SWARTHMORE COLLEGE

The Cognitive Effects of Bilingualism: Language Lateralization and Problem Solving

by

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ABSTRACT

During the past 20 years, interest in bilingualism and second language development has grown enormously, and several inquiries have been researched. One such inquiry has been the effects of bilingualism on the brain, and more specifically, if bilinguals process certain types of information differently than monolinguals.

It is now recognized that bilinguals show early heightened metalinguistic awareness and can solve problems with misleading or distracting information more easily. Some researchers put forth that the right hemisphere of the brain is more active in bilingual language processing than in monolingual language processing. Therefore, because the right hemisphere controls visuospatial abilities, a cause for the increased abilities of bilinguals could be a result of this language lateralization.

In order to test this hypothesis, I performed an experiment on six children which tested their ability to ignore visually misleading information in a mathematical, cognition-related task. The results were mixed.

Considering the numerous variables that affect experiments such as this, I determined that further studies need to be made into the influences of sex, handedness, age, level of proficiency of language(s), the circumstances under which the subject became bilingual, and which languages he or she speaks before a clear conclusion can be reached. This inquiry is thus a collective endeavour of the linguistic, neurobiological, psychological, and cognitive disciplines.

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My deepest thanks also goes out to Serge Levergeois and the teachers at la garderie at the Lycée Français la Pérouse in Corte Madera, CA, Professor Hank Glassman and Mila, and Professor Eric Raimy and Noah—without whose help my research would have been most difficult.

INTRODUCTION

The common view of the implications and effects of bilingualism during the past twenty years have varied immensely. The belief that language learning is a fragile and volatile undertaking and that speaking two languages confuses a child and retards his or her language development is shared even by linguists—Seliger and Vago (1991) for example, saw bilingualism as, "a natural setting for the unravelling of native language abilities" due to their belief that the bilingual's two languages compete, metaphorically, "for a finite amount of memory and processing space."[1] Others believe that bilingualism may drive a child's intelligence to new heights. Due to the latter, and so that children could benefit from any cognitive advantages inherent in being bilingual, many schools adopted the practice of teaching second languages to children starting at the primary school level. For example, Ron Unz, architect of California's Proposition 227, "English for the children," based his political movement on banning bilingual education programs in favour of one-year kindergarten immersion programs for English language learners.[2] However, the case for what these actual cognitive advancements are (if any) and whether teaching young children a second language in school actually stimulates the same supposed benefits that bilingualism offers first begs a distinction between second language *learning* and second language *acquisition*. In this thesis I will discuss the difference between language acquisition and language learning, I will review the definitions of bilingualism and language proficiency, and I will study several views of the cognitive effects of bilingualism—in particular, how language lateralization is affected. I

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[1] Seliger, Herbert W. and Robert M. Vago. *First Language Attrition*. Cambridge: Cambridge University Press, 1991.

will then continue into an explanation and analysis of an experiment I conducted with monolinguals and French-English bilinguals regarding the nature of language lateralization.

Background and Definitions

The distinction between language learning and language acquisition is essential and is the foundation on which Steven Krashen's hypotheses are based. Krashen, of the University of Southern California, is a specialist in theories of language acquisition and development. He asserts that there are two independent systems of language performance—the "acquired system" and the "learned system." With regards to the "acquired system," or acquisition, he states that, "language acquisition does not require extensive use of conscious grammatical rules, and does not require tedious drill."[3] In other words, second language acquisition is the unconscious reception and comprehension of a language. Second language learning, on the other hand, requires a conscious, active effort on the part of the learner (who has already acquired a first, native language). For the second language learner, the desire to learn the second language holds significant weight in the learner's ability to master it. Children of immigrant parents, for example, might put forth effort *not* to learn the language of their parents as a second language because they want to fit in with those around them. For example, when I was young, and relatives spoke to me in either Japanese or Tagalog, I consciously answered back in English because I didn't want to set myself apart from my English-speaking peers.

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[2] Galaburda, Albert M., Stephen M. Kosslyn, and Yves Christen. *The Languages of the Brain.* Cambridge: Harvard University Press, 2002.

[3] Schütz, Ricardo. *Stephen Krashen's Theory of Second Language Acquisition.* 20 August, 2005. English Made In Brazil. 7 March, 2006. <http://www.sk.com.br/sk-krash.html>

I know that this was also the case with several of my multiracial and/or second generation friends. With regards to second language acquisition, however, the second language is mastered—regardless of the child's desire.

Thus, theoretically, the distinction between second language learning and second language acquisition is well delineated. However, the reality is not as clear cut. The mastery of a second (or third, fourth, fifth, etc.) language can be a mixture of both active, conscious learning and subconscious acquisition. Again, circumstance plays a fundamental role in determining how a language is mastered. A second generation child, for instance, may acquire the spoken language from his or her parent(s), but may have to put forth active effort to learn to read and/or write in the language (in Saturday school programs, for example). Similarly, a second generation child may acquire certain everyday phrases from his or her parent(s), but may have to study the language in school to be able to generate any phrase in that language—not just the ones he or she acquired through exposure. In distinguishing between second language acquisition and learning, many non-academic, personality, and attitude-related factors must also be considered, such as how well someone is able to play the part of a native speaker or how willing someone is to let it be known that they are a native speaker. Though there is a definite difference between acquisition and learning, it is important to keep in mind that it is rare for any multilingual person to fit clearly into just one of the two categories.

