The Effects of Bilingualism on Adult Multitasking Abilities:

The Myth and Merit of "Brain Boosting"

by

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A Research Paper
Submitted in Partial Fulfillment of the
Requirements for the
Master of Science Degree
in

Career and Technical Education

Approved: 6 Semester Credits

Research Advisor

Research Advisor

Research Advisor

The Graduate School

University of Wisconsin-Stout

April, 2008

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Title: ***The Effects of Bilingualism on Adult Multitasking Abilities: The Myth and Merit of "Brain Boosting"***

Major: **Career and Technical Education**

Research Adviser: **Desiree Budd, Ph.D.**

Month/Year: **May, 2007**

Number of Pages: **96**

Style Manual Used: **American Psychological Association, 5th edition**

ABSTRACT

The influence of cognitive exercise on the human brain's potential is a great unknown. While skeptical of the many products and processes promoted in the public domain, recent research indicates a viable connection between foreign language use and enhanced mental abilities. In an attempt to scrutinize "brain boosting" theories, this paper analyzed the effects of bilingualism on cognitive processes and its implications for intelligence. Research subjects consisted of 133 college educated young adults divided into 3 groups according to their language experience: monolinguals (English only), bilinguals (English and Spanish) and bimodals (English and American Sign Language). They were subjected to a computerized testing system, Simultankapacitetsprovet (SIMKAP), which was developed as a complex, standardized scenario for measuring multitasking skills. The specific criteria used for defining a boost were related to general

intelligence, child development, and protection from mental decay in the elderly. After reviewing the literature and analyzing SIMKAP results, it was determined that exposure to a foreign language at a young age, and continued use of two languages throughout the individual's lifetime, results in an enhancement of cognitive abilities related to frontal lobe functions. The ramifications of foreign language serving as a mental boost are discussed.

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Acknowledgements

A heartfelt thanks to the ladies: Oma, Bonnie, Nana, Mikko and Laura Bowman. Without their kind and diligent care of my children, this work could not have been started. Thank you to William Nolte II, without whom the work could not have been completed, and thanks to my husband, Hendrik, for his support throughout the long process. I also want to thank my advisors, Dr. Desiree Budd and Dr. Michael Donnelly, for their patient assistance and for allowing access to the Neurocognitive Science Lab.

I wish to acknowledge the following individuals and institutions for their involvement in this research: The Spanish and Psychology Departments at the University of Wisconsin-Eau Claire; the Spanish and Psychology Departments at the University of Wisconsin-Stout; Dr. Patricia O'Connell at St. Paul College, St. Paul MN; Dr. Laurie Swabey at the College of St. Catherine's, St. Paul MN; Dr. Dyan Sherwood- Director of the Metro Deaf School, St. Paul, MN; Dr. Cynthia Roy at Gallaudet University, Washington DC; Dr. Sandy Brown at the Community College of Baltimore County, MD; and Dr. Rusty Rosen at Columbia Teacher's College, NYC.

This work was financially supported in part by UW-Stout grant #131-4-583008.

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Chapter I: Introduction

Could poker, painting, speaking Portuguese, or playing the piano make you smarter? The idea of cognitive exercise improving mental functions is not new. For decades, people who suffered brain damage due to stroke or serious head injury have been treated with cognitive therapy as a way of restoring mental functions (Goldberg, 2001). Today, however, the focus includes not only rehabilitation but also prevention of mental deterioration and even 'enhancement' of intellectual performance.

The desire to better understand the mind's full potential has left the public open to assertions about products or processes which might 'turbo boost' the brain. People are attracted to suggestions that a special tea or video game may slow the aging process and prevent diseases like Alzheimer's, cure learning disabilities such as Attention Deficit Disorder, or speed up infant development, as witnessed by the popularity (and recent debunking) of *Baby Einstein* and *Brainy Baby* products (Zimmerman, Christakis, & Metzoff, 2007).

The media and even science itself often promote the idea of a brain boost. Consider, for example, the following headlines: "Playing Music Can Make You Smarter" (Choi, 2007), "Finger Length Correlates to Performance on SAT" ("Finger-Length," 2007), "Ceiling Heights Affect How People Think" (Mauk, 2007). Even a recent Newsweek cover story posits the question "Can Exercise Really Make You Smarter?" (Carmichael, 2007).

It seems rational to assume that the brain would benefit from improved circulation induced by physical exercise, especially considering that the brain consumes one fifth of the body's oxygen as well as a majority of other nutrients which are all delivered by the

blood (Pinker, 2002). It is also logical that playing a musical instrument and other mental disciplines would stimulate the brain. While the research may be scientifically valid, these headlines and others point out some stunning correlations between the physical world and intelligence. People have many diverse characteristics contributing to their intelligence, including genetics, skills, experience, and knowledge, all of which influence their behavior and task performance. No single measurement (fingerlength, ceiling height, or amount of exercise) can do justice to the complexity of people's mental abilities. Therefore, one needs to be wary of manufacturers promoting their products, or scientists and journalists trying to influence public perception. Nonetheless, new breakthroughs in our understanding of how the brain works, most notably, the phenomena of neurogenesis and neural plasticity, have lent a theoretical possibility to the boost.

Computer neuroimaging technology has opened a literal window to the body's ability to create new brain cells (neurogenesis) in adulthood, and reorganize itself as an individual learns (plasticity). Until recently, human neurogenesis was believed to occur only in utero and during the first few years of life (Goldberg, 2005). The prevailing assumption had been that neurons then began dying off and could not be replaced, and the memory loss associated with old age was attributed to this neuronal decay. Now, however, several sources demonstrate that neurogenesis continues throughout the human lifetime, albeit, not nearly as vigorously as in youth.

Imaging technology also allows us to witness how the brain reorganizes itself as an individual learns, which is referred to as neural plasticity. The cerebral cortex (outer gray matter) is divided into areas with different functions; however, with learning and practice

some of their boundaries can shift, meaning that the area where one ability leaves off and the next one begins can change (Pinker, 2002). This shift explains why, for example, congenitally blind people use their visual cortex to read Braille, and amputees use the part of the cortex which formerly served the missing limb to represent other parts of their bodies.

Plasticity is not limited to repairing or replacing functions (Goldberg, 2001). Research indicates that the most used parts of the brain receive more new cells; a symbiotic marriage of sorts between neurogenesis and plasticity. Therefore, brain areas may expand as a result of learning, experience, or practice. This is illustrated in the case of professional musicians who were shown to have a considerably larger Heschl's gyrus (Elbert, Pantev, Wienbruch, Rockstroh, & Taub, 1995), the area critical for sound processing, which makes them better able to recognize and remember complex melodies (Schulte, Knief, Seither-Preisler, & Pantev, 2002).

Current research on brain plasticity has indicated that learning impacts brain structures and functions, although which specific experiences might enhance certain skills and to what degree are still under special scrutiny (e.g., Draganski et al., 2004; Maguire, et al., 2000; Mechelli, Noppeney, O'Doherty, Ashburner, & Price, 2004). Regardless of the questionable assertions often made about boosting, neurogenesis and plasticity hint at the possibility that cognitive exercise can wield *some* kind of influence on mental functioning and capacity. The question is whether there are influences which could be measured in daily life that result in tangible cognitive benefits such as an increased attention span or heightened sense awareness. What if there was a technique to boost child development independent of any cognotropic drug or offer protection from

memory loss for a growing senior population? If scientists could identify an influence that enhances critical, abstract, and creative thinking abilities, so valued and attributed to success in modern society, then that, indeed, would be a kind of magic. This paper proposes that one possible method for this boosting could be foreign language use.

Early methods of brain exercise (rehabilitation) emphasized particular functions in the hopes that the brain structures corresponding to that function would somehow be modified; for example, if the part of the brain regulating eye/hand coordination is damaged, then eye/hand exercises are prescribed. More recent approaches, however, emphasize general, open-ended effects of cognitive exercise on the brain. Goldberg (2001) uses the athlete metaphor:

> A tennis player or golfer may aim at improving a particular stroke. This is akin to a specific task-oriented cognitive training. Or, he may hope that by practicing a few other strokes, he will improve many strokes and therefore the game as a whole. This is akin to functional system-based cognitive training. Or, finally, he may embark on an exercise regimen with the goal of improving not so much the game in and of itself but the body that plays it-- to increase his strength, coordination and stamina in a very general way. (p. 206)

To boost general intellectual function then, it is necessary to design a workout that engages as many areas of the brain related to higher thinking as possible. Like a well-balanced physical exercise routine, the cerebral process of language is broadly distributed throughout the brain. The perisylvian region of the brain is now considered the major organ for language, but other extensive areas also subserve language: According to

Rodrigues Fornells, (2006, as cited in Schumann, 2006), the dorso-lateral prefrontal cortex (DLPC) and the anterior cingulated cortex (ACC) are involved in language. These results are complimented by findings made by Indefrey (2006) implicating large parts of the temporal lobe and the frontal lobe. Because of the critical relationship for native language (L1) acquisition between a caregiver and child, Depue and Morrone-Strupinsky (2005, as cited in Indefrey, 2006) and Luciana (2001, as cited in Indefrey, 2006) also argue that language is related to the neural substrate for social affiliation; therefore, the extended amygdale, basolateral amygdale, the nucleus accumbens shell, the medial orbital area, and the hypothalamus are involved in language processing.

Not only are the areas for language acquisition and processing broadly distributed, language is also indicative of higher cerebral functioning (vs. motor skills or low-level perception). The mental gymnastics of even a native language exchange are representative of the brain's capacity for complex processing. Memory, attention, and decision making are integral parts of communication (Goldberg, 2005).

Consider the following tasks: keeping track of the beginning of the sentence to the end while tapping into our mental dictionaries, then determining when to parse the information into meaningful chunks; anticipating a person's intent while inferring meaning from ambiguities, metaphor, sarcasm, or just the various definitions for each word; or weighing feelings about the information and then determining a response in order to get the desired affect. This process is impressively complex, yet so natural to humans that it happens imperceptibly. Perhaps that is why language and communication are overlooked as a form of learning. In fact, learning and thinking very often happen through language. Our various grammars and syntaxes allow us to codify complex

information into workable representations— defining our thoughts and allowing us to conceptualize all the things and events of the world (Goldberg, 2005).

Another intellectual benefit of language is that it allows us to generate statements of unknown truth value; it is a tool for modeling not only what is, but also what will be or could be, or determining what we want and do not want (Goldberg, 2001). This not only facilitates setting goals but is reflective of the human ability to contemplate our own state as well as anticipating the intentions of others. A final example of the significance of language as a cerebral process is its ability to shape our cognition by imposing certain patterns on the world. While the notion that language actually creates thought (linguistic relativity) is still debated, a skeptical viewpoint would nonetheless concede that language provides a framework by which we determine events or impressions to be salient. The following chapter will elaborate on this point.

Language seems simple but is, in fact, a very sophisticated marvel of mental engineering and computation; it is the quintessential means with which we understand the world and understand ourselves as earthly, social beings (vs. experiencing the world as sentient beings). To reiterate, then, if cognitive exercise (in the form of learning, experience and practice) truly impacts the structure and function of the brain areas involved in the activity, then it is important to design a mental workout that engages as *many* parts of the brain as possible and that these areas be attributed to higher thinking and reasoning. Language meets these criteria nicely.

Accepting that a broad-based cognitive workout, in this case, second language learning, will result in a general intellectual boost beyond the benefit of knowing another language, then one must choose a method of detection that will measure enhanced

functioning and rule out education as a variable. This paper proposes that superior multitasking abilities serve as one method of detecting a general enhancement.

Americans tend to glorify multitasking and aspire to it. Consider a recent USA Today article: "Alpha Moms leap to top of trendsetters: multitasking, tech-savvy women are expected to be the next to watch" (Horovitz, 2007). The article states, "I'm at my Alpha-mommy-est when I have the most balls in the air- it's multitasking to the nth degree" (p. b-12).

Contrary to the cultural misconception that multitasking means doing more than one thing at a time, a more scientific description is slightly less attractive: the ability to accomplish multiple tasks within the same general time period by frequently switching attention back and forth between them (Restak, 2003). A person may become more efficient, with practice, at switching attention between behaviors, but does not actually do two cognizant tasks at the same time. For example, painting and listening to classical music are activities that would compliment each other, but painting and listening to an audiobook compete because they both use areas of the brain responsible for mental visualization. When conflicting tasks are presented, we switch attention between them, taking extra time and brain power while the frontal lobes disengage the rules of the last task and engage rules for the new operation—resulting in diminished efficiency and accuracy for each activity (Restak, 2003).

Whether our regard for multitasking is overrated, it seems that our modern, real-world environment has made it a prerequisite for social and economic success. This sounds extreme, but consider the recent interest multitasking has generated in such fields as personnel selection (e.g., Stankov, Fogarty, & Watt, 1989), time management

strategies (e.g., Britton & Tesser, 1991), and as an integral part of complex work domains such as space flight (e.g., Sauer, Wastell, & Hockey, 1999), and military command (e.g., Börjes & Rosmark, 2002, as cited in Bratfisch & Hagman, 2003). More importantly for this paper, multitasking has been examined in several studies related to information processing and executive controls of cognition (e.g., Burgess, Veitch, de Lacy Costello, & Shallice, 2000).

The neocortex (also called the frontal lobes) is referred to as the brain's "executive" because of its functions. Among other things, frontal lobes organize the interpretation and expression of language, orient us in time, and make sense of the constant bombardment of environmental stimuli such as visual, auditory, and olfactory sensations (Snowdon, 2001). The frontal lobes ultimately decide, based on past learning and present circumstances, which of our impulses to follow.

