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Effects of Bilingualism on Cognitive Processing in Adults.

Christy J. Witt

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EFFECTS OF BILINGUALISM ON COGNITIVE PROCESSING IN ADULTS

A Dissertation

Submitted to the Graduate Faculty of the
Louisiana State University and
Agricultural and Mechanical College
in partial fulfillment of the
requirements for the degree of
Doctor of Philosophy

in

The Department of Psychology

by
Christy J. Witt
B.A., University of Kansas, 1994
M.A., Louisiana State University, 1998
May 2001
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Abstract

The primary objective of this dissertation was to empirically test the implications of the code-switching hypothesis (Peal & Lambert, 1962) for nonlinguistic cognitive abilities in bilingual adults. It was hypothesized that bilinguals may enjoy cognitive advantages in the nonlinguistic domain for tasks that require abilities related to language switching. To determine if a bilingual advantage exists for the abilities to inhibit the processing of irrelevant information and activate previously suppressed information, bilingual and monolingual adults performed three nonlinguistic tasks designed to measure nonlinguistic task-switching, suppression of irrelevant information, and activation of previously suppressed information. While no differences in performance were observed between the linguistic groups on these tasks, methodological problems with two of the tasks prohibited a conclusive determination about the existence of bilingual advantages. Bilingual adults also performed a language switching task and it was found that linguistic switch costs were positively correlated with nonlinguistic switch costs. The implications of this relationship are discussed in terms of the underlying mechanisms that are utilized for linguistic and nonlinguistic switching. Future directions for exploring bilingual advantages for cognitive processing and elucidating the relationship between nonlinguistic and linguistic switching abilities in adults are discussed.
Historical Overview and Literature Review

Scientific inquiry into the relationship between bilingualism and intelligence began in the early 1920's with the growing popularity of psychometric tests of intelligence. Due to the verbal nature of the intelligence tests, educators and psychologists alike were interested in determining the implications of bilingualism on intelligence test performance of children. Of primary concern was that bilingual children would suffer from some linguistic disadvantages, which would result in unfair assessment of their intelligence (see brief reviews by Diaz, 1983; Hakuta & Diaz, 1985). Several studies were conducted between the early 1920's and the early 1960's in which investigators reported findings that suggested bilingualism produced negative consequences with regard to intelligence and subsequent academic performance of children (see reviews by Arsenian, 1937; Darcy, 1953, 1963). Evidence for the so-called "language handicap" of bilingualism was abundant, and exploration into the negative effects of bilingualism sought to delineate the areas in which the bilingual would demonstrate intellectual deficiencies. Unfortunately, rather than questioning the validity of administering verbal-based tests of intelligence to bilinguals or focusing on the methodological challenges of studying the bilingual population, evidence of the bilingual's linguistic deficiencies resulted in the general belief of the negative effects of bilingualism. Not until Peal and Lambert's (1962) seminal paper on the possible advantages of bilingualism did researchers entertain the possibility that bilingualism may be advantageous in particular respects. Peal and Lambert criticized earlier studies on the grounds that the researchers failed to differentiate "pseudo-bilinguals" from "true bilinguals" and presented their own research in which they found
bilingual children performed significantly better than monolingual children on most cognitive tests, including tests of both verbal and nonverbal intelligence.

**Early Research**

Between the early 1920's and the early 1960's, researchers published evidence suggesting bilinguals do not perform as well as their monolingual counterparts on verbal tests of intelligence (Saer, 1923; Fritz & Rankin, 1934; Barke & Parry Williams, 1938; Darcy, 1946), linguistic measures of vocabulary skill (Saer, 1923; Carrow, 1957) and reading ability (Saer, 1923; Manuel, 1935; Carrow, 1957), and arithmetic reasoning (Manuel, 1935; Carrow, 1957). For the most part, these early studies examined the performance of monolingual and bilingual children between the ages of 2½ and 14½ years of age, with the exception of a group of university students evaluated by Saer (1923). The general conclusion of these studies argued that the bilingual's linguistic confusion fundamentally disturbs the mental functioning of such an individual (Saer, 1923). Although the large majority of studies during these four decades offered evidence for the negative effects of bilingualism, a small number of studies reported findings in which bilinguals performed as well as, and sometimes even better than, monolinguals. For example, Carrow (1957) did not find any differences in the performance of monolingual and bilingual third graders on silent reading comprehension. Additionally, Barke and Parry Williams (1938) reported similar performance on a nonverbal measure of intelligence by monolingual and bilingual 10-11 year olds, whereas Darcy (1946) found that bilingual 2-5 year olds were superior than age-matched monolinguals on a test of nonverbal intelligence.
The first four decades of investigation into the effects of bilingualism on intellectual development and function were plagued by important methodological flaws. The methodological problems stemmed from the particular nature of the bilingual population. One of the most important challenges that faced these researchers was the socioeconomic background of their bilingual samples. Frequently, these researchers obtained their bilingual samples from immigrant populations who were disproportionally clustered in low socioeconomic situations. Manuel (1935) reported superior reading performance of monolingual 2nd-8th graders compared to bilingual children of the same grades, but of significantly lower socioeconomic environment. Even though a positive correlation between socioeconomic status and some intelligence test performances had already been identified at this time (Fukuda, 1925), the majority of these early researchers did not control for socioeconomic status in their studies which would require matching the monolinguals with the bilinguals on this important factor. Regrettably, much too often bilinguals from low socioeconomic backgrounds were compared to monolinguals from more affluent environments (see Cummins, 1976).

In addition to the confounding of socioeconomic status and linguistic experience in these early studies, the appropriateness of the bilingual samples examined in several cases was not always optimal. Across the early studies, researchers examined a wide variety of bilingual populations and in some instances, it is possible that certain bilingual samples consisted of monolingual speakers of a minority language with minimal L2 exposure, rather than individuals who speak two languages (Hakuta & Diaz, 1985). A large portion of these studies included individuals who were proficient in only one
language, usually a non-English first language (L1), and their English proficiency was poor and considerably worse than their English-speaking monolingual comparison groups. Other researchers defined their bilingual samples on the basis of the parents’ native languages (Fritz & Rankin, 1934), family name or even place of residence (in Hakuta & Diaz, 1985). For example, Fritz and Rankin (1934) categorized a sample of 7th-9th grade students as either monolingual or bilingual on the basis of the languages spoken by the students’ parents. Surprisingly, no measure of the students’ linguistic abilities in any language was considered when assigning the individuals to either linguistic group. Before concluding, however, that the early studies of the effects of bilingualism on intellectual functioning are entirely unreliable due to methodological inadequacies, it should be stated that several early studies were more rigorous in their selection of monolingual and bilingual samples than those previously reviewed. One such example is exemplified by the selection of the monolingual and bilingual samples studied by Carrow (1957). Based on parental interviews, third graders were defined as monolingual children if they had been exposed only to English since infancy and could only communicate in English, while the bilingual sample was comprised of children who had been exposed to both English and Spanish since infancy and were able to communicate in both English and Spanish by the age of three. In addition to classifying the children based on these specific linguistic requirements, both language groups were matched on gender and socioeconomic status, and differences in performance between the two groups on a measure of nonverbal intelligence were nonsignificant. The null results are, therefore, more reliable due to the more rigorous methodological standards.
Overall, the first 40 years of research into the effects of bilingualism on intellectual functioning generated a substantial amount of evidence of the negative effects of bilingualism. By the early 1960's, however, Peal and Lambert (1962) set out to explore the positive effects of bilingualism on cognitive processing. Influenced by a discussion by O’Doherty (1958), these researchers speculated that the previous findings of the negative effects observed in the intellectual performance of bilinguals were due to certain characteristics of the samples studied, rather than true bilingualism, because many earlier researchers failed to distinguish between “genuine bilinguals” and “pseudo-bilinguals.” Peal and Lambert conceded that pseudo-bilinguals probably suffer intellectually from the fact that they have not fully mastered either of their languages, but they hypothesized that the true bilingual, that is one who has full mastered both languages, may experience benefits with regard to intellectual development because of their bilinguality. To test their hypotheses, Peal and Lambert administered several measures of French and English proficiency to 10-year olds in French schools in Canada. To be included in the bilingual sample, students had to demonstrate equivalent linguistic skill in both French and English. The monolingual and bilingual samples completed several tests of verbal and nonverbal intelligence. Contrary to the findings of the earlier studies, Peal and Lambert found that bilinguals performed significantly better than monolinguals on verbal and nonverbal intelligence tests even when differences in gender, age, and socioeconomic status were controlled across the two linguistic groups.

Since this important work by Peal and Lambert, researchers have continued to contemplate the implications of bilingualism for cognitive processing. In the past 30
years, attention has been focused on the methodological issues involved in studying bilingualism, as well as the different cognitive abilities that may or may not be differentially affected by bilingualism. In the early 1970's, several studies were published which suggested that bilingualism may influence the early metalinguistic abilities of children, and in the 1980's, researchers focused on the degree of bilingualism as being an important predictor of subsequent positive or negative consequences of bilingualism. More recently, researchers have considered how the degree of bilingualism affects a multitude of cognitive tasks and implications for bilingual education are often considered.

**Bilingualism and Metalinguistic Awareness in Children**

The most common line of inquiry into the effects of bilingualism on cognitive processing has concentrated on metalinguistic awareness in children. *Metalinguistic awareness* refers to the ability to view language not only as a medium of meaningful expression, but to appreciate the objective and functional properties of language, independent of meaning. Recognizing that a word is the discrete unit of language which is combined with other units of different classes according to specific rules is an example of metalinguistic awareness. When certain properties of language are understood, one is capable of analyzing linguistic input objectively (Cummins, 1978). Investigation of children’s language has revealed a progressive understanding of the functional properties of language and an ability to objectively analyze linguistic input. This progressive metalinguistic understanding is often referred to as *metalinguistic development*. Early studies of metalinguistic development in children typically examined monolingual
children's performance on a variety of metalinguistic tasks. The metalinguistic tasks were designed to measure the children's understanding of the arbitrariness of language, the word-referent relationship, the non-physical nature of words, and the concept of "word" as a discrete unit of language, as well as the existence of syntactic rules.

It has been suggested that possessing two linguistic systems may accelerate the bilingual's metalinguistic development. With regard to the concept of arbitrariness of language and the word-referent relationship, researchers have posited that bilinguals are aware of this objective property of language before their monolingual counterparts because bilinguals possess two words, or labels, for each referent. By virtue of this experience, the bilingual is more willing to accept multiple labels for the same referent than the monolingual because the bilingual realizes the label of a referent does not interfere with the existence of the referent. Not only have researchers suggested that bilinguals enjoy a metalinguistic advantage with regard to the understanding of the arbitrariness of language, but that other metalinguistic abilities may be positively affected by bilingualism. For example, some researchers claim that the bilingual's utilization of two different languages with different syntactic qualities may also facilitate the bilingual's realization of the rule-governed nature of language earlier than the monolingual. Furthermore, many researchers contend that the bilingual experience confers a variety of metalinguistic advantages upon the bilingual, well before the appearance of such abilities in the monolingual.

In a number of empirical studies, investigators have compared monolingual and bilingual samples on their performance on a variety of metalinguistic tasks (Ben-Zeev,
1977; Bialystok, 1988; Bialystok & Majumder, 1998; Cummins, 1978; Edwards & Christophersen, 1988; Feldman & Shen, 1971; Galambos & Goldin-Meadow, 1990; Ianco-Worrall, 1972; Merriman & Kutlesic, 1993; Mohanty & Babu, 1983; Pattnaik & Mohanty, 1984; Ricciardelli, 1992; Rosenblum & Pinker, 1983; Yelland, Pollard, & Mercuri, 1993). These studies were designed to measure monolingual and bilingual children’s ability to understand the symbolic quality of language which includes measures of the arbitrariness of language and the word-referent relationship, in addition to the non-physical nature of words, the concept of “word”, and children’s understanding of language as rule-governed.

Regarding the effect of bilingualism on the understanding of the symbolic nature of language, ample evidence has been provided that suggests a bilingual advantage does indeed exist (Ben-Zeev, 1977; Bialystok, 1988; Cummins, 1978; Edwards & Christophersen, 1988; Feldman & Shen, 1971; Ianco-Worrall, 1972; Merriman & Kutlesic, 1993; Mohanty & Babu, 1983; Pattnaik & Mohanty, 1984; Yelland et al., 1993). For example, when children between the ages of 4-16 years are asked if names of objects can be interchanged or if they are asked to actually substitute a new label for a known object, bilingual children appear to perform this task with more success than their monolingual counterparts. Bilingual children were more accepting of interchanging names and substituting new labels for known objects. As detailed below, the findings are more diverse, however, with regard to a bilingual advantage for understanding the word/referent relationship, the non-physical nature of words, the concept of a word, and the syntactic properties of language.
Ricciardelli (1992) and Yelland, Pollard, and Mercuri (1993) compared monolingual and bilingual children’s ability to discriminate between word length and referent size as a measure of their understanding of the word/referent relationship. In the study conducted by Yelland et al., children were asked to name a pictured object and decide whether the name was a “big word” or a “little word.” They were exposed to small objects whose name is a small word (e.g. ant), small objects whose name is big (e.g. caterpillar), big objects whose name is a big word (e.g. hippocampus), and big objects whose name is a small word (e.g. whale). Although Yelland et al. and Ricciardelli both examined children between the ages of 5-6 years, Yelland et al. reported a bilingual advantage on this task, whereas Ricciardelli found no effect of bilingualism.

Cummins (1978), Mohanty and Babu (1983), and Edwards and Christophersen (1988) measured monolingual and bilingual children’s understanding of the nonphysical nature of words by asking questions like “Is the word ‘book’ made of paper?” Does the word ‘bird’ have feathers? Can you buy sweets with the word ‘penny’?” Although Cummins did not observe a bilingual advantage with this task in children aged 8-9 years and 11-12 years, Mohanty and Babu and Edwards and Christophersen did report evidence of a bilingual advantage in children between 4-6 years and 10-16 years.

To measure a child’s understanding of the concept of “word,” children have been given lists of words and phrases and are asked to identify each word. Typically, children are exposed to expressions in which multiple words define one concept like “the furry dog.” Children who do not fully understand the concept of the word “word” will
Pattnaik and Mohanty (1984) and Bialystok (1988) observed a bilingual advantage for this ability in children between the ages of 6-10 years, whereas Edwards and Christophersen (1988) and Ricciardelli (1992) did not find evidence of a bilingual advantage for this metalinguistic ability in children between the ages of 4-7 years.

Finally, when children's understanding of the syntactic properties of language was tested by asking them to detect and correct syntactic errors in their L1, Bialystok (1988), Galambos and Goldin-Meadow (1990), and Ricciardelli (1992) reported finding a bilingual advantage for this metalinguistic ability for children between the ages of 5-8 years, whereas Edwards and Christophersen (1988) and Bialystok and Majumder (1998) did not for children between the ages of 4-9 years.

Arguments that support the notion that a metalinguistic advantage is conferred upon bilingual children claim that it is the bilingual's experience with two labels for each referent and their utilization of two syntactic systems that contribute to the precocious metalinguistic awareness that has been empirically demonstrated for bilingual children. The bilingual experience, therefore, is thought to facilitate an analytic orientation toward language and augment the control of the objective properties of language (Diaz & Klingler, 1991). In attempting to construct an explanatory model of the interaction between bilingualism and metalinguistic awareness, Diaz and Klingler (1991) suggest that the bilingual's superior control of language processing is a direct consequence of bilingualism and that the "systematic separation of form and meaning that is experienced..."
in an early bilingual experience gives children an added control of language processing” (p. 175).

Although it is premature to conclude that all metalinguistic abilities are preferentially enjoyed by bilinguals given the methodological shortcomings of many of the empirical studies, the quantity of evidence demonstrating a bilingual advantage for certain metalinguistic abilities cannot be discounted. Further careful experimentation is necessary in order to delineate the exact effects of bilingualism on metalinguistic development.

**Bilingualism and Cognitive Processing in Children**

During the past three decades, a metalinguistic advantage for bilingual children has been demonstrated, with some degree of consistency, by many researchers. The bilingual advantage for metalinguistic tasks appears to be related to the bilingual’s superior ability to analyze the objective properties of language due to their unique linguistic experience with two language systems. Given the importance of language for other cognitive processes, several researchers have extended the investigation of bilingualism to other cognitive tasks. Some have suggested that the bilingual’s ability to objectively analyze the functional properties of language systems may transfer to other tasks that require symbolic understanding. It is unclear, however, how the metalinguistic skills of bilinguals are related to cognitive abilities that are not directly related to language like nonverbal pattern recognition tasks, for example (Diaz & Klinger, 1991).

Peal and Lambert (1962) suggested that switching linguistic codes while performing cognitive tasks provides the bilingual with a higher degree of cognitive
flexibility that the monolingual does not enjoy. An important limitation of this hypothesis, however, is the absence of an operational definition with regard to the higher degree of cognitive flexibility supposedly enjoyed by bilinguals. Nonetheless, the general flavor of this hypothesis is that the bilingual benefits from an ability to change their cognitive strategies during problem solving with ease and entertain more alternative solutions due to their propensity for analytic problem-solving. Researchers who have explored the effects of bilingualism on cognitive processing in children have employed intelligence tests, measures of cognitive ability, creativity tasks, and measures of academic achievement (Barik & Swain, 1976; Ben-Zeev, 1977; Bialystok & Codd, 1997; Bialystok & Majumder, 1998; Clarkson & Galbraith, 1992; Cummins, 1977; Diaz, 1985b; Genesee, Tucker, & Lambert, 1975; Hakuta, 1987; Hakuta & Diaz, 1985; Hsieh & Tori, 1993; Jarvis, Danks, & Merriman, 1995; Kessler & Quinn, 1980; Lambert, Tucker, & d’Anglejan, 1973; Landry, 1973b; Landry, 1974; Liedtke & Nelson, 1968; Magiste, 1980a; Magiste, 1980b; Murphy, 1990; Pattnaik & Mohanty, 1984; Ricciardelli, 1992; Srivastava, 1991; Torrance, Gowan, Wu, & Aliotti, 1970). The code-switching hypothesis has been very influential in perpetuating a substantial amount of research in the area of bilingualism and cognitive processing, but as Diaz (1983) points out, there is no empirical evidence to support the supposition that the bilingual engages in code switching while performing cognitive tasks.

In reviewing the literature, no differences between monolingual and bilingual children were reported for a variety of nonverbal intelligence measures, although these findings are only speculative considering the characteristics of the samples studied (Barik...
and Swain, 1976; Murphy, 1990). Further experimentation is necessary to elucidate the effect of bilingualism on nonverbal intellectual development for more balanced bilinguals. There is evidence, however, that suggests a bilingual advantage may exist with respect to certain cognitive abilities, namely concepts of conservation (Liedtke and Nelson, 1968) and problem-solving tasks which required control of processing (Bialystok & Codd, 1997; Bialystok & Majumder, 1998). For tasks involving concepts of conservation, the child must be capable of not only focusing her attention on cues of height, length, depth, and size, but also be willing to analyze these cues in conjunction with one another. The bilingual’s heightened ability to perform such tasks may evidence the bilingual’s aptitude for objectification (focusing attention on specific properties of an object) and divergent thinking abilities (approaching a problem from more than one perspective). It is suggested that these bilingual advantages are a result of the bilingual’s greater cognitive flexibility which derives from the bilingual’s language switching experience and the bilingual’s precocious metalinguistic development.

With regard to creative or divergent thinking abilities, the findings of a bilingual advantage are more consistent, even though a variety of creativity measures had been employed by the investigators. For example, Landry (1974) reported a bilingual advantage for divergent thinking abilities based on sixth graders’ performance on the Torrance Tests of Creative Thinking\textsuperscript{1}, while Lambert et al. (1973) observed a bilingual advantage in creativity when the bilingual group outperformed the monolingual group on a number of divergent thinking measures.

\textsuperscript{1}This standardized test measures children’s divergent thinking abilities in terms of fluency (ability to produce several alternatives in response to a problem), flexibility (ability to alternate between different categories in producing responses to a problem), and originality (uniqueness of problem-solving solutions) in problem solving and picture completion tasks.
advantage for creativity measures that required the interpretation of letter and number sequences and the generation of unusual uses for common objects. It appears that experience with two language systems may augment the bilingual’s ability to generate multiple original responses in problem-solving situations. This ability, it is believed, is a consequence of the bilingual’s experience of switching languages. Unfortunately, this explanation is not supported by any research, empirical, anecdotal, or otherwise. Therefore it is necessary to investigate how language switching actually facilitates divergent thinking abilities.

The consequences of bilingualism have also been considered for children’s academic achievement. For example, it is unclear how bilingualism affects mathematic abilities in children. It is reasonable to assume that bilinguals who solve mathematic problems in both languages simultaneously will experience linguistic interference which may ultimately retard their reaction times, but it is not clear if bilinguals will experience a disadvantage if they solve problems in their preferred language.2 With regard to science abilities, bilingualism does not appear to adversely affect children’s performance on standardized science tests (Lambert et al., 1973), and there is preliminary evidence suggesting that bilinguals may benefit from an aptitude in generating scientific hypotheses (Kessler & Quinn, 1980). This aptitude in generating scientific hypotheses may be explained by bilingual children’s superior divergent thinking abilities, although this possibility has not been adequately studied. Therefore, given the small number of

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2Magiste (1980a) observed longer reaction times and poorer accuracy for balanced bilingual children on a mathematical test. The author attributed the bilingual disadvantage to linguistic interference while solving the mathematical problems.
studies on the effects of bilingualism for academic achievement, in conjunction with the methodological shortcomings of some of these studies, there is no clear evidence for a bilingual advantage for scholastic performance in children.

In summary, the findings regarding the effects of bilingualism on the cognitive functioning of children are somewhat less coherent than those found for children’s metalinguistic abilities. The lack of clear consensus on the implications of bilingualism for cognitive processing in children may be a consequence of the diverse tasks used to evaluate the variety of cognitive abilities previously studied. For example, it is possible that bilingualism affects only a small subset of fundamental cognitive abilities related to the possession of two linguistic systems and that these abilities have not been adequately examined in the previous research. While there is no substantive evidence that suggests bilinguals are more intelligent than monolinguals or that academic achievement is impaired by bilingualism as previously believed, there is preliminary evidence that suggests bilinguals may benefit from greater cognitive flexibility and divergent thinking abilities. It has been suggested that these bilingual benefits are a result of the bilingual’s early metalinguistic development and the bilingual’s experience with switching linguistic code, although the specific cognitive mechanisms involved in code switch have not been previously well-defined. Consequently, the effects of bilingualism on cognitive processing in children is not clearly understood due to the diverse findings reported by previous researchers. Future research is necessary to identify the specific cognitive functions that may be affected by bilingualism and discover exactly how the bilingual’s linguistic experience influences the bilingual’s cognitive development.
Bilingualism and Cognitive Processing in Adults

The majority of empirical studies that explore the effects of bilingualism on cognitive processing have examined young populations of bilinguals (i.e. children). An important question, however, is whether the effects of bilingualism on cognitive processing found in children extend into adulthood. It is possible that bilingualism plays an important role in young children during language development, but that the effects of bilingualism do not persist into adulthood when language is already well-established. Consider, for instance, the bilingual advantage for certain metalinguistic abilities that has been demonstrated in children. This effect may not occur in adulthood because it is a short-lived phenomenon. That is, ultimately the monolingual attains more advanced levels of metalinguistic development and catches up to the bilingual, although the exact timing of these attainments is not fully documented.

It has been suggested that the metalinguistic bilingual advantage found in children translates into a precocious appearance of the understanding of certain functional properties of language rather than a superior linguistic ability that is reserved only for bilinguals. If this is true, superior performance by adult bilinguals on tasks of metalinguistic ability would not be expected because it is assumed that all adults, not just bilinguals, would demonstrate a ceiling effect on these tasks. Consequently, no research has been conducted on the effect of bilingualism on the metalinguistic abilities of adults.

For other cognitive abilities, however, the influence of bilingualism in adults is unclear. If bilingualism results in a higher degree of cognitive flexibility than is enjoyed by monolinguals (e.g. Peal and Lamberts’ (1962) code-switching theory), it is
conceivable that this effect is maintained beyond childhood. Therefore, it is necessary to review the literature with regard to the effect of bilingualism on cognitive processing in adults to determine if some of the effects of bilingualism observed in childhood persist into adulthood. Unfortunately, very few researchers have explored the effect of bilingualism on intellectual functioning in adult populations. Those that have considered this question have employed a variety of tasks measuring cognitive skill.

