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The Effect of Language on Cognition in an Acculturated American Sample of Healthy Older Adults

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LOMA LINDA UNIVERSITY
School of Behavioral Health
in conjunction with the
Faculty of Graduate Studies

The Effect of Language on Cognition in an Acculturated American Sample of
Healthy Older Adults

by

K'dee D. Elsen

A Thesis submitted in partial satisfaction of
the requirements for the degree
Doctor of Philosophy in Clinical Psychology

September 2017

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Each person whose signature appears below certifies that this thesis in his/her opinion is adequate, in scope and quality, as a thesis for the degree Doctor of Philosophy.

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ABBREVIATIONS

PFC	Prefrontal Cortex
HAROLD	Hemispheric Assymetry Reduction in Older Adults
PASA	Posterior-Anterior Shift with Aging
WAHA	Walnuts and Health Aging Study
LEAP-Q	Language Experience and Proficiency Questionnaire
TMT	Trail Making Test
COWAT	Controlled Oral Word Association Test
BNT	Boston Naming Task
WAIS	Weschler Adult Intelligence Scale
CPT	Continuous Performance Task
RAVLT	Rey Auditory Verbal Learning Test
RCFT	Rey-Osterrieth Complex Figure Test
BD	Block Design
DS	Digit Span
SPSS	Statistical Package for Social Sciences
ANCOVA	Analysis of Covariance
MANCOVA	Multivariate Analyses of Covariance

ABSTRACT OF THE THESIS

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by

K'dee D. Elsen

Doctor of Philosophy, Graduate Program in Clinical Psychology
Loma Linda University, September 2017
Dr. Adam Aréchiga, Chairperson

Background: Older adults are not only the fastest growing segment of the population (~841 million worldwide) and continually increasing, but are of special concern due to the numerous age-associated deficits, especially those on cognition. Research indicates that knowing multiple languages may act as a protective factor against the deleterious effects of cognitive aging. **Objective:** The purpose of the current study is to examine whether multilingualism protects against the effects of cognitive aging on the domains of executive functioning, linguistic processing, attention, memory, and visuospatial functioning. **Methods:** Participants were 312 healthy older adults (68% female) from the Walnuts and Healthy Aging study at Loma Linda University (Age range = 64-75; $M = 69.42$, $SD = 3.31$). Of the 312 participants, 167 reported speaking one language and 145 reported speaking two or more languages. Preliminary analyses, including descriptives, testing of outliers and assumptions, and correlational analyses, as well as a series of ANCOVAs and MANCOVAs, will be used to test the study's aims and specific hypotheses. **Results:** Education, age, and immigration status were all significant and therefore, controlled for in each analysis. Monolinguals and multilinguals significantly differed on the Stroop Word-Color executive functioning task with multilinguals

performing better. There were no significant differences between language groups among all other cognitive domains. **Discussion:** Implications of both the significant and non-significant findings are discussed, as well as promising follow-up research that will be done to address the limitations and further explain the findings of the current study.

CHAPTER ONE

INTRODUCTION

According to the United Nations 2013 Report, older adults aged 60 years or over are the fastest growing segment of the population with approximately 841 million worldwide. Due to the decreasing rates of mortality and fertility, and an increased life expectancy, this number is projected to more than double to over two billion in the year 2050. Although the quantity of life has increased in regards to the number of years, the quality of life has decreased (National Institute on Aging, 2007; Fabiani, 2008). Older adults are living longer; however, they are more likely to suffer from chronic and degenerative diseases like cancer, diabetes, and Alzheimer's disease, and are also more likely to suffer generally from the deleterious effects of normal aging. Of these problems, Alzheimer's disease, other dementias, and any and all declines of the brain are of special concern due to the threat they pose on the quality of life.

In recognition of this grave concern, numerous studies have investigated and identified a variety of different neuroprotective factors. Conventional health lifestyle factors, like diet and physical exercise, have been thoroughly investigated and supported as protective (Hillman, Erickson, & Kramer, 2008; Angevaren, Aufdemkampe, Verhaar, & Aleman, 2008; Scarmeas et al., 2009). Most recently, researchers have focused on investigating more nonconventional factors like music, games (e.g. Sudoku, crossword puzzles), and language (Wilson et al., 2002; Daffner, 2010; Gold, Kim, Johnson, Kryscio & Smith, 2013). As the world increasingly becomes multilingual due to technological advances, global communication, and traveling, language has become a topic of increasing popularity. The popularity of language and its effect has especially increased

as the amount of literature increases in support of its potential neuroprotective effect and promotion of successful aging (Bialystok, Craik, Green & Gollan, 2009).

Language and its effect on the brain have been studied for many years. Historical perspectives supported the argument that knowing multiple languages had a negative effect on cognition (Smith, 1923; Saer, 1923; Yoshioka, 1929), whereas current perspectives argue that it may have both a positive and negative effect—a positive effect on executive functions and a negative effect on verbal processing (Bialystok, Craik, Green & Gollan, 2009). Although this line of evidence has been supported by various current research studies, the research still remains divided and inconclusive. The current study will take a deeper look at this controversy and shed light on what effect language has on executive and verbal processing, as well as its effect on other cognitive domains that have not been well-researched like attention, memory, and visuospatial functioning. Given the dramatic increase of the population of older adults and their associated risks of cognitive decline, impairment, or dementia, the results from this study may have significant implications for how knowing additional languages can act as a factor that protects against the deleterious effects of normal and pathological aging in older adults, and an overall factor that promotes successful aging for all ages throughout the lifespan.

CHAPTER TWO

BACKGROUND

The Effect of Aging on Cognitive Domains

As previously mentioned, the proportion of older adults (60 years or older) in the world population is continually increasing (UN Report, 2013). This phenomenon commonly referred to as “population aging,” is occurring due to an imbalanced demographic shift in the population caused by an increase in the birth rate of past generations of the early to mid-20th century—like the “baby boomer” 1946 to 1964 cohort (post-World War II)—and a decrease in fertility rates in the 21st century. The imbalanced shift is also attributed to what many refer to as one of the greatest human achievements: prolonged human longevity (Mora, 2013). Many medical and environmental advancements like increasing life expectancy by 30 years in the U.S. by improving the conditions of drinking water and sanitation (Akbarian, Beerli, & Haroutunian, 2013), as well as the overall trend towards living healthier and longer lives, has led to a decrease in mortality rate, an increase in life expectancy, and the ever-increasing older adult population. According to the 2013 United Nations Report, the older adult population quadrupled from 202 million to 841 million from 1950 to 2013, and is expected to triple by 2050 to more than two billion. This dramatic increase in older persons is of great concern because of the associated effects and consequences of aging, especially those on the brain.

Before discussing the effects of aging, however, it is important to understand what aging is and the different types of aging. There is a plethora of various definitions of what aging is, including some simple and others complex. Each definition, however, has the

following overlapping components that identify the aging process as: age- or time-specific and age-progressive or -dependent; a decline, loss, or degeneration of physiological function; and associated with or leading to an increased vulnerability to pathology and mortality (Harman, 1981; Harman, 1991; Staff, Murray, Deary, & Whalley 2004; Drag & Bieliauskas, 2010; Mora, 2013). Synthesizing these definitions into one cohesive definition, aging is a degenerative physiological process due to an accumulation of various changes or stressors over time that the body can no longer adequately counteract; and therefore, it is associated with an increased risk for disease and death.

In the literature on aging, researchers distinguish between three different trajectories of the aging process: pathological, usual, and successful aging (Rowe & Kahn, 1987; Daffner, 2010). Pathological aging, as indicative by its name, refers to the common associated risk of disease in the aging process. Usual or normal aging refers to individuals who experience age-related changes, but these changes are non-pathological. Successful aging, also known as healthy or optimal aging, not only refers to individuals who do not experience pathology, but also who experience little to no functional decline (Jeste, Depp & Vahia, 2010). Rowe and Kahn (1997) further define successful aging as requiring the following three components: low probability of disease and disease-related disability, high physical and cognitive function, and high level of activity and engagement in life. What determines whether an individual will experience pathological, usual, or successful aging?

Researchers have focused on two main categories of aging processes that determine whether an individual will experience pathological, usual, or successful aging: intrinsic aging processes, also referred to as genetic, heritable, or biological; or extrinsic

aging processes, also referred to as non-genetic, environmental, behavioral, lifestyle, or psychosocial (Daffner, 2010). At first, researchers predominantly focused on the role of intrinsic factors and deemed the aging process to be preprogrammed by genetics (Mora, 2013). By using the results of twin and other studies (i.e. studies on intelligence, diseases, genotype statuses, etc.), researchers supported the conclusion that genetic factors influence and can even determine age-related processes (McClearn et al., 1997; Jofre-Monseny, Minihane & Rimbach, 2007). However, as the research continued, studies on the role of extrinsic aging processes (e.g., diet) began to increase in number and in support (Scarmeas & Stern, 2011). The results of numerous studies that investigated the beneficial impact of lifestyle factors like diet/nutrition, exercise, intellectual activities, and others on the aging process solidified the role extrinsic factors played and even put into question the role of genes.

Converging evidence now supports the vital role each plays, separately and interactively. For example, lifestyle factors can interact with genes by activating genes themselves or the proteins that are encoded by the activated genes (Daffner, 2010; Scarmeas & Stern, 2011). Due to this interaction between extrinsic factors with intrinsic factors, as well as due to the element of control extrinsic factors have, many researchers have focused their efforts in studying how extrinsic factors delay both usual and pathological aging, or promote successful aging. A common goal for individuals, society as a whole, and research is to find ways in which we can age “gracefully” and optimally live life amidst the odds of the aging process (Mora, 2013). The current study will focus on the extrinsic factor of language and its impact on protecting against normal aging and promote successful aging, especially in regards to cognitive aging.