Multitasking has garnered the focus of executive function research because the ability to understand complete situations involving several flexible solutions, inherent in multitasking, is representative of the higher thinking associated with the frontal lobes (Burgess, et al., 2000; Ben-Shakhar & Sheffer, 2001). Consider, for example, the remarkable mental work involved when a child contemplates a climb: it takes only a few seconds to estimate the height of the tree and the strength of the branches, which pathway will get him to the highest point, the risks to his health, anticipate his parent's reaction, consider past experiences, evaluate the motives of a goading friend, and then make a decision to stop or go. Oversimplified, the frontal lobes coordinate input from the various brain regions to calculate these thoughts with awe-inspiring speed and ease, unencumbered by the external stimuli of a barking dog or a mosquito bite itch.

Therefore, because of their relatedness for attention, working memory and decision making, the ability to multitask is considered one strategy for measuring executive controls. The working presumption is that bilingualism has the potential to contribute to a general enhancement of cognitive abilities, and that multitasking, representative of executive mental processes, would reflect that enhancement.

While this investigation is grounded in science and based on empirical data, the fundamental goal of the paper is to make certain information accessible to the educated, non-scientific reader. While specifically examining the effects of bilingualism on the brain and how they might contribute to greater mental flexibility, the paper's overarching task is to determine the validity of brain boosting and its implications for an affected public. As a final consideration, findings are evaluated, when applicable, within the framework of American Sign Language (ASL).

Statement of the Problem

Scientific advancements in understanding neural plasticity have been limited but, nonetheless, ushered in a myriad of products and processes available to the consumer. While anecdotal evidence for intelligence-enhancing methods is common in the public domain, theories are diverse and fail to provide a concrete equation for the boost.

Analyzing the relationship between linguistic properties and creative, critical, or abstract reasoning will help better explain *how* we think. While not definitive, results from this work contribute to understanding the influence of language on perception, cognitive processes, and intelligence.

Purpose of the Study

The specific goal of this study is to determine if bilingual adults significantly out-perform monolingual adults with skills related to multitasking. Furthermore, the data collected will provide an empirical foundation for the subsequent analysis of brain boosting. The effects of bilingualism on the brain offer an indication as to the validity of recent theories and put such claims into a more realistic perspective. Any information gleaned from this research could prove beneficial to many disciplines and cast *foreign* language/ASL into broader research efforts within cognitive science, psychology, linguistics, and education.

Research Hypotheses

In response to a review of the literature, the specific hypotheses that this research intended to examine are as follows:

1. There will be a significant difference between the multitasking abilities, as measured by the computerized SIMKAP testing system, on monolingual and bilingual adults.
2. Second language (L2) learning will be shown to boost brain functioning according to the follow criteria: a) offer a protection from decay, and b) enhance general intelligence.

Assumptions of the Study

Typically, a person is considered bilingual if he or she is proficient in two languages. While proficiency in a second language is typically established according to each researcher's own criteria study by study, generally a person is designated as bilingual/proficient even if not attaining native-speaker levels in the second language (Steinberg, Nagata, & Aline, 2001). Likewise, the individual proficient in two languages

of different modalities such as spoken English and signed ASL may also be described as bilingual.

Bilingualism is a complex phenomenon, and much about its functional basis remains unknown. For example, it is difficult to determine if the degree of language differences would influence results: it is unknown how the brain of someone who is an English speaker will accommodate Spanish (both Indo-European), compared to accommodating a tonal language like Chinese, or the use of space and motion, characteristic of ASL; it is also unknown if these specific accommodations are reflected differently in the multitasking demands of SIMKAP.

Furthermore, this study cannot account for the frequency of code-switching. It is unknown how the difference between Spanish majors who may have been exposed to the foreign language more regularly because of several years of classroom instruction or cultural access (TV, radio, movies and CDs), compared to interpreter-training students who, although having less opportunity to code-switch, now experience a fuller immersion. For the purposes of this study, it is believed more important to select groups according to similar levels of knowledge rather than having identical methods of language experience and use. The number of participants with Spanish-speaking parents compared with Children of Deaf Adults (CODAs) will be a consideration during data analysis.

Likewise, inherent in any study of bilingualism, there are great differences between individual language learning abilities depending on one's effort, attitudes, amount of exposure, quality of instruction, age of acquisition (AoA), as well as innate ability.

Definition of Terms

Axonal connections/axonal fibers. The axon is the fiber of a neuron that transports the neuron's outgoing signals to other neurons or muscle cells. (As defined in Indefrey, 2001).

Classifier. A category of signs in ASL that can serve as pronouns as well as show the actions and locations of people, animals, and objects. They may also be used to describe the size and shape and texture of their referents (as defined in Mindess, 20001)).

Children of deaf adults (CODA). The first language for these hearing children may have been ASL, and they may therefore culturally identify with Deaf culture or a mixture of Deaf and mainstream American hearing culture (as defined in Mindess, 2001).

Cognitive science. The study of intelligence (reasoning, perception, language, memory, control of movement) As defined in Indefrey, 2006.

Deaf/deaf. Following current convention, capitalized "Deaf" is used to refer to features of Deaf culture and individuals who identify themselves with the culture; lowercase "deaf" is used for the audiological condition of deafness (as efined in Mindess, 2001).

Dendrite. Fibers of neurons receiving signals of other neurons (As defined in Indefreneys, 2006).

Dorsolateral prefrontal cortex (DLPC, DLPFC). Part of the prefrontal cortex that is known to have important working memory, executive and attentional functions. It encompasses the middle and superior frontal gyri (as defined in Indefrefreys, 2006).

Glia fibers. Extensions of glia cells; part of the neural tissue. They separate nerve cells from blood vessels and also produce the myelin sheath of axons (as defined in Indefreys, 2006t).

Gyrus, gyri. Convex fold of the surface of the brain.

High-level perception. High-level perception involves taking a more global view of sensory information and extracting meaning from the raw material by making sense of situations at a conceptual level. Examples include recognition of objects, grasping abstract relations and situations as coherent wholes (i.e. critical thinking, problem solving) (as defined in Indefreys, 2006).

Linguistic relativity. The hypothesis that thoughts are determined by the categories made available by their language; that differences among languages cause differences in the thoughts of their speakers (Pinker, 2002).

Low-level perception. Low-level perception involves the early processing of information from the various sensory modalities such as sight, sound, touch, and taste (Pinker, 2002)..

Multitasking. The ability to accomplish multiple task goals in the same general time period; engaging in frequent switches between individual tasks such as talking on the phone and reading files (*not* walking and chewing gum). (I don't know anymore, (2008).

Myelin. Substance that forms a sheath around axons which allows for faster signal propagation (Infrey, 2006).

Neocortex, neocortical. The phylogenetically younger and largest part of the cortex; it has six nerve cell layers. Phylogenetically older parts of the cortex such as the olfactory cortex, hippocampus, dentate gyrus are referred to as *allocortex* (Indefrey, 2006).

Neurogenesis. The formulation of nerve cells (neurons). (Indefrey, 2006).

Perisylvian areas. Cortex adjacent to the Sylvian fissure, a deep sulcus between the frontal and the temporal lobe. The term is frequently used as a summary for the language-related areas in the left hemisphere (Indefrey, 2006).

Prefrontal cortex. Summary term for the frontal cortex without the motor and premotor cortex (Indefrey, 2006).

Simultankapacitetsprovet/multitasking *(SIMKAP)*. Swedish acronym for a computerized testing system developed as a complex, standardized scenario for measuring multitasking skills. It is used by governments, corporations, as well as educational and clinical institutions.

Synaptogenesis. The formation of synapses.

Synapse. Contact point between nerve cells, where the electrical signal of one nerve cell's axon induces an electrical signal in another nerve cell's dendrite through the release of chemical substances (transmitters).

Tangles and plaques. Bundles of fibrils (tangles) contained in nerve cells and the storage of metabolic product (plaques) around the nerve cells are the two most important patholgical features of Alzheimer's.

Limitations of the Study

The limitations of this research are as follows:

1. Although the SIMKAP test has been determined a reliable measure for multitasking (total reliability .94-.97/.89-.91), it does not analyze for other specific cognitive processes or possible enhancements, most notably, those specific to the visuospatial routines of ASL.

2. Another unfortunate ramification for this study is that it focuses mainly on young adult subjects (ages 18-39); it did not include the effects of L2 on elderly multitasking abilities.
3. Multitasking, while significant, only represents one quantitative measurement for determining an intellectual boost.

Methodology

Three groups of approximately 40 students (a total of 133) participated in this quasi-experimental hybrid (theoretical/empirical) study to determine if a measurable difference exists in multitasking performance according to language experience. Differences were measured using the computer-program SIMKAP. Data collection was conducted between spring 2005 and summer 2007. Data was analyzed using the Statistical Package for the Social Sciences (SPSS), Fourth Edition. Results and their implications are discussed.

Chapter II: Literature Review

The purpose of this study is first, to determine whether adults with varied foreign language experience will perform differently on the multitasking exercise Simultankapacitetsprovet (SIMKAP); and second, to determine if improved multitasking and other consequences of bilingualism would qualify as a boost to mental acuity. The proof of the existence of a boost would show in early or broadened creativity such as problem solving, or heightened curiosity and/or insight. It could further be demonstrated in the protection from mental decay. A boost would also show itself in the general enhancement of critical, abstract and creative thinking.

Three relevant areas of research for this investigation include 1) neurogenesis and plasticity, 2) double conceptualization, and 3) bilingualism and intelligence. Because intelligence is the most nebulous of the three foci and heavily relates to defining a boost, it is given generous attention from various perspectives throughout this chapter.

Neurogenesis and Plasticity

Boost theories are largely, and vaguely, based on the idea that as you use your brain, it becomes stronger (Goldberg, 2005). This premise is supported by the brain's ability to change its structure and function through environmental experience. Several recent examples of human evidence follow.

British neuroscientists (Maguire et al., 2000) scanned the brains of 16 London taxi drivers whose job requires them to memorize numerous complex routes and locations. They were then compared with the brains of 50 control subjects. The taxi drivers had larger posterior hippocampi, the area presumed to be involved in spatial learning and memory, which is necessary for navigating the city. This demonstrates a relationship

between the size of a brain region (gray matter) and the environmental factors contributing to its use. Furthermore, the longer the cab drivers were on the job, the larger their hippocampi - directly proportionate to the number of years on the job. This suggests that the structure can continue to grow well into adulthood and the growth of a neural structure appears to be stimulated by its use.

More years on the job implies older age, which should suggest hippocampal atrophy but in this case, older hippocampi were larger. This might all due to natural selection: individuals born with larger hippocampi find and enjoy jobs that require spatial memory and therefore become, among other things, cab drivers. However, the next example challenges this stance.

Draganski and colleagues (2004) looked at juggling and plasticity in the brain. Healthy individuals with no prior juggling experience volunteered to participate. They were divided into two groups: those who would receive training and those who would not. Brain magnetic resonance imaging (MRI) scans before training revealed there were no differences between the two groups in terms of gray matter density for the first scan. Three months later, a second scan showed a significant increase in gray matter in the temporal lobes for both hemispheres and in the parietal lobe of the left hemisphere - areas involved in processing the physical activity of juggling. Three months after the practice was stopped, MRI scans showed that the effect gradually diminished because gains in the parietal and temporal lobes were reduced. Therefore, the effects of skill practice on neuronal proliferation in specific parts of the brain could be demonstrated even within a relatively short period of time, and could be taken away.

The often-cited "Nun Study," an example of particular interest because of its relation to language skills, also demonstrates the influence of experience on the structure of the human brain (Snowdon, 2001). Scientists have long agreed that the likelihood of getting Alzheimer's Disease later in life is increased by several factors including a genetic predisposition, stroke, or head trauma but the Nun Study offered evidence that an active intellectual life might protect one from the effects of the disease.

The sisters made good subjects because of the similarity of lifestyles including diet, profession, healthcare, and education (Snowdon, 2001). A large percentage were known for enjoying mental clarity well into their 80s, 90s, and even 100s which made them instrumental in determining why or how some are stricken with Alzheimer's and others avoid it. The nuns who typically defied Alzheimer's had college degrees, were teachers, engaged in mind-challenging activities, and, on average, lived longer than their less-educated participants in the study (scientists also concluded that depression, versus a positive outlook on life, also related to the occurrence of Alzheimer's).

Snowden et al., concluded that their observations were so compelling that the researchers continued to examine a relationship between levels of cognitive health and kinds of mental stimulation One of the most surprising results of the study was that the way the nuns expressed themselves in language, even at an early age, predicted their vulnerability to Alzheimer's later. Scientists evaluated the sisters' autobiographies and discovered a startling correlation between their early life (20's) writings and the likelihood, or lack, of dementia in later years. The writings were analyzed using dual methods and dual blind analyses. The overriding conclusion was that the nuns who tended to write more grammatically complex and conceptually rich essays, retained their

mental energy until much later in life than those who wrote simple factual prose. The method developed for analyzing the writings turned out to be a powerful tool for predicting, with 85-90% accuracy, which nuns would show typical Alzheimer's damage 60 years later. While education reflected cognitive ability, results were not related to the sisters' grades in subjects such as English, Latin, Geometry or Algebra. Instead, it was believed that verbal and analytic intelligence reflected in their writings may signify other properties of the brain such as those related to perception as well as the encoding, processing and retrieval of memory. It may also be inferred from the case studies presented in the book that many of the nuns who retained their mental clarity had a history of bilingualism since a young age.

Another significant result from the Nun Study revealed that the amount of disability seen in people with Alzheimer's did not always reflect how much damage their brains had suffered (Snowdon, 2001). Sister Bernadette maintained the highest level of mental acuity until her death. However, upon postmortem examination, doctors were surprised to find she possessed an extremely high amount of "tangles and plaques" (see definitions)- the hallmarks of the disease. It was surmised that some of the nuns who taxed their minds early in life and continued the practice, allowed the brain to build a protective effect which sustained mental clarity in their advanced years (Goldberg, 2005).