With regards to the optimum age range for second language acquisition (ie. the critical period), there are three main views. The optimal age hypothesis states that young children hold an innate facility for language learning. Chomsky (1959) and Donahue (1965) both assert that languages are best learned between the ages of four and eight. In

addition, the superior ability of children to imitate sounds and mannerisms has been noted several times by researchers such as Delaunay (1977), Hill (1978), Patkowski (1980), Schmidt-Schönbein (1980), and Wilkins (1972). These researchers explain that a major factor in the ease of young children's ability to assume new manners of linguistic behaviour is their relative spontaneity and inhibition, whereas older children and adults tend to be much more self-conscious. Lenneberg (1967) expands on this idea, stating that the optimal range for language acquisition ceases at the onset of puberty.

A second view, shared by such researchers as Scovel (1969, 1978) and Fathman (1975) emphasizes that the optimal period should be constricted to phonological learning. Fathman studied the grammar, pronunciation, and morphology in young immigrants aged 6-15, and concluded that the pronunciation of the younger children was much better, but that the grammar and morphology of the older immigrants was superior. Similar conclusions were drawn by Oyama (1976, 1978) who worked with Italian immigrants and by Selinger, Krashen, and Ladefoged (1975) who studied Jewish immigrants to the US.

The systems for language perception and language production are, to a degree, independent. Evidence for their complete independence is as of yet insufficient, but there is also data that suggests that bilinguals construct one system for perception and maintain two separate output systems.[4] A child learning multiple languages from a young age will initially develop a unified language system. Essentially, the child will tend to fit the new language system that he or she is learning into the old one. A dual system for production is only developed over time. For example, at age three, the child may be aware of

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[4] Albert, Martin L. and Loraine K. Obler. *The Bilingual Brain.* New York: Academic Press, 1978.

learning two languages (ie. he or she might start to differentiate the two), but it is not until around age seven that clear separation of the languages occurs. From this point onward, the child is able to maintain stable separation of the two. Furthermore, when languages are acquired, children first master separate productive phonological and morphological systems and then organize lexical and syntactic patterns.

Whether a second language is purely learned, purely acquired, or is mastered through a combination of the two, a person may eventually come to be considered bilingual, but what exactly does that mean? There are theories that conceptualize bilinguals as two monolinguals in one person.[5] According to Myers-Scoton, the languages of a bilingual are not fused—they are separate subsystems within a single cognitive system. Bilingualism has many faces—the circumstances under which a child became bilingual, the environments in which he or she uses each language, whether the child's scholastic environment encourages or prohibits the use of one language or the other—there are countless factors that differentiate various types of bilinguals, but are there any common factors that unite them?

Some instances of bilingualism arise when the home country maintains the language of a former colonizer as its official language, while inhabitants also grow up speaking the native language (as in the Philippines with Tagalog and English, and in Zaire with French and languages such as Kikongo, Tshiluba, Lingala, and Kiswahili). Other types of bilingualism occur in the home, as a result of interactions with family members (usually one or both parents) whose origins are of another speech community. In these cases, the parent(s) can either move effortlessly between their own first language

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[5] Romaine, Suzanne. *Bilingualism: Second Edition*. Oxford: Blackwell Publishing Ltd., 1989, 1995.

and another one, or they speak almost exclusively their own first language (which is different from the language of the speech community in which they currently reside). Their child, therefore, is exposed to both languages. Still other instances of bilingualism occur when a child moves to a speech community other than his or her own and acquires the second language in his or her academic setting.

As an example of the various settings of multilingual language acquisition, Romaine (1995) defines six types of home language bilingualism, each with varying patterns of social and linguistic dimensions. These are:

TYPE 1: One Person—One Language
- The parents have different native languages with each having some degree of competence in the other's language.
- The language of one of the parents is the dominant language of the community.
- The parents each speak their own language to the child from birth.

TYPE 2: Non-dominant Home Language / One Language—One Environment
- The parents have different native languages.
- The language of one of the parents is the dominant language of the community.
- Both parents speak the non-dominant language to the child, who is fully exposed to the dominant language only when outside the home, and in particular in nursery school.

TYPE 3: Non-dominant Home Language without Community Support
- The parents share the same native language.
- The dominant language is not that of the parents.
- The parents speak their own language to the child.

TYPE 4: Double Non-dominant Home Language without Community Support
- The parents have different native languages.
- The dominant language is different from either of the parents' languages.
- The parents each speak their own language to the child from birth.

TYPE 5: Non-native Parents
- The parents share the same native language.
- The dominant language is the same as that of the parents.
- One of the parents always addresses the child in a language which is not his/her native language.

TYPE 6: Mixed Languages
- The parents are bilingual.
- Sectors of community may also be bilingual.
- Parents code-switch and mix languages.

All of the children under Romaine's classifications become bilingual at home, but under varying circumstances which affect the child's comprehension and ease of use. Dopke (1992) acknowledges this fact in his distinction between reproductive bilinguals and receptive bilinguals. The first class refers to people who have equal command of two languages, the other refers to the less acknowledged class of bilinguals who have full command of one language but can only read and/or write in the other. Myers-Scoton (2006) gives the name "active bilinguals" to the first class and "passive bilinguals" to the second (and also to people who can understand an L2 but choose not to speak it).[6]

MacLaughlin et al. (1995) categorize four types of bilingualism based on prior experience with the second language and subsequent opportunity and desire to hear and use it. According to their categorization, simultaneous bilinguals had equal or almost equal opportunity and development in both languages before the age of three. Receptive bilinguals are children who have had abundant exposure to the second language, but have had few opportunities and reasons to speak it. Rapid sequential bilinguals are children who learn a second language in an early childhood education program after the age of three and have had little or no exposure to the language prior. They tend to be highly motivated in speaking the second language. Finally, slow sequential bilinguals are children who learn a second language after the age of three but have little or no motivation or opportunity to use it.