During the aging process, the brain and its' cognitive abilities begin to progressively deteriorate and decline. The exact age at which cognitive decline begins is debated (Schaie, 2009). Various studies have suggested that decline begins relatively early in adulthood (Allen et al., 2005; Hsu et al., 2008), in the 50s – 70s (Albert & Heaton, 1988; Plassman et al., 1995), and at higher ages (70 or higher; Schroeder & Salthouse, 1994; Aartsen et al., 2002). However, researchers have pointed out a major limitation in the design (i.e., cross-sectional) and conclusions of these studies (Salthouse, 2009). In addressing this limitation by adhering to a longitudinal design, current research has established that there is no exact age; instead, age-related cognitive decline varies based on a range of factors, such as individual factors, environment, and the brain area or cognitive ability in question. Schaie's 2005 longitudinal study, a continuation of her 1965 dissertation, looked at six specific cognitive abilities and found that there was no clear age of cognitive decline. For example, numeric ability began to decline in the late 20s, whereas spatial orientation increased in the late 20s and did not decrease until the 60s. Overall, researchers have concluded that cognitive decline is not linear across the lifespan, accelerates with increasing age (Salthouse, 2009), and results in many deleterious effects on both the anatomy and function of the brain.

The anatomy and function of the brain are both greatly affected by the normal aging process, individually and interactively. In general, aging effects on the anatomy of the brain result in a decrease of regional brain volume (although not uniform across all brain structures) (Salthouse, 2009). More specifically, the aged brain shows signs of decreased myelin integrity (white matter), gray matter, and synaptic density; increased neurofibrillary tangles (increased risk for dementia); impaired neurotransmitter receptor

binding; changes in the cerebrovascular system (e.g. reduced blood flow); and numerous other changes (Drag & Biellauskas, 2009; Salthouse, 2009). These changes in anatomy are often caused by changes in functionality of the brain, as well as these anatomical changes can then lead to changes in functionality. Age-related functional changes that commonly occur in the brain include, but are not limited to: reduced activation in a variety of cognitive domains, concurrent increased activation in other brain areas to compensate for the reduction, and overall reduced specialization of explicit tasks (Mora, 2013).

One of the leading cognitive aging hypotheses, “the processing speed hypothesis,” posits that the decline of processing speed is the main underlying factor contributing to the decline in general cognitive function and performance (Gazzaley, Clapp, Kelley, McEvoy, Knight, & D’Esposito, 2008; Salthouse, 1985; Salthouse, 1996; Lemke & Zimprich, 2005). Processing speed demonstrates one of the earliest declines with age, and has been linked to the breakdown of the myelin sheath (Lu et al., 2011). It is important to keep in mind this contribution of processing speed as we investigate the specific anatomical and functional changes that occur in the aging brain and in relation to each of the cognitive domains of interest—executive function, attention, memory, language, and visuospatial functioning.

Executive Functioning

Executive functioning, although difficult to operationalize and measure, generally refers to a wide range of higher-level neurocognitive processes that are involved in controlling, organizing, regulating, and using large quantities of information, and

executing adaptive and goal-directed behavior (Lezak, 1995; Drag and Bieliauskas, 2010). These higher-level functions have been consistently mapped and linked to the frontal lobe, and more specifically with the prefrontal cortex (PFC) (Alvarez and Emory, 2006; Daffner, 2010). The PFC, due to its high interconnectivity with other brain regions, is responsible for heterogeneity of executive functioning tasks, such as: planning, strategizing, manipulating, inhibition, and decision-making.

Out of the entirety of the brain, the frontal lobe is most disrupted by the aging process, both structurally and functionally (Jackson, 1958; Dempster, 1992; West, 1996). The frontal lobe anatomically deteriorates at a faster rate and the associated cognitive deficits are more pronounced than in any other lobe. Researchers are unclear as to what age decline begins (Salthouse, 2009; Schaie, 2009); however, they have established that a general sharp decline in executive functioning occurs at age 60 (Treitz, Heyder & Daum, 2007). As evidenced by numerous imaging studies, the frontal lobe's anatomy is observed to endure a drastic reduction in volume (atrophy) due to both a reduction in white and grey matter integrity (especially in the anterior regions, i.e. PFC), and an overall increased sensitivity to a breakdown of myelin fibers (Double et al., 1996; Esiri, 1994; Kemper, 1994). The anatomy is also greatly affected by the age-sensitive functional changes. For instance, a drastic deterioration of dopamine function in this lobe occurs (Volkow et al., 2000), along with an overall increase of age-associated deficits in executive function. Neuropsychological tests (e.g., the Stroop task) and experimental paradigms that measure a variety of executive control processes clearly demonstrate a significant decline in the key executive functional processes of inhibition, manipulation, and regulation (Cabeza and Dennis, 2012).

Another common deleterious effect of cognitive aging in the domain of executive functioning is increased PFC activation and connectivity. In numerous studies that used methods like positron emission topography or diffusion tensor imaging, researchers measured activation and connectivity in the PFC hemisphere in older adults and compared it to younger adults performing the same tasks (Grady, 2008; Kramer et al., 2006). Results indicated that older adults showed increased bilateral prefrontal activation and connectivity compared to the younger adults (Reuter-Lorenz, Stanczak, & Miller, 1999; Reuter-Lorenz et al., 2000). The specific increased bilateral PFC activation signifies a reduction in hemispheric asymmetry (known as “Hemispheric Asymmetry Reduction in Older Adults,” the HAROLD pattern) and is often coupled with a common decrease in the occipital cortex known as the “Posterior-Anterior Shift with Aging” (PASA) pattern (Cabeza, 2002; Davis et al., 2008). Researchers suggested that the increased bilateral (or decreased lateralized) prefrontal activation and connectivity could be explained as a compensatory mechanism, the brain’s attempt to reorganize functions, or its inability to properly select and recruit the necessary brain regions for a task (Drag & Bieliauskas, 2010).

The evidence remains inconclusive whether the aging brain and its associated deficits react by compensating or by nonselective recruitment; however, the main implication of this current finding, as well as the previously discussed findings (i.e., anatomical and functional frontal lobe deficits), is that not only is executive functioning in older adults significantly affected and harmed, but due to the extensive interconnectivity with other cognitive regions, it can also lead to negatively affecting other cognitive domains (Drag & Bieliauskas, 2010). This idea that overall age-related

cognitive decline is primarily due to deterioration, both anatomical and functional, of the frontal lobes is pervasive in the field of cognitive neuroscience and is referred to as the frontal lobe hypothesis (Moscovitch, 1992). In the next sections we will discuss the potential effect the deterioration of the frontal lobe and its executive function has on the deterioration of the remaining cognitive domains of attention, memory, language, and visuospatial functioning.

Attention

One cognitive domain highly dependent on the PFC and its executive control processes—and therefore greatly affected by cognitive aging—is attention. According to William James, father of American psychology, “everyone knows what attention is” (1890, p. 403). However, the reality is that we may easily recognize attention when it is used in day-to-day settings, but it is difficult to define and operationalize. For instance, the use of attention is easily identifiable in the example of driving: we must pay attention to the lights, signs, and other drivers; however, to define what it is and when it is being used while driving would be more difficult without specifically knowing the various subcomponents that define attention. Researchers have identified four main subcomponents or types of attention: sustained, selective, divided, and alternating attention (Drag & Bieliauskas, 2010). Sustained attention is the ability to maintain focus and vigilance over time (e.g., maintaining focus over an hour drive). Selective attention, also referred to as inhibition, is the ability to select and focus solely on the appropriate stimuli while ignoring irrelevant stimuli. Divided attention, the third type of attention, is commonly referred to as dual- or multi-tasking. Divided attention is used when one is

able to simultaneously attend to and process stimuli from multiple sources. Lastly, alternating attention, also known as shifting or switching, is the ability to switch rapidly back and forth from one stimulus to another (2010).

As previously discussed, the brain is highly interconnected. The cognitive domain of attention is a prime example of this high interconnectivity, which also makes it difficult to parcel out attention from other mental processes. Attention processes require the activity of multiple brain areas including: all lobes, but predominantly the frontal and parietal lobes; all areas required for the processing of sensory stimuli (e.g., primary visual cortex); the thalamus, tectum, and the limbic system (Kanwisher & Wojciulik, 2000; Corbetta & Shulman, 2002). Of these widespread areas throughout the brain, attention's principal area of activation is the frontal lobe. The frontal lobe is commonly recruited in attention tasks due to its high reliance on, interaction or overlap with the domain of executive functioning (Asplund, Todd, Snyder, & Marois, 2015). Two principal examples are the interactions between selective attention and the executive function of inhibition, and between alternating attention and the executive function of task-switching (Bialystok, Craik, Green & Gollan, 2009). For instance, the Stroop Interference Task is commonly utilized as a measure for attention (more specifically selective attention), when the task more accurately reflects the executive function of inhibition that then mediates the attention processes. Similarly, the Trails B task is used to measure alternating attention, when it primarily measures the executive function of task-switching (Reitan & Wolfson, 1985). Therefore, it is vital to distinguish which areas are sources of attention control (e.g., frontal and parietal lobes) and which regions are responsible for modulation of or

by attention (e.g., temporal lobe), especially in studying and understanding how cognitive aging and possible protective factors may affect attention.