It could be argued that dementia is a lifelong malady affecting some people early in life causing them to write simpler prose. Another option is that genetics and prenatal care are responsible for *all* the aspects of the brains organizational make-up: some people are smarter than others and *that* protects them from later-life dementia. It is also possible that the way a brain develops in the womb and during adolescence also leads to stronger

or weaker structures in later life. In other words, even though Alzheimer's may have done significant structural damage to the tissue, symptoms may not appear because the exercised brain can compensate by establishing new or different connections between nerve cells, essentially rerouting information around the damage caused by Alzheimer's (Goldberg, 2005). The prevailing logic for boost theorists is that the effects of illness should be less severe in the well-conditioned brain because of the extra neural connections and blood vessels which create a cognitive reserve.

While the questions seem to outnumber confident explanations, research consistently demonstrates that the brain's biological makeup for certain abilities is not fixed; adequate rehearsal influences the size and area of the brain directly involved (e.g., Elbert et al., 1995; Maguire et al., 2000; Draganski et al., 2004). This is not to say that thinking about spatial concepts will create an Einstein; the lack of a parietal operculum allowed for an expanded inferior parietal lobule which is the area responsible for processing visual, somatosensory, and auditory integrations as well as where visuospatial, mathematical and movement imagery cognition is processed (Schumann, 2006). Evidently, his unique genetic make-up allowed him to "cognize creatively in domains related to his scientific contributions" (Witelson et al., 1999, as cited in Schumann, 2006). Nor, for that matter, would plasticity create the lesser known Emil Krebs, who reportedly spoke 60 languages - assumed to be possible because he possessed significantly more white matter in the parietal regions, especially in the left hemisphere (De Bot, 2006). While subsequent research supports the legitimacy of a cognitive reserve as observed in the Nun Study, boost theorists generally fail to provide credible evidence for which mental exercises would substantially contribute to this back-up system. Doing

daily crossword puzzles has not been shown to slow the decline of aging brains (Begley, 2006; Restak, 2001); programs and studies claiming to measure an improvement often require major changes in diet, exercise and lifestyle (e.g., Leviton, 1995; Brit, 2005). Rather than an increase of cerebral matter due to learning, the *pre*existence of structures is critical for enabling or facilitating specific aspects of cognitive abilities. In other words, experience will not change the genetic or biological codes for each individual, but it can enable existing structures to meet their potentials.

Despite the recent enthusiasm surrounding the discovery of adult neurogenesis, according to present data, there is no significant postnatal increase in the *total* number of neurons (Uylings, 2006). Because brain development hinges on genetics and environmental influences (including biochemical processes), the most significant period for brain development is during gestation and the first few years of life - when the majority of neurons are created, differentiate, and travel to form the various brain structures. Therefore, besides one's genetics, fetal exposure to environmental factors such as alcohol, radiation, malnutrition, or extreme stress can also profoundly affect the lifelong language and intellectual capacities of the individual. But brain development occurs in several phases, with other processes taking longer and allowing for different environmental manipulations.

Because the neocortex develops late, dramatic environmental circumstances during early childhood can also be relatively decisive for language, social, and other intellectual functions (Uylings, 2006). For example, a lack of human interaction can permanently interfere with *first* language acquisition. This influence is demonstrated in feral children who have grown up in the wild or in isolation during the first four to six

years of their life who are never able to speak complete sentences or learn ASL even in adulthood. So, like neurogenesis, axonal rewiring or axonal extension over a long distance does not happen at a significant rate after the developmental window has closed. This does not mean, however, that the brain cannot change further in adulthood: positive and negative environmental factors (in the form of experience learning – "juggling") remain quite capable of challenging the brain in later years. Experience learning is dependent on the plasticity potential for each mental activity. Playing the piano or learning Portuguese, for example, are not restricted to developmental periods. However, the extent of the flexible reaction is somewhat smaller in adulthood than youth because, not only does the capacity for working memory decline, but the size of dendrites and the maturation of synapses have generally already reached a stable level (Uylings, 2006). That is a partial explanation why the capacity for *some* types of plasticity diminishes with age and it gets harder to learn.

Nonetheless, reports show that, while the genetic contribution is essential, genetics does not specify the destination for all neurons; environmental conditions are also decisive for the functional outcome of an individual (Uylings, 2006). Examples of human plasticity, as previously cited, demonstrate that the brain can respond to our environmental needs, albeit within its biological limits.

New evidence that cognitive exercise changes the structure and function of the brain and perhaps offers a protection from decay ushers in the possibility of brain boosting. Because of the diversity of our jobs, our hobbies, or our education, each person will exercise certain mental functions more than others. If the hippocampus is larger in

cabbies, then one would expect the left temporal lobe (language lobe) to be larger in writers, or the parietal lobe (spatial) to be larger in an architect (Goldberg, 2005).

The idea that different cognitive exertions rely on different parts of the brain makes sense, but can the effects of these exercises manifest into other related abilities? In other words, would the juggler have improved eye-hand coordination for throwing darts? Will the cabbie be better able than another non-cabbie to orient himself in an unfamiliar city? While the studies cited do not elaborate this point, evidence supporting transference of skill comes from American Sign Language research.

Deaf and hearing ASL signers exhibit superior performance, compared to deaf and hearing non-signers, on certain mental processes related to the parameters of signed languages (Emmorey, 2002). Signers are more likely, among other abilities, to generate mental images faster, be more skilled at reverse transformations, and have longer spatial memory (e.g., Chamberlain & Mayberry, 1994; Emmorey & Klima, 1998; Emmorey & Kosslyn, 1996; Klima, Tzeng, Fok, & Bellugi, 1996; Talbot & Haude, 1993). It is reasonable to expect that the repetitive experience of processing motion (signing) into linguistic units (words and phrases) might enhance other abilities related to the use of space, motion, and time.

Research indicates that the visuospatial processing required by ASL can, in fact, impact nonlinguistic processing such as mentally rotating or reversing blueprint models. Furthermore, because some enhanced mental processes have also been recorded in proficient hearing signers, the effects are due to rehearsed experience in the brain and not a condition of deafness (Emmorey, 2002).This suggests that the allocation of brain tissue for perceptual and cognitive (low-level) processes is not done permanently or on the basis

of the exact location of the tissue in the skull, but depends on how the brain itself processes the information. In the case of ASL, the effect transfers to situations other than those involving communication. But this is an example of low-level perception and does not help determine if the effects substantially relate to higher-order thinking. Before presenting evidence for functional influences related to reasoning, the structural basis for bilingual effects on the brain must be established. Examples follow:

Mechelli, Noppeney, O'Doherty, Ashburner, & Price (2003) examined small cubes of brain tissue (voxels) in bilinguals and monolinguals to determine the size of corresponding brain areas (as cited in Goldberg, 2005). Their work revealed that the left angular gyrus contains significantly more gray matter (neurons) and denser underlying white matter (the short local connections between neurons) in bilinguals. The angular gyrus of the left hemisphere is important for reasoning and language, particularly in processing relational constructs such as before and after in time/ who did what to whom/ in front of or behind.

Equally impressive, greater white density was observed in the bilingual left and right hemispheres, representing the long myelinated pathways in charge of connecting distant cortical regions (Goldberg, 2005). Brain areas are not fully functional until the axons connecting them are insulated with myelin, which takes the longest in the frontal cortex and, because the myelinization process continues into adulthood, it allows more time for manipulation (Geidd et al., 1999). An increase in white matter means an increase in myelin volume and indicates a better isolation of the transport of electrical signals. This is important because the number of neurons is only as good as the brain's ability to connect the various complex functions into multiple interactions - "the denser the matrix

of such (mylenated) pathways, the greater the functional capacity of the neuronal network" (p. 254, Goldberg, 2005). It is reasoned that the cognitive activity of linguistic code switching stimulated the growth of gray matter, triggering an *increase* in the cortical area doing the work and the newly needed connections. While these findings are intriguing, a review of the literature did not provide any subsequent evidence supporting white matter increases in the bilingual brain. It should also be stated that VBM analysis is in its infancy and gets varying results (Indefrey, 2006).

A second voxel-based morphometry (VBM) study by Mechelli et al. (2004) found increased gray matter in the inferior parietal lobes of early and late bilinguals compared to monolinguals. Among other functions, this region is sensitive to vocabulary building in children and young adults. Eventhough both bilingual groups were using the second language regularly, the effect was more pronounced in those who started the second language (L2) at a younger age.

Importantly, early bilinguals acquire a second language through social experience and therefore, Mechelli et al. (2004) concluded, the structure of the human brain is altered by the experience of acquiring a second language rather than a genetic predisposition. Like the taxi study, the amount of experience correlated with gray matter density as well as the size of certain brain areas related to the task. There is, thus, another piece of evidence showing years of bilingual speech processing leads to structural changes in the brain.

The obvious next question is then, what might be the effect of several languages on the structures of the brain? Work by Green, Crinion, and Price (2006) examined the whole brain for language-correlated effects in groups of polyglots. Preliminary analyses

indicated a significant effect on an area in the left parietal cortex with a significant effect depending on the number of languages spoken. The peak of the effect is anterior to the area shown in the Mechelli et al. (2004) work. Based on previous research and their own findings, it was concluded that the acquisition of *multiple* languages leads to an expansion of gray matter rather than greater density (Green et al., 2006). This is another piece of evidence that experience influences different brain structures.

It should be briefly noted that the corpus callosum (CC) is another area in which significant structural differences were found between monolinguals and bilinguals (Coggins, Kennedy, & Armstrong, 2004). This should be interpreted with caution however, because group sizes were small and possessed an inherent gender bias (twelve bilinguals= seven females and five males, compared to seven monolinguals= five males and two females).

The challenge for researchers in the field has been to develop working theories to explain these discoveries. The Mechelli (2004) findings, with respect to age of onset acquisition (AoA), can be explained in two ways: either brain density is higher because the second language has been used more over the years, or the density is developed in youth and maintained over time (De Bot, 2006).

Researchers suggest that one, very speculative, explanation for the relationship between age of onset acquisition and brain structure could be synaptic pruning. This refers to the developmental cycle for synapses which rises prolifically during the first few years of life and, in early childhood, begins to go through a marked elimination process until puberty (Chechik, Meilijson, & Ruppin, 1997). Synaptic density then stabilizes at adult levels and is maintained until old age. As a result of the critical developmental

period, the nonuse of available resources could explain these differences in gray/white matter.

The brain is equipped for multiple languages and monolingual children use only one part of the system available. In other words, bilingualism does not lead to an expansion of gray matter, but rather, monolingualism leads to extensive synaptic pruning (De Bot, 2006). This is all very speculative and requires more investigation. As mentioned previously, metabolically, the brain consumes a fifth of the body's oxygen and similarly large portions of its calories and phospholipids; it makes sense that voracious neural tissue lying around beyond its usefulness would get functionally/dynamically recycled into another structure, or get completely eliminated. A lack of pruning might also contribute to the cognitive reserve because Alzheimer's is considered a problem more associated with white matter than with gray matter (Goldberg, 2001).

In response to second language (L2) acquisition, then, the human brain undergoes cortical adaptations to accommodate multiple languages either by recruiting existing regions used for the native language, or by creating new cortical networks. While foreign language experience can change the brain structurally and functionally, the question remains—will the effects reliably manifest into behavior? ASL again provides some real-world examples of this occurrence. Because of signing's unique contribution to this study, its influences deserve some elaboration.

Advantages gained from signing have been well known for years in the speech therapy profession. Speech-language pathologists specializing with toddlers and preschoolers use sign to help facilitate spoken communication; preschool teachers use it to aid memory (Acredolo & Goldwyn, 2002). Similarly, research shows that mothers

advocate the use of sign with pre-verbal infants because it reduces the frustration exhibited by babies unable to manipulate or control their environment through spoken words (Kramer, 2004).

Language deficiency and peculiarities are largely reflected in the development of autistic children. The successful use of signing in autism programs has been growing consistently since the early 1970's in both England and America (Jordan, 1985). The most interesting aspect of signing and autism is that it has often been accompanied by improved vocalization and the ability to use words.

Another indication that perceptual/functional properties of a signed language contribute to behavior is demonstrated in repeated observations that hand movements facilitated speech production otherwise hampered by various types of brain damage (Fay & Schuler, 1980).

Lastly, how and when a child uses gesture may be related to a preparedness to learn. Goldin-Meadow (2003) describes how certain mismatch gestures (gestures unrelated to the accompanying verbalization) may help the thinker formulate and develop new ideas. For example, children who mismatch at a certain point during the acquisition of a math/conservation task arrive at a deeper and longer-lasting understanding of that concept than children who do not. Therefore, mismatch gestures indicate who will most profit from instruction and reveal knowledge that is not found anywhere in a learner's speech. In this way, gestures offer unique insights into a learner's thought processes and often pertain to thoughts of which the speaker is not yet consciously aware.

The connection between ASL and successful alternative communication strategies (babies/autistics/stroke victims), a possible relationship between gesture and readiness to

learn, as well as the manifestation of certain superior low-level perception skills (as described previously), inspire new speculation about the influence of language/language mode on higher cognitive processes. The implication is that, beyond tutoring in a particular subject area, one might be able to build cognitive skills from the inside-out rather than from the outside-in. Much like new techniques in math instruction which teach the relationship between numbers before showing students how to add or subtract, having experience with thinking in an underlying visuospatial framework may offer a person alternative approaches and perspectives to mental tasks.

While these various applications of sign language use are becoming common, experts are careful to avoid making sign another "better baby" gimmick for parents. Scientists are quick to point out that a lack of exposure to sign in no way would slow or impair a baby's development (Emmorey, 2002). Nor does the ASL scientific community attempt to promote the Whorfian notion of linguistic relativity— they flatly deny that the language one uses could qualitatively *create* thought. However, evidence presented does illustrate a pattern of flexibility for the effects of language on perceptive *and* behavioral processes. Admittedly, the real-world evidence presented here is less than scientific and it fails to address whether influences would transfer to domains outside of communication. Other recent bilingual investigations offer a more empirical framework.