Inspired by research examining the role of bilingualism in cognitive functioning in children, Lemmon and Goggin (1989) extended this area of inquiry to adults. The purpose of investigating the influence of bilingualism on cognitive ability was to determine whether the findings detected in childhood persist into adulthood. Monolingual (English) and bilingual (Spanish/English) undergraduates were administered measures of English and Spanish proficiency, in addition to several tasks of cognitive skill. It should be noted that the monolinguals were more proficient in English than the bilinguals which is problematic considering the tasks were administered in English. The tasks of cognitive skill consisted of measures of concept formation, mental reorganization, abstract and divergent thinking, and mental flexibility. Fluency and flexibility of thinking were measured by Guilford’s (1967) Utility and Object Naming Tests and verbal concept formation and abstract thinking ability (cognitive flexibility) were measured by the Similarities subtest of the Wechsler Adult Intelligence Scale-Revised. Performance on these tests reflected the adults’ “ability to change directions in thinking” (p. 143). Lastly, four nonverbal subtests of the Cattell Culture Fair Test were
used to measure abstract thinking and concept formation, and the Booklet Category Test was employed as a nonverbal measure of abstracting ability.

The monolinguals outperformed the bilinguals on three measures of cognitive ability: *WAIS-R Similarities*, *Cattell Culture Fair Test*, and the fluency/flexibility ratio of the *Guilford tests*. When the bilingual group was divided into high and low bilinguals, however, the monolinguals performed significantly better than the low bilinguals on seven of the ten measures. Furthermore, the monolinguals and high bilinguals did not differ on their performance with regard to any of the measures of cognitive skill. This is an important distinction considering the bilinguals, overall, possessed an inferior level of proficiency in English compared to the monolinguals. The authors conclude that the overall differences in cognitive ability observed between the monolinguals and bilinguals was due solely to the performance of the low bilinguals. Additionally, it was suggested that bilingualism may have a negative impact on cognitive ability if the bilingual’s language competence in each language is inadequate. It is perhaps presumptuous, however, to draw such a conclusion considering the low bilinguals were at a linguistic disadvantage with regard to their proficiency in English which undeniably affected their performance on the verbal measures of cognitive abilities.

In another study of the effect of bilingualism on intellectual functioning, Miljkovitch (1980) compared monolingual (English and French) and bilingual (French/English) adults between the ages of 18-25 years on tests of nonverbal intelligence, memory, and classification abilities. The classification task required the adults to discover similarities of shape, color, and number of elements in two reference
categories. The reference categories consisted of line drawings. After the reference categories were learned, the adults had to remember the similarities within a reference category in order to indicate how many of the reference category similarities matched subsequent items.

Controlling for intelligence and memory, the author hypothesized that the bilinguals would have more difficulties on the classification task because “bilinguals who live in daily contact with two languages and have to switch frequently from one language to the other usually do not label the categories they manipulate, even if this does not contribute to solving a problem efficiently” (p. 359). The rationale for such a hypothesis, however, was not made clear by the author. Nonetheless, no differences were reported between the two groups with regard to nonverbal intelligence or memory, but the monolinguals were more successful on the classification task compared to the bilinguals. The author concludes that bilinguals who actively utilize their two languages on a daily basis do not verbally label categories, but that these findings are not expected for those bilinguals who do not utilize their two languages on a daily basis. Interpreting these findings based on the rationale offered by the author is difficult due to the absence of empirical evidence suggesting that monolinguals verbally label the categories they discover, while bilinguals do not. Obviously, this type of evidence is necessary before concluding that monolingual and bilinguals differ in the way in which they interpret and define categories.

findings in the children's literature that suggest bilingualism does not influence intellectual functioning of the individual if an adequate level of proficiency has been achieved in both languages, while Miljkovitch demonstrated that bilinguals were worse than monolinguals in a classification task. It is imperative that more research be conducted to explore the effect of cognitive functioning in adults because the few studies that have been conducted do not offer reliable evidence that an intellectual advantage or disadvantage is associated with bilingualism in adults. Furthermore, the rationale offered by Miljkovitch regarding the different manner in which monolingual and bilingual adults interpret categories must be further investigated.

A few empirical studies have explored the effect of bilingualism on the speed and accuracy with which monolingual and bilingual adults solve arithmetic problems (Geary, Cormier, Goggin, Estrada, & Lunn, 1993; Marsh & Maki, 1976). These studies have been attempted to elucidate the effect of bilingualism on memory retrieval of mathematical facts. Given the paucity of empirical studies that explored these questions, Marsh and Maki (1976) and Geary et al. (1993) have attempted to determine if possessing two languages interferes with the retrieval or processing of mathematical information for a relatively nonlinguistic task.

Marsh and Maki (1976) and Geary et al. (1993) compared monolingual and bilingual adults on their ability to complete mathematic problems. Mathematical problems were used in each study to eliminate a verbal component of previous problem-solving measures. Marsh and Maki asked monolingual (English) and bilingual (Spanish/English) adults to perform one, two, and three operation addition problems at
random. For half of the arithmetic problems, the bilinguals were told to provide a verbal response in English and the other half of the problems, they were to respond in Spanish. The monolingual adults always responded in English. The authors reported that although the error rates of monolinguals and bilinguals were similar, the monolinguals’ mean reaction times were lower than the bilinguals’. They conclude that maintaining two languages actively in memory increased the reaction times of the bilinguals.

In a similar study, Geary et al. (1993) tested monolingual (English), weak and strong bilingual (French/English) adults’ ability to solve simple and complex mathematical problems. The mathematical problems consisted of simple addition and multiplication problems of one or more single-digit integers. In contrast to the study conducted by Marsh and Maki (1976), the bilinguals were not asked to provide a verbal answer to the problems. Rather, they indicated their responses by means of typing the numbers on a computer keyboard. Although the authors found that the solution times for simple and complex mathematic problems are fastest for monolinguals, followed by weak bilinguals, and slowest for strong bilinguals, this trend was not statistically significant in two experiments. The authors suggest that “when the experimental task does not require verbal answers, bilingualism does not substantially impact the rate of solving arithmetic problems” (p. 191).

In addition to examining overall reaction times Geary et al. (1993) also analyzed the adults’ reaction times for several components required in mathematical problem solving. Componential analyses of solution times included the reaction times for calculating the product of columnar digits, encoding digits, and the rate of carrying digits.
to the next column for complex problems. It is unclear as to why the authors chose to examine these elements. No differences between monolinguals and bilinguals were found for calculating the product of columnar digits or encoding digits, but the duration of the carry operation for complex addition and multiplication was statistically longer for the strong bilingual group compared to the other two groups who were combined for the analyses. The authors suggest that bilingualism may impact the speed of executing elementary mathematic operations, although the evidence is only weak at best considering the limited scope of the mathematical component in which significant differences between the groups were found.

It is premature to characterize the influence of bilingualism on cognitive processing in adults given the current paucity of empirical studies. The few studies that have been conducted do not provide any conclusive evidence that bilingualism affects, either positively or negatively, cognitive functioning (Lemmon & Goggin, 1989; Miljkovitch, 1980). When bilingualism has been shown to negatively impact cognitive processing, the negative effects are related to the load on processing imposed by the less-established language rather than the experience of being bilingual (Marsh & Maki, 1996; see Takano & Noda, 1993). When the processing load imposed by maintaining two active languages is reduced by allowing nonverbal responses, however, the negative effects of bilingualism on cognitive processing virtually disappear completely (Geary et al., 1993). Therefore, given the extremely small number of empirical studies that have examined the effects of bilingualism on cognitive processing in adults and the diverse findings reported by previous researchers, substantially more research is needed to
determine if cognitive advantages that have been observed in bilingual children persist into adulthood.

Finally, research into the effects of bilingualism in adults may have been neglected for at least two reasons. First, many researchers interested in the effect of bilingualism on cognitive processing have concentrated their efforts on children due to the educational impact of such a linguistic experience. As previously discussed, early research into the effects of bilingualism on cognitive functioning in children was ignited by the fear that bilingualism may adversely affect a child’s intellectual development and consequent academic performance (Diaz, 1983; Hakuta & Diaz, 1985). Secondly, some researchers have made the assumption that bilingualism affects children during language development and that any advantages of bilingualism in childhood inevitably disappear by adulthood, although there is not a sufficient amount of research to either support or contradict this assumption. Therefore, as a contribution to this previously neglected line of inquiry, the purpose of this dissertation is to explore the consequences of bilingualism that persist into adulthood by empirically testing the code-switching hypothesis\(^3\) (Peal and Lambert, 1962) and its implications regarding the effect of bilingualism for cognitive functioning.

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\(^3\)The code-switching hypothesis will be more elaborately described in the next section.
Theories of Bilingualism and Cognitive Processing

Many scientists interested in the effects of bilingualism on cognitive functioning have attempted to identify the ways in which having access to two language systems influences the intellectual development and cognitive processing of the bilingual. The quantity of diverse empirical findings are indicative of the variety of theoretical explanations offered by researchers. For the most part, explanations of the ways in which bilinguality affects cognitive functioning tend to characterize how bilingualism confers advantages on the bilingual, rather than proposing how bilingualism may interfere with, or impede, cognitive processing as was the case before the early 1960's.

Code-switching Hypothesis (Peal & Lambert, 1962)

Code switching is a bilingual behavior which refers to the phenomenon of "switching" between two (or more) languages. True bilinguals are capable of "switching" between their languages with virtually no difficulty. Peal and Lambert (1962) suggest that the ability to interchange languages while solving a problem accords the bilingual cognitive flexibility that monolinguals do not possess. According to Peal and Lambert, the bilingual children were more successful than the monolingual children on a nonverbal test of symbolic flexibility in their study because:

"[bilinguals] typically acquire experience in switching from one language to another, possibly trying to solve a problem while thinking in one language, and then, when blocked, switching to the other. This habit, if it were developed, could help them in their performance on tests requiring symbolic reorganization since they demand a readiness to drop one hypothesis or concept and try another. [monolinguals] of course could not have developed a habit of alternating languages, and therefore, of making use of two different perspectives. One might thus expect them to be more rigid or less flexible than the bilinguals on certain tests." (p. 15)
This hypothesis holds that the ability to “switch” between languages allows the bilingual to entertain two perspectives, which in turn leads to more cognitive flexibility while interacting with the world. As previously reviewed, several researchers have adopted Peal and Lambert’s (1962) code-switching hypothesis as a theoretical foundation from which they explore the cognitive effects of bilingualism.

**Experiential Enrichment Hypothesis (Cummins, 1976)**

The experiential enrichment hypothesis, termed by Cummins (1976), claims that the bilingual child encounters a more diverse set of experiences due either to her parents’ attempt to compensate for the limited exposure the child will have to each language (Liedke & Nelson, 1968), or because the bilingual’s experiences emanate from two cultures (Peal & Lambert, 1962). In explaining why the bilingual children outperformed their monolingual counterparts on a nonverbal test involving concept-formation and symbolic flexibility, Peal and Lambert (1962) suggest

“The broader a child’s experience, the higher the probability that he will have come into contact with the type of ideas and situations that will assist him in his performance. The bilingual child has been exposed to a wider range of experiences than the monolingual, because his experiences stem from two different cultures. This enriched environment may benefit him on nonverbal tests.” (p. 15)

The belief is that this wider range of experience will result in preferential cognitive growth. It has been suggested that the bilingual’s contact with people, traditions, and beliefs from other cultures enhance the bilingual’s intellectual development. In order for this explanation to be empirically evaluated, one must demonstrate that the bilingual is indeed exposed to a greater quantity of social or cultural experiences, and that this greater quantity of experiences enhances cognitive development (Cummins, 1976).
Objectification Hypothesis (Cummins, 1976; Diaz, 1985, Hakuta, Ferdman, & Diaz, 1987)

Articulated by Cummins (1976) and based on commentaries by Imedadze (1960), Leopold (1949), and Vygotsky (1962), the objectification hypothesis asserts that because bilinguals possess two words for each referent, they are aware of the functional properties of language earlier than monolinguals. According to Cummins (1976), the implication of having access to two language systems, rather than one, and understanding the objective properties of language earlier than monolinguals is the foundation of the objectification hypothesis:

"The objectification hypothesis merely asserts that bilingualism represents a more powerful linguistic instrument than unilingualism with which to operate on the environment." (p. 35)

Compared to monolinguals, bilinguals, especially children, have demonstrated a particular advantage on measures of metalinguistic awareness (i.e. a special "objective" awareness of language and its functional properties independent of semantic reference). Diaz (1985) elaborates on the objectification hypothesis in speculating that bilinguals' ability to objectify language is "conducive to higher levels of abstract thinking and concept formation" (p. 21).

Verbal Mediation Hypothesis (Diaz, 1983; Hakuta et al, 1987)

It has been suggested that experience with more than one language, coupled with early metalinguistic awareness, encourages the bilingual to utilize verbal mediation in performing cognitive tasks. This hypothesis posits that superior bilingual performance on nonverbal problems is due to the bilingual's precocious reliance on verbal strategies while solving such tasks (Hakuta & Diaz, 1985). The bilingual child recognizes the
function of language as an instrument of thought earlier than the monolingual and consequently benefits from a more effective and precocious use of language.

**Threshold Hypothesis (Cummins, 1976)**

Cummins (1976) advanced the threshold hypothesis which proposes that the levels of linguistic competence attained by a bilingual child in both her L1 and L2 may mediate the effects of her bilingualism on cognitive development and processing. Cummins postulates that there may be a threshold level of linguistic competence in L2 which a bilingual child must attain both in order to avoid cognitive deficits associated with inadequate linguistic competency and to allow for the potential cognitive benefits of bilingualism with higher levels of linguistic competency. In order to accommodate empirical evidence available at the time, Cummins posited that there are probably two thresholds of linguistic proficiency that will influence the way in which a bilingual will or will not experience the effects of her bilingualism in terms of cognitive processing (Cummins, 1976, 1987). Although Cummins maintains that these thresholds cannot be characterized in absolute terms, the attainment of the lower threshold would allow the bilingual to escape the negative consequences of insufficient linguistic proficiency in both languages, and the higher threshold would need to be reached in order to benefit from possessing sufficient linguistic competency in two languages. Additionally, it is suggested that the bilingual would not experience any advantages or disadvantages associated with bilingualism if the bilingual was highly proficient in her dominant language, but only moderately proficient in her non-dominant language. With regard to the nature of the relationship between bilingualism and cognitive functioning, Cummins
specifies the role of the threshold level of bilingual competence as an intervening variable rather than a causal variable and suggests that other "more fundamental social, attitudinal, educational and cognitive factors" (p. 23) determine the effects of bilingualism on cognitive growth.

**Level of Bilingualism Hypothesis (Bialystok, 1987, 1988)**

In an attempt to reconcile the inconsistent findings with regard to bilingualism and metalinguistic awareness, Bialystok (1987, 1988) proposed a hypothesis in which level of bilingualism interacts with two metalinguistic abilities in different ways. *Analysis of knowledge* and *control of processes* are two metalinguistic skill components which are claimed to be differentially affected by bilingualism in solving metalinguistic problems (language tasks). Bialystok defines the component skill of *analysis of knowledge* as "the ability to construct explicit representations of linguistic knowledge" (1987, p. 155) and *control of processes* as "the ability to control linguistic processes by intentionally selecting and applying knowledge to arrive at a solution" (1987, p. 155). Although metalinguistic tasks typically incorporate both skill components, these tasks can be defined by the dominant component which is most important to the solution of the language task.

Bialystok (1987, 1988) suggests that the bilingual possesses an advantage, compared to the monolingual, with regard to the skill component of *control of processes*. This advantage, Bialystok maintains, is a result of precocious metalinguistic awareness that has been empirically demonstrated in bilingual children (e.g. Ben-Zeev, 1977, Ianco-Worrall, 1972 and others). With regard to *analysis of knowledge*, however,
only those bilinguals who have attained a high level of proficiency in each language will possess an advantage on metalinguistic problems requiring *analysis of knowledge*, compared to partial bilinguals and monolinguals because this metalinguistic component requires an advanced ability to extract linguistic structures or rules which is hypothesized to be a characteristic of only the bilingual who is highly proficient in both languages.

The way in which the bilingual’s level of proficiency in each language affects her ability to solve metalinguistic tasks that involve both analysis of knowledge or control of processes is similar in spirit to Cummins’ (1976) threshold hypothesis in that the level of the proficiency in each language can predict the effect bilingualism will have on different metalinguistic abilities.

In conclusion, a variety of hypotheses have been advanced which attempt to account for metalinguistic and cognitive advantages that have been observed in bilinguals. For the most part, these hypotheses were conceived to explain the effects of bilingualism in children, although some of the hypotheses could be reasonably applied to bilingual adults (i.e. code-switching hypothesis and threshold hypothesis). Others, however, do not extend themselves to empirical investigation, with children or adults, due to the untestable nature of loosely defined hypotheses. The present study explores the implications of the code-switching, and to a lesser degree the threshold hypothesis, for the adult bilingual population. In this dissertation, it is argued that the underlying mechanism in code switching involves the suppression or inhibition of the language that is no longer in use. This supposition was formulated based on the bilingual’s ability to switch between his/her two languages. Tasks that require switching between simple
cognitive tasks, suppressing information, and activating previously suppressed
information were utilized in testing the code-switching hypothesis as it relates to adults.
Secondly, degree of bilingualism was also considered to determine if this factor is useful
in explaining the inhibitory abilities of bilingual adults.
Implications of Past Research

During the past four decades, a multitude of studies varying in methodological quality have been conducted on the effect of bilingualism on cognitive functioning. The overwhelming majority of these studies have examined the effect of bilingualism in children, rather than adults, and a variety of theories have been proposed to explain the observed cognitive consequences of bilingualism. With respect to metalinguistic abilities of bilingual children, the research is consistent in demonstrating a bilingual advantage for children's understanding of the arbitrary nature of language. For cognitive abilities of bilingual children, however, the research is less consistent. Finally, the paucity of research on the effect of bilingualism in adults prohibits a conclusive summation of the effect of bilingualism on the cognitive processing of adults at this time.

With the publication of Peal and Lambert's (1962) seminal paper reporting a bilingual advantage for intellectual abilities, researchers began to consider the possible cognitive advantages associated with possessing two languages. Peal and Lambert proposed the code-switching hypothesis which posits that bilinguals benefit from a greater degree of cognitive flexibility due to their experience of switching between two linguistic systems in problem-solving situations. They suggest that if the bilingual's ability to switch languages is well-developed, performance on tasks requiring symbolic reorganization will improve as a result of their readiness to discontinue one hypothesis for another more appropriate hypothesis. The author of this hypothesis offers no empirical evidence, however, to suggest bilinguals actually do this. Although there is no empirical evidence which demonstrates that bilinguals do switch languages while
performing cognitive tasks, this hypothesis has generated much research on the effect of bilingualism on cognitive processing.

Several studies from the children's literature support the contention that bilinguals benefit from greater cognitive flexibility on tasks of verbal and nonverbal intelligence (Cummins, 1977; Diaz, 1985b; Hakuta, 1987; Hakuta & Diaz, 1985), cognitive measures of concept formation and conservation (Liedtke & Nelson, 1968), and creativity (Cummins, 1977; Lambert et al., 1973; Landry, 1974; Ricciardelli, 1992; Srivastava, 1991). Although the code-switching hypothesis predicts this bilingual advantage for tasks requiring high degrees of cognitive flexibility, it is unclear how code-switching abilities transfer to these tasks. Moreover, research needs to be conducted on the code-switching behavior of bilinguals to determine the frequency of linguistic switching and how code switching results in enhanced cognitive flexibility. For example, it will be important to determine if bilinguals who engage in frequent code switching demonstrate a greater degree of cognitive flexibility than bilinguals who infrequently code switch and monolinguals.

The primary limitation of the code-switching hypothesis is the lack of explanation of how code switching influences cognitive flexibility. If indeed code switching is responsible for the bilingual cognitive advantages observed in children, future research should focus on the mechanisms involved in code switching that are believed to be transferred to tasks requiring cognitive flexibility. For example, when a bilingual code switches, one language must be deactivated and the other activated to reduce linguistic interference from two fully-activated linguistic systems. Secondly, after the switch is
completed, the bilingual must be capable of inhibiting further processing of the deactivated language to diminish the possibility of interference. If code switching augments the bilingual's ability to deactivate or inhibit thought processes to allow activation of alternative thought processes, a bilingual advantage would be predicted for tasks that require the individual to switch between tasks that require different cognitive abilities. For example, if monolinguals and bilinguals were administered a problem-solving task which required them to generate multiple alternative hypotheses in order to arrive at the correct solution, a bilingual advantage would be predicted by the code-switching hypothesis.

Future exploration into the effects of bilingualism on cognitive functioning in children and adults should focus on the mechanisms responsible for the observed differences in performance among monolingual and bilingual populations. It is necessary to experimentally differentiate between the theories that attempt to explain how bilingualism affects cognitive functioning. Basic principles of cognitive psychology such as inhibition and selective attention may provide researchers with a conceptual framework from which they may postulate testable hypotheses regarding the specific mechanisms responsible for the observed effects of bilingualism on cognitive functioning. If indeed bilinguals are more adept at selectively focusing their attention in certain problem-solving situations, researchers should be able to demonstrate a bilingual advantage for cognitive tasks that require selective attention. For example, in a dichotic listening tasks, subjects are instructed to attend to input in one ear and disregard input in the other ear. This task requires control of selective attention to one stimulus, while
simultaneously ignoring another. It is expected that bilinguals would be more successful that monolinguals on this task if selective attention is responsible for some of the cognitive advantages demonstrated in bilinguals.

Although the code-switching hypothesis has been extensively tested in bilingual children, the few studies on bilingual adults do not provide any evidence of greater cognitive flexibility in bilingual adults. There is no reason to conclude, however, that the code-switching hypothesis is not applicable to the adult bilingual population, even though it was originally conceived as an attempt to explain cognitive advantages in bilingual children. Therefore, the present study empirically evaluated the predictions of the code-switching hypothesis for cognitive processing in bilingual adults.

Cummins' (1976) *threshold hypothesis* provided an essential theoretical contribution to understanding the interaction of bilingualism and cognitive processing by highlighting the importance of linguistic competency in predicting when bilingual advantages for certain cognitive abilities will be detectable. Rather than viewing bilingualism as a unidimensional characteristic, Cummins proposed that the bilingual’s *degree* of linguistic competence in L2 may mediate the effects of bilingualism on cognitive processing. The threshold hypothesis postulates the existence of a threshold level of linguistic competence in L2 that must be attained in order for the cognitive advantages associated with bilingualism to occur. Before this threshold is reached, Cummins speculates, the bilingual will not experience any advantages associated with bilingualism. The principle contribution of the threshold hypothesis is the emphasis it places on the bilingual’s *degree* of bilingualism in determining when cognitive advantages
associated with bilingualism will be apparent. Degree of bilingualism is an important
factor to consider in investigating the effects of bilingualism on cognitive processing.

In some of the previously reviewed literature, bilingualism appeared to be defined
somewhat loosely (i.e. either you are bilingual or you are not), rather than appreciated as
a continuum of L1 and L2 competence (i.e. high levels of proficiency in each language,
high level of proficiency in only one language, low levels of proficiency in each
language). In examining only bilingual children of varying degrees of L2 proficiency, a
few studies have explored the existence of the hypothesized “L2 threshold”, although no
adequate description of this threshold, in terms of the minimum level of L2 proficiency,
has been advanced (Bialystok, Experiment 2, 1988; Diaz, 1985; Galambos & Hakuta,
1988; Hakuta & Diaz, 1985; Hakuta, 1987). Nonetheless, the most prominent
contribution of the threshold hypothesis is its view of bilingualism as a continuum rather
than a unidimensional phenomenon and the emphasis it places on the importance of
degree of bilingualism.

More research is necessary in evaluating the implications of the threshold
hypothesis for understanding the effect of bilingualism on cognitive processing. For
example, future research should be conducted on bilinguals who represent the whole
continuum of bilingualism, rather than a small section, in an attempt to characterize the
hypothesized threshold. This suggestions is very logical, and in an ideal world there
would be no reason not to examine bilinguals who represent every degree of
bilingualism. However in the real world, bilingual samples are not simple to collect and
sometimes researchers are obliged to “make do” with the bilinguals they have access to
even if they are not representative of the whole bilingual continuum. Nonetheless, to further evaluate the threshold hypothesis, bilingual adults in the present study were defined in terms of their linguistic proficiency in each language.

Most importantly, the methodological inadequacies of past empirical studies must be improved. For instance, when comparing monolinguals and bilinguals on measures of metalinguistic awareness or cognitive ability, it is imperative that these samples be chosen with the utmost of care. The samples should be equated with respect to intelligence, SES, and linguistic proficiency in the language of the tasks because each of these factors contribute to the performance of metalinguistic and cognitive tasks. Controlling for such mitigating factors eliminates the potential confounding of bilingualism with these important variables. Secondly, the bilingual’s level of proficiency in each language must be assessed in order to determine the individual’s degree of bilingualism. This is important for interpreting the findings considering that some researchers, namely those who adhere to Cummins’ threshold hypothesis and Bialystok’s level of bilingualism hypothesis, advance different predictions for bilinguals depending on their degree of bilingual balance.