Due to attention's reliance on the PFC and connectivity with other brain regions, when these areas begin to decline, attention processes are also negatively affected. More specifically, age-related decrements in selective and alternating attention have been associated with the domain of executive function, and divided attention has been linked with the domain of memory (Schroeder & Marian, 2012). For example, the aging process leads to decrements in task-switching and general executive functions, which then lead to overall slowing of processes and increased difficulty in the brain's ability to disengage from one task and refocus on a second (alternating attention; Kramer, Hahn & Gopher, 1999; Kray & Lindenber, 2002). Selective attention, which is dependent on the executive function of inhibitory control, has also been found to be negatively affected by the aging process. Decreased inhibitory control results in increased disinhibition and distractibility, and an overall decrease in selective attention. Researchers have also found a relationship between divided attention and memory; specifically a positive relationship, which researchers have explained as being due to the association between attention and executive functioning (Schroeder & Marian, 2012). Contrary to most types of attention, sustained attention—the ability to maintain attention and vigilance over time—has been found to be unaffected by the aging process (Berardi, Parasuraman & Haxby, 2001; Filley & Cullum, 1994). Although the consequences of aging on interacting domains have been found to be predictive of the functionality of attention in older adults, researchers have found the most predictive factor to be a task's level of complexity. As a task's level of complexity increases, attention processes decrease due to cognitive aging.

Memory

Similar to attention, the effects of aging on memory are not global, but specific depending on the complexity of the task and the various subcomponents of memory, including: different memory types like episodic and semantic, and different processes like encoding, storing, retrieval and recognition. When comparing younger adults in their twenties to older adults in their sixties on a series of different tasks for recall and recognition memory, Perlmutter (1978) discovered that there were more age-related deficits for recall memory than recognition. However, after the task eliminated the demands of recollection by adding context and changing it to a recognition format, the aging effects were reduced. The researchers concluded that recall memory—which occurs in the hippocampal area—is affected more because it demands more effortful and strategic cognitive resources than recognition—which occurs in the entorhinal cortex and is more automatic and familiar-based. Similarly, memory processes like encoding and storing that demand less cognitive resources than retrieval have also been found to be less sensitive to the effects of aging (Fernandes, Craik, Bialystok, & Kreuger, 2007).

It is important to note that although memory types and processes that demand less cognitive resources (e.g., recognition, encoding and storing) have been found to be less sensitive in comparison to their counterparts (recall and retrieval), they are still affected by the aging process. Craik and Lockhart (1972) demonstrated this when they compared younger and older adults' encoding abilities and found that the older adults' abilities were inferior to that of the younger adults. Furthermore, neuroimaging studies supported similar findings by showing decreased functional activity in the left PFC and medial temporal lobes in older adults engaging in encoding (Schroeder & Marian, 2012). Age-

related decreases in these areas, as well as in the hippocampus and parietal lobes, have been an overall indicator of poorer memory performance during the later years of life (Cabeza et al., 1997; Stebbins, Carillo & Dorfman, 2002; Daselaar, Veltman, Rombouts, Raaijmakers & Jonker, 2003).

Researchers were also able to replicate the finding that increased complexity increased age-related decrements in memory when investigating other types of memory. In comparing episodic and semantic memory, more age-related decrements were found to occur in episodic memory (Schroeder & Marian, 2012). Episodic memory, defined as a deliberate recall of a personal experience (e.g., 18th birthday celebration), requires greater processing capacity than semantic memory; which is a passive recall of factual information (e.g., historical facts). However, unlike recall and retrieval memory, semantic memory (or also known as crystallized intelligence) has been shown to be unaffected by age-related decline (Drag & Bieliauskas, 2010). Additionally, studies have shown that semantic memory actually increases with age due to the accumulation of knowledge over the lifespan (Bialystok, Poarch, Luo, & Craik, 2014). Overall, researchers have concluded that although memory as a whole does not decline as one would think, specific types of memory and processes are highly sensitive to the process of normal aging.

Linguistic Processing

Language, unlike the domains of executive functioning, attention, and memory that are greatly affected by the aging process, remains relatively intact in the later years of life. The few difficulties that do arise are primarily due to age-related decreases in the other domains that language interacts with or relies on. For example, in studying the

relation between memory and language during the aging process, researchers discovered that apparent language deficits are not pure deficits but instead are caused by deficits in retrieval memory, also known as word-finding difficulty (Barresi et al., 2000; Mortenson, Meyes, & Humphreys, 2006). Furthermore, in comparison to younger adults, older adults show more word-finding difficulties, such as having more fillers for pauses (e.g., “um”), tip of the tongue experiences, and retrieval word errors (Burke, Mackay, Worthley, & Wade, 1991; Heine, Ober, & Shenaut, 1999). In more technical language terms, older adults demonstrate more deficits in phonological retrieval compared to lexical information access. Semantic memory, lexical information access, and overall word and sentence meaning, however, do remain well preserved (Burke, Mackay, & James, 2000). This finding is further supported by studies that used similar retrieval and semantic tasks, but were able to attenuate the age-related effects by giving phonemic cues (e.g., “ra” for rabbit; Drag & Bieliauskas, 2009). Semantic cues (e.g., white and furry), however, did not reduce the language difficulties. Overall, researchers established that the deficits observed were not pure language deficits, but deficits in the domain of memory, as well as due to frontal lobe insufficiency.

The cognitive domain of language experiences age-related deficits due to its dependence on the frontal lobe (further supporting the frontal lobe hypothesis). In two studies conducted by Gold and her colleagues (1988 and 1993), they found that older adults aged 65 and older tended to generate more off-target verbosity and talkativeness; or in other words, the older adults generated more off-topic or tangential discourse. This off-topic talkativeness, however, was not a result of language deficiency, but a result of frontal lobe insufficiency and the lobes inability to inhibit irrelevant topics (Arbuckle &

Gold, 1993; Gold & Arbuckle 1995). The frontal lobe has also been found to play a large role in verbal fluency, sentence comprehension, and text recall, all of which show significant decrements during normal aging. Altogether, these findings support the conclusion that language primarily remains preserved while other related functions (e.g., memory and frontal lobe function) indirectly cause language deficits (Drag & Bielauskas, 2009). This conclusion makes language an ideal variable to study as a protective factor, which will be discussed later on.

Visuospatial Functioning

Dissimilar to language, visuospatial functioning does not remain well preserved during the aging process. In fact, numerous studies comparing language and visuospatial processes demonstrate that visuospatial abilities suffer from more age-related decline than verbal abilities (Jenkins, Myerson, Joering & Hale, 2000). Even when comparing within the same test (the Weschler Adult Intelligence Scale), Goldstein and Shelly (1981) demonstrated that older adults performed more poorly on the visuospatial subtests than the verbal subtests.

Age-related deficits have not only been found when comparing language to visuospatial functioning, but also in studies that have investigated independent visuospatial processes. Researchers discovered that the visuospatial processes, such as complex figure copy, mental rotation, visuospatial construction and processing speed, were all negatively affected by the aging process, with the exception of visual neglect (Geldmacher & Riedel, 1999; Ska, Poissant, & Joanette, 1990). For example, the clock-drawing task, which involves visual motor, construction, and planning abilities, is used to

visually identify normal aging deficits (Kozora, Cullum, 1994; von Gunten et al., 2008). These deficits are evidenced by an older adult's difficulty in placing the correct figures on the clock's face or differentiating between the clock's hands. Abnormal or pathological aging may also be examined if an older adult commits omission errors. Although the research is conclusive on visuospatial skills being age-sensitive, it remains unclear whether the domain itself is vulnerable or if its vulnerability is a result of the complex and indirect interaction with other domains.

Similar to language and the other domains, research suggests that visuospatial abilities interact with and rely on other domains, such as executive functioning, memory, and attention. In a study investigating the relationship between visuospatial and executive functioning, Libon and his colleagues (1994) discovered that age-related deficits were more significant on visuospatial tasks that integrated executive control processes (e.g., problem-solving) compared to the nonintegrative tasks (e.g., complex figure copy). The researchers concluded that the differential deficits in performance were primarily due to the use of executive functions and not merely from visuospatial functions. Thus, this finding also supports the frontal lobe hypothesis previously discussed and the possible confounding deficits on visuospatial functioning.

As Drag and Bieliauskas (2009) discuss in their cognitive aging review, the nature of the domain of visuospatial functioning is heterogenous and often include visuospatial attention, visuospatial memory, and visuospatial orientation. Converging evidence on these processes indicate that there are significant age-associated deficits and a common thread of deficits in processing speed and working memory (Cerella, Poon, & Williams, 1980; Desrocher & Smith, 2005). Although the research remains unclear of the exact

cause of the age-related deficits, it is clear that visuospatial functioning (and all the other domains) is greatly affected by the aging process, whether directly or indirectly. Therefore, it is vital to investigate what potential factors may protect against the deleterious effects of the normal and pathological process of aging, and promote successful aging by targeting these domains directly or indirectly through the main center of control: the frontal lobe and PFC.

Cognitive aging, and its associated deficits, is a normal process that is inevitable and unavoidable. Although the process is irreversible, research has discovered that successful aging is possible. Successful aging, as previously discussed, aims at preventing the loss of and the enhancing of brain capacity and reserve by utilizing brain networks more efficiently and/or utilizing alternative networks and strategies (Rowe & Kahn, 1987; Daffner, 2010). Different factors, experiences, activities, or environments that have been found to contribute to this cognitive reserve and protect against the aging process include, but are not limited to: the conventional factors of education, occupational experience, diet, and physical activity; and recent findings of nonconventional factors like music, games (e.g. Sudoku, crossword puzzles), and language (Wilson et al., 2002; Daffner, 2010; Gold, Kim, Johnson, Kryscio & Smith, 2013). For example, individuals with more educational experience or those who engage in more intellectually stimulating activities have been found to have less functional deficits, regardless of their structural features (e.g., more brain atrophy or evidences of AD at autopsy compared to their counterparts, but less functional manifestations; Scarmeas & Stern, 2011; Abutalebi et al., 2015). Furthermore, this discrepancy between anatomical evidence and little to no clinical manifestation has been explained by these

factors contributing to cognitive reserve and neuroplasticity (Bialystok, Craik, & Luke, 2012; Kroll & Bialystok, 2013). A stimulating mental activity and environment that efficiently utilizes various networks and strategies and that has recently gained a lot of interest around the world is the use of and exposure to multiple languages.