Bialystok, Craik, Klein, & Viswanathan (2004) examined the effects of bilingualism on Simon Task performance. A typical Simon Task involves colored patches that are presented to the right or left of a screen above corresponding response keys. The experimental rule may be "if the patch is red press left, if green press right," and the stimulus patch is then presented either above the appropriate key or the inappropriate key.

The general finding is that incongruent stimulus-response pairs are associated with longer response times than congruent pairs; therefore, smaller effects indicate better cognitive control. The results showed that bilingual children and adults performed better than their monolingual peers. Not only did bilinguals and monolinguals respond differently, but subsequent research using magneto-encephalography (MEG) imaging revealed that they also used different subset areas of the brain to perform the task (Bialystok et al., 2005). Bilinguals activated the prefrontal cortex (PFC) and the anterior cingulated cortex (ACC); monolingual activation was recorded in the middle regions. Bialystok surmised that the ability to ignore the irrelevant cues (color on the wrong side) was a result of the bilingual person rehearsing this ability by ignoring the irrelevant cues of the suppressed language. This was taken as evidence that bilingualism induces the development and maintenance of more efficient attentional control (as influenced by the involvement of the PFC and ACC).

There is common agreement that the bilingual person activates the lexical representation of both languages before producing the particular word in the desired/target language (Costa, Miozzo, & Caramazza, 1999; Green, 1998; Grainger & Dijkstra, 1992). The constant need to inhibit the non-active language, which is not turned off but rather suppressed, provides bilinguals with an enhanced ability to ignore distracting and irrelevant stimuli (Bialystok, 2001). This is similar to the young climber who, while aware of the barking dog, ignored it as inconsequential for his decision making. It is believed that these processes are among the last cognitive skills to emerge in children because of the late development of the frontal lobes which mediate this control (Diamond, 2002).

The Simon Task results indicate that the regulation and inhibition of information applies, not only to language tasks, but also to general cognitive processing. This also helps explain why the early acquisition and regular use of two languages has been shown to improve the cognitive control of children (4-8 years old) in several domains of thought including concepts of quantity (Bialystok & Codd, 1997; Saxe, 1998), spatial concepts (Bialystok & Majumder, 1998), and problem solving (Kessler & Quinn, 1987; Secada, 1991). Other recent studies have shown that there is a bilingual processing advantage found in a variety of simple experimental paradigms such as the dimensional change card sort task (Bialystok & Martin, 2004), and the ability to see the alternate image in a reversible figure (Bialystok & Shapero, 2005).

The exact nature of this superior control is still unclear and, according to Bialystok et al. (2005), appears to be confined to avoiding misleading information, usually perceptual. Nonetheless, the bilingual experience is shown to wield influence on behavior in completely different domains other than language-related tasks—in this case, attentional control. Being better able to ignore salient (important) but irrelevant (unrelated) cues transfers to a wide range of cognitive demands and is regarded as an accelerated development of these skills in children (Bialystok, Craik, & Ryan, 2006).

Further evidence of a bilingual processing advantage was contributed by Costa, Hernandez, & Sebastian-Galles (2008). They found similar results from the Attention Network Task (ANT). This test taps into three different attentional networks: alerting, orienting, and executive control. The study revealed that bilingual participants were faster in performing the task, as well as more efficient in the alerting and executive control networks. In particular, bilinguals were aided more by the presentation of an alerting cue,

and were also better at resolving conflicting information. For example, in a grammatical judgment test, bilingual children are significantly more advanced in making the correct inference when presented with the question "why is the cat barking so loudly?" (Pavlenko, 2005). When the pertinent information is embedded in a misleading or ambiguous context, or requires sustained attention and flexibility, bilingual children outperformed their peers. The ability to solve these problems is traced to developments in the prefrontal cortex (Diamond, 2002). Furthermore, in the Costa et al. (2008) research, bilinguals experienced a reduced switching cost between the different types of trials. These results offer additional evidence that bilingualism exerts an influence in the attainment of efficient attentional mechanisms.

A final investigation of bilingualism and behavioral effects focuses on aging. A review of the literature indicates that the attentional control advantage demonstrated in bilinguals is strong in children, declines to a relatively small effect in older children and young adults, but then reappears strongly in older adults (Bialystok, 2001; Bialystok et al., 2004; Bialystok et al., 2006). Recall that in children the enhancement is considered due to early and repeated suppression of the unwanted language. With regard to aging, the bilingual advantage is attributed to the fact that mental decline in the elderly is related to processing information.

Park (2000) has identified three principal components of cognitive aging: decreases in processing speed, deficits in working memory, and decreases in suppression (i.e. the ability to focus attention on relevant material). "Crystalized" knowledge such as vocabulary, experience, or general world knowledge is all still there (hence, "older and wiser"), but the ability to access the information is less efficient or dependable.

Processing speed, working memory, and suppression are all involved in L2 acquisition and use. Therefore, the specific enhancements related to bilingual code-switching are conveniently among the cognitive muscles which need the most flexing for the elderly. Furthermore, the cognitive functions that depend on executive control (problem solving, inhibiting unwanted stimuli…) show a marked decline in the elderly because of their compromised ability to ignore irrelevant or misleading information (Bialystok et al., 2004). Therefore, one of the negative effects of aging is a reduced control, but bilingualism sharpens and enhances some of the executive functions and, this then, could explain why elderly bilinguals outperformed their monolingual peers on certain attentional tasks (Bialystok, 2001). This is not to say that bilingualism could permanently stop the biological decline associated with age; nor would it reverse the genetic and environmental predispositions for each individual. With increasing age, both L1 and L2 use are affected because of declines in the same areas of language processing (Indefrey, 2006). However, enhanced performance on attentional tasks suggests that the mental exercise of code-switching could raise the threshold before declines in executive controls and working memory are experienced (Bialystok, Craik, & Ryan, 2006).

Therefore, not only will functional demands of bilingualism cause structural changes, but structural adaptations may in turn contribute to changes in functional operations—in this case a more efficient/accurate performance or different areas of the brain engaged in the task.

The general conclusion to this section of the review is that bilingual participants show an advantage in tasks involving executive control because of the need to suppress internal representations of the unwanted language. The mental exercise of code-switching

influences the organization of mental abilities, similar to the experience musicians have when hearing melodies, but, additionally, bilingualism influences performance in non-linguistic tasks related to higher cognitive functions. The next section examines how this experience translates to abstract, critical and creative thinking.

Double Conceptualization

Languages provide us with systems for conceptualizing the world; having more than one language therefore gives the thinker more flexibility for constructing thoughts (Goldberg, 2005). This is not to say that language *is* thought; the ultimate source of all meaning is based on *non-linguistic* experiences (Steinberg et al., 2001). Objects, situations, and events in the world and in our experience provide the mind with the basis for thought. This explains why isolated individuals denied language such as Genie or the Wild Boy of Avegnon, are able to think. It also explains why Helen Keller, after acquiring language, was able to describe her pre-lingual dreams. For example, she used expressions such as: "I obtain the dream in a very curious manner…", "my thoughts declared to me a room with walls made from flowers…", "my mind acts as a sort of mirror…", or "I was informed…" (Wilkerson, 1995). Many creative people including writers, sculptors, and dancers claim that much of their inspiration is realized, not in words, but rather in mental images; physical scientists also describe their creative thinking as geometrical, not verbal; and many experiments have corroborated the idea that visual thinking uses mental graphics rather than language (Pinker, 1994).

Clearly, language alone does not determine our perception of the physical world or establish our worldview (law of gravity/communism/capitalism/feminism…); but different grammars and social constraints offer various means to conceptualize thoughts

and communicate them to others. Differences between language constructions and the cultures that use them contribute to varying cognitive perspectives, often shaping how we sense and perceive the world and ourselves (Pavlenko, 2005). Bilingualism then provides the thinker with vocabulary items unavailable in his own language ("schadenfreude"- satisfaction or pleasure felt at someone else's misfortune), as well as different grammars, syntaxes, and social norms with which to contemplate and structure the information. For example, the common use of collectivist pronouns in Russian is contrary to the American affinity for independent, individual-based declarations; Japanese constructions are politely indirect, but to an American, may be perceived as obtuse.

Further evidence is provided by autobiographical (bilingual) writers who describe that language influences perception by stressing the importance of language for determining a sense of self and the internalization of cultural values (Pavlenko, 2005). Similarly, Marian and Kaushanskaya (2004) showed that the language in which memories are recalled affects the content and description of the memories.

The phenomenon of language structure influencing awareness is illustrated in Slobin's (1996) comparison of Spanish and English. The English sentence, "the bottle floated out of the cave" establishes the core information of the path of motion pertains to the "out"; in Spanish however, the core information of motion-path is applied to the verb, as in "la botella salio flotando"- "the bottle exited floating." Slobin concluded that different languages offer different portraits of our world. He argued that language provides its users with a range of resources for representing thoughts and creating patterns of attention.

These patterns are well illustrated in narratives. The manner in which someone relates the details of a story reveals what events are valued and how the teller perceived them. By examining how stories are told in different languages, we are able to isolate and identify how the different languages (grammatical and lexical representations) and their cultures, impact story form and content.

A study conducted by Jennifer Rayman (1999) demonstrates how ASL may make people inclined to notice or use certain resources available within the language and, in that way, influence their perceptions. She presented the cartoon movie "The Tortoise and the Hare" to a group of native signers and a group of hearing subjects. After watching the story, they were individually asked to re-tell it.

In comparing ASL and English renditions, the content of both stories was nearly equivalent including scene setting, plot development, complicating action, and conflict resolution. However, there were significant differences in rhetorical style and detail (Rayman, 1999). Several expected differences were related to conflicting grammatical structures such as the English use of gender pronouns (he and she…), and ASL relying on gender-neutral indexing. Other surprising differences were revealed in the plot line. For example, Deaf narrators used the starting line as an important character-building event. English storytellers however, often omitted the approach, or even being at the starting line, which was to be inferred by the hearing audience. All of the ASL narrators easily described the action of the raccoon starting the race by raising a hand in the shape of a gun and recoiling it quickly, mimicking a shot. Hearing narrators, if mentioning the starting line, often skipped over these details, saying that "the official started the race."

Another notable difference is in the perspectives taken throughout the story: the English storytellers used a narrator for the majority of the story while the ASLers used role-playing, which gave the impression of characters and dialogue (Rayman, 1999). This does away with any need for repeating "she said… and then he said….". Role-shifting is a typical linguistic resource that follows conventional rules of ASL grammar; it allows for a dynamic sense of immediacy and movement of plot. In English, an analogous representation would have required the storyteller to adapt their voice quality and demeanor to match the characters and to maintain the humble/arrogant characterization throughout the retelling (vs. just describing it at the beginning).

To compliment the use of role-shifting, ASL has a classifier system in its arsenal of linguistic tools. Classifiers allow for a rich variety of representational options to depict action and describe characters (Supalla 1985). By using a range of classifiers, signers show exactly what happens and in what manner and in what spatial relationship - the fast or slow changes in action, the hare and tortoise getting closer or farther away from each other, and how long the distance is maintained - thus creating a vivid picture of events.

ASL storytellers elaborated the point where the hare awoke from his nap and takes off in hot pursuit of the tortoise by showing the manner of running (Rayman, 1999): alternately spinning bent index fingers in a running motion (imagine a cartoon character's legs spinning wildly before taking off). Again, in English, storytellers merely said the tortoise was slower and it would be the responsibility of the listener to imagine a tortoise with stubby thick legs brushing the dusty ground. Signers naturally *show* degree of slowness and the labor involved. English (spoken) versions, however, did not elaborate this point, even though, as pointed out by the written descriptions herein, the information

is equally expressible in speech; nor did they incorporate the gestural possibilities available. Gesture and speech never convey exactly the same information in terms of degree, for example, "the glass is tall" vs. "the glass is *this* tall" (Goldin-Meadow, 2003). Therefore, gesture serves as a natural linguistic resource for speakers to form a holistic communicative system. One would naturally expect these techniques to be prevalent in both renditions, however, gesture, like role-playing, was seldom utilized by the English storytellers. Although ASL's modality facilitates a more visually detailed rendition of the story, questions of culture and grammar certainly must be considered when analyzing cognitive salience.

Clearly, the framing of events in one language leads to thinking within those frames. Different languages even seem to have different constraints for linguistic gesture (Ozyurek, 2000). For example, English has an easily accessible term, "swing," to describe change of location with an arc trajectory as in "Spiderman swings from building to building." There is no equivalent verb or easy paraphrasing for this meaning in Japanese, which would use the expression Spiderman "goes" or "flies." More notable, as English speakers use arched gestures to represent Spiderman's motion, Japanese speakers gesture in straight lines. So, having a readily accessible linguistic expression in one language, but not in another, can also result in different types of gestures. This phenomenon corroborates the notion put forth that language/culture exerts influence on frameworks of thought; this is further indication that the inherent structural differences between two languages/cultures influence how the information will be perceived and shared.

If the language a person uses involves a potential shift in the way they perceive and engage in the world, then second language acquisition provides the thinker with double conceptualizations. It should not matter if the two languages are English and Sign or Spanish or Japanese: the experience of having two frameworks, a double conceptualization, should translate into an enhanced logical and creative flexibility.

This enhancement is illustrated in children's abilities to formulate their own scientific hypotheses. Scientists in Philadelphia devised a series of experiments to measure this skill in different children according to their linguistic experience (Kessler & Quinn, 1987). According to a standardized rating system, the bilingual control group was more than double the rate of success than the monolingual group at forming hypotheses, at wording the explanation, and at creating analogies/metaphors. Researchers concluded that, in learning to manipulate language structures, bilingual children may develop a general cognitive skill that helps explain the relationship between language systems and thought processes providing them with a wider range of options and resulting in a flexibility of thought.