With regard to adults, more research is necessary to characterize the effect of bilingualism in this population. The few studies that have been conducted, however, do not provide conclusive evidence that bilingualism affects cognitive functioning, although several of these studies suggest that bilingualism may adversely affect cognitive functioning in adults. For example, when bilingualism has been shown to negatively impact cognitive processing, the negative effects are related to the load on processing
imposed by the less-established language rather than the experience of being bilingual (Takano & Noda, 1993). As previously suggested, this area of research may have been neglected for at least two reasons. First, several researchers have concentrated their efforts on children due to the educational impact of the bilingual linguistic experience. Secondly, it is plausible that researchers have assumed that bilingualism only affects children during language development and that any effects of bilingualism in childhood inevitably disappear by adulthood because the monolingual eventually “catches up” to the bilingual.

In conclusion, although an enormous amount of research has been conducted on the effects of bilingualism on cognitive processing, questions still remain as to how bilingualism affects certain cognitive abilities. Therefore, this dissertation focuses on determining how bilingualism interacts with cognitive processing and identifying the mechanisms responsible for some of the previously observed cognitive advantages in bilinguals. Furthermore, additional methodologically sound studies are necessary to characterize the consequence of bilingualism for cognitive functioning in adults. The purpose of the present study is, therefore, two-fold. First, an attempt was made to identify the mechanisms responsible for some of the previously observed cognitive advantages in bilinguals. Secondly, the previously neglected population of adult bilinguals was examined under carefully considered methodological conditions.
Methodological Factors

Defining Bilingualism

Researchers who study the effects of bilingualism on cognitive processing are faced with several important methodological considerations. One of the most important issues facing these researchers is related to the definition of bilingualism. The concept of bilingualism is frequently characterized on the individual level - as a feature of a person who possesses two linguistic systems, although it has also been defined as a social psychological concept, and even a societal construct (Hakuta et al., 1987). The challenge in defining bilingualism on the individual level, however, arises from the complex interactions of the factors used to describe the bilingual. For example, Arsenian (1937) highlighted the importance of factors such as degree of bilingualism, degrees of difference between two languages of a bilingual, age when learning second language, method of learning, and attitude toward second language when considering the selection of a bilingual sample. Defining the bilingual population of interest is one of the first methodological issues researchers in this area will encounter.

Selection of the Bilingual Sample

The bilingual population is, by no means, a homogeneous collection of individuals who possess similar linguistic abilities. Bilinguals vary widely in the extent of their linguistic proficiency in each of their languages. For example, some bilinguals are highly proficient in both of their languages, while others have attained age-appropriate levels of proficiency in only one language, and are at best, moderately proficient in the other language. The former conceptualization of bilinguals describes what Peal and
Lambert (1962) refer to as “balanced bilinguals”, while the latter characterization describes what they refer to as “psuedobilinguals.” Peal and Lambert (1962) distinguished between these two types of bilinguals in order to reconcile the seemingly contradictory findings of the first four decades of research in the area of bilingualism and cognitive processing and suggested that the implications of bilingualism for intellectual development are mediated by the degree to which an individual is bilingual. Therefore, the degree of bilingualism is a critical factor in the selection of a bilingual sample.

Integral to the discussion of degree of bilingualism is establishing the bilingual’s level of proficiency in both L1 and L2. In order to make predictions about empirical outcomes and to properly interpret such findings, it is necessary to carefully describe and appraise linguistic proficiency of the bilingual sample under investigation. Most importantly, it is imperative to quantitatively assess the bilingual’s level of proficiency in each language to facilitate the selection of an appropriate monolingual comparison group. Additionally, the degree of balance between the bilingual’s languages is also of interest. For example, some scientists predict positive effects of bilingualism for only those bilinguals who are “balanced” (i.e. highly competence in both L1 and L2) (e.g. Cummins, 1976). Carefully defining the bilingual population to be sampled for a study allows for more precise predictions about the experimental outcomes, in addition to discussing the specific implications of bilingualism for each type of bilingual (i.e. balanced; unbalanced: L1-dominant, L2-dominant, not proficient in either language).

In characterizing the bilingual sample under investigation, it is also necessary to consider such factors as age of acquisition of each language and the method of learning.
each language. The age at which a bilingual begins to learn each language can be a significant indicator of the bilingual's linguistic ability in each language. Although there is no consensus in the literature as to the most/least optimal ages to learn a second language, there are different expectations with regard to cognitive processing depending on the learner's age of acquisition. For example, bilinguals who acquire both languages simultaneously from a very young age and continually maintain each language tend to be of the more "balanced" variety, whereas bilinguals whose acquisition of their L2 occurs much later than their L1 acquisition are more variable in their degree of bilingualism and proficiency in L2, especially if the bilingual does not actively utilize each language on a regular basis. It should be stated, however, that age of acquisition alone does not adequately predict the bilingual's level of proficiency in each language because other important variables such as the bilingual's attitude about the two linguistic environments and the way in which each language is learned contribute to the bilingual's proficiency in each language.

The manner with which a bilingual acquires each of her languages is of particular interest in selecting a bilingual sample. The language learning situation in which a bilingual is completely immersed in the L2, both at school and outside of school, is very different from the bilingual experience of a school-aged child who is enrolled in a foreign language program that consists of three hours of foreign language education a week. These two language learning situations differ not only in the time spent in the L2, but also in the depth of linguistic exposure and breadth of linguistic experiences. The objective of this discussion, however, is not to advocate either type of learning
experience, rather it is to identify the ways in which bilinguals differ in their bilingual experience and to highlight the important factors that should be considered when selecting a bilingual sample in order to explore the effects of bilingualism on cognitive processing.

With respect, therefore, to the selection of a bilingual sample, it is necessary to consider several important factors related to the bilingual experience in defining the bilingual population from which to sample. It is important to consider the bilingual's degree of bilingualism, level of proficiency in each language, age of acquisition and method of learning each language, in order to precisely define the bilingual sample and make specific predictions about the performance of the sample based on these factors. Rather than including anyone who has experience with two linguistic systems as the criterion for the bilingual sample, careful consideration and evaluation of the factors discussed above are useful in characterizing the bilingual sample, formulating predictions about bilingual performance, and discussing the implications of specific types of bilingualism for cognitive functioning.

Matching Monolingual Samples to Bilingual Samples

Cummins (1976) emphasizes the importance of matching monolingual and bilingual samples on critical personal background variables, and reiterates Peal and Lambert’s (1962) conclusion that such samples should be matched on socioeconomic situation, gender, school system, and age to avoid the confounding of influential variables that are known to be related to intelligence. Cummins (1976) also makes a case for matching the two samples on measures of non-verbal intelligence to augment the
degree of control of non-linguistic intellectual variables. However, by matching monolingual and bilingual samples on a multitude of measures, the probability of detecting any differences between the two linguistic groups is decreased (Diaz, 1983). This latter belief is not endorsed in the more recent literature concerning bilingualism and cognitive processing due to the introduction of confounds when appropriate measures of control are not implemented.

In a discussion of the most important "gaps" in the research in this area, Diaz (1985) highlighted the limitations of comparing monolingual and bilingual samples in order to identify the cognitive effects of bilingualism. The argument made is that monolinguals and bilinguals differ in many important respects, not in only linguistic aspects, and that the multitude of non-linguistic differences between monolinguals and bilinguals prevent any conclusive findings, even when critical personal variables are carefully controlled between the two groups. Diaz (1985), therefore, proposes that the within-bilingual sample design is more appropriate for studying the effects of bilingualism on cognitive processing. The relationship between degree of bilingualism and cognitive processing can be explored by looking at bilinguals with varying levels of proficiency in each language, without introducing confounding variables associated with the comparison of monolingual and bilingual groups.

**Tasks**

When deciding upon the measures of comparison for monolingual and bilingual subjects, one must attempt to administer tasks that do not place one linguistic group at a disadvantage relative to the other. This objective can be realized if the tests are given in
the language in which the bilinguals are most proficient (Peal et al., 1962). For example, when comparing monolingual English-speakers to unbalanced Spanish-English bilinguals, it would not be appropriate to utilize an English version of a verbal intelligence measure without first equating both groups on English proficiency due to the fact that the monolingual group would be tested in their L1 while the bilingual group would perform the test in their L2. If, in fact, both groups are not equivalent in their levels of English proficiency, it would be expected that the bilinguals' performance on a verbal intelligence measure would be inferior to that of the monolinguals simply because the bilinguals were less proficient in English, not necessarily less intelligent, than the monolinguals. In order to circumvent this problem, some researchers rely on nonverbal tests of intelligence to protect against any linguistic bias that may exist in their samples of monolinguals and bilinguals. If, however, the researcher is interested in verbal intelligence measures, it is necessary to equate both groups on the level of proficiency of the language in which the verbal intelligence test is administered in order for proper interpretations of the results.

Determining the relative proficiency of each linguistic group is not only reserved for tests of verbal intelligence. Many researchers investigating the effects of bilingualism on cognitive processing focus on metalinguistic abilities of these individuals. The verbal nature of metalinguistic tasks also necessitate the proficiency equivalence of each linguistic group in order to isolate the effects of bilingualism on metalinguistic abilities, rather than confounding these specific abilities with linguistic proficiency. Therefore, researchers who employ tasks of a verbal nature should compare monolingual and
bilingual groups with equivalent levels of proficiency in the language of the task to eliminate the possibility of confounding linguistic proficiency with the abilities measured by the task under investigation.

In conclusion, important methodological considerations face researchers who study the effects of bilingualism on cognitive functioning. In defining the bilingual sample, it is imperative to describe the sample in terms of the important factors reviewed above because bilinguals are not a homogeneous population. Once the bilingual population has been defined, it is necessary to select a comparison monolingual group that has been matched as closely as possible to the characteristics of the bilingual sample. Lastly, researchers must carefully choose the tasks of the study in order to prevent non-linguistic group differences from biasing the results. Each of these methodological considerations are addressed in the present study.
Introduction to the Present Study

As an initial step in exploring the effects of bilingualism on cognitive processing adults, it is necessary to distinguish monolinguals from bilinguals with respect to their linguistic practices. The obvious distinction is that bilinguals have access to two linguistic systems, while monolinguals possess only one linguistic system. However, this obvious difference between monolinguals and bilinguals must be characterized more precisely for experimental hypotheses to be advanced about potentially differential cognitive processing abilities of these two groups. How does having access to two linguistic systems, rather than one, influence the cognitive abilities of bilinguals relative to monolinguals? A constructive approach to answering this question lies in the linguistic practices of bilinguals.

One distinguishing linguistic practice of bilinguals is their ability to switch between two languages. The code-switching hypothesis, proposed by Peal and Lambert in 1962, suggests that bilinguals benefit from enhanced cognitive flexibility, relative to their monolingual counterparts, due to their ability to switch between languages. One of the weaknesses of this hypothesis, however, is that the mechanisms involved in code switching (i.e. those mechanisms for which a bilingual advantage may exist) are not specified. In order to empirically investigate the code-switching hypothesis, the mechanisms involved in language switching must be identified and specific predictions for bilingual performance with respect to the mechanism must be tested. Furthermore, what is meant by the term “cognitive flexibility” must be operationalized within the context the these empirical questions in order to delineate the effects, if any, of
bilingualism on cognitive flexibility. The primary objective of this dissertation, therefore, it to identify the mechanisms involved in code switching and determine if a bilingual advantage exists for abilities that require this mechanism.

Mechanisms of Code Switching

For the purposes of this dissertation, it is posited that one of the fundamental components involved in language switching is the inhibition of a linguistic system not currently in use. For language switching to successfully occur, one language must be inhibited while the other language is activated to reduce linguistic interference from two fully-activated linguistic systems. Consequently, after the switch is completed, the bilingual must be capable of inhibiting further processing of the suppressed language to diminish the possibility of interference. When communication necessitates returning to the once inhibited language, this language must be activated from its suppressed state. If code switching augments the bilingual’s ability to inhibit thought processes to allow for activation of alternative thought processes, a bilingual advantage would be predicted for tasks that require the individual to suppress or inhibit the processing of irrelevant information. Furthermore, a bilingual advantage may also be predicted for tasks that require the activation of previously inhibited or suppressed information. From this characterization of code switching, it can be concluded that linguistic switching requires an inhibitory mechanism and the ability to activate information from a suppressed state. Therefore, the purpose of this dissertation is to determine if a bilingual advantage exists for nonlinguistic tasks that require the inhibition of irrelevant information and the activation of previously suppressed material.
If bilinguals have more practice than monolinguals at switching between languages, and practice enhances performance, it would seem that bilinguals have more opportunities to develop their inhibition abilities than their monolingual counterparts who do not, presumably, have any practice switching linguistic systems. Consequently, it may be argued that bilinguals could possess superior inhibition abilities to their monolingual counterparts due to their ability to switch linguistic systems. To test this hypothesis, monolingual and bilingual adults performed three computer tasks designed to evaluate their ability to suppress or inhibit the processing of irrelevant nonlinguistic information and activate previously suppressed information. To explore these abilities in monolingual and bilingual adults, three computer tasks that are closely modeled after research conducted on monolinguals only by Rogers and Monsell (1995), Gernsbacher and Faust (1991, Experiment 2), and DeSchepper and Treisman (Experiment 1, 1996) were employed. These tasks require the participants to switch between simple cognitive tasks, suppress the processing of irrelevant information, and activate previously suppressed information. In addition to completing these computer tasks, the bilingual participants also performed a language switching task modeled after a number naming task used by Meuter and Allport (1999).

Task Switching

As a measure of the inhibitory abilities of bilingual and monolingual adults, participants in the study completed a task-switching task. Linguistic switching may enhance a bilingual’s ability to switch between cognitive tasks which requires both the suppression of the task no longer in use and activation of the current task, and the ability
to activate the once suppressed task when it is appropriate to “switch back.” The practice of switching between linguistic systems may afford the bilingual with an enhanced switching ability which would also positively affect cognitive task-switching performance. Therefore, it is reasonable to hypothesize that bilinguals would outperform monolinguals on a cognitive switching task that requires the participant to not only inhibit the task not currently in use, but then reactivate the previously inappropriate task when it again becomes appropriate.

Rogers and Monsell (1995) reported a reaction time cost in switching between simple cognitive tasks. Reaction time was longer when the interval between the response to one cognitive task and the presentation of the stimulus for a different cognitive task (R-S) was short. Switching between two simple cognitive tasks requires suppression of the response to the task that was once appropriate and will again be appropriate, but is no longer appropriate on the current trial (i.e. suppression of the now-inappropriate S-R mapping). The participant is presented with a stimulus pair containing a relevant and irrelevant character, and asked to perform a simple task with regard to the relevant character. The irrelevant character of any given stimulus pair may be the relevant character in future trials. Therefore, the participant must be able to continually activate and deactivate or suppress the response to each task (i.e. switch between two different tasks).

Rogers and Monsell (1995) experimentally explored the effect of switching between simple cognitive tasks on the reaction time cost when the irrelevant character of the current stimulus pair appears as the relevant character in a future stimulus pair. The
researchers demonstrated that it is more difficult to switch between cognitive tasks when the irrelevant character on the current trial was once the relevant character on past trials and will be the relevant character on future trials compared to trials in which the irrelevant character is not associated with either task. It was concluded that the switch cost in reaction time reflects the reactivation of the once suppressed response and the suppression of the now-irrelevant cognitive task.

More specifically, participants in these experiments switched between identifying a letter as a consonant or a vowel and identifying a digit as either odd or even in response to a stimulus that consisted of a pair of characters. The sequence of the trials was predictable: letter task, letter task, digit task, digit task, and so on, so that the participant was aware of when the switch was to occur (i.e. every two trials). The cost of switching was assessed by comparing the participants’ reaction time on trials necessitating a switch (letter task, digit task and digit task, letter task) to trials in which no switching occurred (letter task, letter task and digit task, digit task). In the first experiment, the interval between the participant’s response and the following stimulus was 150 ms. In the no-crosstalk condition, the irrelevant character of the stimulus pair was nonalphanumeric (neutral). Therefore, the participant would not experience any interference from the irrelevant character because it is not associated with either of the cognitive tasks. In the cross-talk condition, however, the irrelevant character was either a letter or a digit that was currently associated with the now-inappropriate task (non-neutral). In comparing the participants’ performance on neutral versus non-neutral trials, the researchers were able to evaluate the degree to which an irrelevant character
associated with a now-inappropriate task makes the task harder to suppress. Differences in reaction times quantify this difficulty.

Rogers and Monsell observed a significant switch cost on the switch trials (224 ms) compared to the non-switching trials. It was also found that the switch cost in the non-neutral condition was significantly greater (128 ms) than in the neutral condition. The researchers demonstrated a reliably large cost in reaction time and response accuracy when a participant switched predictably between two simple cognitive tasks. If the practice of switching between linguistic systems provides the bilingual with an enhanced ability to suppress the processing of irrelevant information (in this context, suppressing a once appropriate task that is currently inappropriate) and activate previously suppressed information (in this context, returning to the once inappropriate task that is now currently appropriate), then one would expect bilingual adults to evidence a lower switch cost than monolingual adults when performing a predictable switch between simple cognitive tasks.

Suppression

In exploring the general cognitive mechanism of suppression, Gemsbacher and Faust (1991, Experiment 2) found that less skilled comprehenders were less efficient in suppressing irrelevant nonlinguistic information. The researchers categorized adults as more and less skilled comprehenders based on their performance on the Multi-Media Comprehension Battery (Gemsbacher & Varner, 1988). Both groups of participants viewed scenic arrays of three to six objects that were related with regard to a particular theme (e.g. farm, nursery, kitchen, backyard, office, city street, living room, campsite,
bathroom, and orchestra). Following the presentation of each scenic array, participants saw the name of a test object and were asked to determine whether the test object appeared in the previously viewed scenic array. For half of the trials, the test object was present in the scenic array, and for the other half of the trials, the test object did not appear in the scenic array. Of interest to the researchers was the participants' performance on the trials in which the test object was not present.

For the trials in which the test object did not appear in the scenic array, half of the test objects were typical of a particular scene, while half of the test objects were not typically associated with the scenic array that preceded its presentation. In comparing the participants' reaction time to rejecting typical but absent test objects to atypical and absent objects (interference), the researchers could determine how activated the typical but absent test object was. The presentation of the test objects proceeded the scenic arrays at two intervals: immediately (50 ms) and after one second. Gernsbacher and Faust found that for both more and less skilled comprehenders, typical but absent objects were activated immediately following the presentation of the scenic array as evidence by interference. However, when the test objects were presented after a 1-s delay, more skilled comprehenders were no longer evidencing a reliable amount of interference, while a significant amount of interference was observed for the less skilled comprehenders. The researchers concluded the less skilled comprehenders were less able to suppress the processing of irrelevant information.

For the present study, a modified version of the suppression task employed by Gernsbacher and Faust was administered to monolingual and bilingual adults to compare
the two groups' ability to suppress or inhibit processing of typical but absent test objects (i.e. irrelevant nonlinguistic information). The modification of the task consisted of presenting a visual object as the test object, rather than the name of the test object. This modification was necessary to create a completely nonverbal task for our two groups of participants. A measure of interference due to continued activation of the test object was obtained by comparing the participant's reaction time to reject typical but absent test objects to the participant's reaction time to reject atypical and absent test objects. A second modification of the original study was the addition of two delay intervals. In addition to the immediate delay interval (50 ms) and the longer delay interval (1000 ms), two intermediate delay intervals (300 ms and 730 ms) were included to evaluate the time course of suppression abilities in the monolingual and bilingual participants. It was predicted that both groups will demonstrate activation of the typical but absent test object immediately following the presentation of the scenic array (50 ms). If, however, bilinguals possess a more efficient suppression mechanism as a result of their language switching abilities, it was predicted that bilinguals would exhibit less interference than monolinguals when the test object is presented after longer delays which would be evidence of more effective suppression of irrelevant information. Furthermore, it is possible that bilinguals would exhibit a release of interference at an earlier time delay than the monolinguals.

Negative Priming

As a final measure of the relative inhibitory abilities of monolingual and bilingual adults, the participants in the study completed a negative priming task. The negative-
priming task was utilized to measure inhibitory attentional mechanisms and has been described as a “measure of the efficiency of a process that is critical to general cognitive function” (Milliken & Tipper, 1998, p. 207). To elicit the negative priming effect, the participant is asked to respond to a particular stimulus in the presence of one or more distractors. In the experimental condition, participants respond to a target item in the probe trial that previously appeared as a distractor item in the preceding probe trial (see example in Figure 1). Response times in the experimental condition are compared to response times in the control condition in which target items did not previously appear as distractor items. The negative priming effect is characterized by a slower response time to the target on the test trial that previously appeared as a distractor on the prime trial. It is believed that the response time is delayed due to the suppressed status of the distractor because additional time is needed for the suppression to dissipate. An example of the negative priming task appears in Figure 1.

A variety of negative priming tasks have been employed by researchers and these tasks have also been used to characterize diminished capabilities of inhibiting irrelevant information in clinical and developmental populations (see Milliken & Tipper, 1998). Negative priming is included in this study to provide an additional measure of the inhibitory abilities of the participants under investigation because the task requires both the suppression or inhibition of processing the distractor item and the subsequent activation of the previously suppressed item when it appears as the target item in experimental trials.
DeSchepper and Treisman (Experiment 1, 1996) conducted a negative priming experiment using novel and meaningless shapes. Participants were shown a green shape and a black shape on the left and right sides of a computer screen, respectively, and told to make a same-different judgment. The green shape was overlapped by a red shape that they were told to ignore. On half of the trials, the unattended red shape became the attended green shape on the following trial (negative priming condition). On the other half of the trials, the unattended red shape did not become the attended green shape on the following trial (control condition) (see Figure 2).

The researchers found a significant 34 ms negative priming effect for the novel and meaningless shapes. Participants responded more slowly to the attended shape if it had been previously unattended (or ignored) than if the attended shape had not previously been ignored. If bilinguals are more skilled at inhibiting the processing of irrelevant information, one would expect bilingual adults to exhibit a larger negative priming effect compared to monolingual adults on a nonverbal negative priming task.
Language Switching

In addition to the primary objective of this dissertation to compare the nonlinguistic inhibition abilities of monolinguals and bilinguals, a secondary objective of this dissertation is to compare the linguistic and nonlinguistic switching abilities of adult bilinguals. One view of this relationship is that the general control mechanism necessary for language selection among bilinguals (i.e. language switching) is the same general control mechanism necessary for task switching in other nonlinguistic domains (Kirsner, Lalor, & Hird, 1993; Macnamara, Krauthammer, & Bolgar, 1968; Meuter & Allport, 1999; Paradis, 1980). If this assumption is true, one would expect to see a correlation between both linguistic and nonlinguistic switching abilities in bilinguals. The alternative view is that language is a specialized cognitive ability that possesses its own distinctive language-specific control mechanisms that are not necessarily available or applicable to other nonlinguistic cognitive functions. If this latter view is to be supported, one would not necessarily expect linguistic and nonlinguistic switching abilities to be related. To explore the relationship between bilingual linguistic switching abilities and nonlinguistic
switching abilities, a language switching task was performed by the adult bilingual participants to measure their ability to switch between their two languages. A numeral naming task modeled after the task employed by Meuter and Allport (1999) was used.

Meuter and Allport (1999) tested L1-dominant adult bilinguals' ability to switch between their two languages by naming numerals in either their L1 or L2. These researchers suggested that if a general control mechanism exists for both linguistic and nonlinguistic switching tasks, switching costs observed in other nonlinguistic domains will accurately predict the performance costs of language switching in a bilingual numeral naming task. Previous research on nonlinguistic task switching has revealed an "involuntary persistence of components of the preceding ("pre-switch") task set into the processing of the stimulus for the "switch trial" itself, which we (Meuter and Allport) refer to as task set inertia." (p. 27). The major element of task set inertia is the focus on the "pre-switch" task, rather than the "switch task," which is more important in predicting the magnitude of a switch cost. Using the previously described task switching task as an example, when the character pair appeared in the top-right corner of the screen (nonswitch letter task), the participant categorized the letter as being a consonant or vowel while suppressing the digit task. In this instance, the letter task was the "pre-switch" task set that required the suppression of the digit task. The suppression of the digit task in this "pre-switch" trial is assumed to persist to the beginning of the next trial (switch digit task) which requires a "switch" to the digit task set. Therefore according to Meuter and Allport, the magnitude of the behavioral cost of switching is predominantly affected by the suppression of the task set on the "pre-switch" trial rather than the
suppression of the once appropriate but now inappropriate task set (e.g. letter task) of the “switch trial.”

Meuter and Allport expound upon the Task Set Inertia hypothesis in the context of task switching between two tasks in which one task is behaviorally more dominant than the other. They posit that the more dominant task must be actively suppressed while performing the less dominant task, whereas the less dominant task is not necessarily actively suppressed while performing the more dominant task. Consequently, when switching to the more dominant task following a trial in which the less dominant task was performed, the active suppression of the dominant task from the previous trial will persist to the beginning of the current trial resulting in a larger switch cost when switching to the dominant task. When switching to the less dominant task, however, the switch cost will be smaller because the less dominant task is not necessarily suppressed during the preceding trial in which the more dominant task was performed. The Task Set Inertia hypothesis, therefore, predicts “paradoxical” asymmetric switching costs when one switches between behaviorally dominant and less dominant tasks.

