed the study protocol with a mean age of 79.4 and 16.45 mean years of education. There were 14 participants in the Facebook group, 13 in the Online Diary group, and 14 in the Waitlist group. Demographic characteristics of the groups are shown in Table 1. Collapsed across cohorts, there were no significant differences across conditions in age, education, or gender. Between cohorts, the La Posada group was significantly older (Mean age = 81.75) than the community group (Mean age = 76.28), $t(40) = 2.805$, $p = .007$, and had significantly more males (42%) than the community group (13%), $\chi^2(1, N = 41) = 4.30$, $p = .038$.

*Table 1 Demographic characteristics of participants that completed the study*

| **Group**<br>Subgroup | Age<br>M (SD) | Years of Education<br>M (SD) | Gender<br>(% male) |
|---|---|---|---|
| **Facebook**, n =14 | 80.00 (7.34) | 16.29 (1.94) | 36% (n = 5) |
| Community, n = 6 | 73.17 (3.49) | 16.17 (1.60) | 17% (n = 1) |
| La Posada, n= 8 | 85.13 (4.61) | 16.38 (2.26) | 50% (n = 4) |
| **Online Diary**, n = 13 | 78.38 (7.32) | 16.69 (1.93) | 31% (n = 4) |
| Community n = 5 | 76.80 (8.61) | 16.80 (2.10) | 0% (n = 0) |
| La Posada, n = 8 | 79.38 (6.82) | 16.63 (1.85) | 50% (n = 4) |
| **Waitlist**, n = 14 | 79.29 (6.76) | 16.29 (2.09) | 21% (n = 3) |
| Community, n = 6 | 77.33 (6.50) | 17.50 (1.76) | 17% (n = 1) |
| La Posada, n = 8 | 80.75 (5.57) | 16.13 (2.01) | 25% (n = 2) |
| **Community**, n = 17 | 75.71 (6.27) | 16.82 (1.85) | 12% (n = 2) |
| **La Posada**, n = 24 | 81.75 (6.03) | 16.13 (2.01) | 42% (n = 10) |

## 3.3 Procedure and measures

The two cohorts were tested sequentially over two 12-week periods. Procedures and measures for the two cohorts were identical. Participants in all three experimental groups received a series of baseline tests between one and fourteen days prior to the start of training and again within seven days of completing the 8-week intervention phase (one week of classes and seven weeks of at-home use). The following tests were included:

### 3.4 Neuropsychological tests

Neuropsychological tests were used to assess cognitive function. Participants completed a battery of tests that measure functions shown to be sensitive to age-related cognitive changes including tests of memory, executive function, and speed of processing. We measured verbal memory with the Rey Auditory Verbal Learning Test (RAVLT — Schmidt, 1996) and non-verbal memory with the Rey-Osterrieth Complex Figure Test (Rey-O CFT — Meyers & Meyers, 1995). The RAVLT involves the repeated auditory presentation of a list of unrelated nouns that the participant must recall immediately, after reading another distractor list (short delay), and after a 20-minute delay (long delay). The Rey-O CFT requires participants to copy a complex figure and then produce it from memory after a 20-minute delay. To assess speed of processing, we administered the Digit Symbol Substitution Test (DSST — Lezak et al., 2004) and the Deary-Liewald reaction time (RT) task (Deary, Liewald, & Nissan, 2011). To complete the DSST, participants are presented with a page of symbols and are required to write in the number assigned to each symbol as quickly as possible. The symbol-number pairs appear at the top of the page; the score assigned is the number completed in 90 seconds. The Deary-Liewald RT task includes a simple RT task in which participants press a key on a keyboard as soon as an "X" appears on screen, followed by a complex RT task in which they press one of four keys that corresponds to a specific location on the screen where an “X” may appear. We also gave the Trail Making Test (Reitan & Wolfson, 1985), which provides measures of both visual scanning and processing speed (Trails A) and executive function (Trails B) by measuring the time it takes for participants to connect a series of numbers or alternating letters and numbers. For further measurement of executive function and fluency, we administered the Controlled Oral Word Association Test (FAS) and Category Fluency Test (Benton & Hamsher, 1978), where participants provide as many different words as they can in one minute that either start with a particular letter of the alphabet or belong to a specific category.

### 3.5 McKnight battery

Based on pilot results, we included a battery of tests to examine more specific aspects of executive function. These tests included six tasks from the McKnight battery (Alexander et al., 2012), two for each of three executive functions — updating, shifting, and inhibition — that were previously identified by Miyake and colleagues (2000) as three related, but independent factors. Updating is defined as the monitoring and refreshing of information in working memory and is typically measured by complex working memory span tasks, which show age-related decline (Fisk & Sharp, 2003). Shifting is defined as switching between multiple tasks or mental sets and is typically measured by paradigms where participants learn to perform one task associated with one aspect of a stimulus and a second task associated with a different aspect of the same stimulus, and then switch between these two tasks based on a signaling characteristic of the stimulus like color or location. Both global shift costs, the difference between performance on a dual-task block and single-task block, and local shift costs, the difference between switch trials and repeat trials within a dual-task block, can be calculated. A recent meta-analysis found that there are age effects on global shift costs, but not local shift costs (Wasylyshyn, Verhaeghen, &Sliwinski, 2011). Inhibition is defined as the inhibition of a prepotent response and is typically measured by tasks where a prepotent response is already established such as word reading. Several studies have shown that older adults tend to have more difficulty than younger adults inhibiting prepotent and irrelevant stimuli (see Hasher, Lustig, & Zacks, 2007). The tasks used to measure each component of executive function are described below.

### 3.6 Updating tasks

Letter Memory Test. In this task, adapted from Morris and Jones (1990), participants were asked to continuously report the last four letters presented in a string of consonants (Figure 1). Participants were shown a list of letters presented one at a time for 2000 milliseconds (ms) per letter on the middle of a computer screen. As each letter appeared and the previous letter disappeared, participants were instructed to say aloud the last four letters presented. For example, if the string of letters was “THGBSKR,” then the right answers would be “T … TH . . . THG . . . THGB . . . HGBS . . . GBSK . . . BSKR.” At the end of the string of letters, four dashes appeared on the screen and the participant repeated the last four letters again (in our example "BSKR"). Each trial was 5, 7, 9, or 11 letters long, and was presented in a pre-determined random order such that participants were unaware of the list length. The dependent measure was the total number of correct responses as each new letter in the series was presented, plus the final response (In the example above, the total possible correct would be 8). To be correct, the letters had to be reported in the correct order. There were three trials for each list length, yielding 108 total responses.

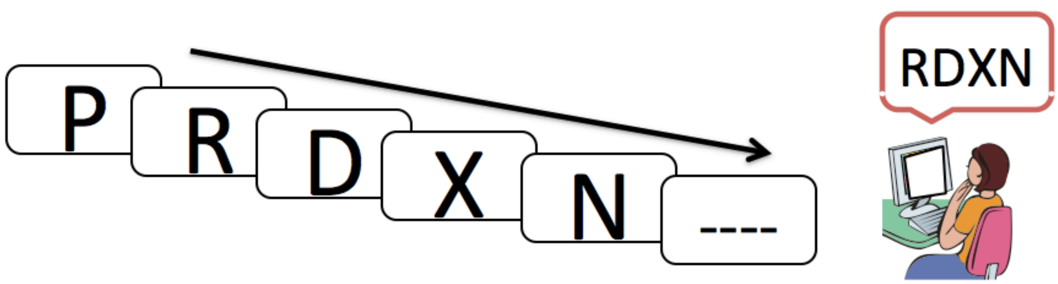


*Figure 1 Letter Memory task.*

Keep Track. In this task, adapted from Yntema (1963; also Miyake et al., 2000), participants were asked to hold in mind the last word presented from one or more specific categories (Figure 2). After familiarization with the words and categories (distances, metals, relatives, furniture, sports, and fruits), participants were shown a list of fifteen words, one at a time, which contained two or three exemplars from the different categories. Each word was presented for 1500ms while the target categories remained on the bottom of the screen. Immediately following the presentation of the list, participants were instructed to write down the last word presented from each of the target categories. The number of target categories varied from one to four, and participants completed three trials for each difficulty level, before progressing to the next higher level. The total number of words to be recalled was 30.