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[6] Myers-Scoton, Carol. *Multiple Voices: An Introduction to Bilingualism*. Malden: Blackwell Publishing Ltd., 2006.

Academic views on the definition of bilingualism are extremely varied—in terms of scope and detail—ranging from the notion that a bilingual can have full fluency in two languages (Bloomfield, 1933) to the idea that a bilingual is one who can just function in each language according to given needs (Grosjean, 1989). Moreover, as evidenced by Romaine's classifications discussed above, there are also several fine-grained typologies in academic work. Because factors such as migration, intermarriage, education, and nationalism lead to differential use of each language, Grosjean claims that bilinguals rarely develop equal fluency in their languages. Due to, and in spite of, the fact that there are countless factors influencing the various "types" of bilinguals that exist, only a very specific type of bilingual child is usually analyzed—those of educated, middle-class families who have made a conscious decision to raise the children with multiple languages. Thus, there is an inherent uncertainty in the validity of generalizing the results of these studies to bilinguals as a whole.

Essentially, someone is considered bilingual when he or she is proficient enough in two languages to function within the framework of each language community and to meet whatever demands might be posed under various circumstances. With regards to language proficiency, Bialystok (2001) proposes a model similar to the notion of agency described by Russell (1996), where language control refers to the amount of attention and inhibition that is in play during cognitive processing. The attention mechanisms regulate, "access to and activation of the mental representations that are involved in performing various tasks."[7] Inhibition refers to repression of these mental representations. Bialystok

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[7] Bialystok, Ellen. *Bilingualism in Development: Language, Literacy, and Cognition.* Cambridge: Cambridge University Press, 2001.

presents four diagrams, the first of which (I.1) represents the varying levels of cognitive demands on the three domains of language use—oral, literate, and metalinguistic (which Bialystok defines as, "the interaction between language knowledge, ability, and awareness")—and the following three are close-up examinations of each domain in itself (I.2, I.3, I.4).

Bialystok's graphs serve to map out the degree of involvement of two cognitive processes in various language tasks or language use situations. The two processes: *analysis* of representational structure and *control* of attention and inhibition called upon during cognitive processing; lay the framework for the cognitive demands made during such situations. Low control (less "skilled") tasks are less cognitively demanding, and thus the degree and nature of language proficiency required for these tasks is relatively low. According to Bialystok, children's conversations, which consist of short utterances about the "here and now," make the, "lowest demands on the cognitive processes."[8] Therefore, high control tasks make great demands on the cognitive process and are considered highly skilled. Examples of such tasks are: academic writing and skimming (while reading). Low analysis tasks, such as early reading, make the least demands on a person's knowledge of grammatical and physical structure of a language. High analysis tasks require in-depth knowledge and awareness of the grammatical and physical structure of language—which why tasks such as simultaneous translation and poetry-writing are labelled as such.

Although Bialystok never makes the labels in her graphs entirely clear, I assume that the x-axis is a measure of analysis (with low levels indicated to the left, and high levels to the right), and the y-axis is a measure of control (with low levels indicated at the

bottom of the graph and high levels indicated at the top). The words and phrases positioned throughout the graph are examples of tasks (performed during everyday life—not necessarily in an experimental setting) which fall into their respective quadrants as a result of the level of control and analysis required for their execution. The positions of the names and titles of people indicate the level of analysis and control upon which those individuals call when performing the tasks for which they are well known.

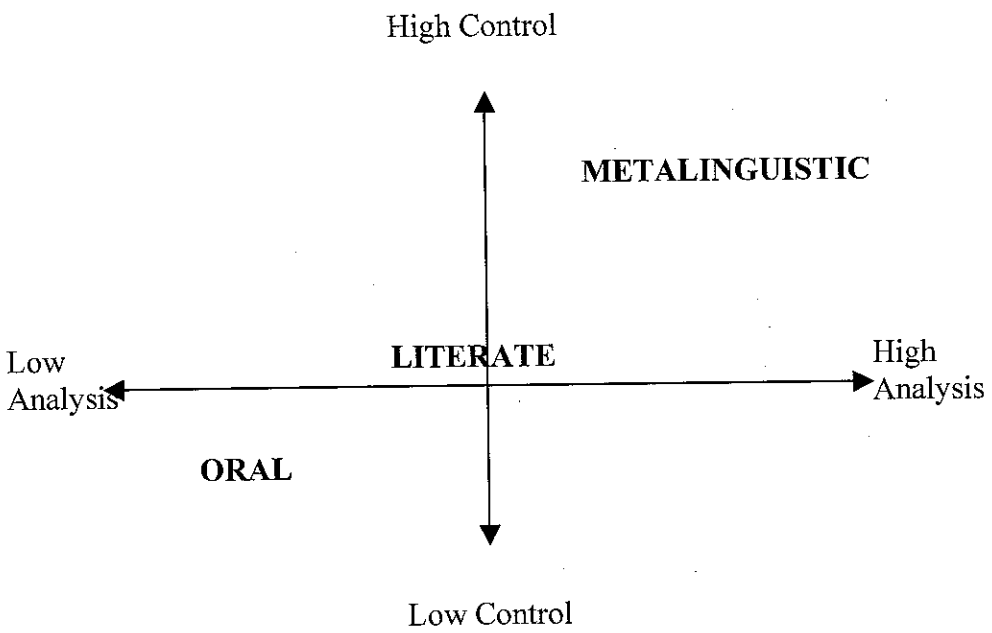

Figure I.I. Three domains of language use indicating values of analysis and control.