This paradoxical asymmetry in switching cost has been demonstrated in several nonlinguistic switching tasks in which behaviorally more dominant and less dominant tasks were studied (Allport, Styles, & Hsieh, 1994; De Jong, 1995; Harvey, 1984; Yeung, 1997). For example, Allport, Styles, and Hsieh (1994) asked participants to switch between two versions of the Stroop color-word task (Macleaod, 1991) which required them to switch between naming the color and reading the word of incongruent Stroop stimuli. Participants were presented with a color word “red” that was printed in
green ink. In response to the color word stimulus, participants switched between the more behaviorally dominant task of reading the word “red” and the less behaviorally dominant task of naming the color in which the word was printed (“green”). The researchers found larger switch costs in switching to the behaviorally more dominant word-reading task compared to the less dominant color-naming task. The asymmetrical switch costs were explained in terms of the Task Set Inertia hypothesis which suggests that while performing the less dominant task (color-naming), the more dominant task (word-reading) was actively suppressed. When a switch to the more dominant word-reading task was then required, the active suppression from the “pre-switch” trial persisted into the beginning of the switch trial resulting in a larger switch cost than when switching to the less dominant color-naming task because this weaker task set was not necessarily actively suppressed during the “pre-switch” trial in which the behaviorally dominant word-reading task was performed.

Meuter and Allport extend the Task Set Inertia hypothesis to the bilingual linguistic switching situation and predict an asymmetrical switch cost for language switching for L1-dominant bilingual with a greater switch cost when switching to the dominant L1. Furthermore, the researchers propose that the degree of asymmetry in the switch cost is dependent upon the relative strength of the bilingual’s two languages (referred to as the Relative Strength hypothesis). The Relative Strength hypothesis predicts that bilinguals who two languages are more equal in terms of their relative strength will exhibit less or even an absence of the asymmetrical switch cost that is predicted for bilinguals whose two languages are not relatively equal in strength.
In contrast to the predictable nonlinguistic switching tasks employed by Rogers and Monsell (1995) and the present study (task switching task), Meuter and Allport (1999) asked bilinguals to switch between naming numerals in their L1 and L2 unpredictably to test the Task Set Inertia and Relative Strength hypotheses previously described. After practicing naming numbers in only L1 and then only in L2, the bilinguals unpredictably switched between their two languages while naming numbers ranging from 1 to 9 in both of their languages. Seated in front of a computer screen, the bilinguals were told to name the numeral in the middle of the computer screen in the appropriate language depending on the color of the rectangle on which the numeral was displayed. The bilinguals named numerals in lists ranging unpredictably from 5 to 14 numbers and they completed a total of 200 lists (approximately 2000 numeral-naming trials per participant). The lists were constructed such that the probability of a linguistic switch was 30% (i.e. switching from L1 to L2 or from L2 to L1), while the probability of not switching was 70% (i.e. continuing to name numerals in either L1 or L2). Each list contained between 0 and 4 linguistic switches.

Meuter and Allport (1999) observed slower reaction times on switch trials compared to nonswitch trials. As predicted by the Task Set Inertia and Relative Strength hypotheses, they observed an asymmetry in numeral-naming reaction times in each language for switch and nonswitch trials. On nonswitch trials, bilinguals were 24 ms faster naming numerals in L1 than L2. However, on switch trials bilinguals were 28 ms faster switching from L1 to L2 than switching from L2 to L1. Their findings, therefore, are consistent with the Task Set Inertia and Relative Strength hypotheses and...
suggest that nonlinguistic and linguistic switching abilities require a common control mechanism.

Interestingly, when the bilinguals were divided into two groups based on their relative proficiency in each language (measured by the difference in the mean of median naming reaction times in L1 and L2), only the bilinguals who exhibited a larger difference in relative proficiency exhibited the response language asymmetry in reaction times for switch and nonswitch trials. Those bilinguals who demonstrated a smaller difference in relative proficiency (i.e. more balanced bilinguals) did not show the response language asymmetry in reaction times for switch and nonswitch trials. Furthermore, they did not show an effect of response language which indicates that they were not faster at naming numerals in one language over the other regardless of trial type. The only significant effect observed for these bilinguals was the switch cost.

The absence of the asymmetric switch cost in the performance of the more balanced bilinguals bolsters Meuter and Allport's arguments that the asymmetry in switch costs found in nonlinguistic domains can be demonstrated in the linguistic domain (Task Set Inertia hypothesis), and that the relative strength of the bilinguals' two languages are useful in predicting whether that asymmetry in switch cost will be observed (Relative Strength hypothesis). In the present study, the bilinguals' linguistic switch costs were examined and compared to their nonlinguistic costs to determine if the behavioral costs of switching are correlated in both domains. If the switching costs are correlated, this would provide evidence for a general control mechanism that mediates switching abilities in both nonlinguistic and linguistic domains.
Present Study

Turning now to an overview of this dissertation, the primary objective of the present study is to compare monolingual and bilingual adults on three measures of inhibition of irrelevant nonlinguistic information. Inhibition is hypothesized to be the fundamental mechanism necessary for code switching. Therefore, the three experiments logically extend from the code-switching hypothesis, which was originally conceived by Peal and Lambert (1962). The three experiments provide an empirical attempt to identify a code-switching mechanism that may explain previously observed bilingual advantages on certain cognitive tasks. If code switching provides the bilingual with an enhanced ability to inhibit the processing of linguistic information and activate previously suppressed information, it is also expected that this ability would generalize to the nonlinguistic domain on nonverbal measures of inhibition.

The inhibition of processing irrelevant information is considered to be a general cognitive mechanism, rather than a language-specific ability. Therefore, if the hypothesized benefits of bilingualism result from a more efficient general cognitive mechanism (inhibition), a bilingual advantage is expected for all three measures of inhibition (i.e. task switching, suppression, and negative priming). Although the code switching hypothesis has been extensively tested in bilingual children, the few studies of bilingual adults do not provide any evidence of greater cognitive flexibility in bilingual adults. There is no reason to conclude, however, that the code switching hypothesis is not applicable to the adult bilingual population, even though it was originally conceived as an attempt to explain cognitive advantages in bilingual children. Consequently,
monolingual and bilingual adults were asked to perform three tasks involving the inhibition of processing irrelevant nonlinguistic information to assess the effect of bilingualism on the general cognitive mechanism of inhibition. Additionally, the implication of Cummin’s (1976) threshold hypothesis for cognitive processing in bilinguals was also considered. Measures of the degree of bilingualism were included in the study to determine if the degree of bilingualism is useful in explaining the adult bilinguals’ inhibitory abilities on the three tasks.

The secondary objective of this dissertation is to explore the relationship between nonlinguistic and linguistic switching abilities in adult bilinguals. Adults bilinguals performed a language switching task, in addition to the nonlinguistic switching task, and the switch costs in reaction time for each task are compared to determine if a correlation exists between the switch costs. It is predicted that a relationship exists between the switching abilities in each task because it is assumed that the control mechanisms necessary for switching in general are utilized for each type of switching task. If a relationship between the switching abilities in each task is observed, this finding will further support the contention made by Meuter and Allport (1999) that linguistic and nonlinguistic switching abilities require general control mechanisms, rather than specialized task-specific control mechanisms.
**Method**

**Participants**

The participants of this study were 27 bilingual adults and 25 monolingual adults who were recruited from undergraduate psychology courses at Louisiana State University (bilinguals: 16 females, 11 males; monolinguals: 15 females, 10 males). More bilinguals were needed to complete 25 bilingual-monolingual matched pairs due to technical problems with the computer in which data for a two different bilinguals was lost for each of the three computer tasks. Consequently, the 25 monolingual participants were matched one-to-one with the remaining 25 bilingual participants on each task. The average age of the participants is as follows: bilinguals: $M=20.85$ years, $SD=3.32$ years and monolinguals: $M=20.96$ years, $SD=2.39$ years ($F=0.02$, $p<.90$). Those participants who were enrolled in introductory psychology courses received course credit for their participation in the study. Participants completed a nonverbal intelligence test, an English proficiency measure, and a demographic and language experience questionnaire in order obtain information regarding general intelligence, English proficiency, gender, age, SES, college major, and foreign language experience. The participants’ college majors can be found in Table 1.

In order for the monolingual adults to be included in the study, they had to have either no previous experience with a foreign language or only minimal exposure to a foreign language such as travel of not more than four weeks to a country in which English is not spoken or no more than two introductory college- or high school- level courses in a foreign language. Most importantly, the monolingual adults did not
understand or speak a foreign language. The bilingual adults were native speakers of a 
language other than English and exhibited at least a moderate level of proficiency in 
English. English proficiency was assessed by the *Peabody Picture Vocabulary Test-
Third Edition, Form IIIB* (Dunn & Dunn, 1997).

Table 1. Frequency of college majors for both linguistic groups

<table>
<thead>
<tr>
<th>Major</th>
<th>Frequency</th>
<th>Major</th>
<th>Frequency</th>
<th>Major</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>B</td>
<td>M</td>
<td></td>
<td>B</td>
<td>M</td>
</tr>
<tr>
<td>Psychology</td>
<td>7</td>
<td>5</td>
<td>Anthropology</td>
<td>0</td>
<td>1</td>
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<td>1</td>
<td>Biology</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Nursing</td>
<td>1</td>
<td>1</td>
<td>Chemistry</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Biochemistry</td>
<td>3</td>
<td>0</td>
<td>Sociology</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Medical/Physicians Asst.or Medical Technology</td>
<td>1</td>
<td>2</td>
<td>Physical Therapy</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Microbiology</td>
<td>0</td>
<td>2</td>
<td>Kinesiology</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>ISDS</td>
<td>4</td>
<td>0</td>
<td>Elementary Education</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>English, German, or French</td>
<td>2</td>
<td>1</td>
<td>Marketing</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

The purpose of studying bilinguals whose L2 is English rather than L1 is to be 
able to have a measure of relative levels of bilingualism, as measured by a standardized 
test of English proficiency. Additionally, an effort was made to include bilingual adults 
with a variety of proficiency levels in English that vary from moderate to highly 
advanced or near-native levels. The purpose of constructing a heterogenous bilingual 
sample with regard to English proficiency is to test the levels of bilingualism hypothesis.
and explore the proposed thresholds of bilingual advantages with regard to inhibitory abilities. Furthermore, an attempt was made to compose the bilingual sample with speakers of a variety of native languages to allow for the possibility of making broader generalizations about bilingualism beyond bilinguals of a particular L1 and L2. The bilingual participants’ first languages were Vietnamese (n=7), Spanish (n=7), Gujarati4 (n=4), Greek (n=2), Korean (n=1), Thai (n=1), French (n=1), Amharic5 (n=1), Chinese (n=1), Romanian (n=1), and Croatian (n=1). All but one bilingual reported that their second language was English. Only one bilingual reported English to be his third language (L2 was French).

Because previous research has demonstrated that variables such as gender, age, SES, and general intelligence may better explain differences in performance on cognitive tasks between monolingual and bilingual children than simply bilingualism, both groups were matched as closely as possible on these variables. In addition to matching the pairs on these variables, an attempt was also made to match the pairs with respect to college major. The pairs were matched perfectly in regard to gender, within 2 points on the measure of nonverbal intelligence (raw score), within 1 point in ratings of SES (out of 5 levels of SES), within 8 years of age (although the average difference in age was only 2.4 years), and as closely as possible on college major (when perfect matches were not possible, matching was done within the college of majors). The particular attributes of the monolingual/bilingual matched pairs are found in Appendix E. In creating matched,

4Gujarati is spoken in India.
5Amharic is spoken in Ethiopia.
or dependent samples, the effect of these variables on the participants’ performance was reduced and any differences in performance between the two samples on the cognitive tasks were attributed to factors related to bilingualism rather than demographic and intelligence differences between the two groups.

Procedure

Phase 1: General Intelligence

The first testing phase of the study consisted of a nonverbal measure of intelligence. Both monolingual and bilingual adults completed the Raven's Advanced Progressive Matrices: Sets I and II (bilinguals: M=22.85, SD=3.61; monolinguals: M=23.08, SD=3.25; F=0.06, p<.2).6 Individual participants’ raw scores on this test are found in Appendix E. According to the Manual for Raven's Progressive Matrices and Vocabulary Scales: Section 4 - Advanced Progressive Matrices (1993) and the timed nature of the test, there are no appropriate norms to which these samples of adults can be compared. This particular measure of intelligence was chosen because of its nonverbal nature, and because it has been frequently utilized as a measure of nonverbal intelligence by previous researchers who have explored the effects of bilingualism on cognitive processing in children. It is imperative to administer a nonverbal measure of intelligence, rather than a verbal measure of intelligence, to both samples as they do not possess equivalent language skills in English. In doing so, a language-free intelligence rating was established for each participant in which differences in English proficiency

6These scores represent the groups’ mean performance on the 36 problems in Set II of the measure (Set I was used as a practice test). The participants were given 40 minutes (timed test) to complete Set II.
were not confounded with any intelligence differences. The intelligence testing procedure lasted approximately one hour.

In addition to the intelligence test, the bilingual participants completed an extensive foreign language questionnaire. The bilingual participants were asked the age at which they first began to acquire English, the context in which they learned English, how much formal and informal exposure they have had to English, any relevant travel they’ve completed to a country where English is spoken, and how much practice they have had at switching between their two languages. The Bilingual Language Experience Questionnaire and mean responses are found in Appendix A and Appendix D, respectively. The bilinguals’ responses to the Bilingual Language Experience Questionnaire are discussed at the beginning of the results section of this dissertation.

Phase 2: Cognitive Tasks

Both monolingual and bilingual participants returned for a second experimental session to complete three computer tasks, a demographic questionnaire, and the *Peabody Picture Vocabulary Test-Third Edition, Form IIIB* (Dunn & Dunn, 1997) as a measure of English proficiency (standard scores: bilinguals: 101; monolinguals: 110). Upon analysis of the participants’ raw scores on the PPVT7, it was apparent that the monolingual adults significantly outperformed the bilingual adults on this measure of

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7Participants began the PPVT on Set 13 (Start Item 145 for ages 17-Adult) and continued completing sets of 12 items until the Basal Set (lowest set of items containing one or no errors) and the Ceiling Set (highest set of items containing eight or more errors) were established. The individual’s raw score was calculated by subtracting the number of errors committed between the Basal Set and the Ceiling Set from the Ceiling Item (last item in Ceiling Set). The last set (Set 17) contained the Automatic Ceiling Item (204).
English proficiency (bilinguals: \( M=174.308, SD=9.40 \); monolinguals: \( M=182.609, SD=11.05 \); \( F=8.56, p<.006 \)). While this difference reflects the monolingual adults' superior receptive English vocabulary, it may also reflect a difference in the conceptual abilities of the two groups.\(^{10}\) The demographic questionnaires for monolingual and bilingual participants are found in Appendices B and C, respectively. The bilingual participants completed a fourth computer task involving language switching. The participants' reaction time and response accuracy were recorded for each of the computer tasks. Each participant was tested individually during the second experimental session and the second experimental session lasted between one hour and 15 minutes to one hour and 45 minutes, for a total of two hours and 15 minutes to two hours and 45 minutes of testing across the two experimental sessions. The four computer tasks are described below in the order of their presentation.

**Task Switching Task.**

**Stimuli**

The methodology of this experiment is modeled closely after a study conducted by Rogers and Monsell (1995, Experiment 1) designed to demonstrate the performance

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\(^{8}\)Based on the mean age of the bilinguals, the percentile rank of their PPVT performance is 53.

\(^{9}\)Based on the mean age of the monolinguals, the percentile rank of their PPVT performance is 75.

\(^{10}\)The participants' raw score on the PPVT is not significantly correlated with their performance on the three computer tasks (task switching: \( r=.14, p<.33 \); suppression: 50 ms: \( r=.12, p<.43 \), 300 ms: \( r=.16, p<.29 \), 750 ms: \( r=.10, p<.49 \), 1000 ms: \( r=.01, p<.95 \); negative priming: \( r=-.06, p<.67 \)).

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cost associated with switching between two simple cognitive tasks. Participants were asked to classify a letter as either a consonant or a vowel and classify a digit as either even or odd. A stimulus pair was presented that consisted of a letter and a digit side by side. For the letter task, the participant responded by classifying the letter as either a consonant (pressing the “Z” key with the left index finger) or a vowel (pressing the “?” key with the right index finger). For the digit task, the participant responded by classifying the digit as either even (pressing the “Z” key with the left index finger) or odd (pressing the “?” key with the right index finger). The stimulus-response mappings are found in Figure 3. The irrelevant character (i.e. the digit during the letter task and the letter during the digit task) was either congruent or incongruent with the correct response to the relevant character of the current task.

![Figure 3. Task switching: Stimulus-response mappings](image)

Procedure

The experiment was conducted using the SuperLab software. The participants first completed 10 practice trials that involved categorizing letters and digits, but did not involve ignoring irrelevant characters or switching between the two tasks. For the actual experiment, the computer screen was divided into four quadrants (top left, top right, bottom right, bottom left). The stimulus pair appeared in one of the four quadrants and on successive trials the location of the stimulus pair rotated in a clockwise order between

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the four quadrants. Participants were told to perform the letter task when the stimulus pair occupies the top two boxes and perform the digit task when the stimulus pair occupies the two bottom boxes. For each participant, the stimulus pair was presented in a clockwise pattern and the task predictably changed on every second trial (e.g. letter task, letter task, digit task, digit task or AABB). The position occupied by the stimulus pair cued the participant to perform the appropriate task. Figure 4 illustrates the clockwise pattern of trials.

For example, when the character pair “K4” appeared in the top left quadrant, the participant performed the letter task by classifying the letter “K” as a consonant by pressing the “Z” key with her left index finger. One the next trial, when the character pair “U9” appeared in the top right quadrant, the participant continued to perform the letter task by classifying the letter “U” as a vowel by pressing the “?” key with her right index finger. The next trial was a switch trial because the character pair “S7” appeared in the bottom right quadrant which requires the digit task. The participant classified “7” as an odd number by pressing the “?” key with her right index finger. Finally, the fourth trial was not a switching trial because the character pair “A6” appeared in the bottom left quadrant which also necessitates the digit task. The participant classified the “6” as an even number by pressing the “Z” key with her left index finger.

The irrelevant character in each trial was associated with a response that was either congruent or incongruent with the response required for the relevant character. For example, when performing the letter task, the character pair “K4” required the left finger response to categorize “K” as a consonant. The irrelevant character, “4”, was
congruent with this response because it would also require the left finger response to categorize "4" as even for the digit task. The character pair "S7", however, contained an incongruent irrelevant character. When performing the digit task, "7" required the right finger response because it is an odd number. The irrelevant character, however, is associated with the left finger response to categorize "S" as a consonant for the letter task.

![Image](image.png)

Figure 4. Task switching: Experimental trials

At the beginning of the first block of trials, the participant was forewarned as to the location of the first stimulus pair. The stimulus pairs appeared in bold 16-point Times New Roman font and remained on the screen until the participant responded. An interval of 150 ms was included between the response of the participant and the presentation of the new stimulus pair (i.e. 150 ms R-S interval). The word "Error" appeared in the middle of the computer screen to alert the participant of an incorrect response. The purpose of the incorrect response alert was necessary to assist the participant in keeping track of which task is currently appropriate. Trials in which errors were committed were omitted from the analyses. Participants were told to respond as quickly and as accurately as possible to the character pair.

Consonants were randomly sampled from the set: G, H, R, and W, vowels from the set: A, E, O, and U, even digits from the set: 2, 4, 6, and 8, and odd digits from the
set 3, 5, 7, and 9. Sequences of stimuli were constructed such that the same character did not appear on two successive trials.

Design

Each participant completed four blocks of 64 trials each, for a total of 256 trials. Ten practice trials appeared before the first block and were not be included in the analyses. The 256 experimental trials were constructed with every combination of the following factors: task (letter or digit), trial type (switch-AB & BA or nonswitch-AA & BB), response (left or right index finger), response on previous trial (left or right index finger), irrelevant character (congruent or incongruent), and irrelevant character on previous trial (congruent or incongruent).

Suppression Task

Stimuli

In order to test the participants ability to suppress the processing of irrelevant nonlinguisitc information, a modified version of the task employed by Gernbacher and Faust (1991, Experiment 2) was used. Participants viewed 32 experimental scenic arrays depicting 8 types of scenes: bathroom, farm, fruit, kitchen, motor vehicles, tools, water animals, and zoo. The objects in each scene were simple black-and–white line drawings. Each scenic array consisted of five objects arrange in a circular configuration.

Each of the 32 experimental (i.e. test item absent) scenic arrays were employed in both the typical and atypical array conditions, for a total of 64 experimental trials. In the typical array condition, the test object is typically associated with the other objects in the array, although it was not presented in the scenic array. For example, when viewing the
tools scenic array (hammer, saw, paint brush, shovel, and wrench), the test object was a pliers. In the atypical array condition for the tools scene, the test object was a pig. Therefore, in the 32 experimental scenic arrays employed in both the typical and atypical array conditions, the test object was absent from the scenic array and the participants were to respond with *no* when asked if the test object appeared in the scenic array. Examples of a typical experimental array and an atypical experimental array are found in Figure 5.

Sixty-four filler arrays were also included in the study. The filler scenic arrays were identical in structure to those used in the experimental arrays. However, the filler arrays were followed by a test object that was present in the scenic arrays. Therefore, the participants were to respond with *yes* when asked if the test object appeared in the scenic array. For example, a filler array of the tools scene (hammer, saw, paint brush, shovel, and wrench) was followed by the test object: hammer. The only difference between the experimental and filler trials is that the test object was absent from the scenic arrays of the experimental trials, while the test object was present in the scenic arrays for the filler trials.

For half of the filler scenic arrays, the test object was typically associated with the other objects presented in the scenic array. For example, the tools scenic array (hammer, saw, paint brush, shovel, and wrench) was followed by the test object: hammer. The other half of the scenic arrays were followed by a test object that was atypical of the scene presented. For example, the tools scenic array (hammer, saw, paint brush, shovel, and pig) was followed by the test object: pig.
Figure 5. Suppression: Experimental conditions

Procedure

The experiment was conducted using SuperLab software. Before beginning the actual experiment, participants named each of the 8 black-and-white line drawings of test objects to familiarize them with the actual test objects. This was done to insure that the participant knew which test items they were looking for among the other items in each scenic array. After the experiment began, the scenic arrays and test objects appeared in the middle of the computer screen. The scenic array remained on the computer screen for a period of 300 ms. Following the presentation of the scenic array, the test object replaced the scenic array on the computer screen either 50 ms later (immediate test interval), 300 ms or 750 ms later (intermediate test intervals), or 1000 ms later (delayed test interval). The presentation of the test objects at each of the delay intervals was blocked, and a latin square counterbalancing scheme was used to control for the order of the blocked delay intervals. Furthermore, each scenic array and test object combination appeared at each delay interval within each typicality condition across the participants to control for the effect of any particular scenic array-test object combination.
The test object remained on the screen until the participant responded. Participants responded to whether or not the test object appeared in the scenic array by pressing the “Z” key with the left index finger to indicate that the test object did appear in the scenic array (yes response) or pressing the “?” key with the right index finger to indicate that the test object did not appear in the scenic array (no response). Participants were told to respond as quickly and as accurately as possible to the test object. The following scenic array appeared 250 ms after a correct response. If an error was committed, the word “Error” appeared in the middle of the computer screen for 1 s. Trials in which errors were committed were omitted from the analyses.

Design

Each participant completed 8 trials in every combination of the following conditions: trial (experimental-absent test object or filler-present test object) x typicality of test object (typical of array or atypical of array) x delay interval (50 ms, 500 ms, 1000 ms, or 1250 ms). Therefore, each participant completed a total of 128 trials, 64 of which were experimental (i.e. test object absent) trials.

Negative Priming Task

Stimuli

Participants completed a negative priming task that is similar to the task used by DeSchepper and Treisman (1996, Experiment 1). Participants performed a negative priming task which involves making same-different judgments in response to novel shapes. The stimuli set consisted of 8 novel closed shapes created with Adobe PhotoShop software. Participants were presented with two overlapping shapes, one
green and one red, and were asked to make a same-different judgment with regard to the green shape and a third black shape that appeared to the right of the overlapping pair, thereby ignoring the red shape of the overlapping pair (prime display). On one half of the prime displays, the ignored red shape of the overlapping pair was the attended green shape in the next (prime display) overlapping shape pair (negative priming condition). On the other half of the prime trials, the previously ignored red shape of the overlapping pair did not appear as the attended green shape on the next (prime display) overlapping shape pair (control condition).

Procedure

The experiment was carried out using the SuperLab software for Macintosh computers. The overlapping green and red shapes appeared on the left side of a white computer screen and the comparison black shape appeared on the right side of the computer screen. Participants were instructed to ignore the red shape and decided whether or not the green shape matches the black shape. If the green and black shapes were judged to be the same, the participant responded by pressing the “red” key of the two-button response box with the left index finger. If the green and black shapes were judged to be different, the participant responded by pressing the “white” key of the two-button response box with the right index finger.