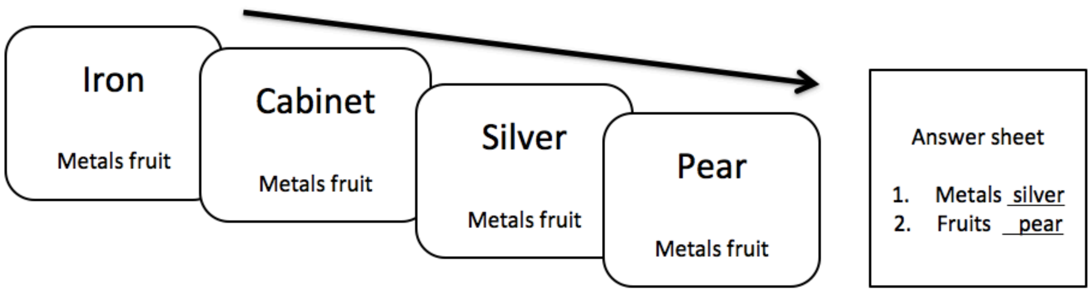


*Figure 2* *Keep Track task.*

**3.7 Shifting tasks**

Number-Letter Task. In this task, adopted from Rogers and Monsell (1995; also Miyake et al., 2000), participants saw a series of number-letter (or letter-number) pairs on the computer screen (e.g. 7A) and made a judgment about either the number or the letter based on the pair's location on the screen (Figure 3). If the pairs appeared on the top half of the computer screen on either the right or left side, participants indicated whether the number was odd or even with the index and middle finger of their right hand on keys marked "Odd" and "Even." If the number-letter pairs appeared on the bottom of the computer screen on the right or left side participants indicated whether the letter was a consonant or vowel with the index and middle finger of their left hand on keys marked “C” and “V.” Participants first completed a block of 30 trials in which all number-letter pairs appeared at the top of the screen, a second block of 30 trials in which the pairs appeared at the bottom of the screen, and finally two blocks of 60 trials in which the pairs rotated clockwise through the four quadrants of the computer screen. Their task in the mixed blocks was to make odd-even judgments when the pair appeared on the top of the screen, and consonant-vowel judgments when the pair appeared on the bottom. After every two trials, the judgment type switched, such that half of the trials required the same judgment type as the previous trial and the other half required a switch. Only RTs for correct responses were counted. Prior to analysis, individual RT data for each condition were trimmed. First, trials with RTs of 200 ms or less were deleted. Then trials that were 2.5 standard deviations (SDs) or more away from the mean were deleted. The global shift cost was calculated as the difference between the average RTs for the mixed blocks and the average RTs for the non-mixed blocks. We also calculated a ratio score ((mixed – non-mixed)/non-mixed) to control for individual differences in processing speed. The local shift cost was calculated as the difference between the average RTs for the switch trials and the average RTs for the non-shift trials in the mixed block. A ratio score was also calculated.

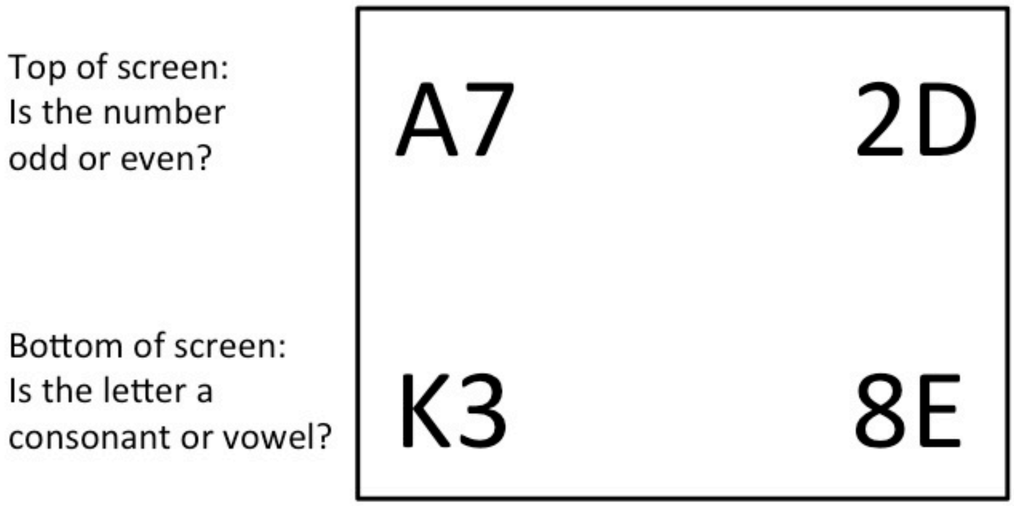


*Figure 3*        *Number-Letter Task.*

Local-Global Task. In this task, described by Miyake et al. (2000), participants were required to switch between identifying the “local” and “global” features of a given figure (Figure 4).  This task utilizes a Navon figure (Navon, 1977), which is a large figure that is comprised of many smaller figures placed next to each other to create the outline of the large figure. In our task, the participants were presented either a large circle made up of smaller triangles or a large triangle made up of smaller circles one at a time on a computer screen in either blue or black.  If the image was black, participants were instructed to make a button press corresponding to the shape of the smaller figures (local identification), and if the image was blue, they were to respond to the shape of the larger figure. Participants pressed a mouse button with their right hand using their middle finger to identify circles and their index finger to identify triangles. Each button was labeled with its respective shape. First, participants saw a block of 24 trials where all of the pictures were black (all local identification); then they saw a block of 24 trials where all of the pictures were blue (all global identification); finally they completed a block of 49 trials where the picture was randomly presented in either black or blue requiring them to shift between the global and local features of the figure (mixed block). The mixed block contained 30 repeat trials with the same color as the previous stimulus, 18 switch trials with a change in color from the previous stimulus (9 of each switch), and the first trial with no previous stimulus for comparison. The first trial and incorrect responses were removed. Only RTs for correct responses were counted. Prior to analysis, each individual's RT data for each condition were trimmed. First, trials with RTs of 300 ms or less were deleted. Then trials that were 2.5 SDs or more away from the mean of the correct trials were deleted. The global shift cost was calculated as the difference between the average RTs for the mixed block and the average RTs for the non-mixed blocks. The local shift cost was calculated as the difference between the average RTs for the switch trials and the average RTs for the repeat trials in the mixed block. Ratio scores were also calculated.

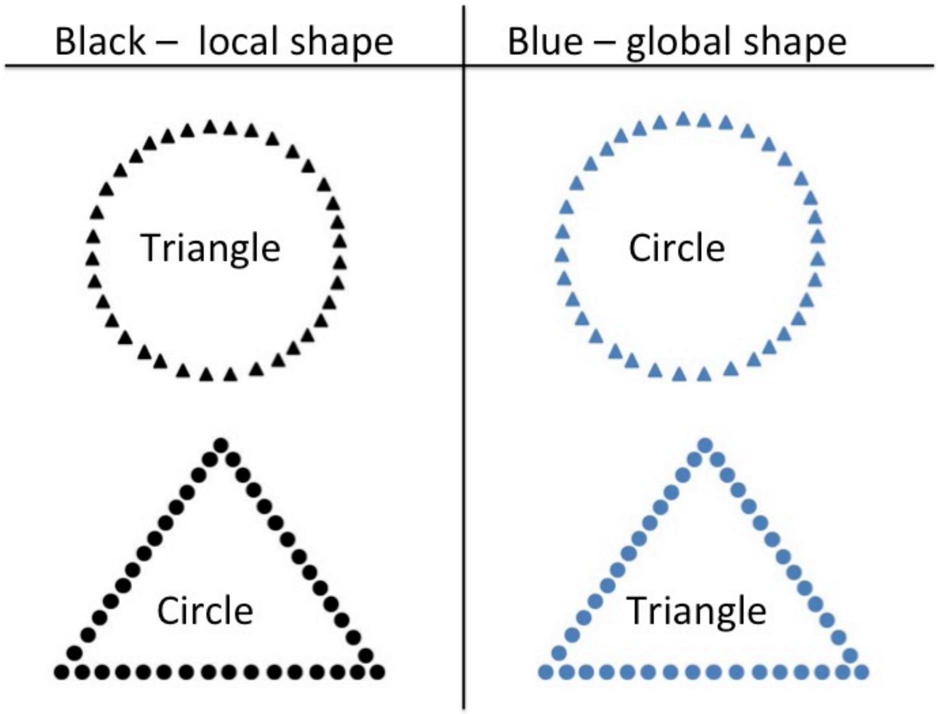


*Figure 4* *Local-Global task.*

**3.8 Inhibition tasks**

Simon Task. In this task, adopted from Simon and Wolf (1963) (see also Simon, 1969 and Castel, Balota, Hutchison, Logan, & Yap, 2007), arrows pointing left or right were randomly presented on the left, right, or middle of the computer screen (Figure 5). Participants were asked to press a button on the right with their right hand if the arrow pointed right and a button on the left with their left hand if the arrow pointed left, regardless of the arrow's position on the screen. On congruent trials, arrows pointed the same direction as the side of the screen on which they appeared. On incongruent trials arrows pointed in the opposite direction to the side of the screen on which they appeared, requiring people to inhibit the prepotent motor response to a stimulus that appears on the same side. On neutral trials, arrows appeared in the center of the screen. There were 120 trials overall with 40 trials for each condition. Participants received feedback after each response and there was a break half way through the trials. Incorrect responses were removed, and individual RT data for each condition were trimmed. First, trials with RTs of 200 ms or less were deleted. Then trials that were 2.5 SDs or more away from the mean were deleted. The Simon effect was calculated as the difference between the average RT for congruent trials and the average RT for incongruent trials. A ratio score was also calculated to control for overall differences in processing speed. Neutral trials were not used in these analyses.