[8] Ibid.

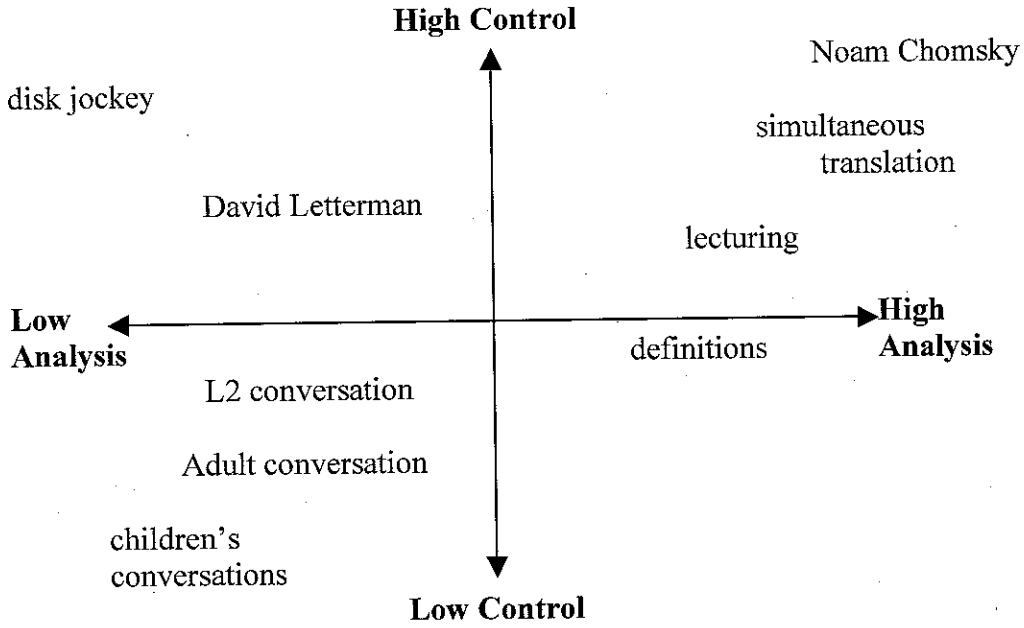

Figure I.2. Tasks included in oral uses of language indicating their demands for analysis and control. (L2 = second language).

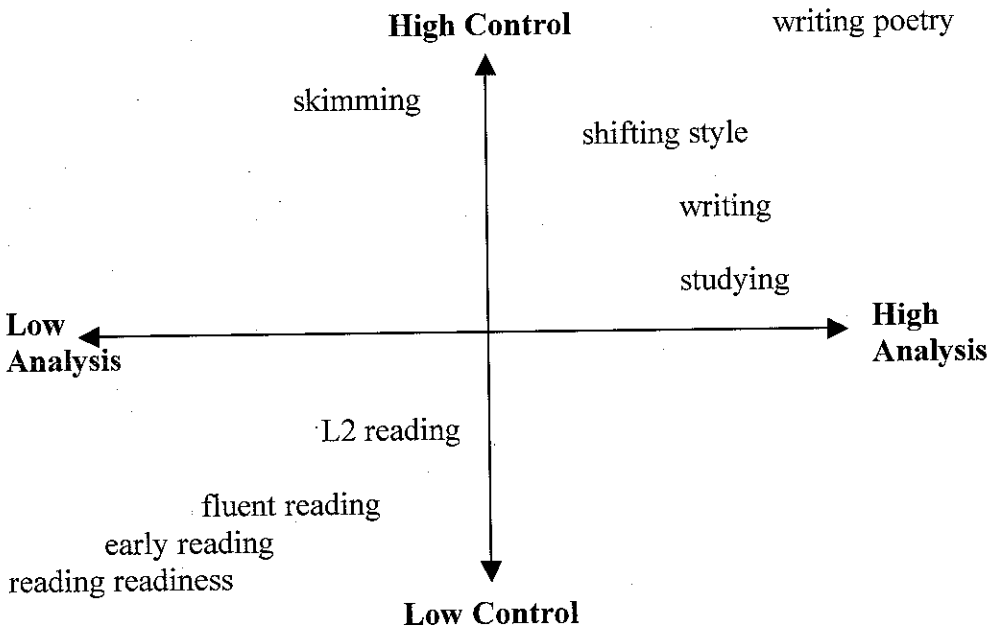

Figure I.3. Tasks included in literate uses of language indicating their demands for analysis and control.