Bilingualism and Multilingualism

Due to the recent technological advances and increased global communication and traveling, the rates of bilingualism and multilingualism have exponentially increased (Bialystok, Craik, Green & Gollan, 2009). It has been estimated that more than half of the world's population uses two or more languages in their daily lives (Grosjean, 2012), and two-thirds of all children are raised in bilingual homes (Bialystok, Craik, Green & Gollan, 2009). Although the majority of this number is due to the highly concentrated pockets of bilingualism in other countries (e.g., 99% of Luxembourg, Germany is bilingual), the United States, and other predominant unilingual countries, has continually increased in its rates of bilingualism (Maguire et al., 2000). In a 2007 survey, 20% of the U.S. population reported a language at home other than English, indicating a 140% increase since 1980 (Shin & Kominski, 2010). With ethnic diversification increasing, these rates are expected to increase in the U.S., as well as globally. This high prevalence and relevance of speaking multiple languages coupled with the need to research neuroprotective factors has led to a boom in the number of research studies devoted to investigating the effects of language, and its effect on cognition.

Language and its effect on the brain have been studied for many years with varied findings on whether it is beneficial or detrimental. Historical research on the effect of

language on cognition (before the 1960s) concluded that the consequences were negative—monolingual (referred to as monoglot or unilingual) individuals demonstrated superior performance on intelligence tests in comparison to bilingual (polyglot) individuals (Smith, 1923; Saer, 1923; Yoshioka, 1929). This conclusion was made on the basis of two main studies. Saer (1923) conducted a study at a university in Wales comparing monoglot students' performances on the Stanford-Binet tests with that of bilingual students in rural and urban areas. Although Saer's findings were only found significant in comparing rural monoglot and bilingual students, and only applicable to dextrality, rhythm, vocabulary, and composition tests, the conclusion extracted from his study was that monoglots were "considerably superior" to that of bilinguals. Smith (1923) also conducted a study comparing monoglots with bilinguals in Wales, but specifically in school children ages 8 to 11. Smith concluded that monoglot children made better progress over the course of two years in expression, vocabulary, and accuracy of thought. Although various studies found a significant benefit of bilingualism or no difference between the two groups (Bialystok, Craik & Luk, 2012), the popular and dominant view at that time was that bilingualism had negative consequences on intelligence; with bilingualism even referred to as a needless hardship for children, causing mental retardation or as the "handicap of bilingualism" (Gray, 1923; Darcy, 1963).

In the 1960s, however, a drastic shift towards viewing bilingualism as advantageous began to take place. Peal and Lambert (1963) conducted a review of the previous representative studies and their methodological limitations, as well as their own study that addressed those limitations. The review segment of the article questioned the

soundness of the conclusion that bilingualism was detrimental. The main argument was that bilingualism and intelligence were not accurately operationalized. Furthermore, variables that frequently confound with language and intelligence (e.g., age, sex, immigration; Guzmán-Vélez & Tranel, 2014) were not controlled for in these past studies. For example, in critiquing Saer's 1923 study, Peal and Lambert highlighted how Saer only found a significant difference between the rural bilinguals and monolinguals, and not the urban students. This finding suggested that the difference found might have been attributed to the uncontrolled variable of socioeconomic status and not language status. After addressing these methodological limitations and controlling these variables in their own study, the authors discovered that bilinguals actually outperformed their monolingual counterparts on a battery of both verbal and nonverbal intelligence tests. The publication of these findings led researchers to begin changing the way they investigated the effects of language on cognitive functioning. Furthermore, the field as a whole began transitioning from a subtractive to additive perspective of bilingualism.

After the 1960s, the rate of published studies supporting the argument that bilingualism was advantageous and not a hindrance grew exponentially. A researcher's question in the field was no longer whether or not bilingualism was beneficial, but in what ways was it beneficial. However, in the quest of specifying the effects of language on the brain, a selective number of studies were still indicating a negative effect, even after having a solid methodology and controlling for the variables Peal and Lambert's (1963) study proposed (Paap & Greenberg, 2013; Paap & Liu, 2014; Ansaldo, Ghazi-Saidi & Adrover-Roig, 2015). Some argue that the shift had resulted in a publication bias and file-drawer problem with only the studies that supported bilingualism being

published (Bruin, Treccani & Salar, 2015). Others argue that a deeper analysis of each of the studies' findings reveals that the effect (whether negative or positive) depends on a variety of factors, such as the cognitive domain, population, language proficiency, age of acquisition, and numerous others (Bilaystok, Criak & Luk, 2012). The current study focuses on two key factors: the cognitive domain, addressing each main domain; and the population, specifically studying the healthy older adult population and the effect of language on cognitive decline. We will first discuss the effect of bilingualism on the various cognitive domains.

The Effect of Bilingualism on Cognitive Domains

Linguistic Processing and Executive Functioning

There are two major trends in the literature on the effect of knowing multiple languages on the brain and its domains. The first major trend is that it has negative effects on the domain of language (also referred to as linguistic or verbal processing; Mindt et al., 2008). Findings have indicated that bilinguals suffer considerably on a wide range of linguistic processes. Bilinguals have been shown to have weaker verbal skills, greater difficulty in word comprehension and production (as evidenced by more tip of the tongue experiences), smaller vocabularies, and are slower and less accurate in tasks like picture-naming (interference of lexical retrieval and decision; Oller and Eilers, 2002; Perani et al., 2003; Portocarrero, Burright and Donovan, 2007). Furthermore, bilinguals' linguistic deficits persist even when tested in their first and dominant language, given the option to respond in either language, or given phonological and semantic cues (Bialystok, Craik, Green, & Gollan, 2009). Although a consistent finding, researchers are unclear as to why

bilinguals' linguistic processes suffer. Some hypothesize that these negative consequences are a result of using each language less; and therefore, creating weaker links and connections within the network of the languages (weaker-links hypothesis; Gollan et al., 2008). Others posit a difficulty in sensorimotor functions or a difficulty in lexical access due to the languages competing (Mindt et al., 2008). If languages compete—resulting in difficulty in linguistic processing—then control and inhibition of the competing languages should be more frequently utilized; which leads to the second major trend of the literature: the positive effects of knowing multiple languages on the executive functions of inhibition, monitoring, task switching, and numerous others.

Researchers hypothesize that since both languages are simultaneously activated in the bilingual brain (or multiple languages in a multilingual brain), the brain's executive function of inhibition must be activated in order to attend to the target language while ignoring the non-target language in a context that requires the use of only one language (Kroll, Bobb, Misra, & Guo, 2008; Bialystok, Craik, & Luk, 2012). In a context that requires the use of both languages, executive controls of monitoring and task switching are then used more often to know when to switch from one language to another. Although a few published studies have found no bilingual advantage in executive functioning, the converging evidence strongly supports the conclusion that bilinguals' executive functions are enhanced in comparison to monolinguals (Kirk et al., 2014; Ansaldo, Ghazi-Saidi & Adrover-Roig, 2015).

Contrasting the previous clear and established research on the domains of language and executive functioning, the research on the effect of bilingualism on the domains of attention, memory, and visuospatial functioning is limited and inconclusive.

As previously discussed, the brain's high interconnectivity and cohesive effort makes it difficult to parcel out the overlapping effects of the various domains; especially parceling out executive functioning, which often plays a large role in numerous tasks. We will discuss each of the remaining three cognitive domains (beginning with attention), and attempt to understand the effect bilingualism has individually on each domain.

Attention

The majority of the research supports the finding that attention is enhanced in bilinguals. Bilinguals, in comparison to monolinguals, have been found to perform better on attention tasks that involve the ability to ignore misleading cues by specifically utilizing selective attention (Bialystok, 2001). For example, Bialystok (1986) compared bilingual and monolingual children on multiple metalinguistic tasks and the use of selective attention. In a grammar judgment task (e.g., "Apples grew on trees") that required no ignoring of misleading cues there was no difference between the two groups; however, in a similar task that required selective attention (e.g., "Apples grow on noses"), bilinguals outperformed their monolingual peers. Similar to executive functions, researchers believe that selective attention is enhanced due to the bilingual brain's ability to focus solely on one language and inhibit the other in a context that requires activation of only one language (selective and sustained attention; Fernandes, Craik, Bialystok, & Kreuger, 2007). Additionally, in a context that requires the use of both languages, the bilingual brain is able to use both languages simultaneously (divided attention) or switch from one to another (alternating attention). These bilingual benefits of attention, however, are often dismissed or overlooked due to being labeled as "attentional control" or

“inhibition” and categorized under the domain of executive functioning instead of attention. This confusion of domains has led to only a few studies that solely investigate the effect of bilingualism on attention. The current study will address this lack of research and endeavor to understand the effect knowing multiple languages has on attention.

Memory

Similar to attention, the research on the effect of bilingualism on the cognitive domain of memory is limited and unclear. A key reason to the research’s lack of clarity is that memory performance is largely dependent on the role two competing systems of executive functions (positive effects of bilingualism) and verbal processing (negative effects) play in memory processes (Luo, Craik, Moreno, & Bialystok, 2013). For example, the majority of the commonly used memory assessments are based on verbal recall or recognition. Prime examples are tasks that require an individual to recall a list of words over various different trials (e.g., Rey Auditory Verbal Learning Test- RAVLT). Multiple studies have discovered that in these types of tasks, bilinguals recall fewer words than monolinguals (Gollan & Kroll, 2001; Michael and Gollan 2005). Researchers, however, are unable to conclude whether the negative effect was due to actual worsened memory performance or deficits in verbal processing. On the other hand, studies that were conducted using non-verbal memory tasks discovered a marginal advantage for bilinguals (Wodniecka, Craik, Luo, & Bialystok, 2010). The authors, however, questioned whether the advantage was then due to the demand and use of executive functions. Studies that used memory tasks that involved both verbal processing and

executive functioning (e.g., working memory tasks that involve executive function of manipulation) found no differences in memory performance between monolinguals and bilinguals (Luo, Craik, Moreno, & Bialystok, 2013). Researchers posited that the null effect may be due to the two competing systems cancelling out the effects of the other, which they tested by increasing the demand for executive functioning in the memory tasks. The results indicated better memory performance for bilinguals; and therefore, concluding that it was the executive functioning and not memory performance was enhanced. Although more research needs to be conducted, the current research suggests that bilingualism has little to no impact on memory performance on its own and any impact may be a result from interacting networks.