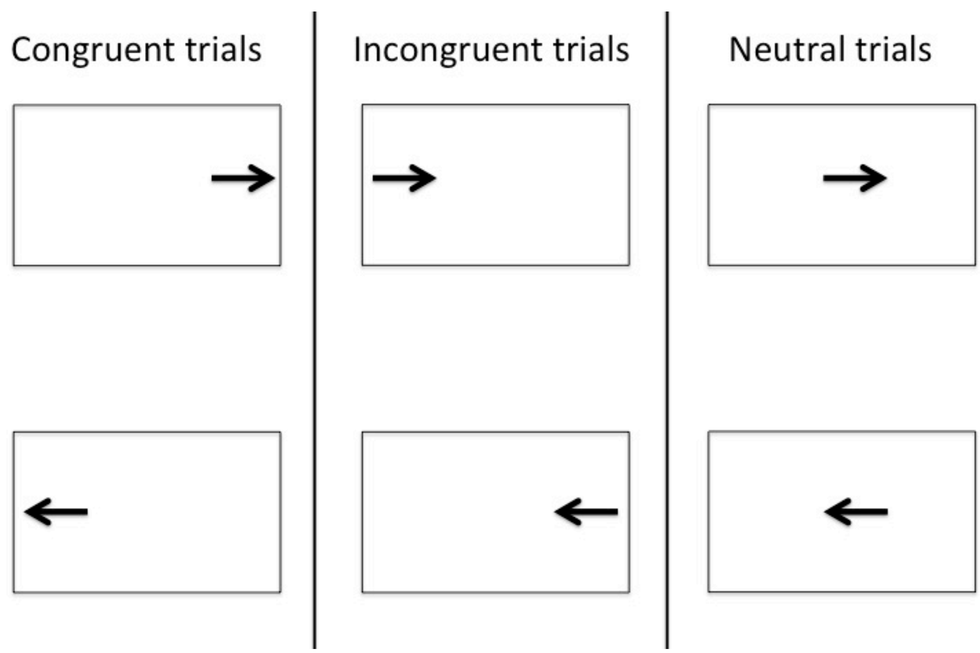


*Figure 5* *Simon task.*

Stroop Task. In this task, adopted from Stroop (1935), participants must suppress a pre-potent response to read a color name and instead say out loud the name of the color in which a word is printed. In this version of the Stroop task (Golden, 1978), participants were first shown a page of "XXXXX" printed in blue, green, and red, with 48 stimuli in each of four columns. Participants were instructed to say the color of each stimulus out loud as quickly as they could for 45 seconds (Color naming). Participants were then shown a page with the words "RED," "BLUE," and "GREEN" printed in incongruent colors and again were told to name the color of the stimuli (Color-word naming). If they made an error, they were instructed to correct themselves in order to move on to the next stimulus. The total number of colors named correctly was recorded. The Stroop effect reflects the difference between the number of colors named in the color naming condition and the number of colors named in the color-word naming condition. A ratio score was also calculated.


*Figure 6* *Stroop task.*

## 3.9 Self-report questionnaires

Participants completed a series of self-report questionnaires including the SF-36v2 (Ware et al., 2007) to assess general physical and mental health, the Beck Depression Inventory version 2 (BDI-II: Beck, Steer, & Brown, 1996) to assess depression, the Quality of Life Enjoyment and Satisfaction Scale (Endicott, Nee, Harrison, & Blumenthal, 1993) to measure quality of life, the Ryff Psychological Well-Being Scale (Ryff, 1989), the Activity Questionnaire (developed by Glisky and colleagues, unpublished) to measure physical, social, and mental activity levels, and several self-report questionnaires to measure social variables. These included the UCLA loneliness scale (Russell, 1996) to assess loneliness, the Medical Outcomes Study Social Support Survey (Sherbourne & Stewart, 1991) and the Lubben Social Network Scale 18-item version (Lubben & Gironda, 2004) to assess social support, and the Social Provisions Scale (Cutrona & Russell, 1987) to assess social support and social integration. We also recorded participants' level of knowledge about Facebook, Penzu, Google, and Amazon to assess for changes in response to learning and using a new website in comparison to other websites. Facebook and Online Diary groups were also given questionnaires to assess how well they knew the other participants in the learning groups due to the fact that some participants were acquainted prior to the study in the La Posada cohort. Finally, all participants assigned to the Facebook or Online Diary groups were given a questionnaire only at baseline to assess their desire to be placed in either group and how much they believed each website would be beneficial to them.

### 3.10 Intervention

Facebook Training. Older adults randomized to the Facebook training group attended three 2-hour Facebook training sessions over the course of one week. We used a Facebook training protocol that was developed by the OASIS Institute's Connections program. The OASIS Institute is an evidence-based program that has been teaching older adults computer skills for over 10 years. They have created a manual on how to use the Facebook interface called The Facebook Starter Kit (OASIS Institute, 2012), which is geared towards older adults. We licensed the use of these teaching materials from the OASIS Institute. During the teaching phase, each participant was given a copy of the manual for use during class and the home-based intervention phase. The training sessions took place in a computer lab classroom (either on campus or at La Posada) where each participant worked on an individual computer. The instruction was delivered through a traditional classroom learning approach with one instructor directing students in the steps to accomplish each task. Real time use of the Facebook website was projected onto a screen that everyone could view. Several graduate and undergraduate "tutors" also attended each session to provide one-on-one and small group instruction. Each course had a two-to-one student to tutor ratio. The teaching program allowed adequate time for breaks, questions, and hands-on practice. Participants completed homework assignments between classes and the instructor monitored progress to ensure that everyone acquired a working knowledge of how to use the website.

During the training course each person was linked to all of the other study participants in their group. Participants were asked not to search for members of other social networks or to connect with anyone who was not a participant in the study using Facebook. Members of the research team checked the privacy settings for each participant to ensure anyone outside of the intervention was unable to search for, view the profile of, or friend any member of the study group. At the end of the training course, participants were given instructions to log on to Facebook once a day at home and to post at least one status update and one comment. A "status update" is a message that a Facebook user posts for their friends to read on Facebook. A comment is a message that a Facebook user posts in response to another user's status update, thus engaging in a back-and-forth dialogue.

The home-based intervention phase of the study continued for 7 weeks. During this time, participants were able to e-mail or call the experimenter if they had a question about how to use Facebook. The experimenter had a researcher profile, which was connected with each member of the group. This served two purposes: 1) the experimenter was able to monitor activities in the group on a daily basis, and 2) participants were able to use the Facebook interface to send a message to the experimenter to ask questions about Facebook use. During the home-based phase, the experimenters did not intervene or interact with participants in any other way.

Control Groups*.* Those assigned to the no-treatment control group received no contact until the 8-week intervention period had lapsed. Those assigned to the Online Diary (active control) group completed the same general procedures as the Facebook group, but instead of learning how to use Facebook they learned how to use Penzu.com. Penzu is a website where users can write and post pictures onto a password protected online diary. Because the OASIS Institute did not have a protocol developed to teach the use of Penzu, the researchers developed a manual that was distributed to participants in this group. After their one-week training phase, participants in the Online Diary group were asked to log on at home to Penzu for the same amount of time (once a day) and in a similar manner (writing diary entries that were 2-3 sentences long) as the Facebook group. In this way, using the online diary was similar to using Facebook, except that writing was not shared, there were no responses to other's postings, and thus no social interaction.

Outcome Measures*.* At the conclusion of the 8-week intervention period, all participants completed the same series of questionnaires and neuropsychological tests that were completed at baseline. During the final visit, we downloaded all of the posts from each participant's individual profile. We replaced identifying information with a unique code and recorded total number of posts and word count for each participant.