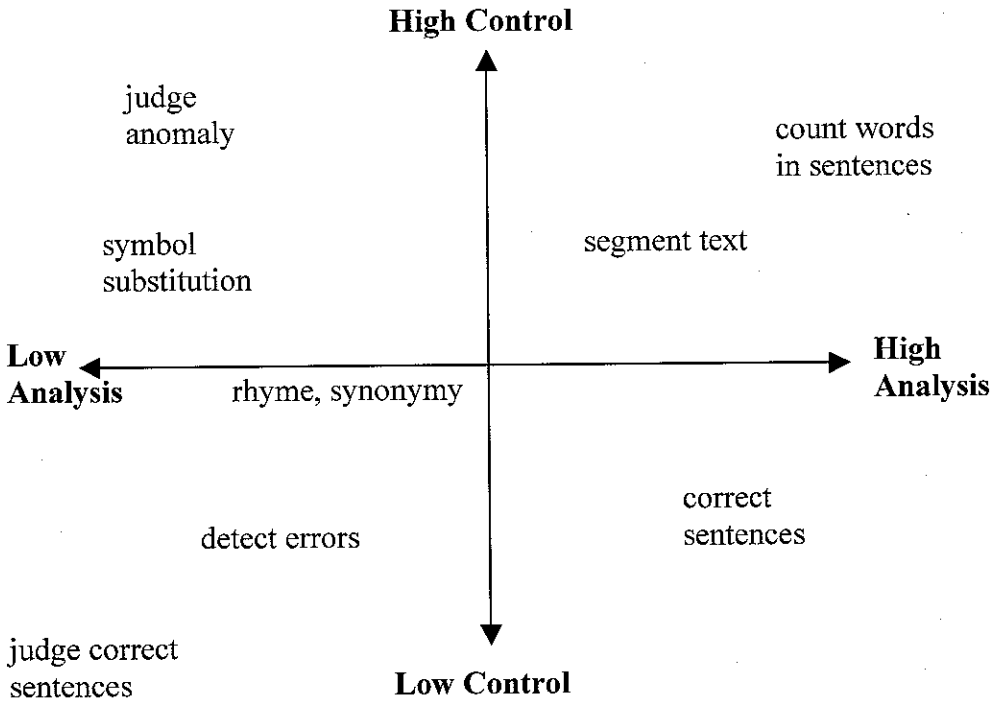

Figure I.4. Tasks included in metalinguistic uses of language indicating their demands for analysis and control.

Figure I.I. is a graph of the three language use domains themselves. She claims that because each subsequent language use domain requires higher levels of both analysis and control, a linear progression is apparent in Figure I.I.

According to Bialystok, the three broad domains of language use—oral, literate, and metalinguistic—can also be diagrammed according to their cognitive demands. She assumes that tasks performed within each of those domains demands varying levels of representational structure analysis and control of attention and inhibition. As mentioned earlier, the words and phrases in the quadrants of graphs I.2, I.3, and I.4 are examples of such tasks.

Because there can be no single definition that captures the multidimensionality in the graphs above (ie. the varying levels of analysis and control required by the oral, literate, and metalinguistic language domains—as well as the varying levels of analysis and control required by each language domain within itself), Bialystok settles on one that sets constraints and limits, stating, "Language proficiency is the ability to function in a situation that is defined by specific cognitive and linguistic demands, to a level of performance indicated by either objective criteria or normative standards."[9] As a result, varying levels of language skills are considered proficient depending on the context—which, I remarked, leads us back to square one. The ultimate goal is to have an objective means of quantifying bilingual proficiency. At the moment, advances in testing sophistication, developmental psycholinguistics, and sociolinguistics are progressing towards its attainment.

Experimental Methods

However, despite the lack of such objective tests, considerable progress has already been made in the domain of psycholinguistics and neurolinguistics. Researchers have conducted a substantial number of experiments into the nature of the cognitive effects of multilingualism. Although evidence as to the exact extent of these effects is inconclusive, the notion that multilinguals may process mathematical information differently has been widely accepted and examined, as evidenced by the many studies conducted by such linguists as: Macnamara (1966), Mägistre (1980), Marsh & Maki (1976), McClain & Huang (1982), and Geary et al. (1993).

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[9] Ibid.

The question of whether monolingual and bilingual children differ in their mastery of the concept of cardinality—the idea that "numbers have significance because they refer to invariant and identifiable quantities"[10]—was tackled by Bialystok & Codd (1997). Their previous research had led them to believe that bilingual children are better able to solve tasks that demand a higher level of control (the same "control" referred to in Bialystok's graphs). They devised two tasks: one which demanded a high level of analysis and another which demanded a high level of control.

The task demanding a high level of analysis was a sharing task in which children had to divide a set of candies into two piles which they agreed were equal, count the number of candies in one of the piles, and then infer the number of candies in the other pile without counting. To solve this task, the children needed to be able to understand the principle of equivalence, which is a fundamental factor of cardinality. Because there was no misleading information in this task, the control demands were low.

The task demanding a high level of control was the towers task in which children were told they were going to build apartment complexes out of blocks. They were told that each block represented one apartment, and that one family could live in one apartment. This task was tricky because both Lego™ blocks and Duplo™ blocks (which are identical versions of Legos, but twice as big) were used. Two towers were presented to the children: a taller tower made of Duplos, which had fewer blocks, and a shorter tower made of Legos, which consisted of more blocks. The children were told to *count* every block in each tower and then tell the experimenter which tower could house more families. This task was challenging because the height of the towers was irrelevant and had to be ignored.

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[10] Ibid.

Bialystok & Codd found that the monolingual and bilingual children performed equally well on the sharing task, but with regards to the towers task, the bilinguals displayed a strong advantage. In this task, the monolinguals were unable to ignore the perceptually misleading info (ie. the height of the towers) even though all the children had been told to count the number of blocks in each tower, while the bilinguals were able to concentrate on the true meaning of the problem (ie. the number of blocks) and focus only on the relevant information. They concluded that the two groups do not differ in their basic knowledge of cardinality but differ in their abilities to apply this knowledge to specific problems.