Visuospatial Functioning

Similar to memory, the effects of bilingualism on visuospatial functioning are commonly overlooked or dismissed due to being categorized under the functions of executive control, as well as working memory. The most consistent finding on the effect of bilingualism on visuospatial functioning is that bilinguals outperform monolinguals on visuospatial tasks (Bialystok, 2010; Lom, Kuntay, Messer, & Leseman, 2014; Morales, Calvo, & Bialystok, 2013). Many researchers, however, believe that this advantage is due to the strong component of executive control and not an actual advantage in visuospatial processes (Abreu, Cruz-Santos, Tourinho, Martin and Bialystok, 2012; Luo, Craik, Moreno & Bialystok, 2013; Alloway, Gathercole, Willis, & Adams, 2004). Luo and his colleagues (2013) predict that even if monolinguals and bilinguals were matched on

spatial abilities, a bilingual advantage would be noted in a visuospatial task due to the element of executive functioning.

There are a few studies that have found a slight difference between monolinguals and bilinguals, or no difference (Messer, Leseman, Boom, & Mayo, 2010; Engel de Abreu, 2011), even when the visuospatial task involved executive functions. In a study that compared elderly monolinguals and bilinguals in a visuospatial interference control task called the Simon task, the results indicated no difference between the two groups (Ansaldò, Ghazi-Saidi & Adrover-Roig, 2015). The functional magnetic resonance imaging (fMRI) results of the study, however, indicated that the groups recruited two different underlying neural substrates. Monolinguals activated more of the frontal regions (right middle frontal gyrus), whereas bilinguals activated areas responsible for visuospatial processing (left inferior parietal lobule). Due to the study's simple task and limitations of not controlling for education (with monolinguals having a higher education), as well as taking into consideration that the frontal regions are more vulnerable to the aging process and neuroplasticity is greater in the bilingual brain, researchers questioned their finding of no bilingual advantage and suggested that they may actually have an advantage in visuospatial functioning. More research, however, is needed to clarify the bilingual effect on the domain of visuospatial functioning, as well as on the other less-researched domains of attention and memory.

We have discussed the importance of considering the specific effect of knowing multiple languages on the various cognitive domains. A second key factor to consider in the research as a whole, as well as specifically for this study, is the population of study. The majority of past studies have focused on the effects of bilingualism on school-aged

children and college students due to the heightened focus on the effect bilingualism had on the cognitive and linguistic development of children and their school performance (Smith, 1923; Saer, 1923; Yoshioka, 1929). As the research on language continued to gain popularity, researchers began studying other populations, including infants, adults, and older adults (Kovács & Mehler, 2009; Bialystok, Martin, & Viswanathan, 2005).

As diverse populations were investigated, researchers began recognizing that the effects of bilingualism (positive, negative, or indifferent) varied based on the studied population. In a review conducted by Bialystok and his colleagues (2012) on the consequences of bilingualism on the brain, they highlighted how advantageous effects were found in children, muted in adults, and most prominent in older adults (Bialystok, Klein, Craik, & Viswanathan, 2004; Bialystok, Craik, & Ryan, 2006; Bialystok, Luk, & Craik, 2012; Bialystok, Poarch, Luo, & Craik, 2014). Although the verbal processing deficits have been found to persist into late adulthood, the bilingual advantage on executive functioning has been found to develop earlier in children, be maintained more efficiently in adulthood, and decline less in older adults, which researchers attribute to the power of neuroplasticity and cognitive reserve. These effects in the older adult population have large implications for the power of knowing multiple languages throughout the lifespan in promoting successful aging, and especially in the older ages of protecting against normal and pathological aging.

In consideration of the global “population aging” phenomenon and the individual effects of aging, numerous studies have been dedicated to investigating the effects of knowing multiple languages on cognition in older adults. Structural studies have found numerous beneficial effects including, but not limited to: increased neural efficiency

(Gold, Kim, Johnson, Kryscio, Smith, 2013), increased white matter integrity in the corpus callosum (Luk, Bialystok, Craik & Grady, 2011), and stronger anterior-posterior connectivity (contributing to increased brain reserve; Bialystok, Craik & Luk, 2012). Furthermore, due to the buildup of cognitive reserve, symptoms of mild cognitive impairment (MCI) or different types of dementia (including Alzheimer's disease) have been found to be delayed by an average of four to five years in bilinguals compared to monolinguals (Ossher, Bialystok, Fergus, Craik, Murphy & Troyer; Bialystok, Craik & Freedman, 2007). Although it is important to note that several studies have not been able to find similar results of a stronger bilingual advantage in older adults (Bialystok, Craik, and Luk, 2008a). The current study will further investigate the effects of knowing multiple languages in conjunction with the specific question of its effect on the various cognitive domains.

Lastly, a key factor to address in understanding the research of the effect of language on cognition is the operationalization of bilingualism. As Peal and Lambert (1963) pointed out in their review, many studies inadequately define bilingualism, which leads to different findings and conclusions. The literature's two polarized findings—one finding a bilingual advantage and the second negating an advantage due to its negative or null findings—although appearing to be in opposition, may both be correct depending on how the studies' authors operationalized "bilingualism." For example, the first is likely to have defined bilingualism as lifelong and simultaneously used every day (otherwise known as balanced bilingualism in the literature); whereas the second is likely to have defined it as knowing two languages, which includes individuals with both imbalanced and balanced bilinguals (Bialystok, Klein, Craik & Viswanathan, 2004; Bialystok, Martin

& Viswanathan, 2005; Kavé, Eyal, Shorek & Cohen-Mansfield, 2008)). The majority of the studies are similar to the first in that they study a population where both languages (or multiple) are in constant high demand (e.g., Spain where Spanish and Catalan are simultaneously used throughout the day). Other studies are similar to the second in that they study populations from countries where immigration rates are high and a mixture of balanced and imbalanced bilingualism occurs (e.g., America where some immigrants continue to simultaneously use both their languages and others who acculturate more and use their native tongue less). Therefore, although both groups are referred to as “bilingual,” there are drastically different and lead to the discrepancies in the research.

With the rate of immigration and acculturation increasing globally, as well as due to the lack of research on the latter imbalanced and balanced bilingualism populations, the current study will investigate the effects of language, imbalanced or balanced, throughout the lifespan. To ensure that other possible confound factors are not contributing for or against cognitive performance, we will control for immigration status and other variables commonly identified in the literature (i.e., education, age, sex), as well as excluding the possible confound of pathology by studying a healthy older adult population.

Current Study

In conclusion, the purpose of the current study is to examine whether the number of languages an individual knows and is exposed to throughout the lifespan contributes to reserve and protects against the effects of normal aging, as well as promotes successful aging among healthy older adults. The first aim of the study is to affirm the findings on

the effects multilingualism has on the two main established cognitive domains of executive functioning and linguistic processing. It is hypothesized that executive functioning performance will be enhanced for those who speak more than one language (multilinguists) compared to monolingualists, whereas linguistic processing performance will be diminished for multilinguists. The second aim of our study is to identify the consequences of the number of languages spoken on the cognitive domains of attention, memory, and visuospatial functioning. It is hypothesized that due to attention's reliance on executive controls, it will be enhanced for multilinguists. Due to the inconclusive and limited findings regarding memory and visuospatial functioning, no specific hypotheses will be made for these cognitive domains. Furthermore, as the research suggests, we will be controlling for the various critical confounding factors of age, sex, education, and immigration status.

CHAPTER THREE

MATERIALS AND METHOD

Participants

General Demographics

Participants were 312 healthy older adults (68% female) between the ages of 64 and 75 ($M = 69.42$, $SD = 3.31$). The sample was 79.7% Caucasian, 8.3% Hispanic, 7.2% African American, 3.7% Asian, and 1.1% “Other”. Participants had a mean of 15.44 years of education ($SD = 3.15$).

Linguistic Demographics

Of the 312 participants, 167 reported speaking one language, 104 reported speaking two languages, 33 three languages, and eight reported speaking four or more languages. The languages known included a large variety with the most common being Spanish, German, French, Chinese, and Filipino (including various dialects like Tagalo and Visayan). The majority of the participants learned their additional language(s) from either immigrating from diverse countries ($N = 47$) including the most common: Mexico, Germany, China, and the Philippines; or from emigrating from the U.S. to other countries including the most common ($N = 28$): Japan, Germany, Mexico, Peru, and Pakistan. Although a large number of the multilingual sample immigrated from another country to the U.S., 306 (~98%) participants reported English as their dominant language. In order to obtain a more homogeneous sample, only participants for whom English is their dominant language were included in the analyses. Participants reported that they acquired their first language (English) at birth, the second language at a mean age of 13 ($SD =$

10.04), and the third language at a mean age of 20 ($SD = 11.54$). Lastly, proficiency ratings of speaking, reading, and understanding varied throughout the sample. The average speaking proficiency rating for participants' first language (English) was 8.35 ($SD = 1.50$), understanding ($M = 8.70, SD = 1.32$), and reading ($M = 8.53, SD = 1.78$). For additional languages speaking proficiency rating was 4.99 ($SD = 2.98$), understanding ($M = 5.82, SD = 2.84$), and reading ($M = 5.40, SD = 3.12$). For the current study, the final sample included 301 participants, with 163 monolinguals and 138 multilinguals after including English-dominant participants only and addressing any outliers.