# CHAPTER 4: RESULTS

## 4.1 Procedural results

Training Results. All participants attended at least two out of the three training classes. Participants who missed a training class were required to meet with a researcher for 30 minutes to cover missed material. In the Green Valley cohort, two participants in the Facebook group missed a class and three participants in the Online Diary group missed a class. In the community cohort, one participant in the Facebook class missed a class and zero participants in the Online Diary class missed a class. At the end of the training classes all participants in both the Facebook and Online Diary groups endorsed the items “I feel confident using Facebook/Penzu” and “I learned more about how to use Facebook/Penzu in this course” as “agree” or “strongly agree.”

Website Use. In order to determine compliance, we examined the total number of posts created by each participant divided by the number of total posts required. The Facebook group was instructed to make two posts per day (one status update and one comment), or 98 total posts. The Online Diary group was instructed to make one post per day, or 49 total posts. There were no significant differences in compliance rates between the Facebook and Online Diary groups, Facebook: Mean (SD) = 77.92% (25.52), Online Diary: Mean (SD) = 90.41% (41.70), $t(25) = -.90$, $p > .05$, or between the La Posada and community groups, La Posada: Mean (SD) = 75.31% (37.29), Community: Mean (SD) = 96.47%

(25.70), $t(25) = -1.63, p > .05$. In the La Posada cohort, compliance ranged from 6% to 131%, including one participant from the Facebook group and two participants from the Online Diary group with less than 20% compliance. In the community cohort, compliance ranged from 61% to 147%.

Participants rated their level of knowledge about the two websites of interest (Facebook and Penzu) and two unrelated websites (Google and Amazon) at baseline and at follow up. For each website participants rated knowledge on a scale of 1 (“no knowledge”) to 10 (“extremely knowledgeable”). A summary of self-reported knowledge level of each website is presented in Table 2. At baseline there were no significant differences between groups on level of knowledge on any of the websites. Separate 2 x 3 mixed ANOVAs for each of the websites showed no significant group differences for Google and Amazon. However, for both Facebook and Penzu, there was a significant Group x Time interaction such that the Facebook group reported significantly greater knowledge of Facebook at Time 2 compared to Time 1, $F(2,38) = 8.22$, $p = .001$, and the Online Diary group showed significantly greater knowledge of Penzu at Time 2 compared to Time 1, $F(2,38) = 253.95$, $p < .001$. There were no other significant differences.

*Table 2 Self-reported levels of knowledge for four websites*

| Group | Facebook M (SD) | | Online Diary M (SD) | | Waitlist M (SD) | |
|---|---|---|---|---|---|---|
| | Time 1 | Time 2 | Time 1 | Time 2 | Time 1 | Time 2 |
| Facebook*** | 2.71 (2.13) | 5.36 (1.22) | 3.08 (1.44) | 2.92 (1.71) | 1.93 (1.44) | 2.0 (1.62) |
| Penzu*** | 1.00 (0) | 1.00 (0) | 1.00 (0) | 7.38 (1.5) | 1.00 (0) | 1.00 (0) |
| Google | 6.93 (1.82) | 6.29 (2.05) | 6.08 (1.93) | 6.85 (1.68) | 6.14 (3.23) | 5.57 (3.16) |
| Amazon | 5.64 (2.82) | 5.36 (2.27) | 6.00 (2.77) | 6.62 (2.75) | 4.93 (3.41) | 4.59 (3.81) |

*Notes: Ratings range from 1 – no knowledge to 10 – extremely knowledgeable. Time x Group Interaction: * = p<.10, ** = p<.05, *** = p<.01.*

## 4.2 Neuropsychological outcome measures

For each of the executive functions — updating, shifting, and inhibition — we created a composite score from the two tasks representing that function. To create the composite measures, raw scores from each task were first transformed into z-scores based on the entire sample distribution at Time 1. The two relevant z-scores were then averaged to form each composite.

Updating. The Letter Memory and Keep Track tasks were used to measure Updating. For the Letter Memory task the outcome measure was total number of correct blocks, and for the Keep Track task the outcome measure was the total number of correct words. One participant in the Facebook group refused to complete the Keep Track task at baseline and so her data were removed from analyses. A summary of performance on each task is presented in Table 3. (Note that for all outcome measures, the effect of interest is the interaction between time and group, showing different changes over time as a function of group).

*Table 3* *Performance on the Letter Memory and Keep Track tasks*

| ` | Facebook M (SD) | | Online Diary M (SD) | | Waitlist M (SD) | |
|---|---|---|---|---|---|---|
| | Time 1 | Time 2 | Time 1 | Time 2 | Time 1 | Time 2 |
| Letter Memory*** | 67.23 (11.28) | 69.77 (10.51) | 68.00 (13.64) | 68.38 (13.92) | 67.43 (9.93) | 59.36 (9.69) |
| Keep Track* | 17.62 (2.84) | 21.15 (3.44) | 18.54 (2.30) | 19.85 (3.69) | 18.00 (3.46) | 19.07 (2.84) |

*Notes: Scores are number correct out of 108 for Letter Memory and number correct out of 30 for Keep Track. Time x Group Interaction: * = p<.10 ** = p<.05, *** = p<.01.*

A 2 x 3 mixed ANOVA showed a significant Time x Group interaction for the Letter Memory task, $F(2,37) = 6.99$, $p = .003$, such that the Waitlist group performed significantly worse at Time 2, paired samples t-test for 1) Facebook: $t(12) = -1.47$, $p = .166$, 2) Online Diary: $t(12) = -0.16$, $p = .874$, and 3) Waitlist: $t(13) = -3.57$, $p = .003$. For the Keep Track task there was a trend towards a significant Time X Group interaction, *F*(2,37) = 2.77, *p* = .076 and a significant main effect of Time, *F*(2,37) = 17.59, *p* < .001, indicating that all groups improved from Time 1 to Time 2, although the increase was only significant for the Facebook group, paired samples t-test for 1) Facebook: *t(*12) = -3.72, *p* = .003, 2) Online Diary: *t(*12)=-1.39, *p* = .191, and 3) Waitlist: *t(*13) = -2.11, *p* = .055.

Figure 7 presents results for the Updating composite measure. A 2 x 3 mixed ANOVA revealed a significant Time x Group interaction, *F*(2,37) = 5.96, *p* = .006. Participants in the Facebook group showed a significant increase in performance compared to no significant change in the other two groups, paired samples t-test for 1) Facebook: *t(*12) = -3.56, *p* = .004, 2) Online Diary: *t(*12) = -1.11, *p* = .288, and 3) Waitlist: *t(*13) = 1.37, *p* = .193. There were no significant group differences at baseline, *F*(2,37) = .17, *p* = .842.

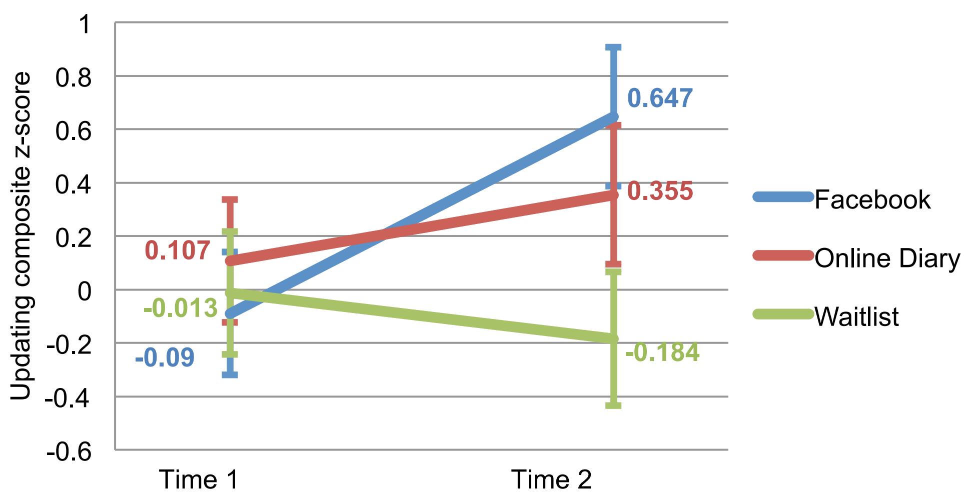


*Figure 7* *Changes in updating composite z-score, demonstrating a significant increase in performance in the Facebook group.*

<u>Shifting.</u> The Number-Letter and Local-Global tasks were used to measure local and global shift costs (calculated as reported in Methods). Because analyses of the difference and ratio scores yielded the same results we report only difference findings**.** For the Number-Letter, one participant's data were removed because she had zero correct responses for one of the non-mixed blocks. For the Local-Global, data were removed or missing for three participants who had zero correct responses for one of the non-mixed blocks and for one participant whose responses failed to record on the computer. Therefore, there were a total of 13 Facebook, 11 Online Diary, and 12 Waitlist participants included in these analyses. A summary of performance on each individual task is presented in Table 4.