With regards to whether bilinguals learn concepts of quantity in general any differently that monolinguals, there is no conclusive evidence. Sax (1998) discovered that bilinguals understand the arbitrary nature of number symbols better than their monolingual counterparts. Macnamara (1996) conducted the first review of studies investigating the effects of bilingualism on children's mathematical skills. He concluded that bilingualism did not impede children's computational ability for mechanical arithmetic, but that it impaired their ability to solve word problems. Upon further examination, however, he attributed this impairment to the fact that the word problems were above the language proficiency level of the bilinguals. Other scholars disagree with Macnamara's conclusion that bilinguals' computational mathematic skills are not affected. Mägistre (1980), Marsh & Maki (1976), and McClain & Huang (1982) all demonstrate that adult bilinguals take longer to solve mental math problems than monolinguals. More specifically, the study of Marsh & Maki (1976) for example, showed

that bilinguals had slower response times and higher error rates when performing mental math in their L2 than their monolingual counterparts.

Historically, researchers generally regarded bilinguals as having a lower IQ than monolinguals—see studies by Darcy (1953) and Náñez et al (1992). However, subsequent research has shown the opposite, and the current focus is on the additive effects attributed to bilingualism—see Peal & Lambert (1962), Geary et al (1993), and Pavlenko (1999, 2000). Baker (2001) states that, "although there is insufficient evidence to satisfy the skeptic, the evidence that currently exists does lead in the direction of bilinguals having some cognitive advantages over monolinguals"[11] (in terms of metalinguistic awareness, for instance). There is also evidence that bilinguals tend to solve certain problems that involve their knowledge of quantity differently. This difference could be due to the fact that different parts of the brain are being stimulated to different degrees during a math related task in bilinguals and in monolinguals. Albert & Obler (1978) report that the left hemisphere is dominant for language and that in bilinguals, there is also a major right hemispheric contribution.[12] In their statistical analysis of more than 100 polyglot aphasics, they discovered that, following right hemispheric lesions, more instances of aphasia were reported in bilinguals (10%) than in monolinguals (1-2%). This evidence led them to their argument that there is a greater right hemispheric contribution to language in bilinguals than in monolinguals.

Their research also suggests that the right hemisphere of the brain plays a key role in second language learning, even during adulthood. They report that learning a second

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[11] Baker, Colin. *Foundations of Bilingual Education and Bilingualism: 3rd Edition.* Clevedon, UK: Multilingual Matters Ltd., 2001.

[12] Albert, Martin L. and Loraine K. Obler. *The Bilingual Brain.* New York: Academic Press, 1978.

language may "alter patterns of cerebral organization," which means that for certain individuals, cerebral dominance for the language which was acquired first may shift from the left to the right hemisphere as a second language is learned. Albert & Obler attribute the shift in the pattern of cerebral dominance in bilinguals to several factors, including: age of acquisition of L2, manner of learning L2, order of language learning, and language specific factors (such as structural differences).

In light of these conclusions, they speculate that when someone starts to learn a new second language, the right hemisphere initially plays the major role, while the left hemisphere is involved to a lesser extent. As proficiency in the second language is increased, the left hemisphere begins to play a more active role, although the right hemisphere continues to contribute. It is due to this dynamic nature of the brain that the right hemisphere may be as capable of acquiring language in adulthood as in childhood. The right hemisphere may even be dominant for one of the languages of a bilingual. Interestingly, the two hemispheres of the brain use different strategies for carrying out their respective linguistic functions. Albert & Obler make four main points:

1. Language organization in the brain of the average bilingual may be more bilateral than in that of a monolingual.

2. Patterns of cerebral dominance may be different for each language in the brain of the bilingual.

3. Differential cerebral lateralization for each language is not random but is influenced by many different factors, including age, manner, and modality of second language acquisition.

4. Cerebral dominance for language in the bilingual is not a rigid, predetermined, easily predicted phenomenon; it is, rather, a dynamic process, subject to variation throughout life and sensitive to environmental, especially educational, influences.[13]

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[13] Ibid.

The conclusions of Albert and Obler—especially the fact that the right hemisphere might play a larger role in language processing of bilinguals—provide a possible neurolinguistic explanation for the fact that bilinguals tend to process visuospatial information more quickly, because the right hemisphere interprets the context of language, is involved with geometrical shapes, deciphering mazes or maps, seeing things in a three-dimensional manner, and correlating diverse relationships. It is also said to be more integrative (ie. better at handling whole or "holistic" concepts). However, I remain somewhat wary of their approach because they fail to differentiate between language acquisition and language learning, which is a fundamental distinction, as previously discussed.

Moreover, Romaine (1989) asserts that there are currently three hypotheses that have received support regarding lateralization in bilinguals.[14] The first is that the left hemisphere is dominant for both languages, the second proposes weaker left lateralization in bilinguals and the third favours a differential lateralization for the two languages. Albert & Obler's theory bridges the second and third types of hypotheses. According to Obler (1989), there is also evidence that reading direction (such as left to right in English vs. right to left in Arabic) may have an effect on laterality.

Regarding right hemispheric involvement in bilinguals, it has also been suggested that acquisition in an informal environment (such as the home versus the classroom) incites right hemispheric involvement. Hasuike et al (1986) purport that several language-specific factors such as language typology, tonality, and directionality of the script could

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[14] Romaine, Suzanne. *Bilingualism: Second Edition*. Oxford: Blackwell Publishing Ltd., 1989, 1995.

determine the degree of involvement of the right hemisphere. An experiment conducted by Genesee et al. (1978) gave evidence that late bilinguals used a more right-hemispheric holistic approach to learning. Mägistre's studies of German/Swedish bilinguals (1992) showed less left hemispheric lateralization than monolinguals, thus supporting the claim of Hasuike et al.