Procedures

General WAHA Longitudinal Study

The Walnuts and Health Aging Study (WAHA) is a two-year longitudinal study analyzing the effects of walnuts on healthy aging, in regard to physical health (e.g., heart disease) and cognition (e.g., memory), and conducted in two locations: Loma Linda, California and Barcelona, Spain. The current study utilized the data solely from the Loma Linda location. The study includes three main stages: the recruitment and screening, randomization, and data collection stages. In the recruitment stage, participants were recruited in the Southern California area by multiple methods, including: mass mailing and distributing of brochures, and advertising through newspapers, newsletters, posters, website/e-mails, and presentations at churches and senior centers. Individuals interested in participating filled out an initial screening form on the web, phone, or through the mail to assess their eligibility based on the following requirements: must be (a) 60 to 80 years old; (b) reasonably healthy; (c) read and write English; (d) available every two months to

visit Loma Linda University; and must not (e) be extremely obese; (f) have uncontrolled diabetes or hypertension; (g) have suffered a tragic loss in the past year; and (h) be allergic to walnuts. Individuals meeting these requirements were invited to attend a group information meeting about the study and given the informed consent form. Participants acknowledged the purpose and requirements of the study by signing the informed consent form. After consent had been given, baseline data of the participants were collected including basic demographic information and mental health questionnaires, blood and urine collection, eye exam results, and cognitive assessments. In the randomization stage, systematic sampling was used to randomly assign half of the participants to the experimental condition of eating walnuts and half to a control condition of a walnut-free diet. To ensure the exclusion of the effects of other nuts, all nuts were excluded from the diets of participants in the control condition.

In the data collection stage, which occurred over the course of two years, multiple health assessments were conducted: dietician visits every two months (including anthropometric measurements), blood and urine analyses every year, and eye exams, questionnaires, and a battery of cognitive assessments at baseline and at the two-year follow up. The battery of cognitive assessments assessed a variety of different cognitive functions including, but not limited to: executive, learning and memory, processing speed, and verbal fluency, as well as screeners for depression and dementia. Participants were also required to complete a packet containing questionnaires every year that assessed for the participants' psychological and general health including: stress, perceived social support, spiritual well-being, and memory self-efficacy. All assessments

and questionnaires were reviewed and approved by the Loma Linda University Institutional Review Board.

Current Study

For the current study, participants were interviewed one-on-one to assess their language experience and proficiency profiles. The interviews averaged five to ten minutes for monolinguals, 15 minutes for those who indicated speaking two languages, and <30 minutes for those who indicated speaking more than two languages.

Additionally, the current study examined the baseline, cross-sectional data of the WAHA study's cognitive assessments. Ten of the measures were analyzed to assess the cognitive domains of executive functioning, linguistic processing, attention, memory, and visuospatial functioning.

Measures

Demographic Characteristics

Participants were asked to report their age, sex, race/ethnicity, number of years of education, and immigration status.

Language Group

The Language Experience and Proficiency Questionnaire (LEAP-Q) (Marian, Blumenfeld, & Kaushanskaya, 2007) is a self-reported questionnaire that assesses for a participant's full linguistic background including current and past language experience and proficiency. The LEAP-Q was used to specifically assess how many language(s) a

participant knows with those who responded “only one” being categorized into the monolingual group and those who responded “more than one” being categorized into the multilingual group. The questionnaire also assesses for other variables including, but not limited to: language dominance, age(s) of acquisition, current exposure to each language measured in percentages, proficiency ratings for three language areas (reading, understanding, and speaking) measured on a scale from 0 to 10, and current exposure to different contexts (friends, family, watching TV, etc.). See Appendix A for full questionnaire.

Executive Functioning

Executive functioning was measured by two tasks: Stroop Color-Word Test (Golden, 1978) and the Trails Making Test Part B (TMT-B; Reitan & Wolfson, 1985). The Stroop task consists of a page of color words (i.e., “red”, “green”, “blue”) printed in a different colored ink where participants are asked to name the color of the ink the word is printed in rather than the word itself. Therefore, the participants must recruit executive controls to ignore the more automatic response of reading the word to effectively attune to the color of the ink. Participants’ performances were recorded as number of correct items completed in 45 seconds, which was converted to t-scores. Higher t-scores indicated better performance. The TMT-B task consists of 25 circles including both numbers and letters on a sheet of paper and participants are required to alternatively connect the numbers and letters in ascending order (i.e., 1-A-2-B-3-C until they reach the circle marked END). Participants are given a maximum time limit of 300 seconds and errors that are made—although not recorded—are reflected in the completion time.

Participants' performances were recorded in seconds, with higher scores indicating poorer performance.

Linguistic Processing

Linguistic processing was assessed using the semantic fluency (Animals) and phonemic fluency (F-A-S) subtests of the Controlled Oral Word Association Test (COWAT; Butler, Retzlaff, & Vanderploeg, 1991), and the Boston Naming Task (BNT; Kaplan, Goodglass, & Weintraub, 1983). For the COWAT animals test, the participants were given the semantic category of animals and asked to name as many animals as quickly as possible in the span of 60 seconds. The COWAT-FAS gives participants one minute for each letter (F, A, and S) to name as many words that begin with that letter as quickly as they can. On both subtests, raw scores reflect the total number of correct words and animals participants were able to name within the given time limits. For the BNT, participants were shown a total of 60 pictures, one at a time, and each for a maximum of 20 seconds. Participants were required to provide the most common name for each picture and were allowed one prompt or phonemic cue. The total number of correct identifications without cue was used to assess participants' linguistic processing with higher scores indicating better performance.

Attention

Attention was assessed using three measures: the Digit Span subtest of the third edition of the Wechsler Adult Intelligence Scale (WAIS-III; Wechsler, 1997), Connors' Continuous Performance Task 2nd edition (CPT-II; Connors and MHS Staff, 2000), and

the Trail Making Test Part A (TMT-A; Reitan & Wolfson, 1985). The Digit Span task consists of 15 items (eight items for digit span forward and seven for backward) and requires participants to accurately repeat the series of digits (ranging from two to eight) in the given order (forward digit-span task) and in the reverse order (backward digit-span task). Participants may receive a maximum of 30 total points, with higher scores indicating higher better performance. For the CPT-II task, participants were instructed to press the space bar or click the mouse when the letter “X” would appear on the computer screen. The task included six blocks and three sub-blocks with 20 trials within each block, and taking a total of 14 minutes to complete. Participants’ attentional performances were measured by the number of times participants correctly discriminated between the signal (non X’s) and noise (X) distributions (known as detectability- d'). Therefore, the greater difference between the signal and noise distributions indicates more discriminative power and ability to detect and distinguish the target stimulus. Low t -scores of d' indicated good detectability. The TMT-A consists of 25 consecutive numbers on a sheet of paper in which the participants are required to connect in sequential order and as quickly as possible (with a time limit of 300 seconds). Participants’ performances were recorded in seconds, with higher scores indicating poorer performance.

Memory

The cognitive domain of memory was assessed using the Rey-Osterrieth Complex Figure Test (RCFT; Osterrieth, 1944) and the Rey Auditory Verbal (RAVLT; Rey, 1941). The RCFT consists of three parts: copy, recall, and recognition. Participants are

first given five minutes to copy the design on a card as accurately as possible. After a three-minute delay and again after a thirty-minute delay, participants are asked to draw the figure again from memory. The last part of the test asks participants to recognize and circle the parts of the figure they remember from the original image. Each of the parts measures a different function, and for the current study, we utilized the thirty-minute delay to measure memory. A maximum of 36 points is possible on each recall score (immediate, 3-minute and 30-minute delays). The 30-minute delayed recall score was used with higher scores indicative of better memory performance. For the RAVLT, participants are orally presented with a list (List A) of 15 unrelated words and are asked to recall as many as they can for a total of five learning trials. List A is then followed by a reading of List B (trial 6), also asking participants to remember as many words as they can. After the reading of List B, participants are asked to recall as many words as they can from the first list (List A). Participants are then engaged in unrelated tasks over the span of the next 20 minutes. After the 20-minute delay, participants are asked to again recall the words from List A. Higher scores are indicative of better verbal memory performance. The delayed recall scores were used for the current study, with higher scores indicating more words recalled and higher performance.

Visuospatial Functioning

The Block Design subtest of the third edition of the Wechsler Adult Intelligence Scale (WAIS-III; Wechsler, 1997) was used to measure visuospatial skills. The task consists of a certain amount of blocks (four to begin with and then increased to nine) and various pictures of block designs. Participants were instructed to assemble the blocks to

match the design as quickly as possible. Participants would then receive a point for the correct design and an extra four to seven points depending on how fast they finished. Raw scores were converted to scaled scores based on the norms with higher scores indicating better performance.

Data Analytic Plan

Preliminary analyses, testing and correcting for outliers, bivariate relationships, and testing for assumptions of multivariate analyses of covariance (MANCOVA), were first conducted. No violations of the assumptions of MANCOVA were found. Outliers that were detected were corrected by transformation of the data from raw scores to z-scores. Apriori analyses of age, sex, education, and immigration status will be conducted to determine whether any significant differences lie among the language groups. Comparisons will be completed using a one-way analysis of variance (ANOVA) and a chi-square test, and if significant differences are found among these demographic variables, they will be controlled for during the main analysis. A series of MANCOVAs will be conducted to test the relationships between the language group and the various cognitive domains of executive functioning, linguistic processing, attention, and memory. More specifically, a MANCOVA will be conducted for each individual cognitive domain to test for differences between the language groups, while controlling for significant covariates. An analysis of covariance (ANCOVA) will be conducted to test the effect of language group on visuospatial processing due to only one assessment test being conducted in the visuospatial domain. For all 12 outcome cognitive assessments, raw and

t-scores will be converted and analyses will be run with the standardized z-scores.