*Table 4 Shift Costs on the Number-Letter and Local-Global tasks*

| | Facebook | | Online Diary | | Waitlist | |
|---|---|---|---|---|---|---|
| | M (SD) | | M (SD) | | M (SD) | |
| | Time 1 | Time 2 | Time 1 | Time 2 | Time 1 | Time 2 |
| Number-Letter Global Shift | 769.82 (231.63) | 602.93 (252.37) | 707.64 (554.00) | 705. 66 (452.30) | 1050.42 (438.15) | 813.83 (408.08) |
| Number-Letter Local Shift | 728.40 (330.36) | 786.72 (342.27) | 658.88 (273.97) | 746.95 (443.06) | 978.44 (523.07) | 907.43 (655.76) |
| Local-Global Global Shift** | 1492.55 (504.95) | 1354.21 (528.52) | 1397.68 (521.12) | 1812.28 (720.22) | 1950.82 (1207.2) | 1520.38 (765.37) |
| Local-Global Local Shift | 412.31 (433.24) | 353.12 (312.06) | 308.61 (291.73) | 409.58 (578.26) | -27.03 (773.03) | 546.45 (519.99) |

*Notes: Individual task scores are in milliseconds. Time x Group Interaction:*
** = $p<.10$ ** = $p<.05$, *** = $p<.01$.*

For global shift cost, a 2x3 mixed ANOVA found no significant effects for the Number-Letter task, and a significant Time x Group interaction for the Local-Global task, $F(2,33) = 3.31$, $p = .048$. Participants in the Facebook and Waitlist groups showed decreases in global shift costs compared to increases in the Online Diary group. However, none of the simple main effects were significant.

Figure 8 presents the data for the Global Shift Cost composite. A 2 x 3 mixed ANOVA also revealed a significant Time x Group interaction for the global shift composite score, *F*(2,33) = 4.01, *p* = .028, demonstrating similar effects. Post hoc tests showed a significant decrease in global shift costs after 8 weeks for the Waitlist group and no significant changes in the other two groups, paired samples t-test for 1) Facebook: *t(*12) = 2.06, *p*=.062, 2) Online Diary: *t(*10)=-1.15, *p* = .278, and 3) Waitlist: *t(*11)=2.34, *p*=.039. A One-Way ANOVA revealed there was a trend towards significant group difference at baseline, *F*(2,33) = 2.53, *p* = .095, such that the Waitlist group had higher shift costs compared to the Facebook, *t(*23) = -1.80, *p* = .085, and Online Diary group, *t(*21) = -1.77, P = .091. Considering this trend towards baseline differences, we also analyzed the data without the Waitlist group. A 2 x 2 mixed ANOVA of the global shift composite showed a significant Time x Group interaction, *F*(2,22) = 4.37, *p* = .048, although there were no significant differences between Time 1 and Time 2 in either group as stated above.

Figure 9 presents analyses of the Local Shift Cost composite. For local shift cost, there was a trend towards a significant main effect of Time, *F*(2,33) = 3.46, *p* = .072, such that local shift costs increased in all groups at Time 2. There was no significant interaction, *F*(2,33) = .96, *p* = .394.

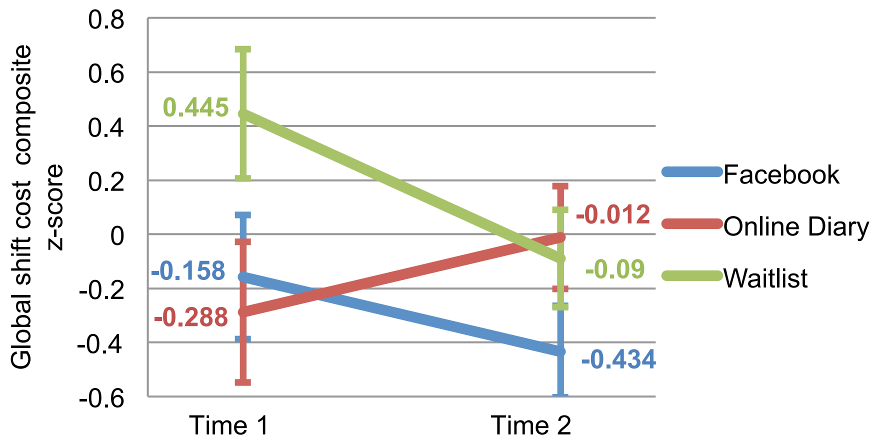


*Figure 8* *Changes in Global Shift composite z-score, demonstrating significant decrease in global shift cost in the Waitlist group.*

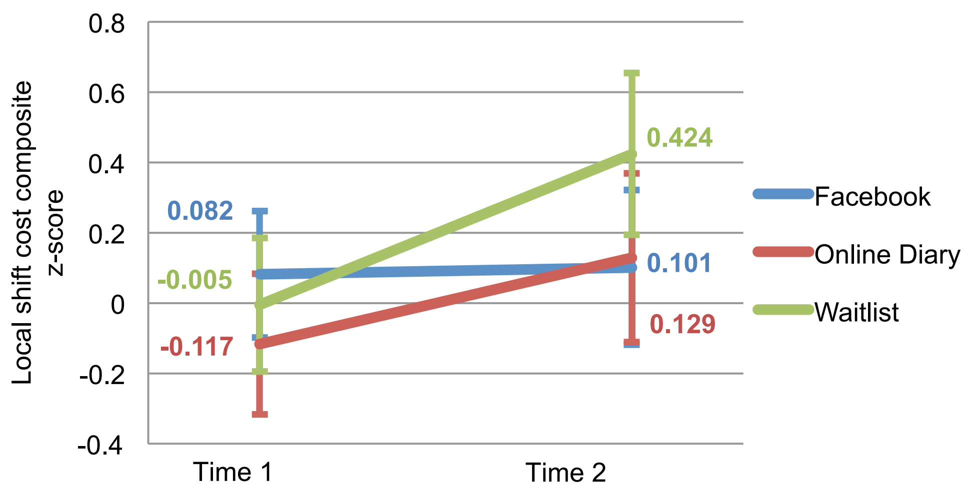


*Figure 9* *Changes in local shift costs composite z-score.*

Inhibition. The Simon and Stroop tasks were used to measure Inhibition. Because analyses of the difference and ratio scores (calculated as reported in Methods) yielded the same results we report only difference findings. Due to an administration error Inhibition measures were not collected for all participants. There were four participants in the Facebook group and six in the Online Diary group that completed the wrong form of the Stroop and so their data were not included in analyses.  There were three people in the Facebook group, two in the Online Diary group, and one in the Waitlist group that had incomplete data due to a computer error on the Simon task.  Therefore, the following analyses included seven Facebook participants, seven Online Diary participants, and thirteen Waitlist participants. A summary of performance on each task by group is presented in Table 5.

*Table 5 Performance on the different components of the Simon and Stroop tasks*

| | Facebook M (SD) | | Online Diary M (SD) | | Waitlist M (SD) | |
|---|---|---|---|---|---|---|
| | Time 1 | Time 2 | Time 1 | Time 2 | Time 1 | Time 2 |
| Simon Congruent | 611.13 (66.79) | 620.76 (48.14) | 639.83 (111.41) | 616.52 (108.22) | 736.85 (171.72) | 694.77 (114.57) |
| Simon Incongruent | 750.41 (122.26) | 745.55 (105.66) | 783.75 (165.40) | 736.47 (146.20) | 860.59 (166.07) | 799.47 (122.51) |
| Simon Effect Difference | 139.27 (70.48) | 124.80 (109.73) | 143.692 (88.57) | 119.95 (116.04) | 123.74 (81.53) | 104.71 (61.88) |
| Stroop Color condition | 61.71 (7.83) | 62.43 (9.24) | 60.71 (14.87) | 61.43 (10.50) | 59.85 (8.95) | 61.46 (9.67) |
| Stroop Color Word condition | 32.71 (4.39) | 32.43 (4.79) | 34.86 (10.43) | 36.71 (8.32) | 30.54 (8.10) | 32.62 (7.52) |
| Stroop Effect Difference | 29.00 (5.16) | 30.00 (5.80) | 25.87 (8.78) | 24.71 (5.96) | 29.31 (6.47) | 28.85 (6.05) |

*Notes: Simon scores represent average RTs in milliseconds; Stroop scores represent average number correct. There were no significant Time x Group effects.*

A 2 x 3 mixed ANOVA of the individual tests and of the composite measure (shown in Figure 10) revealed no significant main effects or interactions.