Other tasks which bilingual children outperformed their monolingual peers are, for example, generating unusual uses for common objects, as well as solving ambiguities—i.e. "why is the cat barking so loudly?" (Pavlenko, 2005). In fact, mental flexibility - the ability to see things in a new light and contemplate many options creatively, depends on a complex neural system of connections to and from the various brain structures - and requires frontal lobe involvement (Goldberg, 2001).

With regard to artistic expression, bilingualism would not override a sculptor's innate talent nor a singer's amount of training. However, the creative process requires

making new associations out of old ones; the more connections an individual has, the more associations available to inspire and direct the creation (Fuster, 2003; Goldberg, 2005). Basically, this means that creativity involves unusual connections, reorganizing existing information, and internalizing it - with the objective to find expression in the hands/voice of the artist and all under prefrontal cortex (PFC) control. Having more than one framework for conceptualization, exercising the PFC with code-switching, and possibly possessing greater connections between brain regions, implies that bilingualism has the potential to aid the creative process.

Bilingualism and Intelligence

The possibility that learning a second language could have a positive effect on intelligence was not something even considered until very recently (Steinberg et al., 2001). It is still widely and skeptically debated. Early criticism is documented in the beginning of the 1900's, a time when conceptions and experimental methodology involving language and intelligence were at a rather naïve level. The American attitude at the time was one of isolationism (anti-foreign influences). Perhaps the earliest study on bilingualism and intelligence was done by Goddard (1917, as cited in Steinberg, 2001) who gave the English-language version of the Binet intelligence test to 30 recent adult immigrants at Ellis Island. Goddard classified 25 of the 30 people as feeble-minded. Later, Goddard used results to petition Congress to enact more restrictions limiting immigration (Steinberg, 2001). Similar results were found in comparisons of monolinguals and bilinguals in Wales where the use of two languages was deemed to cause permanent "confused thinking" (Saer, 1923).

Even though more positive attitudes toward foreign languages evolved during the 1960's, other methodological problems persisted based on linguistic, socio-economic, and cultural biases (Steinberg et al., 2001). Once proper experimental controls were used with adequate tests, a different outcome became apparent. Unexpectedly, positive effects were reported and such results have continued to be documented to the present. One of the first studies to find a positive effect on intelligence for bilingualism was that of Peal and Lambert (1962). The subjects in this study were 164 elementary school children age ten with similar socio-economic backgrounds. They were given a variety of intelligence tests and the bilingual children (equal ability in both languages) had significantly higher scores on 15 out of the 18 measures. Peal and Lambert concluded that bilingualism results in greater mental flexibility and abstract thought.

Since that time, studies have supported a connection between learning a foreign language and certain social/cognitive benefits in children. Such benefits include a better understanding of a native language and linguistic principles, a heightened awareness of communication and intent, critical analysis of cultural differences, and improved music and math skills (Bain & Yu, 1980; Eisner, 2000; Frantz, 1996). It has also been well documented that bilingual grade school children outperform monolingual students on intelligence quotient (IQ) tests (Bain & Yu, 1980).

Additional evidence is provided by American Sign Language research indicating that knowledge of a signed language also produces cognitive advantages in hearing children (Capirci, et al., 1998). For example, school scores show that hearing children of Deaf parents generally excel in academics (Daniels et al., 2001); and early sign language exposure promotes *spoken* language learning and results in higher scores on repeated

verbal ability tests. Another revealing study concluded that children age eight who were exposed to sign scored a significant average of twelve points higher on the Wechsler Intelligence Scale for Children (WISC-III) compared to 8-year-olds who were not exposed to sign (Acredolo & Goodwyn, 2002).

Regardless of these findings, the scientific community is reluctant to attribute any larger significance to a connection between language and intelligence. There are several causes for apprehension: cognitive research had demonstrated that thought and intellectual processes develop independently of language; one language is equally capable of expression as another language, regardless if the languages are attributed to a primitive (isolated) or sophisticated population (Pinker, 1994). However, this refers to having a language, not bilingualism. Furthermore, it is widely assumed that the benefits for bilingual children, described previously, do not carry over into adulthood because of other influences such as environmental differences, motivation, quality of educators/materials, opportunities, and genetics (Pinker, 1994). However, a new study reveals that IQ scores in childhood greatly predict later adult IQ scores (Wenner, 2007).

Another potential obstacle confronting correlations between bilingualism and intelligence is the contemporary American attitude of "political correctness." It is presently undesirable to acknowledge differences in mental capacity between the sexes, or the races, or cultures or, through rational extension, between linguistic backgrounds. It would seem un-American to define someone's intelligence according to any one thing, including childhood IQ tests. Genetics, early environmental experiences, socio-economic situations would, and should, have to be considered. But it should not *negate* the importance and validity of the IQ or other documented evidence.

Regardless of our present collective sensibilities, there is little to no documented proof that language does or does not affect intelligence in a permanent way (Pinker, 1994). This is probably related to our limited definition of intelligence. Any understanding of how smart an individual may be has been confined to basic academic subjects and written test scores but science now has several means for measuring it. The long-regarded IQ factor has been joined by the more friendly multiple intelligences (MI), as well as biological analyses and societal criteria (Sternberg, 2005). The MI approach analyzes domain-specific intelligences such as math, art, or interpersonal relations. These categories broadly correspond to the cognitive variables systematically studied by neuroscientists and tested by clinical neuropsychologists.

Biological approaches to measure intelligence, such as patterns of electroencephalograms (EEGs), speed of neural transmission, or patterns of activation, have ended up correlating psycho-physiological data with scores on conventional intelligence tests, but no biological index or set of biological indices seems to provide a conclusive answer either (Sternberg, 2005). The main means of assessing intelligence societally is through observations of everyday behavior. However, the same actions that in one society may be considered intelligent/smart are different in other societies. Therefore, the intelligence of actions must be judged in a cultural context.

While standard tests of general intelligence can not measure everything, they do seem to measure something important. For example, problem-solving tasks like Raven's Progressive Matrices which, on their own, measure something closely similar to the IQ, are obtained by averaging scores across a variety of sub-tests with differing content and are believed to be closely concerned with the functions of the prefrontal cortex (Duncan,

1990; Duncan et al., 2000). Craik and Bialystok (2005) propose that intelligence is comprised of two major elements: knowledge and control. They suggest that propositional and procedural knowledge, as well as control, the means by which a person utilizes stored knowledge to the best adaptive advantage, are intimately linked aspects of intelligence.

This vein of inquiry will be revisited in chapter five. For now, a more contemporary description of intelligence, grossly oversimplified, is the ability to use knowledge to overcome obstacles to achieve goals (Pinker, 2002); or rather, to process information effectively (Pinker, 1997). So, on the one hand, science has long held the belief that language is not related to intelligence, but new developments within neuro/psycho/linguistics may require us to rethink past suppositions.

A final consideration of the research evidence shows that early bilingualism will not harm the intellectual or cognitive development of a child in any way. In addition, there is mounting evidence that it may even benefit intellectual functions in children and the elderly. Furthermore, although neural plasticity is limited to the confines of individual genetics and types of environmental exposure, research indicates that bilingualism influences frontal lobe functions. However, the nature of this control, and its boundaries, are still unclear. Lastly, while it is still debated whether language can be responsible for *creating* one's thoughts, bilingualism offers an individual the means for double conceptualization, thereby serving as a conduit for flexible responses to one's experiences and cognitive demands.

Chapter III

The purpose of this research is to determine if young bilingual adults (ages 18-39; mean age 22.5) would outperform their monolingual peers at multitasking. Multitasking represents one way to measure higher-order cognitive skills. Therefore, the assumption is that, beyond communicating in another language, the mental exercise of learning and using another language will contribute to a greater overall intellectual boost. The method chosen for measuring multitasking abilities is the computerized program SIMKAP (Simultaneous Capacity/Stress Tolerance Test).

The following narrative will describe the participants of the study, give a more detailed account of SIMKAP, and outline the methodological limitations confronting this research.

Subject Selection and Description

Volunteers (a total of 133 participants) are assigned to three sample groups according to their language experience—Group A: (45) college upperclassmen majoring in Psychology who did not possess foreign language proficiency; Group B: (49) college upperclassmen with a concentration in Spanish; and Group C: (39) upperclassmen from ASL or Interpreter Training Programs (ITP). In an effort to find individuals with comparable foreign language experience, four participants working with ASL (teachers and aides) were also included.

The English and Spanish student groups were solicited from the University of Wisconsin- Eau Claire and the University of Wisconsin- Stout. ASL participants were recruited from several schools in Minneapolis/St. Paul area including the College of St. Catherine, St. Paul College, and the Metro Deaf School. Enrollment in the ASL programs

was limited and, therefore, inquiries were also made to ASL programs at Gallaudet University, DC, Columbia Teacher's College-NY, and the Community College of Baltimore County, MD.

An attempt was made to match genders across the three groups; however, because foreign language programs have a female bias, there were more males in the monolingual group (14/5/1). Participants were approved according to the years of second language (L2) experience. "Bilingual" in this context, refers to someone who can function in each language according to given needs (i.e. social, academic, or professional). The ASL and Spanish participants ranged in L2 experience from three to 29 years. Monolinguals may have been briefly exposed to a foreign language, but they could not have taken more than one year of formal instruction and not within the last two years. If they took a college level course, their performance in that class was also considered.

Procedures

The Dean of Students at each institution was contacted by e-mail. The correspondence included an introduction, brief explanation about the study, and a request to proceed (Appendix A). Subsequent contacts included faculty members responsible for the Institutional Review Board (IRB) process as well as the foreign language department chairpersons. After obtaining IRB approval from each institution, efforts were then made to contact faculty members of upper level courses willing to sacrifice class time for the brief presentation.

During the classroom visits, students and faculty received a printed handout which detailed the information presented verbally. The information included a description of the research project goals, testing method, terms of confidentiality, contact

information, and conditions for disqualification (Appendix B). Conditions warranting elimination pertained to medications for neurological problems including ADD or depression, language/learning problems such as dyslexia, and L2 experience requirements. Prospective volunteers not matching the criteria were asked to refrain from participating.

Students then had the opportunity to ask questions and volunteer by marking the participation timesheet (Appendix C). During the sign-up period, it was made clear that declining to participate would in no way hinder the student's grade for the class. Some professors opted to exit the room or continue the lecture during this time. Some monolingual students were offered class credit for participating, however, this is not considered a motivating factor; other research projects being conducted at the same time offered additional incentives and were worth more credits. It is believed that the participants were motivated to perform well because, in addition to learning something interesting about themselves, multitasking is an important component to many jobs and, as explained in the presentation, participating in this study would make a useful talking-point for employment interviews.

While classes in Spanish and psychology are often quite large and individuals are less likely to know others participating in the project, interpreter training programs are much more intimate. Participation was enthusiastic so a large percentage of the upper classmen were involved with the project, which had the inherent risk of reducing anonymity. It was asked that those who participate not talk with other members in the program about individual results. Scores were to be approached with the same confidentiality inspired by the training programs for performance-testing situations. In

this way, participation in the SIMKAP avoided becoming a means of competition or hostility between program members.

Experimental Design

Students that agreed to participate were contacted by an e-mail reminder informing them where and when testing would take place. Although the SIMKAP program is approximately 40 minutes long, one hour increments were allowed between appointments. This provided the time necessary for explaining each participant's results. It also diminished the chance for participants to make remarks about the program in passing, and additionally helped maintain the confidential integrity of the process.

Some facilities offered private library rooms or testing labs; others used private offices, unused classrooms, or a secluded library desk. Subjects had the option to use headphones when necessary. They were first asked about left or right handedness and the mouse, computer, and chair were adjusted for comfort. They were then asked about their age, gender, and years of language experience. Participants were also asked about any other training which could influence their multitasking performance such as military or management experience or if they were a trained pilot/trucker. It soon became apparent that essentially all the participants routinely performed activities that could account for multitasking: they were classically trained musicians, single parents working and going to school, managers, business owners, training for online poker tournaments, military reservists... The basic universal demands of employment and hobbies and home-life made these influences rather superfluous and did not change the test dynamic. Linguistic background therefore remained the essential research variable.

Volunteers were then instructed about the testing process, why paper and pen were provided (solving problems or writing reminders), and to be as quick and as accurate as possible. It was equally stressed to each participant that they should "just have fun" and approach SIMKAP as a video game or tool to learn more about themselves and not a test that would influence success or failure in their chosen academic programs.

During the practice phases, participants were allowed to pause the program and ask the administrator for more clarification. The administrator was located directly outside the testing area for easy accessibility. After taking the SIMKAP, each participant was given a verbal explanation about the results and, when available, received a copy of their scores (Appendix D).

Instrumentation

SIMKAP is primarily intended for personnel selection, career counseling, as well as clinical diagnosis and assessment (Bratfisch & Hagman, 2003). Additional areas of use are traffic psychology (especially railway and aviation), and military psychology. It is also used for training purposes at universities and colleges. Operationally, SIMKAP is based on the definition of simultaneous capacity and stress tolerance. Simultaneous capacity (multitasking), is defined as the performance achieved when simultaneously dealing with routine tasks and tasks demanding cognitive performances (problem solving). Stress tolerance is defined as the extent to which performance differs when dealing with corresponding routine tasks under normal (baseline) and stress conditions.