At the beginning of each prime/probe trial, the word “Ready?” appeared in the middle of the computer screen to forewarn the participant of the upcoming prime/probe trial. A fixation point appeared in the middle of the computer screen for 300 ms, followed immediately by the prime display. The display remained on the screen until the

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participant responded. Immediately following the participant’s response, the probe display appeared and remained on the computer screen until the participant responded. The next prime/probe trial began after a delay of 1 s. If an error was committed, the word “Error” appeared in the middle of the computer screen for 1 s. Trials in which errors were committed on either the prime or probe displays were omitted from the analyses.

Design

Participants completed 14 prime/probe trials in every combination of the following conditions: probe type (negative priming or control) x prime response (same or different) x probe response (same or different). Each participant completed 10 practice trials, followed by 112 experimental trials.

Language Switching Task

Stimuli

Bilingual participants also performed a language switching task that was similar to the task used by Meuter and Allport (1999). Bilingual participants named Arabic numerals in their L1 and L2 (English), switching between their two languages unpredictably. The stimuli consisted of the Arabic numerals, 1 through 9, which were presented in random order on the computer screen one at a time in short lists of 16 numerals. The numerals were 6 cm high in Times New Roman font and appeared either at the top center of the computer screen or the bottom center of the computer screen. The location of the numeral (top or bottom) indicated to the participant in which language to name the numeral. For example, participants were told to name the numeral
in their L1 when it appeared at the top of the computer screen and name the numeral in L2 (English) when it appeared at the bottom of the computer screen.

Within each short list of 16 numerals, the number of unpredictable language switches ranged from 6 to 9 switches. Language switches (switch trials) occurred in two ways: switching from L1 to L2 and switching from L2 to L1. Trials in which no switching was required (nonswitch trials) were in either L1 or L2. Within each list, there were no more than three consecutive switch trials or nonswitch trials. Across all of the lists, the probability was .5 that a particular trial required a language switch [$p$(switch)$=.5$], and consequently the probability was .5 that a particular trial did not require a language switch [$p$(nonswitch)$=.5$].

The rate in which the numerals appeared on the screen was response driven by use of the voice activation key. After the participant named a numeral, the following numeral appeared 400 ms later. The first numeral in each list was preceded by an asterisk which appeared either at the top or bottom of the computer screen for 500 ms to tell the participant in which language to respond. The first numeral in each list was considered as a practice trial and these practice trials were not included in analyses.

Procedure

SuperLab software for Macintosh computers was used to conduct the experiment. Participants were tested individually and were seated approximately 45 cm from the computer screen and voice key. Participants were asked to name the numerals as quickly and as accurately as possible in the appropriate language indicated by the location of the numeral.
At the beginning of the experiment, participants practiced naming numerals in blocked lists in each language. Participants began by naming the numerals 1-9 in a blocked list in their L1 as quickly as possible. Immediately following the list of numeral to be named in L1, the participants then named the same numerals in their L2 as quickly as possible. After the practice lists, the participants were told that they would be required to switch unpredictably between their two languages for the actual experiment that consisted of 12 lists of 16 numerals. Reaction times which reflect the triggering of the voice key were recorded. Reaction times for any trial in which an error was made were not included in the analyses. Errors consisted of naming a numeral in the wrong language and mixing languages within the same numeral-naming response. Additional reaction times were excluded from analyses for trials in which extraneous environmental noise triggered the activation of the voice key.

Design

Immediately following the practice lists, participants completed 12 lists of 16 numerals each (15 experimental numerals) for a total of 180 experimental trials (and 12 practice trials). Each participant completed 45 trials in every combination of the two independent variables: trial type (switch, nonswitch) and language (L1, L2).

Overall Design

The reaction times and error rates were analyzed by ANOVA for repeated measures for each of the four computer tasks. Linguistic group (monolingual or bilingual) was included as a within-subjects or repeated factor in the first three computer tasks because the two linguistic samples were matched one-to-one in terms of nonverbal
intelligence, gender, age, and SES. The repeated measures analyses provide information on the effect of linguistic experience on switch cost, suppression of typical but absent test objects, and negative priming. Level of English proficiency, degree of bilingualism, and linguistic and general switching abilities were also considered as possible predictors of performance on these tasks. Specifics of each analysis will precede each results section.

Although linguistic group was treated as a repeated factor due to the matched nature of the linguistic pairs, the variability within each matched pair is presumably higher than if this factor was truly manipulated within-subjects. Therefore, the variability among the participants' reaction times within each linguistic group was compared for each task to determine if the measures of variability for each linguistic group were very different. Upon inspection, it was determined that the difference in variability of reaction times for the two linguistic groups was not sufficient to treat the factor of linguistic group as a between-subjects factor.
Results and Discussion

For this dissertation, 27 bilingual adults and 25 monolingual adults, equated in terms of nonverbal intelligence, age, gender, SES, and college major (n=25 matched pairs), performed three computer tasks designed to measure the ability to inhibit the processing of irrelevant information as an experimental investigation of Peal and Lambert’s code-switching hypothesis. Repeated measures analyses were conducted to explore the inhibitory abilities within each group of participants and compare these abilities across both samples to determine if any differences exist between the two linguistic groups. The code-switching hypothesis predicts that bilinguals will outperform their monolingual counterparts on certain measures of cognitive ability. The purpose of the study was to investigate the source of these hypothesized bilingual advantages by examining the underlying mechanisms involved in code-switching.

Bilingual Language Questionnaire and General Switching Abilities

In general, the bilingual participants were highly proficient bilinguals. On a 5-point scale designed to measure overall bilingualism, the bilingual participants rated themselves as being highly proficient in each of their two languages (Bilingualism section, #2-5: $M=2.07$, $SD=1.08$). When asked how often they currently use each of their two languages (1(Never)-5(Always)), they rated their LI: $M=3.93$, $SD=1.07$ (Native language section, #1) and L2: $M=4.50$, $SD=0.63$ (Second language section, #5-11), $F=7.18$, $p<.013$. Therefore, the bilinguals currently use their L2 more frequently than their L1. Interestingly, when asked to rate their proficiency in L1 (Native language section, #2) and L2 (Second language section, #15), the bilinguals' ratings were almost
identical for each language (L1: $M=4.41, SD=1.01$; L2: $M=4.41, SD=0.69$). This suggests that the bilinguals in the present study were almost completely balanced bilinguals.

With respect to the frequency with which they switch between their two languages, the bilinguals' mean language switching rating was 3.44 ($SD=1.34$) on a 5-point scale with 1 representing rarely switching and 5 representing switching all of the time (Language switching behavior section, #1). Not only were the bilinguals moderately frequent language switchers, they also reported language switching to be rather effortless (1: easy/not at all effortful; 5: difficult/extremely effortful) (Language switching behavior section, # 2-3: $M=1.76, SD=1.04$). According to the bilinguals, the most highly rated reason for switching between their two languages is to facilitate communication (i.e. to allow the current listener to understand), $M=3.96, SD=1.28$.

Finally, with respect to general switching abilities, the monolinguals and bilinguals did not differ significantly in their ratings of the ease(1)/difficulty(5) with which they switch between two different tasks (monolinguals: $M=2.72, SD=0.74$; bilinguals: $M=2.28, SD=0.98$, $F=2.52, p<.13$).

**Task Switching Task**

The task switching task required not only the inhibition of processing the irrelevant character and task, but also the activation of the previously suppressed character and task. For example, when the participant was performing the letter task, the participant must successfully ignore or disregard the processing of the digit to correctly categorize the letter as either a consonant or a vowel. However, when the task
switched to the digit task, the participant must be capable of inhibiting the processing of the letter associated with the previously appropriate task, and activate the digit task that was the previously inappropriate, but now appropriate, task. The task switching task is most analogous to the language switching situation and is therefore the most important task for the study. Not only was irrelevant information being inhibited and once inhibited information being activated, but this process was continually and predictably switching between two tasks.

Because bilinguals may preferentially enjoy the ability to inhibit the processing of irrelevant information and are possibly better able to activate previously suppressed information than monolinguals, a bilingual advantage was expected for this task which would be evidenced by faster reaction times on both switch and nonswitch trials and a lower switch cost compared to the monolinguals. Recall that the switch cost is determined by the difference in reaction times and error rates between nonswitch and switch trials. The reaction times for switch trials were expected to be longer than the reaction times for nonswitch trials. Switch costs were calculated as the difference between switch and nonswitch trials. It was expected that bilinguals would respond more quickly on both trial types because of they may be better at ignoring the irrelevant character. Secondly, it was hypothesized that the bilinguals would exhibit a smaller switch cost, relative to the monolinguals, due to their ability to inhibit the processing of the irrelevant character and task, and activate the previously suppressed character and task.
Study Results

The mean of the individual participants' median reaction times were analyzed due to the positively skewed nature of reaction times for this task. Trials in which an error was committed were excluded from the analyses. The removal of reaction times associated with errors constituted approximately 7% of the observations. Table 2 shows the mean of the participants' median reaction times (and standard deviations in parentheses) and error rates for both linguistic groups (bilinguals and monolinguals) and both tasks (digit and letter) for switch and nonswitch trials. Switch costs were calculated by subtracting the mean reaction time and error rate for the nonswitch trials from the mean reaction time and error rate for the switch trials.

Table 2. Task switching: Mean of participants' median reaction times

<table>
<thead>
<tr>
<th>Trial Type</th>
<th>Switch</th>
<th>Nonswitch</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bilinguals</td>
<td>1320 (287)</td>
<td>777 (155)</td>
<td>543 ms</td>
</tr>
<tr>
<td></td>
<td>8.8%</td>
<td>4.3%</td>
<td>4.3%</td>
</tr>
<tr>
<td>Monolinguals</td>
<td>1342 (385)</td>
<td>793 (247)</td>
<td>549 ms</td>
</tr>
<tr>
<td></td>
<td>9.3%</td>
<td>5.7%</td>
<td>3.6%</td>
</tr>
</tbody>
</table>

A repeated measures analysis of variance was performed on the dependent measures of reaction time (in milliseconds) and error rate with the following factors:

---

10 In addition to the nature of the distribution of the reaction times, median reaction times were used in order for correlations (bilinguals participants only) to be made on switch costs for this task and the language switching task that requires median reaction time analyses.
linguistic group (bilingual or monolingual), trial type (switch or nonswitch), task (digit or letter), and current irrelevant character (congruent or incongruent). With regard to reaction time, participants responded more quickly on the nonswitch trials ($M=785$, $SD=139$) compared to the switch trials ($M=1331$, $SD=256$), $F(1, 24)=191.18$, $p<.0001$. There was also a main effect of the current irrelevant character, $F(1, 24)=6.51$, $p<.05$. Participants were faster to respond when the current irrelevant character was incongruent with the correct response ($M=1041$, $SD=197$) than when it was congruent with the correct response ($M=1076$, $SD=169$). No main effects were observed for linguistic group or task, $F$'s<0.43.

The two main effects are qualified by two interactions. The current irrelevant character significantly interacted with trial type ($F(1, 24)=9.43$, $p<.05$) and task ($F(1, 24)=4.78$, $p<.05$). The interaction between current irrelevant character and trial type indicates that participants responded at the same rate on nonswitch trials regardless of whether the current irrelevant character was congruent ($M=786$, $SD=129$) or incongruent ($M=785$, $SD=154$) with the correct response ($Q=0.13$, $p>.05$), while participants responded more quickly on switch trials in which the current irrelevant character was incongruent ($M=1297$, $SD=269$) compared to congruent ($M=1366$, $SD=253$) with the correct response, $Q=8.90$, $p<.05$. It should be noted that there is a larger switch cost when the irrelevant character was congruent (580 ms) than incongruent (512 ms) with the correct response, $Q=8.77$, $p<.05$. The interaction between the current irrelevant character and task indicates that there was not a difference...
in response times on the digit task when the current irrelevant character was either congruent ($M=1070$, $SD=183$) or incongruent ($M=1062$, $SD=236$) with the correct response ($Q=0.94$, $p>.05$). On the letter task, however, response rates were faster for incongruent current irrelevant characters ($M=1020$, $SD=179$) compared to congruent current irrelevant characters ($M=1081$, $SD=177$), $Q=7.13$, $p<.05$. No other significant interactions were observed, $F$’s$<2.65$.

A repeated measures analysis of variance on error rate revealed three main effects. First, participants committed more errors on switch trials ($M=9\%$, $SD=0.05$) than nonswitch trials ($M=5\%$, $SD=0.04$), $F(1, 24)=56.73$, $p<.0001$. Secondly, marginally more errors were committed on the digit task ($M=7.9\%$, $SD=0.06$) compared to the letter task ($M=6.2\%$, $SD=0.05$), $F(1, 24)=4.41$, $p=.0532$. Thirdly, the participants made more errors when the current irrelevant character was incongruent ($M=8.7\%$, $SD=0.06$) rather than congruent ($M=5.3\%$, $SD=0.05$) with the correct response, $F(1, 24)=16.42$, $p<.05$. The main effects of current irrelevant character for both reaction time and error rate are consistent with the speed-accuracy trade-off. While participants responded more quickly when the irrelevant character was incongruent with the relevant character, they committed more errors on these trials.

These main effects are qualified by the significant interactions of the current irrelevant character with both trial type ($F(1, 24)=8.91$, $p<.05$) and task ($F(1, 24)=5.86$, $p<.05$). The interaction between trial type and current irrelevant character reflects the smaller difference in error rates between nonswitch and switch trials when a congruent is present (nonswitch: $M=4\%$, $SD=0.04$; switch: $M=6.7\%$, $SD=0.05$; $Q=8.29$, $p<.05$).
compared to the larger difference in error rates between nonswitch and switch trials when the irrelevant character is incongruent (nonswitch: $M=6\%$, $SD=0.05$; switch: $M=11.4\%$, $SD=0.07$; $Q=16.58$, $p<.05$). The switch cost was larger for the incongruent irrelevant characters (5.4%) compared to the congruent irrelevant characters (2.7%), $Q=8.29$, $p<.05$. The interaction between current irrelevant character and task revealed that participants made a similar number of errors on both tasks when a congruent irrelevant character was present (digit: $M=5.6\%$, $SD=0.05$; letter: $M=5\%$, $SD=0.04$; $Q=1.78$, $p>.05$), while they made significantly more errors on the digit task compared to the letter task when an incongruent irrelevant character was present (digit: $M=10.2\%$, $SD=0.07$; letter: $M=7.3\%$, $SD=0.06$), $Q=8.59$, $p<.05$.

These two-way interactions are further qualified by a four-way interaction of linguistic group, trial type, task, and current irrelevant character ($F(1, 24)=5.82$, $p<.05$). The error rates for each of the 16 conditions can be found in Table 3. The four-way interaction reflects the higher error rates typically associated with incongruent irrelevant characters on switch trials for either task, but more so for the monolinguals, although the monolinguals appeared to commit more errors on the letter task overall compared to the bilinguals.

Finally, the hypothesized main effect of linguistic group and interaction between linguistic group and trial type were not significant for either reaction time or error rate. The absence of such effects are extensively explored. Explanations for why these predicted effects were not observed are discussed in the upcoming “data exploration” section.
Table 3. Task switching: Error rates the each of the 16 conditions

**Bilinguals**

<table>
<thead>
<tr>
<th></th>
<th>Digit</th>
<th>Letter</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nonswitch</td>
<td>C</td>
<td>I</td>
</tr>
<tr>
<td></td>
<td>3.9%</td>
<td>6.4%</td>
</tr>
</tbody>
</table>

**Monolinguals**

<table>
<thead>
<tr>
<th></th>
<th>Digit</th>
<th>Letter</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nonswitch</td>
<td>C</td>
<td>I</td>
</tr>
<tr>
<td></td>
<td>4.3%</td>
<td>9.3%</td>
</tr>
</tbody>
</table>

Comparison to Rogers and Monsell (1995)

Although there was no effect of linguistic group, several findings in Rogers and Monsell’s (1995) original study were replicated. First, and most importantly, reaction times and error rates were greater for switch than nonswitch trials in both studies. Rogers and Monsell reported an average switch cost in reaction time of 224 ms and an average error cost of 4.2%, whereas in the present study the average switch cost in reaction time was 564 ms with an average error cost of 4%. The smaller cost in reaction time reported by Rogers and Monsell may be attributed to the fact that their participants completed not only an extensive amount of pre-experimental training (practice), but also performed the task on two separate days in order for the researchers to examine the effectiveness of practice in reducing switch costs. Secondly, the present study also replicated Rogers and Monsell’s finding that participants commit more errors when an
incongruent irrelevant character is present than when the irrelevant character is congruent with the correct response.

Although all of the main effects of the original study were replicated by the present study, several additional effects and interactions were observed in the present study that were not reported in Rogers and Monsell’s (1995) study. First, it was found that participants in the present study responded more quickly when the irrelevant character was incongruent with the correct response. Secondly, interactions between the current irrelevant character and both trial type and task revealed that the current irrelevant character only had an effect on the response rate on switch trials and the letter task. Thirdly, participants made more errors on the digit task compared to the letter task. Lastly, the interaction between task and current irrelevant character on error rate reveals that the current irrelevant character only had an effect on the digit task (participant committed more errors when the current irrelevant character was incongruent with the correct response compared to when it was congruent with the correct response).

Data Exploration

Because the hypothesized interaction of linguistic group and switch cost was not significant, several attempts were made to determine if any extraneous variables unsystematically affected the results and obscured any differences in reaction time than may exist between the two linguistic groups. Several possible explanations were investigated. As a first attempt, pairs with high error rates (average error rate greater than 15%) were removed from the analysis. The removal of two highly inaccurate pairs
did not significantly increase the difference in switch cost between the monolingual and bilingual participants.

Secondly, the analyses were conducted on mean reaction times, rather than the mean of individuals’ median reaction times, with a variety of trimming methods to control for the slightly positively skewed nature of the reaction time frequency distribution. In addition to mean reaction time analyses, the observations were subjected to a log transformation as a second attempt to control for the slight skew of the data set. Neither method produced the hypothesized interaction.

As a third attempt to observe an interaction between linguistic group and switch cost, bilinguals who infrequently switch between their two languages were removed from the analyses. According to the original hypothesis, a bilingual advantage may exist in nonlinguistic task switching because of the bilinguals’ practice with linguistic switching. Therefore, it was reasonable to remove any bilinguals who were not “practiced” at switching between their two languages because the hypothesized bilingual advantage may not be extended to this group. Bilinguals who rated the frequency of switching between their two languages (Language switching section: #1) less than “4” were removed from the analyses (n=11). The resulting mean and median analyses on reaction time revealed a larger difference in switch cost between the monolinguals and bilinguals (10 ms for median reaction times; bilinguals: 522 ms; monolinguals: 532 ms), but this difference was not statistically significant with only 14 matched pairs.

Following the previous line of reasoning, it was decided to remove bilinguals who rated themselves as being “less bilingual” (i.e. not highly proficient in both
languages). This was done to obtain a sample of bilinguals who were highly proficient in both languages which may mediate any bilingual advantages in task switching.13 Bilinguals whose average ratings of bilingualism (Bilingualism section: #2-5) were greater than “2” were removed from the analyses. Mean and median reaction times for the remaining 15 pairs of participants revealed an even larger difference in switch cost between the monolinguals and bilinguals (52 ms for median reaction times; bilinguals: 522 ms; monolinguals: 574 ms), but this difference was not statistically significant.

Analyses were also conducted on pairs with bilinguals whose age of L2 acquisition was before age 5 years (n=12), pairs with bilinguals whose age of L2 acquisition was after age 5 years (n=14), and pairs with only balanced bilinguals (i.e. bilinguals whose mean bilingualism rating was less than or equal to 1.75 on scales of bilingualism ranging from 1 (balanced bilingual) to 5 (unbalanced bilingual), n=14). This was done to determine if age of L2 acquisition and/or degree of bilingualism mediate the effects of bilingualism on nonlinguistic switch costs. The difference in switch costs between monolinguals and bilinguals whose age of L2 acquisition was less than 5 years was 63 ms (bilinguals: 551 ms; monolinguals: 488 ms). The difference is in the opposite direction of the hypothesized bilingual advantage, although it is not statistically significant. When bilinguals who age of L2 acquisition was greater than 5 years, the difference in switch costs between the two linguistic groups was 29 ms (bilinguals: 566 ms; monolinguals: 595 ms). Although this difference is in the hypothesized direction, it, too, is not statistically significant. Finally, when only balanced bilinguals were included

11Cummins threshold hypothesis

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in the analyses, there was a nonsignificant 16 ms difference in switch costs between the balanced bilinguals and monolinguals in the hypothesized direction (bilinguals: 535 ms; monolinguals: 519). Therefore, age of acquisition and degree of bilingualism do not appear to mediate the effects of bilingualism on nonlinguistic switch costs, although this conclusion is only speculative given the small sample sizes.

As a last attempt to uncover any differences between the performance of the two linguistic groups that may not have been captured by the original analyses, the criteria for constructing the matched pairs were examined. Recall that each monolingual-bilingual pair was matched as closely as possible in terms of gender, age, nonverbal IQ, SES, and college major. Although the pairs were matched perfectly on gender and very closely with respect to nonverbal IQ (within 2 points) and SES (within 1 point), due to the nature of the samples it was more difficult to match on age (within 8 years with an average deviation of 2.4 years) and college major (at least within a particular college). Pairs that were not perfectly matched on all variables were inspected to determine if the differences in switch costs within individual pairs were in line with the hypothesized trend (i.e. smaller switch cost for bilinguals), stood in contrast to the hypothesized trend (i.e. larger switch cost for the bilinguals), or revealed no difference in switch cost at all. It was determined that slight mismatches in SES, age, and college major did not explain any systematic switch cost trend between the pairs. Only 3 of the 25 pairs differed by 2 points on the nonverbal intelligence measure and these 3 pairs showed either a larger switch cost for the bilinguals or no difference in switch cost for the pair. Therefore, these three pairs were removed from the data set. The analyses on the median reaction
times of the remaining 23 pairs revealed a 33 ms difference in switch cost between the two groups (bilinguals: 535 ms; monolinguals: 568 ms), but once again this difference was not statistically significant.

Finally, power analyses were performed on the difference in switch costs between the bilinguals' and monolinguals' reaction time. As previously stated, the difference in switch costs for these two groups was 6 ms (SD=319). The standardized effect size for this study is only 0.02σ and the power of the study is only 0.05. Consequently, it was determined that approximately 17,500 matched pairs of bilinguals and monolinguals would be needed for this difference in switch cost to be statistically significant when α is 0.05 and 1-β (power) is 0.80! It was concluded that this study suffered from an inadequate sample size of matched pairs and an extremely low level of power.

**Suppression Task**

The suppression task required that participants suppress the activation of typical but absent objects. It was suggested that a scenic array provokes that activation of all objects, both present and absent, that conceivably belong in the particular thematic category. However, to respond correctly in the typical but absent experimental trials, the participant must successfully suppress the activation of items typical of the thematic array that were not present in the scenic array presentation. Gernsbacher and Faust (1991) demonstrated that skilled comprehenders are not able to suppress the typical but absent objects initially following the scenic array (i.e. when the test item was presented at a 50 ms delay interval), but they were successful in suppressing these items at the longer delay interval (1000 ms). Successful suppression of the typical but absent items are
measured by calculating an interference score. This score represents the difference in reaction time between typical but absent trials and atypical but absent items at each of the two delay intervals.

If bilinguals are better able to suppress irrelevant information, it was hypothesized that they would exhibit less overall interference at each of the test object delay intervals. Furthermore, it was hypothesized that they would demonstrate a release from interference at an earlier delay interval compared to the monolingual participants.

Study Results

The average of participants' median reaction times and average error rates for the experimental trials (i.e. test objects absent from scenic array) were subjected to a repeated measures analysis of variance with the following independent variables: linguistic group (bilingual or monolingual), typicality of test object (typical or atypical), and delay interval (50 ms, 300 ms, 750 ms, or 1000 ms). Trials in which participants committed errors were omitted from the analyses which constituted approximately 15% of the observations. Table 4 represents the monolinguals' and bilinguals' average median reaction times (with standard deviations in parentheses) and average error rates for the experimental trials. An interference score was computed by subtracting the participants' latencies to reject test objects after viewing atypical arrays from their latencies to reject test objects after viewing typical arrays.

With regard to reaction times, only the main effect of delay interval was significant, \( F(3, 72)=7.15, p<.05 \). The Tukey post-hoc multiple comparison procedure revealed that participants responded more quickly at the longer 750 ms delay interval.
(M=544, SD=159) compared to the immediate 50 ms delay interval (M=671, SD=148), $Q(4, 72)=4.57, p<.05$. None of the other five comparisons reached significance, $Q's<2.95$ and no other main effects or interactions were significant, $F's<0.96$. Figure 6 displays the amount of interference experienced by each linguistic group at each of the delay intervals. The interference scores that are graphically depicted in Figure 6 represent the difference in reaction times to typical and atypical absent test objects that are found in Table 4.