Statistical analyses will be performed using SPSS (IBM version 22).

CHAPTER FOUR

RESULTS

Apriori Analyses: Covariates

The results of a one-way between subjects ANOVA indicated that there were significant differences between monolinguals and multilinguals in age, education, and immigration status. Monolinguals were significantly older ($M = 71.07$, $SD = 4.12$) than multilinguals [$M = 69.78$, $SD = 3.69$; $F(1,310) = 8.34$, $p < .01$]. Multilinguals reported more years of education ($M = 16.38$, $SD = 2.88$) than monolinguals [$M = 15.39$, $SD = 2.54$; $F(1,310) = 10.40$, $p < .01$]. There was a significant difference between language groups in regards to immigration status with multilinguals (92%) more likely to have immigrated compared to monolinguals (8%), $\chi^2(1, N = 310) = 42.83$, $p < .001$. There was no significant difference between the language groups in regards to gender, $p > .05$. Therefore, age, education, and immigration status was controlled for in all of our main analyses.

Table 1. Results of ANOVA and chi-square differences comparing differences of demographics and control variables by language group.

Variable	Language Group				<i>F</i>	χ^2	<i>p</i>
	Monolingual (<i>N</i> = 163)		Multilingual (<i>N</i> = 138)				
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>			
Age	71.07	4.12	69.78	3.69	8.34	-	.01
Education	15.39	2.54	16.38	2.88	10.40	-	.001
Sex (<i>N</i>)	Female	Male	Female	Male			
	107	60	97	48	.40	-	.53
Immigration Status (<i>N</i>)	Yes	No	Yes	No			
	5	162	42	103	-	42.83	.000

Main Analyses: MANCOVAs/ANCOVAs

Due to the small correlations between the two assessments (Stroop and TMT-B; $r = -.24, p < .001$) of executive functioning, two one-way between-subjects ANCOVAs were used to test the hypothesis that executive functioning will be enhanced in multilinguists compared to monolinguals. Multilinguals performed significantly better than monolinguals on the Stroop Word-Color task [$M = -.42, SD = .98$ vs. $M = -.61, SD = 1.00; F(1, 303) = 7.14, p < .01$]. When compared on the Trail-making Test-B, however, there was no significant difference between monolinguals and multilinguals, $p > .05$.

Due to the general moderate correlations between the three assessments of linguistic processing (FAS and Animals $r = .39, p < .001$; Animals and BNT $r = .35, p <$

.001; FAS and BNT $r = .28, p < .001$) and the MANCOVA assumptions met, a one-way between-subjects MANCOVA was used to test the hypothesis that linguistic processing will be diminished in multilingualists compared to monolingualists. Language group did not significantly predict linguistic processing performance, $p > .05$.

Due to the non-significant and small correlations between the three assessments of attention (Digit Span and TMT-A, $r = -.18, p < .001$; Digit Span and CPT-II, $r = -.04, p > .05$; TMT-A and CPT-II, $r = -.03, p > .05$), three one-way between-subjects ANCOVAs were used to test the differences between language groups on attention. There were no significant differences between monolinguals and multilinguals on any of the three attention tasks, p 's $> .05$.

Given the close-to-zero correlation between the assessments of memory (RCFT and RAVLT, $r = .18, p < .001$), two one-way between-subjects ANCOVAs were used to test the effect of language on memory performance. On both memory tasks, there were no significant differences found between the language groups, p 's $> .05$.

Lastly, a one-way between-subjects ANCOVA was conducted to test the effect of language on visuospatial functioning. The results indicated that there was no significant difference between monolinguals and multilinguals in visuospatial functioning performance, $p > .05$ (see Table 2 for summary of results of main analyses).

Table 2. Summary of results for main analyses of five cognitive domains with means (M) and standard deviations (SD) of each language group.

Variable	Language Group				<i>F</i>	<i>p</i>
	Monolingual (<i>N</i> = 163)		Multilingual (<i>N</i> = 138)			
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>		
Executive						
Stroop	-.61	1.00	-.42	.98	7.14	.008
TMT-B	-.37	.98	-.33	1.01	.083	.77
Linguistic						
FAS	-.05	.93	-.16	1.18	.56	.46
ANIM	.68	.96	.55	1.25	.72	.40
BNT	.44	.73	.30	.95	1.29	.26
Attention						
DS	.04	.94	-.05	1.06	.48	.49
TMT-A	-.57	.70	-.62	.67	.002	.96
CPT-II	-.20	.99	-.19	.88	.29	.59
Memory						
RCFT	-.36	.92	-.37	1.03	.06	.80
RAVLT	1.30	1.34	1.16	1.22	.90	.34
Visuo-Spatial						
BD	-.01	.94	.02	1.04	.001	.98

Note. Stroop = Stroop Word-Color Test; TMT-B = Trail-Making Test part B; FAS = phonemic fluency test; ANIM = Animals; BNT = Boston Naming Task; DS = Digit Span; TMT-A = Trail-Making Test part A; RCFT = Rey Complex Figure Test; RAVLT = Rey Auditory Verbal Learning Test; BD = Block Design.

CHAPTER FIVE

DISCUSSION

Summary of Results

This study explored the effect of language on the whole brain by examining the effect of multilingualism on each cognitive domain. More specifically, this study sought to affirm previous findings on the advantageous effect of multilingualism on executive functioning and deleterious effect on linguistic processing, and explore the effects of multilingualism on memory, attention, and visuospatial functioning.

In terms of demographic characteristics, multilinguals differed from monolinguals in education, age and immigration status. In regards to education, multilinguals reported an average of one additional year of education in comparison to monolinguals. This is important to note because by controlling for this difference between the groups, the difference (or lack of difference) is not mistakenly attributed to the difference of languages known. Similarly, any differences among education must also be controlled for. The literature strongly supports the conclusion that higher education is linked to better cognitive reserve (Fratiglioni et al., 1991; Launer et al., 1999; Habib, Nyberg, & Nilsson, 2007). As highlighted in Ansaldo and colleagues (2015) study, no bilingual advantage was found due to not controlling for education, which was found to be higher among monolinguals and may have canceled out the advantageous effect of bilingualism (Gollan, Salmon, Montoya, & Galasko, 2011). Von Gunten and colleagues (2008) discovered a similar finding of enhanced cognitive performance in a clock-drawing task for participants with higher education, as well as due to being younger in age.

In regards to age in the current study, monolinguals were significantly older in age. Similar to the previous finding on education, this is important to control for so as not to misattribute monolinguals' poorer (age-related) cognitive performances to the hypothesized protective effect of multilingualism (as previously highlighted in the Von Gunten et al., 2008 study). Especially in consideration of our sample of older adults, it is important to control for age and its possible effects on cognition that have been supported in the literature (e.g., cognitive decline in older age; Daffner, 2010).

The two groups also differed in regards to immigration status with more multilinguals reporting immigrating to the United States in comparison to monolinguals. In the debate of whether bilingualism is beneficial to cognition, many researchers (both in favor and against) have highlighted the necessity of teasing apart bilingualism and immigration status to again ensure that the difference in cognition is attributed to language and not immigration status (Chertkow, Whitehead, Phillips, Wolfson, Atherton, & Bergman, 2010; Kousaie & Phillips, 2012; Fuller-Thomson, Milaszewski, & Abdelmessih, 2013).

While controlling for these demographic variables in the main analyses, a significant difference was found on a test of executive functioning that measures divided attention and response inhibition (Stroop Color-Word Test). This result confirms our initial hypothesis and is consistent with the literature (Kirk et al., 2014; Ansaldo, Ghazi-Saidi & Adrover-Roig, 2015). Although the groups did not have significantly different scores on another executive test (TMT-B), this is still an important finding. By discovering that one executive test significantly differed and not the other, this result supports the necessity of multiple assessments in measuring the same cognitive domain

and encourages both researchers and neuropsychologists to integrate multiple assessments in their battery of tests. As previously discussed, the brain and its multiple functions and processes of each domain are complex and multifaceted and require multiple assessments to most adequately assess each individual domain. There is no “one golden standard” that comprehensively measures each major cognitive domain individually. For example, both Stroop Color-Word and TMT-B are tasks that have been established as executive functioning tasks; however, these tasks vary in what aspects of executive functioning they measure. Stroop Color-Word measures the executive function of inhibitory control (Stroop, 1935), whereas TMT-B primarily measures the executive function of task-switching (Reitan & Wolfson, 1985). Therefore, a possible explanation for the discrepancy in significance between the Stroop Word-Color test and TMT-B is that multilingualism may be beneficial for specific executive functions (e.g., inhibitory control) and may have no effect on others (e.g., task-switching). Further research should be conducted on comparing the effects of multilingualism on multiple assessments of the same domain.

Contrary to what was hypothesized and the previous literature, no disadvantage was found for multilinguals in regards to their linguistic processing. Multiple assessments were utilized to measure linguistic processing due to various linguistic tests often utilizing other mental processes (e.g., a linguistic task also engaging executive functions), and to ensure accurate measurement in order for no difference found to be attributed to functions other than linguistic capabilities.

In consideration of the accuracy of the linguistic assessment tools and its contradiction to previous strong literature support, a possible explanation for these results

is that the levels of fluency of multilingualism were not strong enough to have an effect on linguistic processing. The current study's sample did not consist of balanced multilinguals (equally fluent in their multiple languages; Bialystok, Craik, Klein, & Viswanathan, 2004). For example, it is possible that the effect of language on executive functioning was found even with multilinguals demonstrating a minimal level of fluency in their second language(s) due to the strong relationship between language and executive functioning; whereas, an effect on linguistic processing is only be found when multilinguals demonstrate a higher level of fluency This possible explanation can also be applied to explaining the lack of significance for memory, attention, and visuospatial functioning. Future research should be conducted to address this limitation by comparing cognitive performances of multiple groups with low and high levels of fluency (i.e., comparing balanced and imbalanced bilinguals).