According to the authors of the test (Bratfisch & Hagman, 2003), reliability coefficients regarding the total performance for simultaneous capacity and stress tolerance vary between 0.94 and 0.97, and between 0.89 and 0.91, respectively. The

parallel test reliability coefficients are 0.96 for perceptual speed (baseline) and 0.84 for accuracy (also baseline). Other than the face validity (respondents think immediately of real situations where several things must be handled simultaneously) and the logical validity (the operational definition just described) measures are highly reliable as the content is established through factor analysis. According to Borjes and Rosmark (2002), prognostic validity has also been demonstrated for occupations which demand a high degree of multitasking (as cited in Bratfisch & Hagman, 2003). Additional reports of factorial evidence for the independence of SIMKAP from other tests and further evidence for its validity has been reported by Braun, Huttges, Timm, Wieland, and Willamowski (2002). The objectivity of evaluation for the SIMKAP is also very high due to the measuring precision of the equipment and the automatic calculation of the test results (Bratfisch & Hagman, 2003).

Data Collection

Research data was collected using a Toshiba Satellite personal computer. The SIMKAP program and 150 applications were purchased from Lafayette Instruments. Due to financial constraints, SIMKAP was administered individually rather than by a network of computers. However, the test is presented in the same way to all respondents and instructions were routinely described by a single administrator, therefore, the variation that multiple administrations might introduce was avoided.

People with limited computer experience were not disadvantaged because the program only requires participants to mouse-click. Several participants were eliminated due to technical/equipment problems or failing to meet the project criteria (i.e. amount of

L2 experience, learning disabilities). Those eliminated were five participants from the English group, four from the Spanish group and another four from the ASL group.

Methodology

SIMKAP consists of five parts. Each part has its own instruction and practice phase whereby respondents can become acquainted with the tasks. The first three parts use the same matching process but different content; the goal is to identify and cross off, as quickly and as accurately as possible, matching pairs of numbers, then letters, and then geometric shapes. These three parts take three minutes each.

In the fourth part, uncomplicated problem solving is required. Of the 24 intellectually simple questions, they are either logical-numerical (e.g., "Continue the following series: 2, 5, 8, 11"), logical-verbal (e.g., "Which word differs from the others: cow, pig, horse, house?"), or arithmetic (e.g., "What is 34 minus 7?"). The questions are posed aurally via the personal computer speakers and the respondents select their answers by clicking on the list of possible replies at the bottom of the screen. This part takes approximately five minutes. The first four parts of the test establish the baseline – a person's speed and accuracy performance under normal conditions, to be compared with "stress tolerance" conditions in the final section, the fifth part, when tasks are combined.

The fifth subtest, the multitasking phase, not only requires participants to continue matching and solving questions similar to those in the fourth part, but they will also be asked additional questions which require folders to be opened. For example, to find out where the person is supposed to be at 11:00 am on Wednesday, the respondent must click on a button labeled "calendar." Further complication is introduced when some of the questions have to be answered with a delay. Using a timer in the top right corner of the

screen, the program voice might say, "When the timer reads 1:35, answer the following question ...". The fifth part of SIMKAP takes 18 minutes.

SIMKAP differed from other possible testing methods in several ways. For example, the Wisconsin Card Sort Test (WCST) has long been a staple for measuring multitasking (Wikipedia, 2008). A participant is given a stack of cards and then must match them to a number of stimulus cards presented in hierarchical levels of complexity. It is widely used by psychologists and neurologists for patients with brain injury or mental illness because it successfully determines problems with attention, working memory, and visual processing. Therefore, it is loosely termed a "frontal lobe" test on the basis that patients with any sort of frontal lobe lesion generally do poorly at the test. However, it relies on visual processing and does not require the kind of reasoning and verbal processing inherent in the SIMKAP evaluation.

Similarly, the Simon Task described earlier relies heavily on eye-hand coordination; Bialystok et al. (2005) determined that participants more experienced at video games may have had an advantage in performing the Simon activity. SIMKAP, on the other hand, incorporates some eye-hand coordination as part of the process, but it also requires linguistic processing, as well as addressing the demands of conflicting "cerebral geography."

Cerebral geography refers to the principle that the brain works best with the activation of different, rather than identical, brain areas. For example, doodling while talking on the telephone is not a problem for most people because they use different brain areas, engage different muscles and induce different sensory experiences (Restak, 2003).

SIMKAP is designed to interrupt the flow of the main activity in several ways (i.e. reading calendar notes while listening to new questions) and combines many types of conflict. For example, when activities are alternated such as calculating math problems and identifying shapes, not only is the speed of perception and performance impeded, but the accuracy is also diminished (Restak, 2003).

SIMKAP also incorporates other frontal lobe functions such as meta-cognition and adaptive decision making. For example, the participant might analyze the process to determine a more efficient way to accomplish the tasks such as prioritize, create a routine, or develop a conscious means to organize the notepaper. The cognitive processes involved in resolving ambiguous situations (prioritizing) are very different from those involved in solving strictly deterministic situations such as 37 + 5 = ... (Goldberg, 2001). Multitasking requires planning, guidance by internal representations, mental flexibility, and working memory— aspects of frontal lobe function. Therefore, it was determined that SIMKAP served as an adequate testing method for the purposes of this study.

Data Analysis

During the fifth (multitasking) part, the computer calculates the number of correctly marked numbers, letters and figures as three speed measures; the percentage of errors is calculated separately for each subset, as three error measures. For the intellectually simple questions and the calendar/telephone book questions, the number of correctly answered questions is calculated.

The authors of the test suggest that an overall measure is calculated by adding the three standardized speed measures plus the three standardized error measures plus three times the standardized number of correctly answered questions. Data was entered into the

excel spreadsheet and then analyzed using SPSS according to the Fourth Edition. The prevailing statistical relationship between foreign language experience and multitasking abilities was a linear one.

Chapter IV: Results and Discussion

This quasi-experiment was designed to determine the various effects of bilingualism on frontal lobe functions. This scenario is unique in that it focused on multitasking abilities, and it incorporated another language mode: American Sign Language (ASL). Information gleaned from this work is applied to the overarching goal to determine if the effects of second language (L2) learning can manifest into other cognitive skills in the form of a 'brain boost'.

Experimental Design

The computerized program SIMKAP was used to collect data for 133 college educated subjects between the ages of 18-39 (mean age 22.5) with varying amounts of second language experience (0-29 years). Other variables were considered including gender, level of education, and type of language or "group." Level of education was categorized by a number system established in the SIMKAP software: 1 = high school/GED not completed; 2 = completed high school or currently in a vocational program; 3 = completed vocational training (associate degree); 4 = currently in an undergraduate program; 5 = completed a university or college degree.

The demographics for each group were as follows: The monolingual group, after eliminations, had 40 participants (26 females and 14 males), ages 18-30 (mean age 20.5), and 39 members had an educational level 4 (only one participant at level 5). Because foreign language programs possess an inherent, female bias, this group had a larger percentage of male participants. However, SPSS analysis indicated that gender was not a determining factor for the results.

The Spanish bilingual group had 45 participants (40 females/5 males), and ages ranged from 19-30 (mean age 21.8). Forty-four members of this group had an educational level of 4, and one participant had a level 5. The Spanish group's mean for L2 experience was 7.5 years.

The ASL group was rather different. Because the pool of qualified subjects is more limited, and persons in interpreter training programs are more diverse (just out of school, or returning to school, or specializing within their respective fields), the demographics for this group were slightly dissimilar from the other two groups. The ASL group consisted of 35 participants (34 female and one male). They ranged in age from 19-39 (with four participants over age 30, the mean age was 24.2). The level of education was in four categories: level 2= four participants; level 3= seven participants; level 4= 11 participants; and level 5= 13 participants. The mean for L2 experience was 5.9 years. Not only was this group slightly smaller than the others (40/45/35), and slightly older than the others, and had less L2 experience than the Spanish group, but one third of the participants had less education. These discrepancies will be discussed later.

Results

A linear regression analysis was conducted, using SPSS Fourth Edition, to evaluate how second language experience relates to multitasking performance. Results indicate a positive, although weak (beta .269), relationship between years of L2 experience and SIMKAP performance. Seven percent of the variance of SIMKAP was accounted for by its linear relationship with L2, with a p= .03.

The regression equation for predicting the overall multitasking ability is as follows:

Predicted Overall SIMKAP = 1.287 Overall L2 Experience + 542.049

This humble correlation is to be expected because the great majority of the subjects tested are at the peak age for working memory capacity. Similar to the results of the Simon/MEG study (Bialystok et al., 2004), and the ANT study (Costa, et al., 2008), there should be very little variance in these kinds of abilities in young adults. Furthermore, inherent in all studies analyzing groups of bilinguals, and studies of this size, individual differences (IDs) are in play. Therefore, this correlation, although slight, is not trivial.

A multiple regression analysis was then conducted to evaluate how well the L2 experience, in combination with other variables, predicted multitasking. Additional considerations were gender, age, level of education, and group. It was revealed that level of education was the only other determinant for multitasking. The result was a slightly stronger correlation. The regression equation with bivariate correlation predictors was significantly related to the SIMKAP scores R squared = .072, adjusted R squared = .093; $F(2, 117) = 7.08$, $p < .001$. This yields a 9-10% variance on multitasking scores accounted for by its relationship to the linear combination of L2 and level of education.

If more education is a significant part of the equation, then one would assume that the ASL group, of which, one third of the participants were level 2 and 3, would be at the bottom of the performance scale. The following figure and Tables 1 and 2 show, however, that this was not the case.

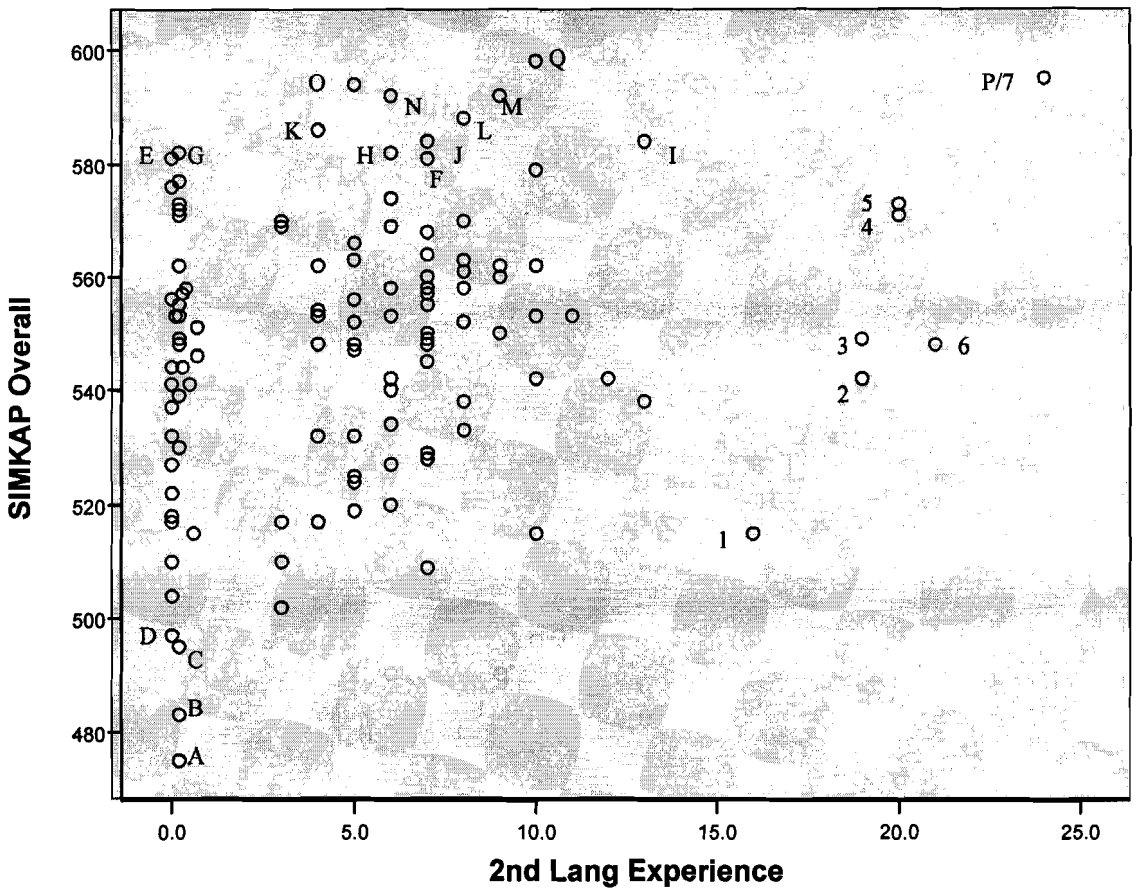

Figure 1. Scatter-plot representation of multitasking performance and L2 experience.

Table 1

Lowest Scores

Location	Gender	Score	Ed. Level	Age	Lang. Group	Yrs. Of Exp.	Age of Acquisition
A	F	475	4	19	Eng.	.2	----
B	F	483	4	22	Eng.	.2	----
C	M	495	4	19	Eng.	.2	----
D	F	497	4	21	Eng.	0.0	----

Equally vexing, if level of education is paramount to this equation, then the participants with an education level of 5 should make a strong showing in the highest scores. Again, this was not the case.

Table 2

Highest Scores from 580-600

Loc.	Gender	Score	Educ.	Age	Group	Yrs.Exp.	AoA
E	F	581	4	22	Eng.	0	----
F	M	581	4	20	Span.	7	13
G	F	582	4	19	Eng.	0	----
H	F	582	4	21	Span.	6	15
I	F	584	5	29	ASL	13	16
J	F	584	4	20	Span.	7	13
K	F	586	4	22	ASL	4	18
L	F	588	4	22	ASL	8	14
M	F	592	4	20	Span.	9	11
N	F	592	4	20	Span.	6	14
O	F	594	4	21	Span.	5	16
P/7	F	595	5	24	CODA	24	0
Q	F	598	4	24	Span.	10	14

Subjects with less education (level 2 and 3) could possibly be disadvantaged when solving the intellectual tasks specifically required by SIMKAP. Examples would be answering "how much is 14 minus 5 divided by 3?" or "'letters' are to reading as

'numbers' are to…?" Another question similar to those on the program: "Sara is shorter than Robert who is taller than Lisa. Who is the tallest?" While none of these questions are intended to measure one's knowledge, someone with more education might be more practiced at accessing judgments, or more confident in making judgments, about the knowledge. Lower levels of education, then, should have a greater detrimental impact on performance, and this would account for the absence of lower educational levels in the highest SIMKAP scores.