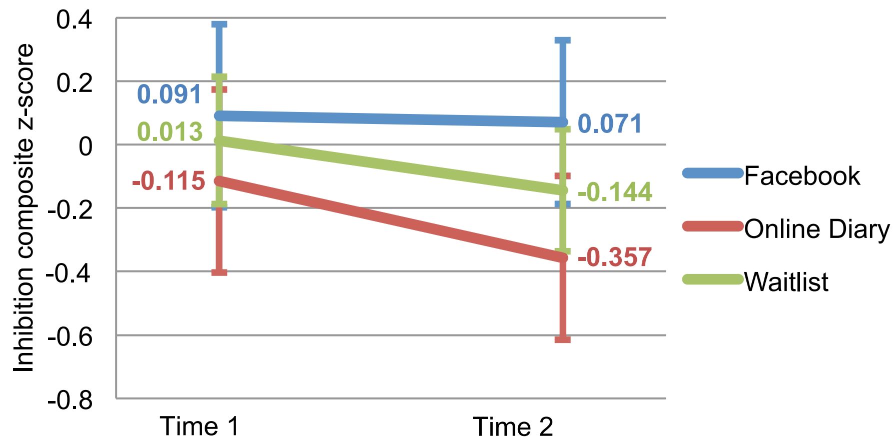


*Figure 10* *Changes in inhibition composite z-score.*

Trail Making Test. For the Trail Making Test we examined completion time for parts A and B, and then examined the difference between part A and B and a ratio score to control for basic speed of processing differences.

Analysis of Trails A and Trails B performance is presented in Figure 11. A 2x3 mixed ANOVA revealed a significant Time x Group interaction, $F(2,38) = 3.40$, $p = .044$, for Trails B performance. A similar, but not significant, pattern was observed in Trails A performance, $F(2,38) = 2.52$, $p = .094$. Post-hoc paired samples t-tests revealed that only the Facebook group showed a significant improvement in performance following the intervention, Trails A: $t(13) = 2.40$, $p = .032$, Trails B: $t(13) = 2.74$, $p = .017$, in contrast to the Online Diary group, which showed a non-significant improvement, Trails A: $t(12) = 1.38$, $p = .192$, Trails B: $t(12) = 1.39$, $p = .190$, and the Waitlist group, which showed non-significant declines, Trails A: $t(13) = -1.00$, $p = .337$, Trails B: $t(13) = -1.19$, $p = .256$.

Analysis of the difference scores between Trails A and B and the ratio scores showed no main effects of time or group and no interaction, suggesting that the executive component of Trails B was unaffected by the intervention.

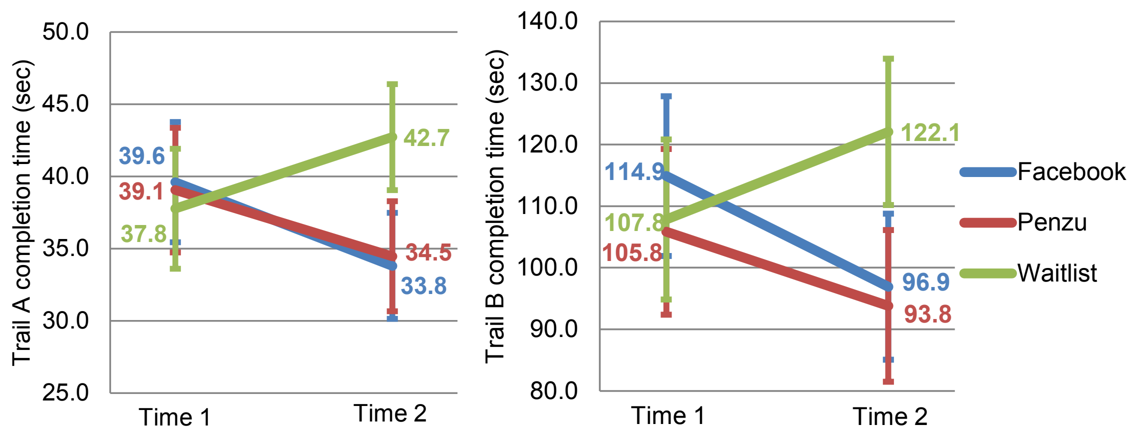


*Figure 11* *Changes to Trails A and Trails B performance.*

#### *4.2.1 FAS/Category test*

We also examined the Controlled Oral Word Association Test and Category Fluency and found no significant changes from Time 1 to Time 2 in any of the groups.

#### *4.2.2 Memory*

For verbal memory, we examined immediate, short delay, and long delay recall on the RAVLT. For visual memory, we examined copy scores, delayed recall, and forgetting (Copy – Delay) on the Rey-O CFT. A summary of performance on each is presented in Table 6.

*Table 6 Performance on tests of memory*

| | Facebook Mean (SD) | | Online Diary Mean (SD) | | Waitlist Mean (SD) | |
|---|---|---|---|---|---|---|
| | Time 1 | Time 2 | Time 1 | Time 2 | Time 1 | Time 2 |
| RAVLT Immediate | 4.86 (1.35) | 5.29 (1.44) | 4.77 (1.42) | 5.85 (2.44) | 4.93 (1.33) | 5.79 (1.97) |
| RAVLT Short Delay | 6.86 (3.08) | 7.43 (3.63) | 8.46 (3.53) | 9.00 (3.67) | 7.87 (3.80) | 9.43 (4.16) |
| RAVLT Long Delay | 7.07 (3.52) | 7.57 (3.27) | 7.62 (3.82) | 8.69 (3.75) | 8.43 (3.65) | 8.79 (4.51) |
| Rey-O CFT Copy | 31.32 (3.38) | 31.32 (3.46) | 31.77 (3.73) | 31.08 (2.85) | 32.57 (4.19) | 32.64 (3.39) |
| Rey-O CFT Delay | 12.39 (5.37) | 13.93 (6.64) | 15.46 (7.03) | 15.04 (5.85) | 13.64 (6.53) | 13.50 (5.83) |
| Rey-O CFT Forgetting | 18.93 (5.52) | 17.39 (6.05) | 16.31 (7.14) | 16.04 (5.40) | 18.93 (4.96) | 19.14 (4.69) |

*Notes: Scores on the RAVLT are number correctly recalled out of 15 possible words and scores on the Rey-O CFT are points given for number of details recalled out of 36. RAVLT = Rey Auditory Verbal Learning Test. Rey-O CFT = Rey-Osterrieth Complex Figure Test. There were no significant Time x Group effects.*

On the RAVLT, a 2x3 ANOVA revealed a significant main effect of Time for immediate recall, $F(2,38) = 8.93$, $p = .005$, and short delay recall, $F(2,38) = 6.54$, $p = .015$, and a trend towards significant main effect of Time for long delay recall, $F(2,38) = 3.60$, $p = .065$. These main effects revealed that all groups recalled more words at Time 2 than at Time 1, presumably reflecting practice effects from prior exposure to the tests. There were no significant Time x Group interactions.

On the Rey-O CFT, there were no significant changes from Time 1 to Time 2 in any of the groups.

### *4.2.3 Speed of processing*

The Digit Symbol Substitution Test (DSST) and the Deary-Liewald RT test were used to measure basic speed of processing. For the DSST, we examined total number correct. For the Deary-Liewald RT test, we looked at average RT for the simple and complex versions of the task. A summary of performance on each is presented in Table 7.

*Table 7 Performance on speed of processing tasks*

| | Facebook Mean (SD) | | Online Diary Mean (SD) | | Waitlist Mean (SD) | |
|---|---|---|---|---|---|---|
| | Time 1 | Time 2 | Time 1 | Time 2 | Time 1 | Time 2 |
| DSST | 36.29 (6.46) | 37.00 (8.54) | 37.46 (7.71) | 40.85 (9.92) | 32.93 (6.60) | 35.57 (7.62) |
| Deary-Liewald Simple RT | 320.23 (66.25) | 328.87 (46.69) | 307.39 (62.70) | 305.24 (50.34) | 333.57 (85.95) | 311.94 (40.55) |
| Deary-Liewald Complex RT | 585.17 (72.18) | 600.46 (110.65) | 563.70 (106.95) | 568.83 (93.08) | 631.03 (101.48) | 613.03 (92.83) |

*Notes: The Digit Symbol Substitution Test is total number completed in 90 seconds. The Deary-Liewald scores are Reaction Times in milliseconds. DSST = Digit Symbol Substitution Test. RT = Reaction Time. There were no significant Time x Group effects.*

For the DSST, we found a significant main effect of Time, $F(2,38) = 10.58$, $p = .002$, such that all participants completed more items at Time 2 than Time 1, indicating faster speed of information processing. There were no significant Time x Group interactions.

For the Deary-Liewald RT test, there were no significant changes from Time 1 to Time 2 in any of the groups.