Due to the limited literature on the effects of language on memory, attention, and visuospatial functioning, no hypotheses were made; although possible outcomes of beneficial effects were suggested due to these processes' close associations with executive functions. The current study found no effect, neither positive nor negative. A possible explanation for these results, as previously alluded to, is that the reduced level of fluency in their second language(s) among the immigrant multilingual sample may not have produced a strong enough effect on these cognitive domains in comparison to monolinguals. Although considered a possible limitation of the current study's sample, these non-significant findings provide valuable information in regards to the effect of multilingualism on cognition in an acculturated immigrant sample.

The majority of studies conducted on the effect of bilingualism, even those conducted in the U.S., obtain unique samples of balanced bilinguals (using both languages equally, 50-50), which does not accurately represent the general American bilingual public. Although no census has been gathered on what percentage of the American population are balanced bilinguals, general statistics suggest that the majority of American bilinguals are imbalanced. According to the American Community Survey Report (2007), 19.7% reported speaking a language other than English at home, with the majority of this population (55.9%) rating their English-speaking ability as "very well." In the current sample, all but six of the self-identified multilingual participants (96%) reported English as their dominant language (although not their native tongue; $N = 51$, 35% of English non-native tongue) with the overall sample reporting low levels of proficiency in their secondary languages ($M = 5.00$, $SD = 2.99$). Therefore, these results, although not reflective of most multilingual samples and studies, provide new insight into the effect of multilingualism in an American sample, which includes both high rates of both immigration and emigration.

In addition to considering the variable of balanced/imbalanced multilingualism and level of proficiency in an American sample, age of acquisition should also be considered (Bak, Nissan, Allerhand & Deary, 2014). Researchers have found that the age of acquisition of secondary language(s) (also referred to as age of onset of bilingualism) affects the brain, with earlier acquisition having more significant effects (Luk, De Sa & Bialystok, 2011; Pelham & Abrams, 2014). Although the literature is inconclusive of what cutoff age delineates early versus late acquisition and determines whether the effects will be significant, this variable should be studied in an American sample due to

the varying ages of acquisition with later acquisition often due to immigration/emigration or early acquisition for the children of the immigrants. In the current study, several of the participants in the current sample were immigrants and learned their secondary language(s) at later ages ($M = 12.97$, $SD = 10.08$), which could explain the non-significant findings. Therefore, future studies should be conducted to study the effects of multilingualism in an American sample, taking into consideration the various influences of immigration/emigration, level of proficiency, and age of acquisition.

Future Research

In light of the aforementioned limitations of the study, future research should be conducted to address these limitations, and to specifically tease apart the different possible confounding language factors that may be also influencing cognition (e.g., age of acquisition, level of proficiency, etc.). To specifically address the limitation of the current sample's imbalanced bilingualism, future research will be conducted in comparing the current imbalanced, multilingual American sample with a balanced multilingual sample. By controlling for similar variables and having similar samples, minus the aspect of the utilization of their languages, we would be able to better test the proposed hypotheses of the effects of language on the various cognitive domains. As previously and briefly mentioned, the same current study was simultaneously conducted in Barcelona, Spain utilizing the same protocol and including the identical cognitive assessments. One major differing factor of the sample in Spain, however, is that the participants are balanced bilinguals, using both of their languages daily and equally. Therefore, we plan to compare the results of the current study with that of the Spaniard

sample to determine whether the level of fluency determines the effects (both advantageous and disadvantageous) on each cognitive domain.

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APPENDIX A

LANGUAGE EXPERIENCE AND PROFICIENCY QUESTIONNAIRE

Northwestern Bilingualism & Psycholinguistics Research Laboratory
 Marian, Blumenfeld, & Kaushanskaya (2007). The Language Experience and Proficiency Questionnaire (LEAP-Q): Assessing language profiles in bilinguals and multilinguals. *Journal of Speech Language and Hearing Research*, 50 (4), 940-967.
 Adapted to pencil-and-paper version by Marilyn Logan

Language Experience and Proficiency Questionnaire (LEAP-Q)

Last name		First name		Today's Date	
Age		Date of Birth		Male <input type="checkbox"/>	Female <input type="checkbox"/>

(1) Please list all the languages you know in order of dominance:

1	2	3	4	5
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(2) Please list all the languages you know in order of acquisition (your native language first):

1	2	3	4	5
---	---	---	---	---

(3) Please list what percentage of the time you are *currently* and *on average* exposed to each language. (*Your percentages should add up to 100%*):

List language here:					
List percentage here:					

(4) When choosing to read a text available in all your languages, in what percentage of cases would you choose to read it in each of your languages? Assume that the original was written in another language, which is unknown to you. (*Your percentages should add up to 100%*):

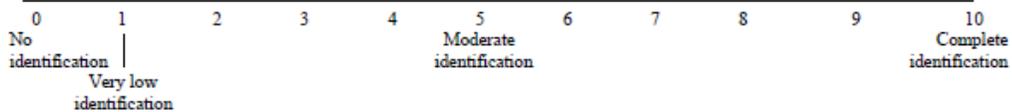
List language here:					
List percentage here:					

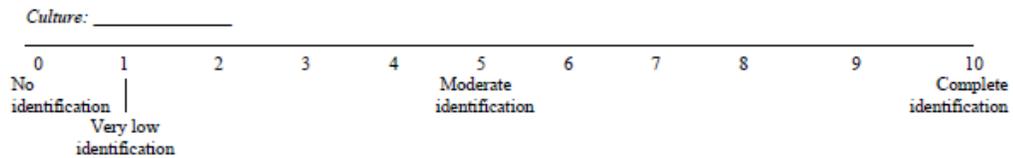
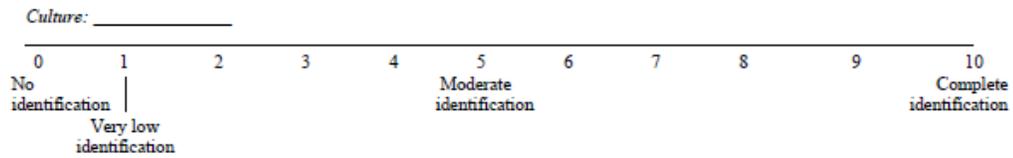
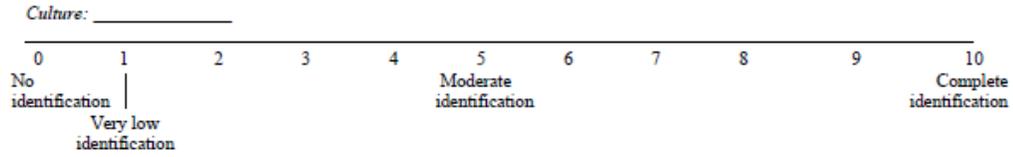
(5) When choosing a language to speak with a person who is equally fluent in all your languages, what percentage of time would you choose to speak each language? Please report percent of total time. (*Your percentages should add up to 100%*):

List language here					
List percentage here:					

(6) Please name the cultures with which you identify. On a scale from zero to ten, please rate the extent to which you identify with each culture. (Examples of possible cultures include US-American, Chinese, Jewish-Orthodox, etc.):

Culture: _____





(7) How many years of formal education do you have? _____

Please check your highest education level (or the approximate US equivalent to a degree obtained in another country):

- | | | |
|--|---|--|
| <input type="checkbox"/> Less than High School | <input type="checkbox"/> Some College | <input type="checkbox"/> Masters |
| <input type="checkbox"/> High School | <input type="checkbox"/> College | <input type="checkbox"/> Ph.D./M.D./J.D. |
| <input type="checkbox"/> Professional Training | <input type="checkbox"/> Some Graduate School | <input type="checkbox"/> Other: |

(8) Date of immigration to the USA, if applicable _____

If you have ever immigrated to another country, please provide name of country and date of immigration here.

(9) Have you ever had a vision problem , hearing impairment , language disability , or learning disability ? (Check all applicable).

If yes, please explain (including any corrections):

Language:

This is my (native second third fourth fifth) language.

(1) Age when you...

<i>began acquiring this language:</i>	<i>became fluent in this language:</i>	<i>began reading in this language:</i>	<i>became fluent reading in this language:</i>

(2) Please list the number of years and months you spent in each language environment:

	Years	Months
A country where this language is spoken		
A family where this language is spoken		
A school and/or working environment where this language is spoken		

(3) Please circle your *level of proficiency* in speaking, understanding, and reading in this language:

Speaking

0	1	2	3	4	5	6	7	8	9	10
None	Very low	Low	Fair	Slightly less than adequate	Adequate	Slightly more than adequate	Good	Very good	Excellent	Perfect

Understanding spoken language

0	1	2	3	4	5	6	7	8	9	10
None	Very low	Low	Fair	Slightly less than adequate	Adequate	Slightly more than adequate	Good	Very good	Excellent	Perfect

Reading

0	1	2	3	4	5	6	7	8	9	10
None	Very low	Low	Fair	Slightly less than adequate	Adequate	Slightly more than adequate	Good	Very good	Excellent	Perfect

(4) Please circle how much the following factors contributed to you learning this language:

Interacting with friends

0	1	2	3	4	5	6	7	8	9	10
Not a contributor	Minimal contributor				Moderate contributor					Most important contributor

Interacting with family

0	1	2	3	4	5	6	7	8	9	10
Not a contributor	Minimal contributor				Moderate contributor					Most important contributor

Reading

0	1	2	3	4	5	6	7	8	9	10
Not a contributor	Minimal contributor				Moderate contributor					Most important contributor

Language tapes/self-instruction

0	1	2	3	4	5	6	7	8	9	10
Not a contributor	Minimal contributor				Moderate contributor					Most important contributor