It is reasoned that once an individual is academically successful in his/her undergraduate work, postgraduate work is not exponentially more taxing, therefore, individuals with levels 4 and 5 would be more similar in their abilities to solve the intellectual tasks in SIMKAP, and this explains the absence of a preponderance of level 5 associated with the highest scores. Clearly, while level of education contributes to results obtained in this project, language experience remains the major determining factor.

Other methods for analyzing the relationship of education and years of language experience on multitasking skills were considered. Although more years of education signified older aged participants, and older participants should perform worse, older participants generally had more years of L2 experience and they performed better. Therefore, experience and age of acquisition (AoA) were scrutinized.

Table 3

Most Years of Experience: Scores are Rated from Lowest to Highest

Location	Gender	Score	Educ.	Group	Age	Yrs.Exp.	AoA
1	F	515	5	ASL	24	16	8
2	F	542	4	Nat.Spn.	19	19	0
3	F	548	4	Nat.Spn.	21	21	0
4	F	549	2	CODA	19	19	0
5	F	571	5	ASL	39	20	19
6	M	573	4	Nat.Spn.	20	20	0
7	F	595	5	CODA	24	24	0

*Native Spanish speakers are denoted by "Nat. Spn.," and "CODA" is used to represent Children of Deaf Adults.

In contrast to other projects, the native bilinguals (5) represented a very small percentage of the research subjects in this evaluation. Therefore, the great majority of participants were first exposed to the foreign language in their teens. However, in this circumstance, even five years of foreign language use seemed to represent a threshold for benefit. While many of the other research tasks (i.e. Simon, ANT, card sort) discovered a strong correlation between abilities and age of acquisition and a similar correlation exists here, it would seem that results in this case are due to more years of experience rather than reflecting age of acquisition.

Discussion

In accordance with bilingual research described in the previous chapter, it was expected that bilinguals should generally perform slightly better than monolinguals on

the multitasking test, and that years of experience and age of acquisition should also contribute to better performance. Although these results were confirmed, age of acquisition did not seem to be a major contributing factor influencing multitasking performance. Because the average AoA was much later than in the studies previously cited, and benefits can be recorded in less years of experience, it is uncertain that the inhibitory mechanism is responsible for the results obtained from SIMKAP.

Even though some of the older bilinguals should have shown a decline in multitasking abilities due to age and decreased working memory capacity, several outperformed their younger counterparts. It is unknown if these results are a reflection of the attentional/inhibitory enhancement described earlier, or if the multitasking abilities would not be reflective of something else. According to Konig, Buhner, & Murling, 2005, working memory was proven to be the major predictor of SIMKAP. Their hierarchical multiple regression analyses revealed that differences in controlling attention, a function provided by working memory, rather than the differences in attention itself, contributed to the successful performance in complex multitasking scenarios. Working memory has been implicated in several studies of attentional control (De Fockert, Rees, Frith, & Lavie, 2001; Berti & Schroger, 2003; Engle, 2002). Therefore, it is surmised that results are more strongly attributed to an enhanced working memory.

Similar to the Nun Study, education naturally reflects cognitive ability, but linguistic ability in early adulthood may be more closely related to improved memory (Snowdon, 2001). Recall that the research indicated a decline in grammatical complexity in later life was associated with working memory limitations in healthy younger adults; the ability to use and develop complex grammatical constructions was a strong predictor

for avoiding Alzheimer's in later life. It could be that even a moderate control of another language enhances abilities related to working memory in young adults, influencing their ability to encode, process and retrieve information. The L2 memory might make those mental processes more efficient and extend one's working memory capacity. Surprisingly, working memory enhancements have not been detected in bilingual children (Bialystok, 2005). Nonetheless, several studies corroborate a link between working memory and its influence on attention (Costa et al., 2008; Berti & Schroger, 2003).

It is possible that the effects of bilingualism on working memory are not manifested into behavioral consequences until later in a person's development. It could also be that the critical period for different aspects of language learning is more flexible than currently believed and that there is a basic misconception about the nature of language learning compared to second language learning. However, this is all conjecture; without imaging technology, a larger pool of participants, different ages being represented, and a better understanding of the biochemical processes involved, it is difficult to know the cause from the consequence. It is also impossible, from the limited scope of this study, to determine if there are any variations between monolingual, bilingual, and bimodal areas of the brain responsible for multitasking operations.

While this data cannot illuminate any questions about the effects of a signed language on inhibitory controls, it does illustrate another similarity between spoken and signed languages; effects of bilingualism on the mental processes involved in multitasking are not limited to speech. Furthermore, the benefits from ASL were recorded in an older and less educated population with less years of experience, suggesting that

enhancements may be obtained after only a few years of childhood exposure and can continue into older age.

Regardless of the exact cause or combination of influences, the results indicate that linguistic code-switching, in combination with more education, has the potential to create a slight improvement (9-10%) in cognitive skills related to multitasking. Based on the magnitude of the correlation coefficient, we can conclude that, overall, multitasking scores were moderately related to L2 experience $r^2 = .065$. However, this relationship changes slightly when variables are combined. The only other predictor was education, with a bivariate r squared= .093.

The results herein generally confirmed previous findings— benefits from code-switching are evident in multitasking abilities as measured in SIMKAP. Furthermore, even limited exposure to ASL, like spoken bilingualism, similarly affects cognitive processes related to multitasking.

Chapter V: Conclusion

While cautious not to exceed the bounds of the information presented, this paper combines several respectable sources of data and applies an overarching rationale to their relationship. The result is a convergence of evidence supporting the theoretical assumption that the effects of bilingualism, including ASL, constitute a legitimate brain boost. While neurogenesis and plasticity are largely used to explain boost theories, effects of bilingualism seem to involve something more than the size and density of brain structures. It is true that the frontal lobes of bilinguals have been recorded performing tasks which are done in different areas of the monolingual brain (e.g. Bialystok, et al., 2005), but this alone does not explain why effects have been documented in various domains outside of linguistics. The influence of bilingualism on cognition appears to be related, not to the accumulation of knowledge, but rather, to the processing of knowledge. Most of these benefits have been recorded in children and are attributed to attentional controls (Bialystok, 2001). As described in this paper, bilingual children are able to ignore irrelevant stimuli and solve ambiguities in order to accomplish various tasks more efficiently and accurately than their peers (i.e. card sort, image reversal, forming hypotheses, math concepts…).

A general cognitive benefit acquired in youth appears to be sustained into adulthood, although the effects are less pronounced and may be attributed to other influences rather than attentional control alone. Results from this study indicate that even early teen ages of onset acquisition provide a benefit associated with multitasking/working memory. Although early exposure to a second language encourages additional wiring and gray matter density (Mechelli et al., 2004; Goldberg, 2005), later

neural activity is believed to be more important in strengthening and preserving the brain (Pinker, 2002). Therefore, a link between early bilingualism and life-long code-switching would contribute to a cognitive reserve in later life. This reserve would then provide some individuals with a slower rate of diminished capacity related to processing speed, working memory, and attention (Bialystok et al., 2006; Goldberg, 2005).

Specific causes for these bilingual lifespan enhancements are not yet well-determined but several possible factors have been outlined in this paper. Some of these factors include greater neural/synaptic connections for communication between regions, greater myelinization, greater working memory capacity, inhibitory and suppression enhancement, as well as possible bio-chemical adaptations. These certainly are not the only possible causes, but they are representative of the complexity of factors contributing to the workings of the brain. These benefits - enhanced cognitive development in children, sustained processing advantages in young adulthood, and a reserve in old age - help address the larger question of bilingualism and general intelligence.

Useful approaches to measure intelligence include the intelligence quotient (IQ), multiple intelligences (MI), societal judgments, and biological processes. Alone, none of these methods adequately represent intelligence, however, combined, they demonstrate a variety of empirical techniques that all positively correlate bilingualism with an intellectual advantage.

Even though both sign and speech bilingual children tend to outperform their monolingual peers on IQ tests, and childhood scores are proven to greatly predict adult IQ scores (Wenner, 2007), this is not wholly accepted as proof that a bilingual effect is in play. Standardized intelligence test scores are limited in their assessment. Additionally, it

has been established that both signed and spoken bilingualism influence certain low-level perceptive processes and thereby have the potential to impact various skills including math concepts, visual tasks, creativity, and problem solving— categories related to Multiple Intelligences. However, MI measurements do not explain why linguistic tasks would cross over into widely diverse cognitive domains. Simply accepting that both low level and high level cognitive influences occur is not enough to represent a valid theory about intelligence, certainly not by itself. Furthermore, the nature of language as a social tool for communication lends itself for enhanced societal competence: heightened awareness of self, society, and metalinguistics (Bialystok, 2001; Sternberg, 2005). Because multitasking is a valued skill in our society, other cognitive benefits derived from bilingualism, unrelated to communication, could be considered a contribution to social intelligence. However, the intellectual capacity which we are referring to in this paper would not be adequately defined by MI and social markers alone. It has also been determined that the cognitive exercise of linguistic code-switching is reflected in biological adaptations (VBM, MEG, MRI-ANT). This is the most compelling evidence for an effect on general intelligence because attentional control and working memory are foundational to intelligent behavior (Sternberg, 2005); and as predictors of intelligence (Schweizer & Moosbrugger, 2004; Ben-Shakhar & Sheffer, 2000; Conway, et al., 2003). Again, none of these things (IQ, MI, biological processes), in isolation, is definitive evidence for a bilingual boost to intelligence. Nonetheless, the convergence of several measures does exit.

The accumulation of empirical data verifies benefits from bilingualism in a variety of mental tasks. Therefore, it is accepted that bilingualism not only impacts critical

intellectual processes, but that these effects manifest into function and behavior. It is not a vast leap of inference to claim that bilingualism enhances activity in the frontal lobe, and the frontal lobe is largely involved in human intelligence and therefore bilingualism also enhances intelligence. It does not, however, suggest that enhanced general intelligence equates to an intelligent person. The intellectual processes related to general intelligence (i.e. attention, working memory, processing speed), are not synonymous with individual strengths and weaknesses including one's motivation, opportunity, education, or genetic make-up. This paper does not claim that mental dexterity is simply due to better or worse biases in attention and memory; however, they are important constructs for intelligence, and even a slight improvement in their functioning would explain the diversity and longevity of beneficial effects recorded in bilinguals.

Bilingualism does not represent some radical change in human potential because of its influence on the structures and functions of the brain. The cognitive differences between bilingual and monolingual children, college-age adults, and the elderly are small. We are more alike than dissimilar. However, the mental gymnastics of code-switching exerts *some* influence on the structures and functions responsible for perception, thinking, language and memory. The effects are small but noteworthy because they involve essential cognitive processes that underlie much of our intellectual life, as well as the social dimensions of double conceptualization, creativity, alternative world views, and other potential consequences that resonate through an individual's lifetime from youth to old age. Therefore, regardless if the causes are not yet well defined, even small degrees of benefit from bilingualism are not trivial.

When results and subsequent theories have such far-reaching implications, it is a natural inclination to draw other, unsubstantiated correlations. For example, because socially unacceptable violence is suppressed by the inhibitory controls of the frontal lobes, and foreign language enhances those controls, then it could be rationalized that a bilingual person would be less prone to violence. These and other unproven correlations are detrimental to any worthwhile debate about how the mind works.

Equally erroneous would be to assume that a bilingual person would be less likely to commit acts of stupidity or be immune to the ravages of Alzheimer's simply because bilingualism impacts one's cognitive development and mental health. It is not the intention of this paper to prescribe bilingualism as a panacea for neurological conditions affecting society, nor will it cure an individual's propensity for folly. That said, problems such as Autism, Attention Deficit Disorder, Alzheimer's, as well as debilitating afflictions such as Tourette's Syndrome are a scourge and certainly deserve to have the scientific community look for answers wherever possible. The effects of early bilingualism on attentional control, working memory, and biochemical/cognitive processes certainly merits continued investigation. Scientists face the challenge of further hypothesizing and testing answers to these questions; society faces the challenge of maintaining a healthy skepticism and critically evaluating those answers.

