SIGNS OF ENHANCEMENT? A COMPARISON OF VISUAL SPATIAL SKILL IN SIGNERS AND NON-SIGNERS

by

JANICE A. SPRINGFORD

B.A., The University of British Columbia, 1987

A THESIS SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF
MASTER OF ARTS
in
THE FACULTY OF GRADUATE STUDIES
(School Psychology)

THE UNIVERSITY OF BRITISH COLUMBIA
November 2006
© Janice A. Springford, 2006
Abstract

The effect of sign language experience on performance of visual spatial tasks was investigated in this study. Performance by signers and non-signers was compared on the Knox's Cube Test—Revised (KCT—R) in standard and experimental administrations, Color Trails Test Parts 1 & 2 (Form A) (CTT), and the Benton Test of Facial Recognition (BFT). Participants were 30 Deaf adult signers, 28 hearing adult signers, and 30 hearing adult non-signers. Deaf and hearing signers were also compared as subgroups of 1) native signers who learned sign language from their Deaf signing parents and 2) non-native signers who began to learn sign language later in childhood or in adulthood. Analysis of variance on raw and/or total scores indicated that hearing signers outperformed non-signers significantly on the CTT, Part 2. Both Deaf and hearing signers significantly outperformed non-signers on the CTT, Part 1. Differences between hearing signers and non-signers approached significance on the experimental administration of the KCT-R. No differences between signers and non-signers were found on the Benton Test or the KCT-R, standard administration. This study suggests that sign language experience may be enhancing some general visual spatial skills.
# Table of Contents

Abstract ............................................................................................................ ii  
Table of Contents ............................................................................................ iii  
List of Tables .................................................................................................. v  
List of Figures .................................................................................................. vi  
Acknowledgements ......................................................................................... vii  

Chapter One: Introduction ............................................................................... 1  
Areas of Skill Enhancement ........................................................................... 1  
Purpose of this Study ....................................................................................... 2  
Connection to Previous Studies ........................................................................ 3  

Chapter Two: Literature Review ......................................................................... 5  
Visual Spatial Properties of Sign Language ..................................................... 6  
Sign Language and Neurological Organization .................................................. 8  
Language Modality Effects versus Sensory Compensation .......................... 10  
Differential Performance by Deaf and Hearing Subjects on Visual Spatial Tasks 15  
  Motion Processing ......................................................................................... 16  
  Face Processing .......................................................................................... 16  
  Mental Imagery .......................................................................................... 17  
  Cognitive Flexibility and Seriation ............................................................... 17  
Present Study ................................................................................................. 18  
Research Questions ........................................................................................ 19  
Hypotheses ...................................................................................................... 20  

Chapter Three: Methodology ........................................................................... 22  
Overview of Participants ................................................................................ 22  
Recruitment of Participants .......................................................................... 23  
Description of Participants ............................................................................ 25  
  Deaf Signers: Subgroup Descriptions .......................................................... 25  
  Hearing Signers: Subgroup Descriptions ..................................................... 26  
  Hearing Non-signers .................................................................................. 26  
Measures .......................................................................................................... 27  
  Demographic Sheet ..................................................................................... 27  
  Center for Epidemiological Studies Depression Scale .................................. 27  
  WAIS-III Block Design ................................................................................. 28  
  Knox's Cube Test-Revised ......................................................................... 28  
  Color Trails Test ........................................................................................ 30
List of Tables

Table 1.1  Identification of Participant Groups and Subgroups......................2
Table 4.1  Task Means and Standard Deviations for Deaf Signers, Hearing Signers and Hearing Non-Signers........................................35
Table 4.2  Task Means and Standard Deviations for Signing Subgroups and Hearing Non-Signers.........................................................38
Table 4.3  Benton Test of Facial Recognition: Mean percentage correct for Deaf Signers, Hearing Signers and Hearing Non-signers.............................................40
Table 4.4  Benton Test of Facial Recognition: Mean percentage correct for Subgroup Signers [and Hearing Non-signers]...............................................40
Table 5.1  Age Range in Years and Education Levels (%) Across Participants.................................................................44
List of Figures

Figure 3.1 Knox's Cube Test-Revised, Layout........................................29
Acknowledgements

Financial support for this research was provided in part by the Cordulla and Gunter Paetzold Fellowship, and grants from the Department of Educational and Counseling Psychology and Special Education and the Disability Resource Centre, both at the University of British Columbia.