## 4.3 Self Report Outcome Measures

### *4.3.1 Social variables*

We examined the UCLA Loneliness scale, the Medical Outcomes Study (MOS) Social Support Survey, Lubben Social Network Scale, and the Social Provisions Scale to assess different aspects of social connections and perceived support. One participant in the waitlist group failed to fill out both sides of the UCLA Loneliness Scale at Time 1 and so there data was removed from analysis of this scale. A summary of performance on each is presented in Table 8.

*Table 8 Performance on social variables*

| | Facebook M (SD) | | Online Diary M (SD) | | Waitlist M (SD) | |
|---|---|---|---|---|---|---|
| | Time 1 | Time 2 | Time 1 | Time 2 | Time 1 | Time 2 |
| UCLA Loneliness | 35.00 (10.36) | 34.43 (7.86) | 34.46 (8.45) | 35.15 (7.58) | 38.31 (7.71) | 38.39 (8.35) |
| MOS- Social Support | 79.36 (14.69) | 77.86 (13.62) | 76.25 (14.02) | 76.25 (12.41) | 74.14 (17.04) | 75.07 (14.73) |
| Lubben Social Network | 34.71 (6.24) | 34.86 (7.10) | 33.62 (9.54) | 34.23 (8.11) | 32.79 (7.73) | 33.79 (6.91) |
| Social Provisions | 84.86 (9.30) | 84.21 (8.95) | 85.17 (5.62) | 80.92 (8.87) | 83.50 (9.04) | 81.64 (9.69) |

*Notes: Scores represent summed scores of all items endorsed on each scale. For the UCLA loneliness scale scores can range from 20 (less lonely) to 80 (more lonely). For the MOS-Social Support Survey scores can range from 19 (less support) to 95 (more support). For the Lubben Social Network Scale scores can range from 0 (less support) to 65 (more support). For the Social Provisions Scale scores can range from 24 (less support) to 96 (more support). MOS = Medical Outcome Survey. Time x Group Interaction: * = p<.10, ** = p<.05, *** = p<.01.*

A 2 x 3 ANOVA revealed a main effect of Time on the Social Provisions Scale, $F(2,37) = 7.28$, $p = .010$, such that, on average, self-reported levels of social support decreased over time, Time 1 Mean = 84.51 (Standard Error = 1.31), Time 2 Mean = 82.26 (Standard Error = 1.46). Because of this significant effect, the subscales of the Social Provisions Scale were examined including the guidance, reliable alliance, reassurance of worth, attachment, social integration, and opportunity for nurturance scores. There was also a significant main effect of Time on the guidance, *F*(2,38) = 8.71, *p* = .005, reliable alliance, *F*(2,38) = 6.05, *p* = .019, and opportunity for nurturance, *F*(2,38) = 5.99, *p* = .019, subscales, reflecting a decrease in these social provisions over time in all groups. Additionally, there was a significant Time x Group interaction on the guidance subscale, *F*(2,38) = 4.96, *p* = .012, showing the Online Diary group reported a significant decrease in guidance from Time 1 to Time 2, paired sample t-tests: *t(*12) = 3.15, *p* = .008, compared to non-significant decreases in the Facebook and Waitlist groups. There were no significant changes from time 1 to time 2 in any of the groups on the UCLA Loneliness, MOS-Social Support, or Lubben Social Network scales.

### *4.3.2 Lifestyle questionnaires*

We examined the Quality of Life Scale, the Ryff Scale of Psychological Well Being, the Activity Questionnaire, and the SF-36 (both physical and mental health) to examine health and lifestyle. A summary of performance on each is presented in Table 9. There were no significant changes from Time 1 to Time 2 in any of the groups on any of these lifestyle questionnaires.

*Table 9 Changes on self-report lifestyle questionnaires*

| | Facebook M (SD) | | Online Diary M (SD) | | Waitlist M (SD) | |
|---|---|---|---|---|---|---|
| | Time 1 | Time 2 | Time 1 | Time 2 | Time 1 | Time 2 |
| Quality of Life | 0.76 (0.14) | 0.74 (0.25) | 0.80 (0.11) | 0.79 (0.08) | 0.75 (0.24) | 0.80 (0.16) |
| Ryff Well Being | 215.21 (19.45) | 208.64 (33.93) | 214.31 (21.44) | 213.92 (21.20) | 210.64 (24.73) | 215.50 (28.59) |
| Activity Questionnaire | 116.21 (12.07) | 116.93 (9.27) | 114.33 (16.09) | 112.58 (14.59) | 106.93 (17.35) | 107.71 (18.95) |
| SF-36 physical | 44.17 (11.13) | 42.63 (9.91) | 40.42 (9.18) | 40.84 (12.28) | 46.61 (10.07) | 45.95 (12.59) |
| SF-36 mental | 58.03 (6.45) | 57.55 (7.34) | 56.51 (7.55) | 56.02 (4.60) | 56.33 (7.42) | 53.51 (10.19) |

Notes: *The Quality of Life Enjoyment and Satisfaction Scale scores represent a percentage based on the total number of items answered. For the other three scales, scores represent summed scores of all items. The Ryff Well Being Scale can range from 42 (less well-being) to 252 (more well-being). The Activity Questionnaire can range from 39 (less active) to 234 (more active). The SF-36 scores are norm-based scale scores.* There were no significant Time x Group effects.

## 4.4 Correlations with compliance

In order to examine the relationship between how often a participant used Facebook and their improvements in cognitive function, we analyzed number of Facebook posts during the study and changes in Updating (see Figure 12). Although not significant, there was a medium-sized correlation between compliance, reflected by number of Facebook posts divided by the total number of posts required by the intervention guidelines, and changes in the Updating composite in the Facebook group, $r(13) = .477$, $p = .099$. This correlation may not be significant due to the small number of participants in the present study. The same relationship was not observed in the Online Diary group, $r(13) = -.213$, $p = .484$.

# CHAPTER 5: DISCUSSION

Results of this study revealed significant improvements in the Facebook group, compared to the Online Diary and the Waitlist control groups, on a composite measure of updating, which reflects the manipulation and maintenance of information in working memory. Further, there were no differential benefits for the Facebook group in any of the other executive function or memory tests. There was also a medium sized, although not significant, positive correlation between the number of Facebook posts and improvements in updating performance in the Facebook group, while there was no relationship between number of diary posts and improvements in updating in the Online Diary group. These results suggest a rather specific effect of the use of Facebook on an executive function associated with working memory, an effect that was enhanced the more that people used Facebook and subsequently transferred to experimental laboratory tasks that required updating.

Both the Facebook and Online Diary groups made improvements on the A and B component of the Trail Making Test (although only significant in the Facebook group), suggesting perhaps an improvement in visual scanning or search processes associated more generally with the use of online websites. There were no other significant differences between pre- and post-test performance among the three groups. These results confirm our hypothesis about the impact of learning and using Facebook on some aspects of executive function. However, they do not support our hypotheses that Facebook may have broader effects on cognitive functions such as memory, and on social support systems and feelings of loneliness.

Although we did not observe significant changes on any of the social support, social integration, or loneliness questionnaires, Facebook is a social activity such that Facebook users share information and opinions with others via this medium. Participants in the Facebook group formed and maintained new relationships with the other participants in their group during the 8-week intervention period. Therefore, whether we observed changes on social self-report measures or not, participants in the Facebook group were engaged in new social contacts while the control participants were not. It is therefore still possible that the social aspects of the Facebook intervention may be influencing the changes in cognition that were observed in this group. Our findings fit with research from Ybarra and colleagues (2012) demonstrating that even brief social interactions can lead to improvements in executive functioning. Therefore it is not unreasonable to suggest that daily increases in social contacts, whether or not they are perceived subjectively as increased social support and engagement, may lead to increased performance on some tasks of executive function. Ybarra, Winkielman, Yeh, Burnstein, & Kavanagh (2011) propose that engaging in more social activity that requires cooperation or getting to know and understand another’s point of view may change how one allocates executive function resources. They state, “social interaction could temporarily increase cognitive accessibility of flexible processing styles or particular operations that subsequently overlap with executive function tasks (e.g., switching routines, memory routines).” If these effects can be observed after a brief encounter, it is possible that increased multiple exposures to social interactions may lead to cognitive benefits and perhaps ultimately to increased perceived social support. However, the current data set is unable to answer directly the question about whether increases in social interactions contribute to improvements in working memory.