Table 4. Suppression: Average median reaction times (and standard deviations), error rates, and interference scores for each condition of the experimental trials

<table>
<thead>
<tr>
<th>Delay Interval</th>
<th>50 ms</th>
<th>300 ms</th>
<th>750 ms</th>
<th>1000 ms</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Atypical</td>
<td>Typical</td>
<td>Interference</td>
<td></td>
</tr>
<tr>
<td>M: 647 (255)</td>
<td>M: 646 (278)</td>
<td>M: -1 ms</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.5%</td>
<td>17.5%</td>
<td>15%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>B: 665 (233)</td>
<td>B: 726 (302)</td>
<td>B: 61 ms</td>
<td></td>
<td></td>
</tr>
<tr>
<td>9%</td>
<td>22%</td>
<td>13%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.5%</td>
<td>12%</td>
<td>10.5%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>B: 591 (223)</td>
<td>B: 601 (274)</td>
<td>B: 10 ms</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3%</td>
<td>18.5%</td>
<td>15.5%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4%</td>
<td>12.5%</td>
<td>8.5%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>B: 574 (236)</td>
<td>B: 555 (291)</td>
<td>B: -19 ms</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.5%</td>
<td>15.5%</td>
<td>13%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>M: 580 (240)</td>
<td>M: 598 (266)</td>
<td>M: 18 ms</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2%</td>
<td>15%</td>
<td>13%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>B: 614 (254)</td>
<td>B: 632 (344)</td>
<td>B: 18 ms</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4.5%</td>
<td>16.5%</td>
<td>12%</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
In examining the error rates, main effects were observed for both delay interval, $F(3, 72)=3.14$, $p<.05$, and typicality of test object, $F(1, 24)=69.89$, $p<.0001$. Fischer's least significant difference (LSD) test\textsuperscript{14} revealed that participants committed significantly more errors at the 50 ms delay interval ($M=12.75\%$, $SD=0.08$) compared to the longer delay intervals (300 ms: $M=8.75\%$, $SD=0.06$, $t(72)=2.59$, $p<.05$; 750 ms: $M=8.63\%$, $SD=0.06$, $t(72)=2.67$, $p<.05$; and 1000 ms: $M=9.5\%$, $SD=0.07$, $t(72)=2.11$, $p<.05$). The number of errors committed at the longer delay intervals, however, did not differ significantly from one another, $t's<0.57$. With respect to the typicality of the test objects, participants were more accurate in their responses when the test object was atypical of the scenic array ($M=3.6\%$, $SD=0.03$) than when the test object was typical of the scenic array ($M=16.2\%$, $SD=0.08$). No other main effects or interactions were significant, $F's<2.34$.

![Image](image-url)

**Figure 6. Suppression: Interference for both linguistic groups**

\textsuperscript{14}It should be noted that the Fisher's least significant difference (LSD) test is an extremely liberal multiple comparison test. The Tukey, Newman-Keuls, and Bonferroni multiple comparison procedures did not reveal any significant differences between the error rates at each of the delay intervals.
Comparison to Gernsbacher and Faust (1991, Experiment 2)

Gernsbacher and Faust (1991, Experiment 2) found that both more skilled and less skilled comprehenders experienced a significant amount of interference from the typical but absent test object at the immediate 50 ms delay interval (more skilled comprehenders: 74 ms; less skilled comprehenders: 82 ms), while only the less skilled comprehenders were still experiencing a significant amount of interference at the longer delay interval of 1000 ms (more skilled comprehenders: 7 ms; less skilled comprehenders: 86 ms). In the present study, only the bilinguals evidenced a trend of interference at immediate 50 ms delay interval, although this trend was not statistically significant, \( p < .15 \) (bilinguals: 61 ms; monolinguals: -1 ms). Interestingly, at the intermediate 300 ms interval, the bilinguals showed a decreasing trend in interference (10 ms) while the monolinguals began to show some trend of interference (40 ms) from the typical but absent test object. At the longer 750 ms delay interval, both linguistic groups demonstrated a reduction in the trend of interference from the typical but absent test object (bilinguals: -19 ms; monolinguals 2 ms). Finally, at the longest delay interval, both groups showed the same trend of interference (18 ms). Although there were no

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13 However, Gernsbacher and Faust report (in a footnote) that the three-way interaction between comprehension skill, delay interval, and typicality was not statistically reliable at \( p < .14 \).

14 Issues related to the power of this study are addressed in a later section.

15 Possible explanations for the absence of a trend of interference for the monolinguals at the immediate delay interval are explored in the next section.

16 These measures of interference are not statistically different from zero.
statistically significant instances of interference due to the inadequate power of the study, the patterns of interference within and between the linguistic groups are briefly discussed.

In comparing the two studies, it appears that the bilinguals' pattern of interference at the immediate delay interval (50 ms) and the longer delay intervals (750 ms and 1000 ms) was similar to the pattern reported by Gernsbacher and Faust for the more skilled comprehenders. A separate analysis of the bilinguals' performance at the immediate 50 ms delay interval and the longer 750 ms delay interval revealed a main effect of delay interval, $F(1, 24)=10.99, p<.05$, and a marginal interaction of delay interval and typicality, $F(1, 24)=3.51, p<.0731$. These findings are similar to Gernsbacher and Faust's findings for the more skilled comprehenders at the immediate and delayed test intervals in which interference was observed at the immediate delay interval and the interference disappeared at the longer delay interval.

The trends in performance of the monolinguals, however, do not resemble the performance of either the more skilled or less skilled comprehenders of the previous study. In comparing the two studies, it is necessary to focus on the differences between the participants and methodology in the two studies that may explain the different trends. First of all, Gernsbacher and Faust tested adults who scored in the top third or the bottom third on a standardized test of comprehension. In the present study, it was assumed that a normal distribution of comprehension abilities was found in each linguistic group tested which may explain the unclear trend in interference reduction across the longer delay intervals. Secondly, the participants in Gernsbacher and Faust's
study were exposed to scenic arrays that varied with respect to the number of objects in each array (3-6). Presumably, the task was easier when fewer objects appeared in the array. In the present study, each array consisted of five objects which means that the present task may have been more difficult to perform and therefore obscured the trends across the delay intervals. Lastly, the medium of the test item is not the same in the original study and the present study. Gernsbacher and Faust used words as test items, while black-and-white drawings were used in the present study to meet the nonlinguistic requirements of the dissertation.

Data Exploration

In examining the results reported by Gernsbacher and Faust (1991) in conjunction with the interference trends in the present study, the performance by the monolinguals at the 50 ms delay interval was rather puzzling. The monolinguals did not experience the trend of interference at the 50 ms delay interval that was observed for the bilinguals and both groups of participants in the previous study. The frequency distributions for both monolinguals and bilinguals at the 50 ms interval for both typical and atypical experimental arrays were examined to determine if there were any strange response patterns for the monolinguals in the typical test object condition. In examining the frequency distributions, anticipatory responses were identified which constitute 23% of the data set. Anticipatory responses were defined as reaction times less the 250 ms which is the minimum time needed to perform the simplest of cognitive tasks and execute a motor response. Reaction times of less than 250 ms were classified as being anticipatory because the participant anticipated and formed a response to the test object before it
appeared and their reaction time simply reflected the motor execution of the response. This was possible when the participants identified the test object in the scenic array of objects. While both bilingual and monolingual participants exhibited anticipatory responses (i.e. reaction times less than 250 ms), the frequency of these types of responses did not explain the unexpectedly fast reaction times for the monolinguals in this condition.

Due to the presence of the anticipatory responses by both monolinguals and bilinguals, mean analyses were performed in which reaction times of less than 250 ms were removed to determine if the anticipatory responses were responsible for obscuring the previously reported trends in interference reduction across longer delay intervals. Mean analyses of reaction time did not offer any conclusive evidence that anticipatory responses were masking the existence of interference for the monolinguals in 50 ms typical experimental condition. In fact, the removal of anticipatory responses and reaction times greater than 1500 ms did not change their mean reaction time in the typical condition, but increased the mean reaction time in the atypical condition which resulted in a difference between these two conditions that is more in line with facilitation than interference (50 ms: typical: M=693; atypical: M=645; interference=-48).

Because of the unexplainable performance of the monolinguals at the 50 ms interval, it was decided to examine the differences between the linguistic groups at the 300 ms interval in which more expected trends were observed. Even though there was a 10 ms difference in response rates for typical-atypical conditions for the bilinguals and a 40 ms difference in response rates for typical-atypical conditions for the monolinguals,
these differences were neither significantly different from one another, nor were they significantly different from zero which indicates that neither group experienced a significant amount of interference from the typical but absent test object at this delay interval.

An attempt was made to determine if nonverbal intelligence was useful in understanding the performance of the monolingual participants. Because Gernsbacher and Faust demonstrated that comprehension skill mediates the pattern of interference experienced at immediate and longer delay intervals and because comprehension skill is related to intelligence, separate analyses were performed for monolinguals scoring below the median (raw score of 23) on the measure of nonverbal intelligence and for monolinguals scoring above the median on this measure. The 13 participants who scored below the median on the nonverbal intelligence measure exhibited an unexpected vacillating pattern of interference across the delay intervals (-54 ms at 50 ms, 16 ms at 300 ms, -40 ms at 750 ms, and 57 ms at 1000 ms). The 12 monolinguals who scored above the median showed a more expected pattern of interference (55 ms at 50 ms, 66 ms at 300 ms, 48 ms at 750 ms, and -26 ms at 1000 ms). The same separate analyses were also conducted with the addition of the bilingual matched pairs. Not only were there no statistically significant instances of interference, but there was no interaction between linguistic group, typicality, and delay interval. Due to the extremely small sample sizes, none of the interference scores were statistically different than zero, but given the trends for the monolinguals, it is plausible that general nonverbal intelligence may possibly affect patterns of interference across delay intervals.
The counterbalancing scheme of the experimental trials blocked on delay interval was also examined to determine if the order in which the participants were exposed to the blocked delay intervals had an effect on their performance. Although the participants were evenly and randomly assigned to the four combinations of delay interval presentation (Latin square) before the linguistic pairs were assembled, after the pairs were assembled the frequency of each linguistic group in each combination of delay interval presentation was uneven. Therefore, nine pairs were removed in order to obtain an equal number of monolingual and bilingual participants in each combination of delay interval presentation. Median analyses were conducted on the remaining 16 pairs and no differences in interference patterns between the two linguistic groups were observed across the delay intervals.

In addition to exploring any possible effects of nonverbal intelligence and counterbalancing schemes on the participants' performance on this task, age of L2 acquisition and degree of bilingualism were also examined to determine the effects of these factors on the bilinguals' suppression abilities. Interference scores at each delay interval were compared for pairs with bilinguals whose age of L2 acquisition was before age 5 years (n=12), pairs with bilinguals whose age of L2 acquisition was after age 5 years (n=14), and pairs with only balanced bilinguals (i.e. bilinguals whose mean bilingualism rating was less than or equal to 1.75 on scales of bilingualism ranging from 1 (balanced bilingual) to 5 (unbalanced bilingual), n=14). None of the analyses revealed a significant effect of typicality or a significant interaction of typicality and delay interval which would evidence suppression of typical but absent test items. Most importantly,
there were no hypothesized interactions of typicality, delay interval, and linguistic group which suggests that age of L2 acquisition and degree of bilingualism do not explain the absence of differences in inference patterns across the four delay intervals between the two linguistic groups.

A last attempt was made to explore the effect of the order of delay interval presentation on the response patterns of the two groups. The matched pairs were separated and a between subjects analysis was performed on the median reaction times for the first blocked delay interval for each participant. The analyses did not show a difference in interference scores between the two linguistic groups regardless of the first delay interval presented. Therefore, it was concluded that the order of the blocked delay intervals does not explain the unusual performance of the monolinguals at the immediate 50 ms delay interval.

Finally, power analyses were performed on the difference in interference scores (atypical-typical) between the monolinguals' and bilinguals' reaction time at each delay interval. Table 5 shows the standardized effect size, observed power, and necessary sample size given $\alpha=0.05$ and $1-\beta$ (power)=0.8 for these differences to be statistically significant for each delay interval. As with the task switching task, the suppression task suffers from an inadequate sample size and an extremely low level of power.

**Negative Priming Task**

The negative priming task required the inhibition of processing the irrelevant shape (red), and the activation of this previously ignored/suppressed shape when it
Table 5. Suppression: Standardized effect size, power, and sample size for each delay interval

<table>
<thead>
<tr>
<th>Delay interval</th>
<th>Difference in interference scores (st. dev.)</th>
<th>Standardized effect size</th>
<th>Observed power</th>
<th>Sample size needed</th>
</tr>
</thead>
<tbody>
<tr>
<td>50 ms</td>
<td>62 ms (292)</td>
<td>0.21</td>
<td>0.0764</td>
<td>138</td>
</tr>
<tr>
<td>300 ms</td>
<td>30 ms (231)</td>
<td>0.13</td>
<td>0.0643</td>
<td>367</td>
</tr>
<tr>
<td>750 ms</td>
<td>21 ms (196)</td>
<td>0.11</td>
<td>0.0618</td>
<td>540</td>
</tr>
<tr>
<td>1000 ms</td>
<td>0 ms (227)</td>
<td>0</td>
<td>0</td>
<td>N/A</td>
</tr>
</tbody>
</table>

became the attended shape on the negative priming trials. If a bilingual advantage exists for the inhibition of processing irrelevant information, it was hypothesized that a larger negative priming effect would be observed for the bilinguals compared to the monolinguals.

Study Results

Reaction times less than 250 ms or greater than 5000 ms and reaction times associated with an error on either a prime or probe trial were excluded from the analyses. The criteria for excluding the upper limit reaction times and those associated with errors are consistent with the procedure used by DeSchepper and Treisman (1996, Experiment 1). The excluded observations accounted for approximately 8.4% of the data. The mean reaction times (in milliseconds) and standard deviations (in parentheses), and error rates for the control trials following an unrelated prime and the negative priming trials in which the currently attended shape (green) had been the previously ignored shape (red) can be found in Table 6 for each linguistic group (bilinguals and monolinguals) and each response sequence (different-different, different-same, same-different, same-same).
A repeated measures analysis of variance on reaction time did not reveal any main effects of linguistic group (bilingual or monolingual), trial type (control or negative priming), or probe response (different or same), $F$'s < 3.77. There was, however, a main effect of prime response, $F(1, 24) = 4.88$, $p < .05$. Participants responded more quickly on prime trials requiring the “different” response ($M = 1179$, $SD = 231$) than those trials requiring the “same” response ($M = 1208$, $SD = 267$). None of the factors significantly interacted with one another, $F$’s < 1.63.

Collapsing across prime and probe responses, the bilinguals’ mean reaction time for the control trials was $M = 1137$, $SD = 265$ and their mean reaction time for the negative priming trials was $M = 1146$, $SD = 761$ (9 ms difference). For the monolinguals, the mean reaction time for the control trials was $M = 1247$, $SD = 369$ and their mean reaction time for the negative priming trials was $M = 1244$, $SD = 356$ (-3 ms difference). Median reaction times were also calculated because of the positively skewed nature of the data set. The bilinguals exhibited a 17 ms difference between control and negative priming trials, and the monolinguals exhibited a 11 ms difference between these trials. Although the differences in median reaction time for both groups were in the direction of the negative priming effect, neither difference was statistically significant.

A repeated measures analysis of variance on error rates did not reveal any main effects of linguistic group, trial type, prime response, or probe response ($F$’s < 3.16). Linguistic group did, however, significantly interact with trial type, $F(1, 24) = 9.03$, $p < .05$. Separate ANOVA’s for each linguistic group revealed that the bilinguals committed significantly more errors on control trials ($M = 6.9\%$, $SD = 0.09$) compared to
negative priming trials ($M=5.2\%$, $SD=0.09$), $F(1, 24)=6.08$, $p<.05$, while there was no significant difference in the number of errors committed by the monolinguals for the two trial types (control: $M=2.3\%$, $SD=0.02$; negative priming: $M=3.2\%$, $SD=0.03$), $F<2.33$.

Evidently, the bilinguals were more accurate on negative priming trials compared to control trials, whereas the monolinguals were equally accurate on each trial type.

Table 6. Negative priming: Mean reaction times, standard deviations, and error rates

<table>
<thead>
<tr>
<th>Bilinguals</th>
<th>Control</th>
<th>Negative Priming</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prime Response</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Probe Response</td>
<td>Different</td>
<td>Same</td>
</tr>
<tr>
<td></td>
<td>1100</td>
<td>1186</td>
</tr>
<tr>
<td></td>
<td>(238)</td>
<td>(320)</td>
</tr>
<tr>
<td></td>
<td>5%</td>
<td>8.6%</td>
</tr>
<tr>
<td></td>
<td>1128</td>
<td>1133</td>
</tr>
<tr>
<td></td>
<td>(301)</td>
<td>(270)</td>
</tr>
<tr>
<td></td>
<td>3.7%</td>
<td>10.3%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Monolinguals</th>
<th>Control</th>
<th>Negative Priming</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prime Response</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Probe Response</td>
<td>Different</td>
<td>Same</td>
</tr>
<tr>
<td></td>
<td>1269</td>
<td>1283</td>
</tr>
<tr>
<td></td>
<td>(414)</td>
<td>(442)</td>
</tr>
<tr>
<td></td>
<td>1.8</td>
<td>3.7%</td>
</tr>
<tr>
<td></td>
<td>1214</td>
<td>1221</td>
</tr>
<tr>
<td></td>
<td>(337)</td>
<td>(364)</td>
</tr>
<tr>
<td></td>
<td>2.7%</td>
<td>1.1%</td>
</tr>
</tbody>
</table>
Comparison to DeSchepper and Treisman (1996, Experiment 1)

The most problematic aspect of this study is that the negative priming effect reported by DeSchepper and Treisman (1996, Experiment 1) was not elicited in either linguistic group. Although the methodologies employed by DeSchepper and Treisman and the present study were identical with the exception of different novel shapes, a significant negative priming effect was not observed in the present study. DeSchepper and Treisman found a significant 34 ms difference in mean reaction time between the negative priming and control conditions, whereas the participants in the present study exhibited nonsignificant 9 ms (bilinguals) and -3 ms (monolinguals) differences in mean reaction time between the two conditions. When median reaction times were examined, DeSchepper and Treisman reported a 28 ms difference in the direction of the negative priming effect, while the nonsignificant differences in median reaction time for the present study were only 17 ms (bilinguals) and 11 ms (monolinguals), albeit in the direction of the negative priming effect. With regard to the error rates in the present study, the bilinguals committed significantly more errors on the control trials (7%) compared to the negative priming trials (5%), while there was no significant difference in the number of errors committed by the monolinguals in either condition. Although DeSchepper and Treisman found a trend similar to that of the bilinguals in their error rates (4% on control trials and 3% on negative priming trials), this difference was not statistically significant.

\[17\] DeSchepper and Treisman did not report any analyses on median reaction times so it is unknown if this median difference of 28 ms is statistically significant.
It is not clear why the present study did not replicate the negative priming effect reported by DeSchepper and Treisman and a previous pilot study in which a marginally significant 42 ms negative priming effect was observed. One possible explanation may lie in the substantially longer reaction times of the present participants compared to the participants in the original study. DeSchepper and Treisman's participants responded, on average, after 625 ms (with an average standard deviation of 121 ms), whereas the participants in the present study responded on average, after 1194 ms (with a standard deviation of 343 ms). It is possible that these longer reaction times have somehow masked the negative priming effect which may have a time course that expires after a relatively long response latency. Furthermore, the high variability of the present participants' responses coupled with their longer response times may indicate that the participants in the present study found the task more difficult than the participants in the original study which interfered with the negative priming effect.

Another explanation may lie in the number of trials completed by participants in each study. For example, the participants in the original study completed more than twice as many trials (240 trials) as the participants in the present study (112 trials), even though participants in both studies completed a similar number of practice trials. The differences in average reaction time between these two studies may be due to the fact that the participants in the original study developed a more efficient and consistent response rate across the larger number of trials, while the participants in the present study did not have an opportunity to establish such a response pattern across the fewer number of trials which may explain their longer and more variable response rates.
A third explanation as to why the present study did not replicate the negative priming effect reported by DeSchepper and Treisman may be related to the way in which DeSchepper and Treisman conducted their analyses. Reaction time data tends to be positively skewed which requires “trimming” techniques that remove impossibly fast and extremely slow reaction times in order for a more normal distribution of reaction times to be analyzed with respect to mean response latencies. Although DeSchepper and Treisman conducted analyses on the participants’ mean reaction times, no trimming techniques were reported. The absence of trimming techniques calls into question the validity of analyzing mean reaction times for positively skewed data. A more appropriate technique for analyzing positively skewed reaction times is to conduct the analyses on median reaction times, rather than mean reaction times. Although DeSchepper and Treisman reported a difference of 28 ms in median reaction times between the negative priming and control conditions, they failed to mention if this difference was statistically significant. If this difference was not significant, the results of the present study would not stand in contrast to the results of DeSchepper and Treisman.

Data Exploration

In addition to conducting analyses on the participants’ median reaction times in the present study, reaction times were also subjected a log transformation and a variety of trimming techniques in order to explore a more optimal method of analyzing the positively skewed reaction times. To control for the presence of anticipatory responses

18 Reaction times were never greater than 5 s because each display was terminated either after the participant’s response or after 5 s if a response had not been made.
in the data set (i.e. reaction times less than 250 ms), the log transformation was performed on reaction times in which 250 ms had been subtracted. Although the log transformation was useful in reducing the positive skew of the data set, no differences were observed between the negative priming and control conditions. In addition to the log transformation, several trimming techniques were also performed. Reaction times less than 250 ms were removed as a lower limit, and reaction times greater than 2050 ms (2.5 standard deviations above the mean) or 2220 ms (3 standard deviations above the mean) were removed as upper limits. Again, these methods proved to be successful at reducing the positive skew of the data set, but neither produced the negative priming effect.

As a last attempt to analyze the positively skewed set of reaction times, a trimming technique utilized by DeSchepper and Treisman (1996) in their subsequent experiments was employed. Reaction times longer than 3 standard deviations from the mean for each of the eight conditions were discarded. The mean and medians for each condition were then compared and if they differed by more than 10%, the longest remaining reaction time was eliminated and the means were recalculated. This final trimming technique was not useful in detecting the negative priming effect, but it was useful in highlighting the fact that DeSchepper and Treisman also had a difficult time demonstrating the negative priming effect in later experiments in which they found considerable individual differences which included both negative priming and facilitation effects. DeSchepper and Treisman reported both statistically significant and nonsignificant negative priming effects based on mean reaction times ranging from 5 ms.
to 55 ms in later experiments. Although they also included the differences in median reaction time\textsuperscript{21}, analyses on the negative priming effects of median reaction times were not reported.

Finally, analyses on mean reaction times using the same trimming method as the initial analyses (i.e. reaction times less than 250 ms and greater than 5000 ms were removed) were conducted on pairs with bilinguals whose age of L2 acquisition was before age 5 years (n=12), pairs with bilinguals whose age of L2 acquisition was after age 5 years (n=14), pairs with only balanced bilinguals (i.e. bilinguals whose mean bilingualism rating was less than or equal to 1.75 on scales of bilingualism ranging from 1 (balanced bilingual) to 5 (unbalanced bilingual), n=14), and pairs in which both the monolingual and bilingual participants were fast responders (i.e. mean reaction times less than 1200 ms which was the overall mean reaction time for all participants, n=18).

When age of acquisition was considered, there was no evidence of a negative priming effect for either linguistic group for bilinguals who began learning their L2 before or after the age of 5 years. Interestingly, when only balanced bilinguals were examined, the bilinguals evidenced a 22 ms difference between negative priming and control conditions in the direction of facilitation rather than negative priming, while the monolinguals evidenced a 27 ms difference between these same conditions in the direction of a negative priming effect. However, there was no significant effect of negative priming and no interaction between trial type and linguistic group which may be due to the small

\textsuperscript{19}The differences in median reaction time were smaller than the differences in mean reaction time which highlights the potential positive skew of their reaction time data.
sample size. Finally, when only fast responders were examined, both linguistic groups showed similar differences in reaction times between the two trial types (9 ms for the bilinguals and 10 ms for the monolinguals), although no significant negative priming effect was observed for either group. Therefore, age of L2 acquisition and faster overall response rates were not useful factors in eliciting the negative priming effect, although the trend of differences in reaction times between the two trial types for balanced bilinguals and monolinguals was in the hypothesized direction. Unfortunately, the nonsignificant nature of these analyses prevent any further interpretation of these difference, but may suggest future directions for this line of inquiry.