However, an experiment conducted by Soares & Grosjean (1981) gives contradicting evidence. They concluded that monolinguals and bilinguals both show left hemispheric dominance in language processing. Vaid & Hall (1991) support this view. Myers-Scoton (2006) claims that both monolinguals and bilinguals generally have their language centres in the left hemisphere of the brain. Her conclusion is based on the most recent experiments, thus rendering it, quite possibly, more reliable than the others. Her statement also contains the caveat "generally," indicating that she does recognise some evidence of right hemispheric dominance.

The number of conflicting studies has been a source of frustration for many linguists. Paradis (1990) criticises the lack of comparability between studies and the methodology. Sussman et al. (1982) and Obler et al. (1982) disapprove of the kinds of methods used to judge the relationship between bilingualism and hemispheric dominance. The two methods most commonly used in such studies are: dichotic listening and visual tachistoscopic presentation. These tests are limited for three reasons: the mode of sensory input is totally unlike that found in the real world, only a minimal degree of language processing is needed to perform the tasks (and is cognitively closer to receiving a linguistically related symbol or sign than to a linguistic message), and they both measure perception, even though it is the non-dominant sphere that possesses these abilities.

Pilot Experiment

In order to investigate the claims regarding language lateralization in bilinguals, I conducted an experiment of my own which is based on the principle that the right hemisphere of the brain controls visuospatial processing, among other functions. My experiment was similar to the towers task administered by Bialystok & Codd (1997), in that it demanded a high level of control due to the presence of visually misleading information.

I conducted my pilot experiment on a total of six children between the ages of 3 and 5—two French/English bilinguals who spoke and were immersed in French at school and who spoke both French and English in their homes, two French/English bilinguals who spoke and were immersed in French at school but spoke only English in their homes, and two monolingual English-speakers.[15] Although I spoke with the bilingual children in both French and English, the experiment itself was conducted entirely in English. The experiment consisted of arranging two straight rows of five flat, brightly coloured, circular plastic chips (approximately 1.5 inches in diameter) while the child's eyes were closed. Although each row consisted of five chips, they were spaced apart further in one row than in the other—making it longer. After the chips were arranged, I ask the child to open his or her eyes and tell me which row he or she thought contained more chips. To verify that the child was certain of his or her answer, I conducted the experiment two times with each child, asking "Are you sure?" after the child had answered during the second trial.

Initially, the bilingual children all replied that the longer line contained more chips. Even after I asked them "Are you sure?" during the second trial, all but one child affirmed their initial answer, reasoning that the longer line must contain more chips. The one child whose response differed told me, "Wait! [pause] They're the same. It's just that there's more space between the buttons in the longer one." This child spoke both English and French at home.

Both of the monolingual children also thought initially that the longer line contained more chips. After asking if they were sure, one child stuck with the answer "yes," while the other hesitated after the original statement and answered, "I don't know."

This experiment was also conducted with actual buttons (as opposed to coloured disks) by Psychology students at Swarthmore College in the fall of 1988 on a 3 year-old boy. This child was not bilingual, but had spent every summer since birth in Italy. When this child was asked which line contained more buttons, his answer was an unequivocal "They are the same." Startled by his quick response, the experimenter repeated a variant of the experiment with two glasses of water—one tall and slim, the other short and wide, but each glass contained the same volume of water. Again the child answered that the glasses had the same amount of water. Apparently, the answers to these questions were so obvious to him that he told his mother that he was afraid that the lady (conducting the experiments) was "stupid."

The results of my chips experiment indicate a possibility that bilingual children are better able to ignore visually misleading cues, as shown by the second response of

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[15] My experiment was conducted on one of the monolingual children by the parent of the child (rather than myself). I gave the parent a strict written procedure to ensure that the experiment was conducted in a

one of the bilingual children who speaks and is immersed in French at school but speaks both English and French at home. The bilingual children who speak French only at school responded similarly to the monolingual children, suggesting that learning a language from a young age in school (about 3 years-old) does not stimulate the same cognitive benefits as second language acquisition. However, one of the monolingual children indicated that he was unsure of his response of "yes" and changed his answer to "I don't know," although he could not explain his hesitation. Moreover, after the experiment, I asked the children who responded that the longer line contained more chips (after having been asked, "Are you sure?") to count the chips in each line. After counting five chips in each row, each of these children, monolingual and bilingual, seemed surprised and a little confused. It seemed that they could not rectify the fact that the longer line and the shorter line were both composed of the same number of pieces. Therefore, I am lead to believe that the results of my experiment might have been clouded by age and the cognitive development of all children in general, regardless of how many languages they speak. The monolingual child who answered, "I don't know" and the bilingual child who recognised that the two lines contained an equal number of buttons were also the two oldest children in the study (age 5). It appears that these children are leaving or have left the stage when they believe that size = quantity.

As an adjunct to my basic chips experiment, a variation in which the chips were placed in shapes was conducted on the monolingual children.[16] This time, two identical shapes (ie, square vs. square or triangle vs. triangle) were made with the chips, one large

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manner as similar to the others as possible.