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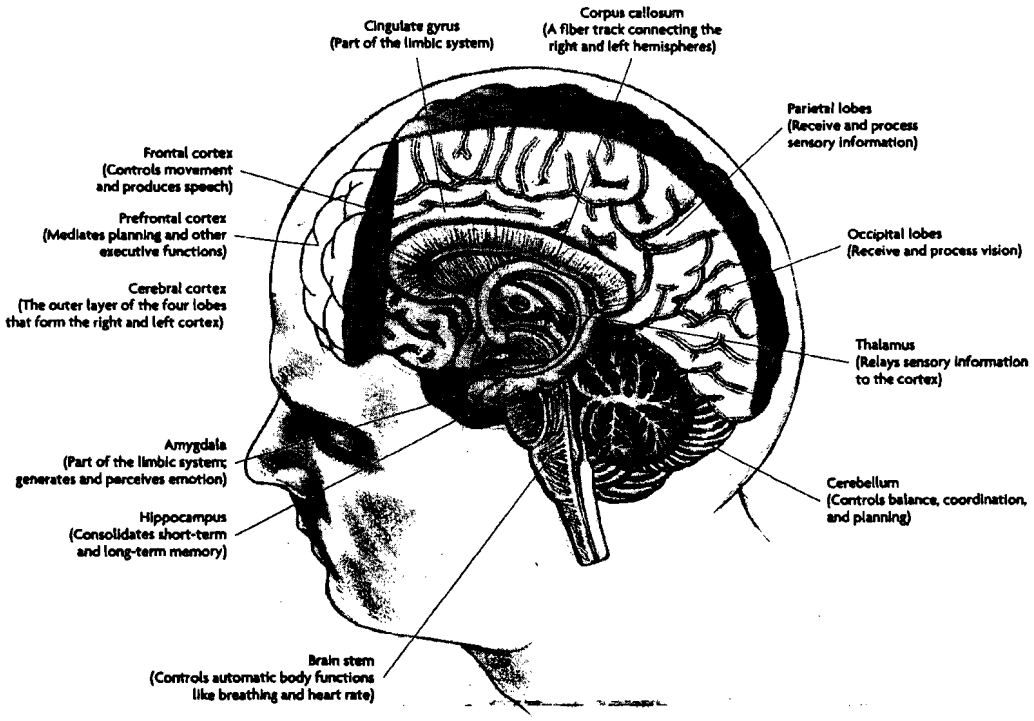
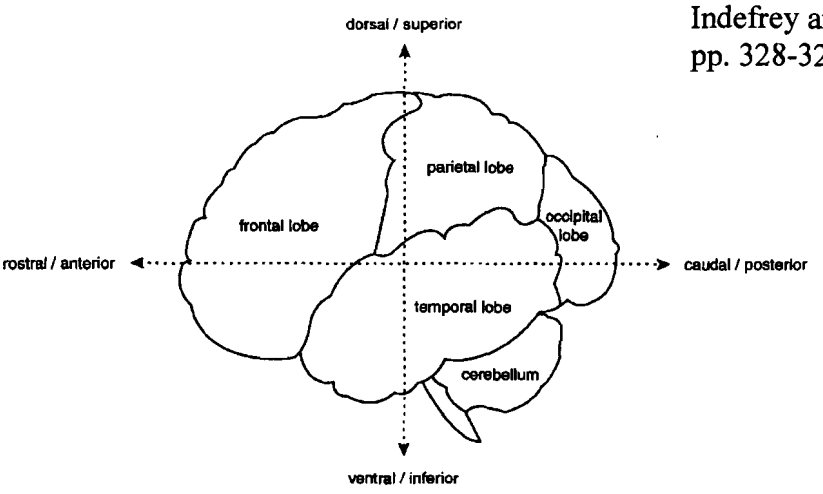
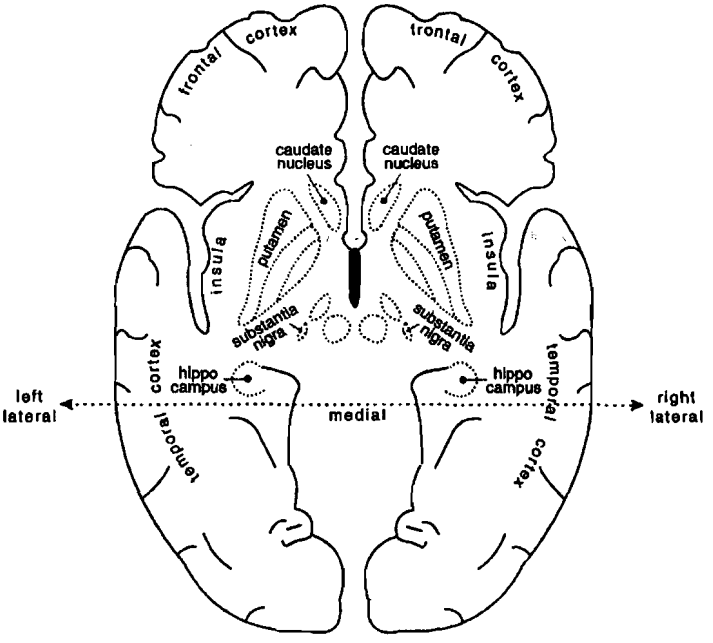
Appendix A: Images of the Brain

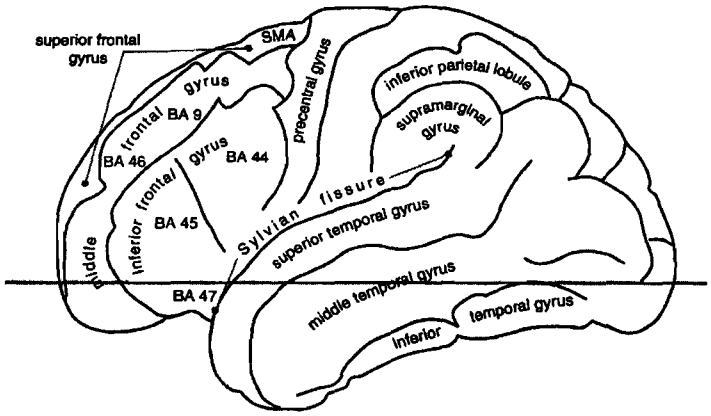


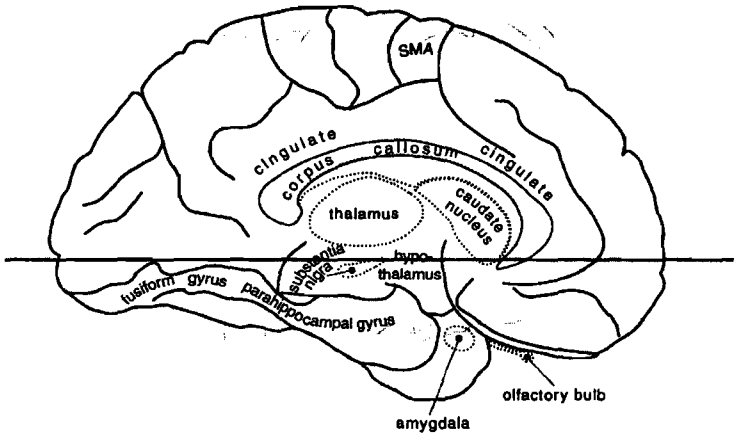
Restak, (2001), p. 21

Indefrey and Gullberg, (2006). pp. 328-329






superior frontal gyrus
SMA
middle frontal gyrus
BA 9
BA 46
inferior frontal gyrus
BA 44
BA 45
precentral gyrus
Sylvian fissure
inferior parietal lobule
supramarginal gyrus
superior temporal gyrus
middle temporal gyrus
BA 47
inferior temporal gyrus


SMA
cingulate
corpus callosum
cingulate
thalamus
caudate nucleus
subthalamus
hypo-thalamus
substantia nigra
fusiform gyrus
parahippocampal gyrus
olfactory bulb
amygdala

Appendix B: Letter of Request

To *Name*, *Title* (Dean of Students/ Department Chairperson)--

I am a graduate student at the University of Wisconsin-Stout. I'm in the process of collecting data for my thesis work and I require more research subjects.

(for Chairpersons)—I have been instructed to contact you by *name*, Dean of Students.

The main purpose of this work is to determine if the mental gymnastics inherent with bilingual code-switching will result in improved high-level cognitive skills. I hope to determine if bilingual adults will outperform monolingual adults in multi-tasking exercises.

There would be no cost to your program or institution-- my only needs would be access to possible participants and a small testing area with a table, two chairs, and an outlet.

The methodology to be used is a 40 minute computerized SIMKAP program (time includes instructions and practice questions). I intend to have a sign-up sheet with individual testing times for approximately 50 volunteers.

Because of financial constraints, SIMKAP can only be administered one test at a time; therefore, I would need your facilities for approximately 1 week.

If this sounds feasible, and if it is a project you would like to support, I would greatly appreciate the opportunity to work with your program.

I request your permission to contact the IRB Director and the Foreign Language Chairperson.

Please contact me with any thoughts or concerns.

Sincerely, Nan Boese

nboese@programmed.com

Appendix C: Classroom Presentation Handout

This project has been reviewed by the UW-Stout IRB as required by the Code of Federal Regulations Title 45 Part 46

This work is financed in part by grant #131-4-583008. Results will be published.

TITLE: The Effects of Language Bi-Modalism on Adult Multitasking Abilities

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TEST LOCATION: To be arranged.

DESCRIPTION:

The purpose of this work is to determine if adults with foreign language experience (signed and spoken languages), perform differently on a multi-tasking test when compared to monolinguals (English). Multitasking serves as one potential strategy for measuring high-level perception (i.e. critical, abstract and creative thinking). Therefore, the greater question to be addressed is if foreign language experience would not contribute to other high-functioning mental tasks. Looking for more answers about how we think will help better define the conflicting theories about how the mind works and challenge our present notions about the influence of language on perception, cognitive processes, and intelligence.

The strategy to be used for measuring multi-tasking is the computerized program--'SIMKAP' (Simultaneous Capacity/Stress Tolerance Test). SIMKAP consists of five subtests (or 'games'). In all parts of the test, possible answers are presented on the bottom of the screen and the participant simply mouse-clicks their response. The first three parts involve matching numbers, then letters, and finally geometric figures. The forth part consists of 24 intellectually simple questions which are either logical-numerical ("continue the following series: 2, 5, 8, 11"), logical-verbal ("which word differs from the others: cow, pig, horse, house?"), or arithmetic ("what is 14 minus 7?"). The fifth part of the test requires participants to work on matching numbers or letters or figures while solving questions similar to those in part four. They will also be required to answer additional questions ("you are invited to lunch. On which day do you have time?"). These answers can be found by clicking on a calendar, a telephone book, or a clock displayed on the screen. The entire testing process, including directions and practice questions, takes approximately 40 minutes.

Participants in the study will consist of 150 volunteer students from various institutions. They will be assigned to three sample groups (fifty each) according to their language experience. **Students that currently suffer from neurological problems such as ADD or Depression, as well as anyone afflicted with language problems such as Dyslexia, are asked to refrain.**

BENEFITS AND RISKS:

Participants will get a rare opportunity to learn something about themselves- their ability to multi-task. Multi-tasking is an important component for many careers and would make a nice talking-point for any job interview situation.

If a respondent has an extremely poor performance due to extenuating circumstances such as over-fatigue or test anxiety, there would be no pressure for them to re-take the test; Nor should they be concerned that their performance would taint the overall data.

CONFIDENTIALITY:

Respondents receive a copy of their results upon completing the exercise and their data is automatically and anonymously calculated in with the previously collected administrations.

RIGHT TO WITHDRAW:

If, at any time during the process, a student wishes to withdraw from the study, the computer program will be terminated.

IRB APPROVAL:

This study has been reviewed and granted an exemption by the University of Wisconsin-Stout's Institutional Review Board (IRB). If you have any questions or concerns regarding this study please contact the Investigator or Advisor. If you have any questions or concerns or reports regarding your rights as a research subject, please contact the IRB Administrator.

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Appendix D: Participant Sign-up Sheet

Contact information: Nancy Boese
nboese@programmed.com
(715) 833-0272

If you would like to make your appointment on the half-hour, please initial both lines and specify the time most convenient for you.
Although the time intervals are for one hour, the instructions, practice questions, and test take approximately 40 minutes.
Individual results may be obtained immediately after taking the test. Questions regarding how to evaluate the results may be directed to the 'contact information' listed above.

Test-site location: To be arranged.

Optional (24hrs prior)

Your Initials	Date	Time	Electronic reminder
	Sept., 24 (Sun.)		
NB(sample)		8:00-9:00am	nboese@programmed.com
		9:00-10:00am	
		10:00-11:00am	
		11:00-12:00pm	
		12:00-1:00pm	
NB(sample)	1:30-	1:00-2:00pm	boesen@uwstout
NB	2:30	2:00-3:00pm	
		3:00-4:00pm	

Optional (24hrs prior)

Your Initials	Date	Time	Electronic reminder
	Feb., 12th (Mon.)		
		9:00-10:00am	
		10:00-11:00am	
		11:00-12:00pm	
		12:00-1:00pm	
		1:00-2:00pm	
		2:00-3:00pm	
		3:00-4:00pm	
		4:00-5:00pm	
		5:00-6:00pm	
		6:00-7:00pm	

Appendix E: SIMKAP Result Form

C-22 / 5yrs
born 3/30/1979, female, 27;10 years, Education level 5
Scoring code: sign

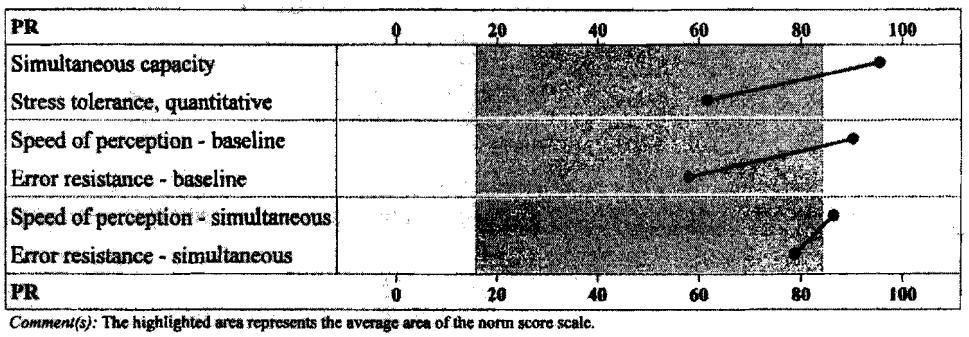
Simultaneous Capacity/Multi-Tasking (SIMKAP)
Test measuring simultaneous capacity and stress tolerance.
Test administration: 2/16/2007 - 11:57...12:45, Duration: 48 min.

Test results - Austrian norm sample:

Test variable	Raw score	PR
Simultaneous capacity	552	96
Stress tolerance, quantitative	305	62
Results - baseline		
Speed of perception - baseline	333	90
Error resistance - baseline	303	58
Results - simultaneous		
Speed of perception - simultaneous	330	86
Error resistance - simultaneous	319	79

Comment(s): The percentile rank (PR) results from a comparison with the comparative sample 'Austrian norm sample'.

Profile - Austrian norm sample:



Comment(s): The highlighted area represents the average area of the norm score scale.