Language Switching Task

The final study conducted in this dissertation was a language switching task performed only by the bilinguals. The purpose of including a linguistic switching task was twofold. First, it was included to explore the bilinguals' language switching abilities. Secondly, the language switching task allows comparisons to be made between nonlinguistic and linguistic switching in bilinguals. Recall that Meuter and Allport (1999) observed an asymmetrical switch cost when bilinguals switched between their more dominant L1 and their less dominant L2. However, when the bilinguals were separated into partial and balanced bilinguals according to the relative strength of their two languages, the asymmetry in switch costs was only observed for the partial bilinguals, while no asymmetry was observed for the balanced bilinguals. Meuter and Allport determined the degree of bilingualism based on the bilinguals’ relative speed in naming numerals in each of their two languages.
Study Results

Median reaction times (in milliseconds) and mean error rates were analyzed for the 27 bilingual participants who were matched with monolinguals on the three nonlinguistic computer tasks. These dependent variables were subjected to repeated measures analysis of variance with two independent variables: trial type (switch or nonswitch) and response language (L1 or L2). Median reaction times and error rates are found in Table 7. With regard to median reaction times, main effects were observed for trial type, \( F(1, 26) = 63.33, p < .0001 \), and response language, \( F(1, 26) = 51.56, p < .0001 \). Participants named numerals more quickly on nonswitch trials (\( M = 535, \ SD = 87 \)) compared to switch trials (\( M = 611, \ SD = 115 \)), and they were faster to respond in their native language (\( M = 536, \ SD = 104 \)) than in their second language (\( M = 610, \ SD = 101 \)). There was no interaction between trial type and language for reaction times, \( F = 0.87 \).

When error rates were analyzed, it was found that only the trial type affected performance, \( F(1, 26) = 32.08, p < .0001 \). Participants made significantly more errors on switch trials (\( M = 10.8\%, \ SD = 0.07 \)) compared to nonswitch trials (\( M = 7\%, \ SD = 0.07 \)). There was no main effect of language and the two independent variables did not significantly interact with one another, \( F's < 0.03 \).

Comparison to Meuter and Allport (1999)

Both Meuter and Allport and the present study found that bilinguals named numerals more quickly on nonswitch trials compared to switch trials. While both studies demonstrated performance costs associated with language switching, the asymmetry in switch costs reported by Meuter and Allport was not replicated in the present study.
Whereas Meuter and Allport found that bilinguals responded more quickly when responding in L1 than L2 on nonswitch trials (a 24 ms difference), but more quickly in L2 than L1 on switch trials (a 28 ms difference), the bilinguals in the present study always responded more quickly in L1 than L2 on both types of trials (a 74 ms difference). Secondly, the asymmetry in switch costs reported by Meuter and Allport was also demonstrated in analyses of the difference between switch and nonswitch trials (i.e. switch cost) for each response language. The bilinguals evidenced a significantly longer switch cost when responding in L1 (143 ms) compared to L2 (85 ms). The bilinguals in the present study, however, did not exhibit a significant asymmetry in switch costs for either response language (71 ms when responding in L1 and 79 ms when responding in L2). Therefore, the primary difference between the two studies is that Meuter and Allport demonstrated an asymmetrical cost of switching between L1 and L2, whereas the bilinguals in the present study did not.

Table 7. Language switching: median reaction times (and standard deviations) and error rates

<table>
<thead>
<tr>
<th>Trial Type</th>
<th>Switch</th>
<th>Nonswitch</th>
<th>Switch Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Language</td>
<td>L1</td>
<td>L2</td>
<td></td>
</tr>
<tr>
<td></td>
<td>572 (113)</td>
<td>649 (106)</td>
<td>71 ms 10.8%</td>
</tr>
<tr>
<td></td>
<td>501 (82)</td>
<td>570 (79)</td>
<td>4% 6.8% 7%</td>
</tr>
</tbody>
</table>

The fact that the present study did not replicate the asymmetrical switch costs found by Meuter and Allport is not problematic, however, considering the highly...
proficient nature of the bilinguals in the present study. When Meuter and Allport examined bilinguals whose relative strength of their two language was nearly equal\textsuperscript{22}, no asymmetry was detected in the performance cost of switching. Therefore, the absence of the asymmetrical switch cost for the bilinguals in the present study is in line with Meuter and Allport's findings for the bilinguals whose relative strength of their two languages was nearly equal, even though the bilinguals in the present study responded 74 ms faster in L1 than L2 across both trial types. Furthermore, the absence of the asymmetry in switch costs in the present study provides additional evidence supporting the conclusion that the bilinguals in the present study were overall highly proficient balanced bilinguals.

**Power Analyses**

Power analyses were performed on the switch costs of the bilinguals' reaction time. The average linguistic switch cost for the bilinguals was 76 ms (SD=49)\textsuperscript{23} and the power of the study was 0.4522.

**Relationship Between Nonlinguistic and Linguistic Switching in Bilinguals**

The purpose of exploring the relationship between nonlinguistic and linguistic switching in bilinguals was to determine whether the mechanism(s) responsible for control processes necessary for both tasks are the same (i.e. general control processes) or different (function-specific control processes). On the one hand, if the modular view

\textsuperscript{20}As an index of relative language proficiency, Meuter and Allport separated the bilinguals into two groups according to the mean difference in reaction time of naming numerals in L1 compared to L2. It is those bilinguals who demonstrated a smaller difference in reaction time that did not demonstrate the asymmetrical switch cost that was seen for bilinguals with a larger difference in reaction time.

\textsuperscript{21}This mean and standard deviation were obtained by collapsing over response language.
of language is to be supported, one would not necessarily expect that the same control processes are utilized in linguistic and nonlinguistic tasks because each module has its own specialized control processes, hence a relationship between the two tasks would not be expected. On the other hand, if language is a general cognitive function, one would expect a relationship between nonlinguistic and linguistic switching because both cognitive functions rely on the same general control processes. Therefore, the performance costs associated with switching in both the nonlinguistic and linguistic contexts were compared to determine if there was a relationship between linguistic and nonlinguistic switching in bilinguals.

Repeated measures analysis of variance, correlational and regression analyses were conducted on the task switching and language switching performance of the 25 bilingual participants who were matched with monolinguals on the task switching task. Table 8 displays the participants’ average median reaction times and error rates for each task in addition to the switch costs associated with each task.

Table 8. Language switching versus task switching: Median reaction times, error rates, and switch costs for bilinguals

<table>
<thead>
<tr>
<th>Trial Type</th>
<th>Switch</th>
<th>Language Switching</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1314 (273)</td>
<td>611 (102)</td>
</tr>
<tr>
<td></td>
<td>8.8%</td>
<td>11.4%</td>
</tr>
<tr>
<td>Nonswitch</td>
<td>757 (129)</td>
<td>533 (74)</td>
</tr>
<tr>
<td></td>
<td>4.3%</td>
<td>7.4%</td>
</tr>
<tr>
<td>Switch Cost</td>
<td>557 ms</td>
<td>78 ms</td>
</tr>
<tr>
<td></td>
<td>4.5%</td>
<td>4%</td>
</tr>
</tbody>
</table>
Reaction time and error rates were subjected to a repeated measures analysis of variance with the independent variables of task (task switching or language switching) and trial type (nonswitch or switch). With regard to reaction time, the main effects of task ($F(1, 24)=233.29, p<.0001$) and trial type ($F(1, 24)=132.37, p<.0001$) were qualified by an interaction of these two variables ($F(1, 24)=277.91, p<.0001$). First, participants responded more quickly naming numerals on the language switching task ($M=572$, $SD=85$) than categorizing letters and digits on the task switching task ($M=1036$, $SD=195$). Secondly, as previously reported, participants responded faster on nonswitch trials ($M=645$, $SD=73$) compared to switch trials ($M=963$, $SD=158$) on both tasks. The interaction reflects the smaller switch cost experienced by the bilinguals on the language switching task (78 ms) compared to the task switching task (557 ms), $Q=44.26, p<.05$.

Analysis of the error rates revealed only a main effect of trial type, $F(1, 24)=58.06, p<.0001$. As previously reported for each task, participants committed more errors on switch trials ($M=10.1\%, SD=0.05$) compared to nonswitch trials ($M=5.8\%, SD=0.03$). There was no main effect of task or interaction between task and trial type, $F's<0.2$.

In addition to the analysis of variance, the performance costs of switching in both the nonlinguistic and linguistic domains were compared to determine if a relationship exists between the two. This was done to test to satisfy the second objective of this dissertation which was to explore the switching behaviors of bilinguals and the factors that mediate these abilities. The switch costs in reaction time associated with each task
were significantly positively correlated, \( r = 0.54, p < .05. \) The positive correlation indicates that bilinguals who exhibited a high switch cost on the nonlinguistic switching task also exhibited a high switch cost on the linguistic switching task, and those who exhibited a low switch cost on the nonlinguistic switching task also exhibited a low switch cost on the linguistic switching task. The positive correlational relationship between performance costs for nonlinguistic and linguistic switching tasks corroborates Meuter and Allport's (1999) findings that performance costs in nonlinguistic switching accurately predict the performance costs of switching in linguistic tasks. Therefore, it appears that in the present study a general switching ability was available and utilized in both the nonlinguistic and linguistic domains.

Given that bilinguals' nonlinguistic switching abilities were related to their linguistic switching abilities, regression analyses were performed to determine if the performance cost of switching in the linguistic task can be predicted by not only general switching abilities, but other measures related to language switching and bilingualism. For example, if a highly proficient balanced bilingual frequently and effortlessly switches between her two languages, will she prove to be an effective language “switcher” (i.e. exhibit a low linguistic switch cost)? If the contrary is true (i.e. if she is a less proficient bilingual who infrequently and effortfully switches between her two languages), will she prove to be an inefficient language “switcher” (i.e. exhibit a high linguistic switch cost)?

To ascertain if degree of bilingualism, the frequency and effortfulness of language switching, the error rates did not reveal a significant relationship between task switching and language switching, \( r = -0.001. \)
switching, and general switching abilities were useful predictors of the magnitude of switch cost associated with linguistic switching, regression analyses were performed with these independent variables.

Using the stepwise regression technique, nonlinguistic switch costs, the bilinguals' self-ratings of degree of bilingualism, frequency and effortfulness of language switching, and general switching abilities were regressed on their linguistic switch costs to determine if variability in these factors accounted for variation observed in linguistic switch costs. Nonlinguistic switch costs was the first regressor because it had the highest correlation with linguistic switch costs. The explained variance was $R^2 = 0.2942$ which indicates that variability in nonlinguistic switch costs accounted for approximately 29% of the variability in linguistic switch costs ($B_1 = 0.16, F(1, 23) = 9.59, p < .05$). On step 2, it was determined that adding general switching abilities\(^25\) would lead to the largest increase in explained variance ($R^2$). The explained variance significantly increased from $R^2 = 0.2942$ to $R^2 = 0.4046$ and the regression coefficient for general switching abilities was marginally significant, $B_2 = -18.15, F(2, 22) = 4.08, p < .06$. On the third and final step, degree of bilingualism\(^26\) was added to the model. The explained variance increased from

\(^{25}\)The bilinguals rated the effortfulness of general switching abilities on the Bilingual Language Experience Questionnaire (Section: General switching abilities). A rating of “1” indicated that the bilingual found switching between two different tasks to be extremely easy, while a rating of “5” indicated that the bilingual found switching to be very difficult.

\(^{26}\)Degree of bilingualism was determined from response to questions #2-5 of the Bilingualism section of the Bilingual Language Experience Questionnaire (a rating of “1” indicated that the bilingual was highly proficient in both languages, while a rating of “5” indicated that the bilingual was only highly proficient in one language, but not proficient in the other language).
$R^2 = 0.4046$ to $R^2 = 0.4904$; the regression coefficient was only marginally significant, $F(3, 21) = 3.54, p < .07$. With the addition of the third independent variable, it can be concluded that approximately 49% of the variation in language switch costs can be explained by variation in nonlinguistic switch costs, general switching abilities, and degree of bilingualism. The regression coefficients, test statistics, and p-values for the final model are found in Table 9. None of the other independent variables (frequency or effortfulness of language switching) were significant at the p-value of 0.15 and were therefore not included in the final regression model. A summary of the stepwise procedure for the dependent variable, language switch cost, can be found in Table 10.

Table 9. Final regression model of the dependent variable, language switch costs

<table>
<thead>
<tr>
<th>Independent Variable</th>
<th>Parameter Estimate ($\beta$)</th>
<th>$F(3, 21)$</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nonlinguistic switch cost</td>
<td>0.1862</td>
<td>15.35</td>
<td>0.001</td>
</tr>
<tr>
<td>General switching abilities</td>
<td>-20.2538</td>
<td>5.57</td>
<td>0.03</td>
</tr>
<tr>
<td>Degree of bilingualism</td>
<td>15.7402</td>
<td>3.54</td>
<td>0.07</td>
</tr>
</tbody>
</table>

According to the final regression model, nonlinguistic switch cost was the best predictor of the magnitude of the linguistic switch costs. This is not surprising given the previously described positive relationship between these two variables. While general switching abilities were also useful in predicting language switch costs, the direction of this relationship is puzzling. It suggests that bilinguals who reported difficulties in

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$R^2 = .4904, F(3, 24) = 6.74, p < .01$
switching between two tasks in general exhibited low switch costs on the language switching task. This self-report measure may not accurately describe the bilinguals’ ability to switch between two tasks because it is a subjective rating of effortfulness rather than objective measure of performance. Finally, degree of bilingualism was a moderately effective predictor of language switch costs. Bilinguals who rated themselves as being more highly proficient in both languages also exhibited lower switch costs. This suggests that highly proficient bilinguals experienced less performance disturbance when switching between their two languages because each of linguistic system was adequately established. One would expect a higher switch cost for bilinguals whose two languages were not equally well-established because activation of the less-established language would require a greater level of suppression of the more-established language.

<table>
<thead>
<tr>
<th>Step</th>
<th>Variable</th>
<th>Partial $R^2$</th>
<th>Model $R^2$</th>
<th>$F$</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Nonlinguistic switch cost</td>
<td>0.2942</td>
<td>0.2942</td>
<td>9.59</td>
<td>.0051</td>
</tr>
<tr>
<td>2</td>
<td>General switching abilities</td>
<td>0.1104</td>
<td>0.4046</td>
<td>4.08</td>
<td>.0558</td>
</tr>
<tr>
<td>3</td>
<td>Degree of bilingualism</td>
<td>0.0859</td>
<td>0.4904</td>
<td>3.54</td>
<td>.073</td>
</tr>
</tbody>
</table>

Relationship Between Suppression, Negative Priming, and Linguistic Switching in Bilinguals

Correlational analyses were also performed between language switch costs and the suppression and negative priming performance of the bilinguals to explore the possible relationships between the mechanisms necessary for linguistic switching and
those necessary for suppression and negative priming. First, language switch costs were compared to interference scores on the suppression task at each delay interval of the experimental conditions. A positive correlation between language switch costs and interference scores would indicate that bilinguals who were efficient in suppressing the activation of typical but absent objects from scenic arrays were also successful in suppressing the activation of the inappropriate language on a switch trial. Conversely, bilinguals who were not efficient in suppressing the activation of typical but absent were also ineffective in suppressing the activation of the inappropriate language. Neither reaction time nor error rates of language switch costs were significantly correlated with interference scores at any of the delay intervals on the suppression task. Therefore, it appears that there is not a relationship between the mechanisms involved in language switching and the mechanisms necessary for the suppression of typical but absent objects, although this interpretation is only tentative given the nonsignificant interference scores of the suppression task.

Correlational analyses were also conducted to determine if a relationship existed between the bilinguals' language switch costs and their measures of negative priming. It was hypothesized that a positive correlation between these two variables would indicate that bilinguals who exhibited a high language switch cost, presumably due to the persisting suppression of the previously inappropriate language of the "pre-switch" trial that became the appropriate language of the "switch" trial, would also exhibit a high negative priming effect due to the persisting suppression of the previously unattended shape of the prime trial that became the attended shape of the subsequent probe trial.
The initial correlation analysis did in fact reveal a significant positive relationship between language switch costs and negative priming in bilinguals, $r=0.42$, $p<.05$. The scatterplot of this data is found in Figure 7. However, when the extreme outlier was removed from the analyses, the correlation between these two variables was no longer significant, $p<.28$. Therefore according to these studies, a significant relationship does not appear to exist between the bilinguals' language switch costs and measures of negative priming.

![Figure 7. Scatterplot of language switch costs and negative priming](image)

**Figure 7. Scatterplot of language switch costs and negative priming**
General Discussion

The principal hypothesis for this dissertation was that bilinguals, by virtue of their ability to switch between two linguistic systems, may enjoy cognitive advantages in the nonlinguistic domain for tasks that require abilities related to language switching. It was postulated that practice with language switching may augment the bilingual’s ability to perform certain cognitive functions that require similar mechanisms utilized in language switching. Although cognitive advantages for bilinguals were not found in the three experimental tasks comparing monolinguals and bilinguals, the null results may be a consequence of inadequate power and methodological problems rather than an absence of true differences in performance between the monolingual and bilingual adults. Therefore, it is unclear whether Type II errors were committed in the three tasks or if no differences exist between the two linguistic groups.

In this dissertation, it was postulated that the primary underlying mechanisms of code-switching are the bilingual’s abilities to inhibit the processing of irrelevant information and activate previously suppressed information. In order for bilinguals to successfully switch between their two languages, they must be capable of inhibiting the processing of the language not currently in use. Furthermore, they must also be able to activate the once inhibited or suppressed language when it becomes appropriate again. If, by virtue of their practice switching between their two languages, bilinguals have enhanced these abilities, it was expected that bilinguals would outperform their monolingual counterparts on nonlinguistic cognitive tasks that require these same

\[26^\text{A Type II error is the probability of failing to reject a false null hypothesis (p=\beta).}\]
abilities. It was suggested that bilinguals may be more effective “suppressors” of irrelevant information and more effective “activators” of previously suppressed information as a result of being “practiced” language switchers, compared to monolinguals who presumably are not “practiced” switchers. Consequently, the code-switching hypothesis predicts a bilingual advantage for tasks that require the inhibition of processing irrelevant information and the activation of previously suppressed information. As a test of the code-switching hypothesis, monolingual and bilingual adults performed three nonlinguistic experimental tasks designed to measure their ability to switch between simple cognitive tasks, suppress the activation of typical but absent information, and activate previously suppressed information in an attempt to discover bilingual advantages for these abilities.

Task Switching

When monolinguals and bilinguals switched between categorizing letters as either consonants or vowels and categorizing digits as either even or odd, both linguistic groups evidenced performance disturbances due to switching in both their reaction times and error rates. It was hypothesized that the bilinguals would exhibit a smaller switch cost compared to the monolinguals, given the bilinguals’ practice with switching between their two languages. While the findings replicated Rogers and Monsell’s (1995) original study, no significant differences were observed between the two linguistic groups with respect to the magnitude of the switch costs. The bilinguals experienced a 543 ms switch cost, while the monolinguals experienced a 549 ms switch cost. Even though the 6 ms difference in switch costs between the two groups was in the predicted direction,
this difference was not statistically significant. Given the extremely small standardized
effect size of only 0.02, the insufficient sample size to evaluate such a small effect, and
very low power, no bilingual advantage for nonlinguistic switching was detected.
Consequently, no conclusive determination can be made as to whether a bilingual
advantage exists for nonlinguistic switching.

If a Type II error was not committed, the absence of a bilinguals advantage for
the nonlinguistic switching task may be related to the participants' familiarity and
practice with the two nonlinguistic tasks. When bilinguals switch between their two
languages, it is assumed that the two languages are well-established and familiar and the
bilinguals have ample practice switching between their two languages. Consequently,
they are well-practiced at suppressing a familiar task (speaking in L1, for example) when
performing a similarly familiar task (speaking in L2). When a switch is initiated, it is
assumed that they are equally well-practiced at activating the previously suppressed
familiar task (speaking L1) and suppressing the now inappropriate familiar task of
speaking L2. For the nonlinguistic switching task, however, neither linguistic group was
well-practiced at switching between the two unfamiliar nonlinguistic tasks as illustrated
by their sizable switch costs relative to the smaller switch cost reported by Rogers and
Monsell (1995) whose participants were substantially more practiced in switching
between the two simple cognitive tasks.

Perhaps a bilingual advantage for nonlinguistic switching would have been found
if the participants were more practiced with the simple cognitive tasks or if they had
performed a nonlinguistic switching task that more closely resembled a familiar real-
world switching situation for which they were well-practiced. It is conceivable that a bilingual advantage exists for switching between familiar and practiced tasks, rather than unfamiliar and unpracticed tasks. Although this argument is plausible, it limits the predicted bilingual advantage for nonlinguistic switching by suggesting that switching between two familiar and well-practiced tasks is qualitatively different than switching between two unfamiliar and unpracticed tasks. Therefore, this argument seems to be an unlikely explanation for the absence of a bilingual advantage for the nonlinguistic switching task. The more likely explanations are that a Type II error was committed or that practice with language switching does not result in a bilingual advantage for nonlinguistic task switching.

Suppression

When monolinguals and bilinguals were tested on their ability to suppress the activation of typical but absent items in the suppression task, no differences in interference scores were found between the two linguistic groups. It was hypothesized that the bilinguals would exhibit smaller amounts of interference at each time interval, and perhaps demonstrate an absence of interference at earlier delay intervals compared to the monolinguals given their practice with suppressing irrelevant information while language switching. The absence of statistically significant differences in the interference scores between these two groups may be a result of a lack of statistical power or methodological shortcomings of the task that may have masked any differences that exist between the two groups.
The most problematic aspect of this study is that the findings of Gernsbacher and Faust (Experiment 2, 1991) were not replicated in either linguistic group which calls into question the appropriateness of this task for measuring suppression abilities in either group.27 Although there were trends of interference in each linguistic group, higher variability in reaction times and smaller effect sizes compared to the original study negated any statistically significant evidence of interference. Therefore, it remains speculative as to whether any difference in suppression abilities exists between the two linguistic groups. Future research should focus on designing a completely nonlinguistic task that effectively measures suppression abilities so that an accurate comparison of performance can be made between monolinguals and bilinguals.

Negative Priming

Lastly, monolinguals and bilinguals performed a nonlinguistic negative priming task to determine if the bilinguals’ language switching practice affected the magnitude of their negative priming effect relative to the monolinguals. For this dissertation, it was hypothesized that bilinguals would exhibit a greater negative priming effect compared to monolinguals because of their practice with suppressing irrelevant information while language switching. It was thought that bilinguals would be more effective “suppressors” of irrelevant information which would translate into a greater negative priming effect when the once irrelevant and suppressed information became the relevant information on negative priming trials. It was also possible, however, that bilinguals

27Possible explanations for not detecting significant amounts of interference were provided in the previous section.
would exhibit a smaller negative priming effect compared to monolinguals. The reasoning behind this alternative hypothesis focuses on the bilinguals’ ability to activate previously suppressed information, rather than suppress irrelevant information. Instead of observing a bilingual advantage for suppression abilities, it was also conceivable that a bilingual advantage would exist for activation abilities, namely activating previously suppressed information. Perhaps bilinguals are effective “activators” of previously suppressed information which would translate into a smaller negative priming effect compared to the monolinguals.

Even though both explanations were possible, neither outcome was observed in the results of the negative priming task. Not only was there no difference in the magnitude of the negative priming effects for the two linguistic groups, neither group exhibited reliable negative priming effects. Questions were raised in the previous section about the appropriateness of conducting statistical analyses on mean reaction times given the positively skewed nature of the reaction time data, in addition to the reliability of the nonlinguistic negative priming effect reported by DeSchepper and Treisman (1996). Nonetheless, it is concluded that the negative priming task was not successful in eliciting the negative priming effect for nonlinguistic stimuli which in turn prevents any meaningful conclusions to be made about potential differences in the magnitude of negative priming effect for the two linguistic groups.

Given the comparisons between the monolingual and bilingual adults’ performance on the three experimental tasks, it remains to be seen whether bilinguals are more effective “suppressors” of irrelevant information and/or more effective “activators”
of previously suppressed information. Only one of the three experimental tasks designed to measure suppression and/or activation of suppressed material was successful in replicating previous research, thereby resulting in a valid measure of suppression and/or activation, although no bilingual advantage was detected. The other two tasks did not replicate the previous research and are therefore invalid measures of suppression and/or activation of suppressed material. Modified versions of the present experimental tasks would be useful in elucidating the role of suppression of irrelevant information and activation of previously suppressed information in explaining potential cognitive advantages for bilinguals. Secondly, more research is necessary to explore the possible bilingual advantages for cognitive processing as a result of code switching and should concentrate on exploring the independent roles of the two proposed mechanisms involved in language switching.

Future research on the possible bilingual advantages associated with code switching should focus not only on valid measures of the underlying mechanisms of code switching, but also on tasks that would allow one to measure the ability to suppress irrelevant information independently of the ability to activate previously suppressed information to determine if a bilingual advantage exists for both mechanisms or only one. Unfortunately, the tasks in this dissertation did not adequately allow for independent examination of the two underlying mechanisms of code switching given the inadequate statistical power of the tests and the methodological problems with the suppression and negative priming tasks. Table 11 illustrates the predicted outcomes for the present tasks
given the nature of the possible bilingual advantage(s) in cognitive processing related to bilingual code switching.