[16] This adjunct experiment was the idea of the parent who conducted my chips experiment on his child. I thought it might lead to some interesting insights, so I also conducted it on the other monolingual child.

and one small, and the child was asked which shape contained more chips. Four chips were used to make a square and three chips were used to make a triangle. This time, one child (just under age 5) stated right away that there were an equal number of chips in each shape, while the other (age 3) continued to point at the larger shape, indicating that she believed it contained more.

Again, my impression is that the differences in age of the children may well have overshadowed any linguistically-related, cognition-based conclusions. This time, my impression is that the older child has firmly grasped the concept of the number of sides/corners certain shapes have and that they do not change, regardless of the shape's size. This is the reason why this task was very easy for him. The younger child must not have had such a firm grasp of this concept yet, which is why she applied the size = quantity reasoning to this task as well.

Ideally, in experiments of this nature, the age of the children should be as similar as possible to avoid any developmentally related cognitive factors (such as the size = quantity idea). In addition, research indicates that handedness and sex also have significant influences on lateralization. Research (albeit inconclusive) suggests that women may use both hemispheres more symmetrically for speech and other functions than males.[17] With regards to handedness, researchers are still searching for a clearer understanding of its relationship with lateralization. The brain is adaptable under various circumstances, and research suggests that cerebral control of skills depends on the location of various cerebral control centres and on varying levels of neurotransmitters

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Unfortunately, at this point, I had already conducted the chips experiment on the bilingual children and did not have the opportunity to go back and conduct the adjunct experiment on them.

[17] *Right brain, left brain – what's what?* Health News, April 1992. accessed 6 April, 2006. <http://www.findarticles.com/p/articles/mi_m0857/is_n2_v10/ai_12206759)#continue>

such as dopamine. Therefore, the extent to which handedness and sex would affect experiments of this type is unknown, but I believe that using subjects of the same sex and handedness would help reduce the effect of other factors, nonetheless.

It is also quite possible that experiments, such as my chips experiment and Bialystok & Codd's towers task, may have nothing to do with mathematical cognition, but may actually test how well a child listens to directions. The outcomes of these tests may just imply that bilingual children listen more closely to directions than monolingual children. A way to test this hypothesis would be to give children a task with highly specific directions that does not involve math—to draw or colour something a particular way, for example. If this hypothesis is correct, bilingual children may follow the directions more closely.

Conclusions

Although advancements in technology, such as brain imaging, have elucidated much about the brain, a large part of it still remains a labyrinth. Despite recent neurolinguistic and psycholinguistic studies into the nature of language, lateralization, and multilingualism, it is still impossible to state with 100% clarity how these concepts are related, but some initial findings have been made with relative certainty.

Romaine concludes that neither the "bilingual brain" nor the "bilingual lexicon" is a unitary, static phenomenon. The cognitive results of bilingualism, like the definition of bilingualism itself, depend heavily on a variety of circumstances. According to Romaine, "different words or word types may be stored and accessed differently."[18] Therefore, the

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[18] Ibid.

language storage systems for Japanese/Chinese bilinguals may differ from those of a Norwegian/English bilingual. Varying proficiencies at different ages, pathological disturbances, and the nature of the task that a subject is required to perform in a certain environment may also affect hemispheric lateralization. The degree to which a bilingual may function as a monolingual depends most heavily on his or her degree of proficiency in the second language.

Baker (2001) states that bilinguals, "have advantages in thinking styles, particularly in divergent thinking, creativity, early metalinguistic awareness, and communicative sensitivity."[19] He goes on to say that research on the metalinguistic advantages of bilinguals is strong, and that it suggests that bilinguals are aware of their languages at an early age—separating form from meaning, and having reading readiness earlier than monolinguals. Dr. Charmian Kenner's experiences in her study of bilingual six year-olds in London (2004) confirms Baker's statement that bilingual children display early metalinguistic awareness, saying that bilingual children tend to compare their language systems, which results in a heightened awareness of how language works. Bialystok's studies (2001) demonstrate this metalinguistic awareness. She concludes that bilingual children are able to inhibit attention to misleading information "of greater salience or complexity" than monolinguals.

There is also evidence that the two hemispheres are not the only parts of the brain affected by multilingualism. Burgess & Shalice (1996), Kimberg, D'Esposito, & Farah (1997), Luria (1966), and Perret (1974) all demonstrate that the performance profile of bilingual children is the reverse of that reported for patients with frontal lobe damage—

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[19] Baker, Colin. *Foundations of Bilingual Education and Bilingualism: 3rd Edition.* Clevedon, UK: Multilingual Matters Ltd., 2001.

implying that bilinguals may show heightened frontal lobe activity compared to monolinguals. The frontal lobe controls such tasks as reasoning, planning, parts of speech, movement, emotions, and problem solving. For patients with frontal lobe damage, tasks that require switching attention, especially with distracting information, are difficult. This finding is in keeping with Bialystok's conclusion that bilingual children are better able at ignoring misleading cues than their monolingual counterparts.

Thus, while the exact nature of bilingualism's effect on the brain and cognition is not entirely clear, the current view is that bilinguals show early heightened metalinguistic awareness and can solve problems with irrelevant or distracting information more easily than monoglots. In order to investigate these claims further, studies should take into account sex, age, handedness, the level of proficiency of each language, the type of bilingual (the circumstances under which the subject become bilingual), and the languages that the bilingual speaks. Within themselves, these variables are complex, and the extent of their influence on the brain and cognition is also uncertain—emphasizing the fact that this investigation is a joint effort on many fronts: neurological, linguistic, psychological, and cognitive.

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