It is also possible that Facebook was more cognitively complex and challenging than the Online Diary website, thus requiring more cognitive engagement and leading to improvements in cognitive function. Evidence for this is suggested in the scores on the face-valid test of how much each participant learned about several different websites. Although each of the active groups learned more about the particular internet site that they were using, participants in the Online Diary group reported acquiring greater knowledge about Penzu, with an average change of 6.38 on the 10-point scale, than those in the Facebook group reported learning about Facebook, with an average change of 2.65. These findings suggest that learning Facebook was more difficult. In addition, the Facebook interface necessarily had more information to be processed because content was generated from both self and others, whereas content was only produced by the individual on the Online Diary website. The generated content from others appeared on the news feed in real time, requiring participants to filter through these changes while maintaining their current goal, a task that appears, on its face, to require updating. Research from Alloway and Alloway (2012) demonstrated that in adolescents, checking friends' status updates on Facebook was related to verbal and non-verbal working memory performance, suggesting Facebook may engage and improve these cognitive tasks.

Interestingly, the Facebook group improved *specifically* on measures of updating, but not on shifting or inhibition, suggesting that this might be the primary executive function associated with Facebook activities. This finding is consistent with Miyake's theory that there are at least three independent kinds of executive function, which may contribute differentially to different cognitive tasks. In the present study, engaging in interactive activities on Facebook may have involved primarily the executive function of updating with lesser need to engage the processes of shifting and inhibition. Additionally, we observed improvements in Trails A and B in both the Facebook and Online Diary groups, suggesting that learning and using these tasks required visual search for relevant information on a visual display. Both Facebook and Penzu have several icons and menus displayed on the screen, which require visual search and selection to locate the desired icon among several distractors. This may have led to some general improvement in visual search and scanning ability that later transferred to the laboratory task of Trail Making. These findings thus appear to be generally consistent with the view that cognitive training is generally domain-specific, namely that training in one domain does not transfer to another domain. At the same time, however, the findings show that specific processes trained in the context of one task may transfer to quite different tasks, in this case from the real-world Facebook task to the highly controlled laboratory tasks.

This work adds to a growing body of literature suggesting there are various activities that older adults can participate in that may help them to maintain or improve specific areas of cognitive function. However, it is likely that for benefits to be maintained over time, the activities need to be continued beyond the controlled intervention phase and integrated into people's everyday lives. Only a few of the participants who learned Facebook have continued to use the website. Although opinions of Facebook varied, at least 50% of participants stated that Facebook was not for them after participating in the research study. Initially, we hypothesized that Facebook might be a more engaging medium than repetitive brain training computer games. While this was true for some participants, others found Facebook to get in the way of their daily life and expressed relief when the study protocol was over and they were no longer required to post everyday. There may, however, be particular individuals who might find online social networking to be rewarding, interesting, and intrinsically motivating. Our long-term goal is to reach older adults who are socially isolated. In the present study, we were unable to achieve this objective. Research has shown that aging is not necessarily related to declines in social support and social resources (Martire, Schulz, Mittelmark, & Newsom, 1999). People who volunteered for the study, although mostly living alone, were socially active and engaged as are most older adults who volunteer for research studies. Some participants found that

Facebook detracted from those activities. Having demonstrated the beneficial cognitive effects of this intervention, in future studies it will be important to find ways to reach individuals who truly are not socially engaged. It may be that the benefits will be even greater in this group and that positive changes in social variables will be observed as well.

Additionally, the experimental design limited participants to using Facebook to connect only with other research participants in their Facebook class during the study. They were prohibited from using Facebook to connect with real life friends or family. Participants may have been unable to form meaningful bonds with other research participants despite their daily interaction online, or these bonds were insufficient to elicit changes on self-report measures of social support, social integration, and loneliness. It is possible that using Facebook as a way to increase the frequency of social contacts among already established relationships may have more effect on perceived social support and loneliness, compared to using Facebook as a way to initiate and form new relationships.

## 5.1 Limitations

There are several limitations to the present study. First, there was a small sample size, limiting the statistical power to observe differences after the intervention period. Some tests, especially the inhibition tasks, had a large amount of missing data that further affected the power to observe significant changes. It is possible that with a larger sample, significant changes in other domains may be observed. Second, because of this small sample size and people's varying schedules, participants were only quasi-randomized. Therefore, this was not a truly randomized controlled trial of Facebook as an intervention. Also, due to limited resources, the same individual performed aspects of the testing and intervention and so was not blinded to group assignment. A study with larger sample, randomized group assignment, and blinded testers is needed to address these concerns.

Finally, participants were only permitted to interact on Facebook with other study participants during the intervention period. Most people use Facebook to connect with real life friends and family and therefore this study lacks some ecological validity.

**5.2 Future directions**

There are many potential avenues for future research. First, it will be interesting to determine why the Facebook group improved performance on updating specifically. Several different possibilities to explore are outlined above. It may be helpful to obtain more objective measures of social support such as ratings from others, Electronically Activated Recorder (EAR) data, or periodic counts of social interaction. Additionally, it may be meaningful to analyze the specific transcripts of the Facebook and Online Diary participant's posts to see if there were meaningful differences among what participants wrote about and whether that was related to changes in either cognitive or social functioning. For example, coding the posts for elicitation of different types of social support, as well as whether participants received or provided social support (Brown, Nesse, Vinokur, & Smith, 2003), may be related to changes in self-reported levels of social support and/or cognitive function. Because participants in the present study used Facebook to connect only with other research participants, rather than real life friends and family, it may be interesting to examine the types of interactions and types of relationships that formed between participants, including the frequency (number of unique virtual conversations) and depth (number of comments on one topic) of interactions. Despite the lack of significant findings on social measures, a few participants appeared to form friendships through Facebook that they reportedly planned to continue after the conclusion of the study. In fact, some participants used Facebook to arrange for face-to-face meetings. Determining what ways participants used Facebook to form these friendships may help to better design interventions to increase social support and interaction using online media.

Second, as mentioned above, it is possible that I was unable to observe significant changes in social variables because of the characteristics of the sample. The majority of our population was not subjectively lonely and had large amounts of social support and social engagement. Future studies should target older adults who are truly socially isolated and may be unable to leave their home for various reasons including physical or mental disability.

Third, given the beneficial effects of Facebook on cognition, it may be helpful to recruit participants with mild or moderate cognitive impairment. It is possible that socializing over the Internet is less cognitively demanding than face-to-face interactions because it allows one to review and edit one's thoughts and comments before they are posted, as opposed to having to keep on track with a real time conversation. If it is possible to teach patients who are experiencing memory problems how to use Facebook, then there is potential to help them improve or maintain cognitive function, or to improve social connections in daily life that would otherwise not be available.

Another way to examine the utility of social interaction might be to include a social only control group. For the present research, the aim was to isolate the social components and control for the cognitive aspects of learning a new skill, by including the active Online Diary control group. However, another approach would be to include a social control group that does not learn a new skill, but still engages in social interaction. One option may be to have participants engage in an e-mail chain. All of the older adults in our study had an e-mail address and had various levels of familiarity with using e-mail. If this is a skill that is already learned, an e-mail chain may provide online social interaction, without the cognitive component of learning a new skill. However, there would almost certainly be cognitive demands associated with email chains. In fact, the difficulty inherent in any social control group is the inability to control the cognitive demands of the social interaction.

Finally, although this study was unable to observe changes in social support or loneliness in older adults, it remains an interesting challenge to determine why social support is related to cognitive function. Cohen (2004) has proposed that increases in social support may have a stress buffering effect while increases in social integration may have a main effect on physical health, independent of stress, by promoting positive psychological states, increasing access to information about health and others, and motivating positive health behaviors. Ybarra and Winkielman (2012), based on their findings that brief social encounters boost executive functioning abilities, hypothesize that the process of engaging with another, such that you are building and updating a rich representation of the other party, engages executive functioning abilities. Elucidating these theories will provide more ideas for potential ways to intervene and improve upon cognitive function in older adults.

In the time since this research was completed, Facebook.com has undergone several changes including changes to the ways in which this website uses personal information to gain advertisement revenue and the ways in which advertisements are presented to consumers of this free service. This research utilized Facebook.com because it is the most widely used social networking website in the world and had the highest potential for participants to connect with real life friends and family following the study, which we hypothesized would encourage usage. However, Facebook.com is merely one online social networking tool and it is possible that other social networking activities may also yield positive results on cognition in healthy older adults. It is of the utmost importance for anyone who uses online social networking to understand the privacy policies and the ways in which their information may be used. Many older adults in our study had Facebook accounts but were unaware of this fact. The most frequently cited explanation was that a friend or family member had signed them up for an account and then failed to provide them with the education and training in order to be able to use the account. I caution against this as it puts people of all ages at risk for having their information used in ways that may make them uncomfortable or vulnerable to scams for example. There are many options for online social networking that may be rewarding and beneficial for older adults, and careful attention must be made to find one that is right for each individual.

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