According to this table, if bilinguals outperformed monolinguals on every aspect of the task switching and suppression tasks, only a significant difference in performance between the two groups on the negative priming task would allow for a distinction to be made between bilinguals as being good "suppressors"/average "activators" and good "suppressors/activators." As previously discussed, if the bilinguals exhibited a significantly greater negative priming effect, it could be argued that they benefit by being good "suppressors" (and average "activators"), whereas no differences in the negative priming effect would suggest that they benefit by being both good "suppressors" and "activators." In order to conclude that bilinguals benefit from code switching by being good "activators" (and average "suppressors"), one would not expect to see significant differences in reaction time between the two linguistic groups on nonswitch trials in the task switching task and in interference scores in the suppression task, although faster reaction times would be expected on switch trials and for switch costs in the task switching task in addition to a smaller negative priming effect for the nonlinguistic negative priming task. Therefore, improved versions of the three nonlinguistic tasks may be useful to future researchers who are interested in exploring bilingual advantages associated with language switching. If such advantages exist, these tasks may prove to be useful in teasing apart the independent/dependent contribution of the two underlying mechanisms of code switching proposed in this dissertation.
Table 11. Predicted outcomes for possible bilingual advantages in cognitive processing for the three experimental tasks (in reaction time)

<table>
<thead>
<tr>
<th>Possible Bilingual Advantage</th>
<th>good “suppressors”</th>
<th>average “suppressors”</th>
<th>good “activators”</th>
</tr>
</thead>
<tbody>
<tr>
<td>Task Switching</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nonswitch trials&lt;sup&gt;a&lt;/sup&gt;</td>
<td>B&lt; M</td>
<td>B= M</td>
<td>B&lt; M</td>
</tr>
<tr>
<td>Switch trials&lt;sup&gt;b&lt;/sup&gt;</td>
<td>B&lt; M</td>
<td>B&lt; M</td>
<td>B&lt; M</td>
</tr>
<tr>
<td>Switch cost&lt;sup&gt;b&lt;/sup&gt;</td>
<td>B&lt; M</td>
<td>B&lt; M</td>
<td>B&lt; M</td>
</tr>
<tr>
<td>Suppression</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Interference&lt;sup&gt;a&lt;/sup&gt;</td>
<td>B&lt; M</td>
<td>B= M</td>
<td>B&lt; M</td>
</tr>
<tr>
<td>Negative Priming</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Negative priming effect&lt;sup&gt;b&lt;/sup&gt;</td>
<td>B&gt; M</td>
<td>B&lt; M</td>
<td>B= M</td>
</tr>
</tbody>
</table>

“B”=Bilinguals; “M”=Monolinguals; <sup>a</sup>=suppression only, <sup>b</sup>=suppression and activation

Language Switching

To address the secondary objective of this dissertation which was to explore the relationship between linguistic and nonlinguistic switching in bilinguals, bilingual adults also performed a language switching task in which they switched unpredictably between naming numerals in each of their languages. The rationale for exploring this relationship was grounded in the fundamental question as to whether language is a general cognitive function or a unique and highly specialized process. On the one hand, if language is considered as a general cognitive function, it stands to reason that control processes responsible for task switching in the nonlinguistic domain are similar to the control processes responsible for language switching in bilinguals because both switching tasks rely on similar general cognitive processes. On the other hand, if language is a unique
human function, it could be argued that linguistic control processes involved in language switching are not necessarily available for general cognitive functions. Therefore, the bilinguals’ performance on the nonlinguistic and linguistic switching tasks was compared to determine if a relationship existed between the switch costs in each domain.

Before comparing the bilinguals’ switch costs on the task switching and language switching tasks, however, a recap of the bilinguals’ performance on the language switching task and a comparison of their performance to the original study by Meuter and Allport (1999) is in order. Recall that bilinguals in both studies demonstrated a performance cost associated with language switching. Bilinguals responded more quickly in naming numerals on nonswitch trials compared to switch trials. The bilinguals in the present study, however, deviated from the bilinguals in the original study by not exhibiting an asymmetry in switch costs when responding in either language.  The absence of asymmetrical switch costs that had been observed in the original study by Meuter and Allport was explained by the highly proficient nature of the more balanced bilinguals who participated in the present study.

Recall that Meuter and Allport predicted asymmetrical switch costs for bilinguals whose two languages were not relatively equal in strength.  This prediction was extended to the linguistic domain based on previously observed asymmetries in switch

28 Recall also that when Meuter and Allport separated the more balanced bilinguals from the less balanced bilinguals, the asymmetrical switch costs were not longer observed for the more balanced bilinguals which is consistent with the present study of more balanced bilinguals.

29 Task Set Inertia hypothesis (Meuter & Allport, 1999).
costs that have been found in the nonlinguistic domain for behaviorally more and less
dominant tasks. They further qualified their predictions concerning asymmetrical
language switch costs by suggested that the magnitude of asymmetry in linguistic switch
costs is dependent on the relative strength of the bilingual’s two languages. For
example, if a bilingual was more highly proficient in one language relative to the other,
one would expect to see an asymmetrical switch cost for language switching. However,
if the bilingual is nearly equally proficient in each language, one would expect to see a
smaller asymmetry or an absence of asymmetry in the linguistic switch costs. Therefore,
given the absence of asymmetrical switch costs in the present language switching task, it
was concluded that the bilinguals in the present study were nearly equally proficient in
each of their two languages. This conclusion was also supported by the bilinguals’ self-
ratings of their proficiency in L1 and L2 which were almost identical, in addition to their
self-ratings of degree of bilingualism which suggested that on average they consider
themselves highly bilingual.

Returning now to the main purpose of including a language switching task in this
dissertation, the relationship between nonlinguistic and linguistic switch costs in
bilinguals was examined to determine if performance costs observed in one domain were
related in any way to performance costs in the other domain. It was suggested that if
similar control processes were utilized for both switching tasks, the bilinguals’ switch
costs would be positively correlated. A significant positive correlation was indeed
observed and it was concluded that effective nonlinguistic task “switchers” were also

30Relative Strength hypothesis (Meuter & Allport, 1999).
effective language "switchers," while less effective nonlinguistic task "switchers" were also less effective language "switchers." This conclusion provided additional support to Meuter and Allport's (1999) contention that "bilingual language switching reflects processes that are fundamentally similar to task switching in other domains" (p. 36).

Regression analyses contributed additional support to the idea that similar control processes are available for switching tasks in the nonlinguistic and linguistic domains. Nonlinguistic switch costs, in conjunction with degree of bilingualism, were found to be significant predictors of the linguistic switch costs.31 A subsequent regression analysis was performed to determine if variation in degree of bilingualism self-ratings significantly accounted for variation in the bilinguals' nonlinguistic switch costs. The rationale for this inquiry was that if degree of bilingualism is positively correlated with language switch costs, and if language switch costs are positively correlated with nonlinguistic switch costs, perhaps degree of bilingualism is also related to nonlinguistic switch costs. The resulting nonsignificant analysis revealed that the two measures were not related (p<.64). Therefore, it remains to be seen if there is a causal relationship between degree of bilingualism and the magnitude of language switch costs, and if this relationship has any specific theoretical implications for nonlinguistic switch costs. This avenue of questioning will provide future researchers with an empirical foundation to investigate the nature of the relationship between these factors.

31Recall that self-ratings of effortfulness of general switching abilities were also identified as significant predictors of the language switch costs, although the puzzling direction of the relationship calls into question the appropriateness of this measure for the regression analyses.
Conclusions and Future Directions

An empirical investigation of the code-switching hypothesis was conducted in this dissertation to determine if cognitive advantages exist for bilingual adults who are able to switch between their two languages. Although the code-switching hypothesis has generated much research into the possible cognitive advantages associated with bilingualism, the specific mechanisms necessary for language switching have not previously been clearly identified. Thus, a rigorous empirical investigation of the role of these language-switching mechanisms in explaining previously observed bilingual advantages for cognitive processing has not been conducted prior to this dissertation. Unfortunately, two of the three nonlinguistic cognitive tasks utilized in this dissertation were not effective in measuring the hypothesized mechanisms of suppression and activation of previously suppressed material in either linguistic group. Therefore, the performance of the two linguistic groups on these tasks could not be compared to examine the source of possible bilingual advantages in cognitive processing that may be related to language switching. Consequently, the jury is still out as to whether practice with language switching may explain previously observed bilingual advantages in cognitive processing.

Although a substantial amount of research has been conducted during the past four decades on the effects of bilingualism on cognitive processing, evidence of cognitive advantages for bilingual children or adults for a variety of abilities has not been consistently demonstrated across a variety of cognitive tasks and a conclusive determination regarding the source of these hypothesized bilingual advantages has not
been adequately defined or studied.32 Secondly, the paucity of research on the effects of bilingualism in adults has been extremely under-researched for reasons previously discussed. Therefore, Peal and Lambert’s (1962) code-switching hypothesis was useful for this dissertation in providing not only a theoretical foundation for exploring possible bilingual advantages for inhibition abilities, but it was also directly applicable to the under-studied population of bilingual adults. Cummins’ (1976) threshold hypothesis was also examined in this dissertation because it, too, was applicable to bilingual adults, although the homogeneous nature of the bilingual sample with respect to degree of bilingualism did not allow for an adequate examination of this hypothesis. Consequently, more research is necessary to determine if indeed bilingual advantages previously observed in children persist into adulthood, and if so, the cognitive mechanisms responsible for these advantages must be clearly defined and empirically tested.

A secondary investigation in this dissertation focused on the bilinguals’ ability to switch between their two languages and the possible factors that may be related to the magnitude of the observed linguistic switch costs. The bilinguals demonstrated the predicted performance costs associated with language switching, although there was no evidence of the asymmetrical switch cost that had been previously reported by Meuter and Allport (1999). It was concluded that the highly proficient nature of the balanced bilinguals in this study was responsible for the absence of the predicted asymmetry.

32 The exception being the consistent findings of a metalinguistic advantage for bilingual children with respect to the understanding of the arbitrariness of language. However, it is not clear if this metalinguistic advantage is a result of a precocious understanding of the symbolic nature of language or if it reflects a more fundamental cognitive processing advantage.
Because the bilinguals were almost equally proficient in each of their two languages, switching unpredictably from one language to the other did not require more suppression of one language over the other.

With regard to bilingual language switching, it would be interesting to examine bilinguals' ability to predictably switch between their two languages to determine if anticipatory reconfiguration of the task set greatly reduces the performance cost of language switching. Although Rogers and Monsell (1995) and this dissertation have demonstrated reliable performance costs for nonlinguistic switching even when switching was predictable, no comparison has been made between predictable and unpredictable switching for the same task to determine if switch costs are greatly reduced when the individual has ample opportunity to "re-organize" the S-R (stimulus-response) mappings in advance of the task. Rogers and Monsell may argue that the switch costs will remain even with predictable switching and longer R-S intervals, but they examined only unfamiliar tasks that were largely less practiced than language switching. For example, the average linguistic switch cost found in this dissertation with unpredictable switching was only 76 ms compared to the higher average nonlinguistic switch cost of 564 ms with predictable switching. With the exception of the predictability of switching in these two tasks, the second most obvious difference between these two tasks is the participant's familiarity with the tasks between which they were switching. Perhaps predictably switching between practiced tasks, like language switching, may greatly reduce or even eliminate the rather small linguistic switch costs that have been found for unpredictable language switching.
Finally, the bilinguals' language switch costs were also compared to their nonlinguistic switch costs and other measure related to bilingualism to determine if linguistic and nonlinguistic switching are related and if measures related to bilingualism are useful in predicting the magnitude of the language switch costs. First, it was determined that nonlinguistic and linguistic switch costs were positively correlated which suggested that similar control mechanisms were available and may be utilized for both types of switching tasks. Future investigation should focus on the nature of this relationship, although it is hypothesized in this dissertation that the common underlying mechanisms of suppression of irrelevant information and the activation of previously suppressed information may be the source of the positive relationship. Secondly, nonlinguistic switch costs and degree of bilingualism were found to be useful in predicting the magnitude of the linguistic switch costs. For future researchers, Cummins' threshold hypothesis will provide a theoretical framework for exploring the relationship between degree of bilingualism and potential cognitive advantages for bilinguals. It will also be constructive to further explore the relationships between nonlinguistic and linguistic switching and degree of bilingualism to identify the underlying factors responsible for these relationships.

In conclusion, this dissertation contributed to the research of the effects of bilingualism on cognitive processing by identifying the underlying mechanisms involved in code switching which allowed for an empirical investigation for the code-switching hypothesis and its implication for possible bilingual advantages in cognitive processing. Secondly, adults were examined to determine if previously observed bilingual advantages...
for cognitive processing in children persist into adulthood because the bilingual adult population has not been sufficiently studied in the past. Thirdly, bilingual language switching was also explored and compared to nonlinguistic task switching which resulted in additional evidence supporting the contention that similar control processes are available and utilized for both nonlinguistic and linguistic switching. Based on the findings of the four experiments in this dissertation, therefore, three avenues of future research are warranted: 1) comparing monolingual and bilingual adults’ performance on tasks that measure the ability to suppress irrelevant information and the ability to activate previously suppressed information both individually and in combination; 2) exploring bilingual language switch costs when switching is performed predictably; and 3) elucidating the relationship between linguistic switch costs and nonlinguistic switch costs and degree of bilingualism.
References


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Appendix A: Bilingual Language Experience Questionnaire

Language Background

1. What is your first language (native language/mother tongue)? ____________________________

2. List your next three languages in order of competence
   1. _______________________________  3. _______________________________
   2. __________________________________________

3. List any other languages you have learned, include at what age you learned them and how long
your exposure was to them (for example, perhaps you had one semester of a Russian as a senior
in high school (age 18 years)).

<table>
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<tr>
<th>Language</th>
<th>Age</th>
<th>Description and duration of exposure</th>
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</tbody>
</table>

4. Linguistic Environments

Please list every language environment you have lived in and the length of time you have spent in
each environment.

<table>
<thead>
<tr>
<th>Age (from-to)</th>
<th>Country/Language Environment</th>
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<tbody>
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</tbody>
</table>

Native Language/Mother Tongue

1. How often do you currently use this language? Always 1 2 3 4 Never 5

2. How fluent/proficient are you in your native language? No command of the language Native-like fluency 1 2 3 4 5

Second Language

1. How did you learn this language? (ex. school, home, foreign country, hobby, work, academic exchange program, etc.)

2. At what age did you begin learning this language? (age in years and months–ex. 12 years; 4 months)
   Age:___________ years; ___________ months
3. How much exposure did you have to this language while you were learning it? (ex. 3 years in primary school for one hour three times a week, one semester in college—5 hours a week; 6.5 years in a foreign country—total immersion; 1.75 years as a missionary in a country where my second language is spoken—60% of daily interactions in second language)

4. Have you ever lived in a country where this language is spoken? YES NO

If YES, at what age and for how long? __________ (age) __________ (duration of stay)

5. How much do you currently use your 2nd language? 1 2 3 4 5
6. How much do you currently read in your 2nd language? 1 2 3 4 5
7. How much do you currently write in your 2nd language? 1 2 3 4 5
8. How much do you currently speak in your 2nd language? 1 2 3 4 5
9. How much do you currently use your 2nd language at school? 1 2 3 4 5
10. How much do you currently use your 2nd language at home? 1 2 3 4 5
11. How much do you currently use your 2nd language at work? 1 2 3 4 5
12. How frequently do you find yourself searching for a word that won’t come to you in your second language when you are speaking? 1 2 3 4 5
13. How frequently do you find yourself searching for a word that won’t come to you in your second language when you are writing? 1 2 3 4 5
14. How frequently do you find yourself searching for the meaning of a word in your second language when you are reading? 1 2 3 4 5
15. Rate your proficiency level in your second language. No command of the language Native-like fluency

Language Switching Behavior

Definition of language switching: Language switching occurs when a bilingual interchanges (or switches) between his/her two languages.

For example, if you are speaking Spanish with a South American friend and an American friend arrives, you will switch to speaking English with the American friend, and then switch back to Spanish to converse with the South American friend.

1. How frequently do you switch between your 1st and 2nd languages daily? Rarely All of the time

2. How easy/difficult is it for you to switch between your 1st and 2nd languages? Easy Difficult

150
3. How effortful is it for you to switch between your 1st and 2nd languages?

Not at all effortful: 1 2 3 4 5

Extremely effortful: 1 2 3 4 5

4. Why do you switch between your 1st and 2nd languages?

Rarely: 1 2 3 4 5

All of the time: 1 2 3 4 5

preference: 1 2 3 4 5

to talk in code/secretly: 1 2 3 4 5

for fun: 1 2 3 4 5

out of necessity: 1 2 3 4 5

to facilitate communication: 1 2 3 4 5

(so current listener can understand)

for translating purposes: 1 2 3 4 5

other: (explain): 1 2 3 4 5

Bilingualism

1. Do you consider yourself bilingual? YES NO

If YES, for what two languages? __________________________

2. How bilingual do you consider yourself? Highly proficient in both languages: 1 2 3 4 5

Highly proficient in 1st, but not proficient in 2nd: 1 2 3 4 5

3. How bilingual do you consider yourself with respect to your speaking abilities? 1 2 3 4 5

4. How bilingual do you consider yourself with respect to your speaking abilities? 1 2 3 4 5

5. How bilingual do you consider yourself with respect to your speaking abilities? 1 2 3 4 5

General switching abilities

Switching ability refers to the phenomenon when you have to switch between doing two things at once. Here is an example of what may be considered as a switching ability: Talking to someone on the telephone about your phone bill while working on the computer writing a class assignment. When you’re on hold with the phone company, you can work on the computer, but when the telephone company representative returns to the line, you have to stop typing your paper and start talking about your phone bill.

Think of other examples in which you have to switch between doing two different tasks.

How easy/difficult is it for you to switch between two different tasks in general?

Extremely easy: 1 2 3 4 5

Very Difficult: 1 2 3 4 5

Do you do anything in your work or daily life that involves switching between two tasks? Please describe this experience of switching between two tasks.
Appendix B: Demographic Questionnaire: Monolinguals

Gender: F M

Nationality: ______________________

Age: _______ years _______ months

Native Language: ______________________

Date of birth: Month _______ Day _______ Year _______

Marital status:

1. single
2. married
3. divorced/separated
4. widowed

Education: (indicate the highest level completed)

1. high school
2. vocational school
3. 1-2 years of college/university
4. 3-4 years of college/university
5. 1-2 years of graduate/professional school
6. 2-5 years of graduate/professional school

Childhood: (indicate the situation that best describes the majority of your childhood)

1. raised by both your father and mother
2. raised by a parent and step-parent
3. raised by your father only
4. raised by your mother only
5. raised by (a) legal guardian(s)
6. other (explain): __________________________

For the majority of your childhood, what was socioeconomic situation of your family compared to other families in your country.

1. lower class
2. low middle class
3. middle class
4. upper middle class
5. upper class

Do you have any experience with a foreign language? YES NO
If yes, please describe your experience on the back of this form (i.e. 2 semesters of college-level French; spent 1 month in Japan on summer exchange program).

Are you able to speak and/or understand any language other than English? YES NO
If yes, please describe your proficiency in the foreign language on the back of this form (i.e. understand well, but don’t speak; understand and speak well).
Appendix C: Demographic Questionnaire: Bilinguals

Gender: F  M

Age: _______ years _______ months

Nationality: ______________________

Native Language: __________________

Date of birth: Month _______ Day _______ Year _______

Marital status:
1. single
2. married
3. divorced/separated
4. widowed

Education: (indicate the highest level completed)
1. high school
2. vocational school
3. 1-2 years of college/university
4. 3-4 years of college/university
5. 1-2 years of graduate/professional school
6. 2-5 years of graduate/professional school

Childhood: (indicate the situation that best describes the majority of your childhood)
1. raised by both your father and mother
2. raised by a parent and step-parent
3. raised by your father only
4. raised by your mother only
5. raised by (a) legal guardian(s)
6. other (explain): ___________________________

For the majority of your childhood, what was socioeconomic situation of your family compared to other families in your country.
1. lower class
2. low middle class
3. middle class
4. upper middle class
5. upper class
Appendix D: Bilingual Language Experience Questionnaire (Results)

Native Language/Mother Tongue

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<tr>
<th>Question</th>
<th>Scale</th>
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<th>3</th>
<th>4</th>
<th>Always</th>
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</thead>
<tbody>
<tr>
<td>1. How often do you currently use this language?</td>
<td>(M=3.93, SD=1.07)</td>
<td></td>
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<tr>
<td>2. How fluent/proficient are you in your native language?</td>
<td>(M=4.41, SD=1.01)</td>
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Second Language

<table>
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<th>4</th>
<th>Always</th>
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</thead>
<tbody>
<tr>
<td>2. At what age did you begin learning this language?</td>
<td>(M=6.27 years, SD=5.89 years)</td>
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<tr>
<td>5. How much do you currently use your 2nd language?</td>
<td>(M=4.81, SD=0.48)</td>
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<td>6. How much do you currently read in your 2nd language?</td>
<td>(M=4.59, SD=0.89)</td>
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<td>7. How much do you currently write in your 2nd language?</td>
<td>(M=4.56, SD=0.89)</td>
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<td>8. How much do you currently speak in your 2nd language?</td>
<td>(M=4.74, SD=0.53)</td>
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<td>9. How much do you currently use your 2nd language at school?</td>
<td>(M=4.65, SD=1.02)</td>
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<td>10. How much do you currently use your 2nd language at home?</td>
<td>(M=3.81, SD=1.27)</td>
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<td>11. How much do you currently use your 2nd language at work?</td>
<td>(M=4.28, SD=1.37)</td>
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<td>12. How frequently do you find yourself searching for a word that won't</td>
<td>(M=2.15, SD=1.03)</td>
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<td>come to you in your second language when you are <em>speaking</em>?</td>
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<td>13. How frequently do you find yourself searching for a word that won’t</td>
<td>(M=2.26, SD=1.10)</td>
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<tr>
<td>come to you in your second language when you are <em>writing</em>?</td>
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<td>14. How frequently do you find yourself searching for the meaning of a</td>
<td>(M=2.48, SD=1.16)</td>
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<tr>
<td>word in your second language when you are <em>reading</em>?</td>
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<td></td>
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<tr>
<td>15. Rate your proficiency level in your second language.</td>
<td>(M=4.41, SD=0.69)</td>
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</tr>
</tbody>
</table>
Language Switching Behavior
1. How frequently do you switch between your 1st and 2nd languages daily? (M=3.44, SD=1.34)
   Rarely  2  3  4  5  All of the time
   1  2  3  4  5

2. How easy/difficult is it for you to switch between your 1st and 2nd languages? (M=1.59, SD=1.03)
   Easy  2  3  4  5  Difficult
   1  2  3  4  5

3. How effortful is it for you to switch between your 1st and 2nd languages? (M=1.93, SD=1.24)
   Not at all effortful  4  5  Extremely effortful
   1  2  3  4  5

4. Why do you switch between your 1st and 2nd languages? (M=2.73, SD=1.12)
   preference:  1  2  3  4  5
   (M=3.08, SD=1.49) to talk in code/secretly:  1  2  3  4  5
   (M=2.38, SD=1.33) for fun:  1  2  3  4  5
   (M=3.89, SD=1.25) out of necessity:  1  2  3  4  5
   (M=3.96, SD=1.28) to facilitate communication:  1  2  3  4  5
   (M=3.38, SD=1.13) for translating purposes:  1  2  3  4  5

Bilingualism
2. How bilingual do you consider yourself? (M=1.85, SD=0.95)

3. How bilingual do you consider yourself with respect to your speaking abilities? (M=2.07, SD=1.36)

4. How bilingual do you consider yourself with respect to your speaking abilities? (M=2.15, SD=1.23)

5. How bilingual do you consider yourself with respect to your speaking abilities? (M=2.22, SD=1.31)

General switching abilities
How easy/difficult is it for you to switch between two different tasks in general? (M=2.19, SD=1.00)
### Appendix E: Matched Pairs

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<tr>
<th>Pair</th>
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<th>Age</th>
<th>SES</th>
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Vita

Christy Witt was born in Lincoln, Nebraska, in 1971. She received her degree of Bachelor of Arts in psychology and french from the University of Kansas in 1996, and her degree of Master of Arts in psychology from the Louisiana State University in 1998. She expects to receive her degree of Doctor of Philosophy in psychology with a doctoral minor in experimental statistics to be awarded at the Louisiana State University Commencement in May of 2001.
DOCTORAL EXAMINATION AND DISSERTATION REPORT

Candidate: Christy J. Witt

Major Field: Psychology

Title of Dissertation: Effects of Bilingualism on Cognitive Processing in Adults

Approved:

Major Professor and Chairman

Dean of the Graduate School

EXAMINING COMMITTEE:

[Signatures]

Date of Examination:

December 7, 2000