Data collection and volunteer recruitment were important and time consuming tasks and appreciation is expressed to Sarah Chan, Allison Mitchell, Ariadne Patsiopoulos and Lynda Thiessen for their efforts, as well as to other members of the Adult Development and Psychometrics lab who helped out along the way.

Thanks also to the members of the Deaf communities in Vancouver, B.C., London, Ontario, Washington State and California who participated in and supported this research.

Special thanks to my advisor, Dr. Anita Hubley, for her support and encouragement, and to the members of my committee: Dr. Laurie Ford, Dr. Susan van Gurp, Dr. Janet Jamieson, and Dr. Bruno Zumbo.
Chapter One

Introduction

A small but intriguing area of research that developed in the 1980s and 1990s examines the relationship between visual spatial skills and sign language experience. Studies involving children (e.g., Bellugi, O'Grady, Lillo-Martin, O'Grady Hynes, van Hoek & Corina, 1990; Courtin, 2000) as well as adults (e.g., McCullough & Emmorey, 1997; Talbot & Haude, 1993) have found a difference between Deaf signers and hearing non-signers on a variety of visual spatial skills. These differences appear as enhanced ability for the signers. Such studies have provided evidence suggesting that knowing and using a visual and spatial language, such as American Sign Language, can and does enhance visuospatial skills.

Areas of Skill Enhancement

Although previous research has shown that many signers demonstrate better performance than non-signers, not all visuospatial skills are enhanced in signers. For example, skills such as drawing, copying, and visual perceptions appear to be unaffected by sign language use (Bellugi, et al., 1990; Parasnis & Kirk, 1998). Researchers have suggested that the explanation for this lies in the linguistic characteristics of sign language itself. Sign language production and comprehension recruit specific visual spatial cognitive skills. By analyzing the grammar, syntax and use of space in sign language, researchers have surmised that some standard measures of spatial skill tap the same abilities needed for sign language comprehension. Enhanced performance for signers have been shown on measures of face processing, motion processing, mental imagery, and
cognitive flexibility and seriation, highlighting the benefits of sign language experience.

Purpose of this Study

It was the purpose of this study to compare the performance of signers and non-signers on several currently available and standardized visuospatial tests. The adult participants in this study were carefully chosen to allow focus on the interplay of three important areas of interest: sign language status (signer or non-signer), hearing status (Deaf or hearing), and age of acquisition of sign language (native or non-native signer—sign language was the first language or not). To clarify, the participants in this study were classified in groups and subgroups as follows in Table 1.1:

Table 1.1
Identification of Participant Groups and Subgroups

<table>
<thead>
<tr>
<th>Groups</th>
<th>Subgroups</th>
</tr>
</thead>
<tbody>
<tr>
<td>Deaf Signers (DS)</td>
<td>Deaf of Deaf signing parents (DD): native signer</td>
</tr>
<tr>
<td></td>
<td>Deaf of Hearing parents (DH): non-native signer</td>
</tr>
<tr>
<td>Hearing Signers (HS)</td>
<td>Hearing of Deaf signing parents (HD): native signer</td>
</tr>
<tr>
<td></td>
<td>Hearing of hearing parents (HH): non-native signer</td>
</tr>
<tr>
<td>Hearing non-signers (HNS)</td>
<td>No subgroups</td>
</tr>
</tbody>
</table>
Given that this is a fairly new area of research, relatively few tests of visuospatial ability have been utilized thus far to study the effects of sign language modality on visuospatial cognition. Some of these tests are research-specific and are not readily available. Other more common tests (e.g., Trail Making Test) have been modified to accommodate the age of specific research participants. Therefore, the present study utilized readily available and standardized tests to examine and compare the performance of signers and non-signers on the visuospatial tasks of face processing, mental imagery, and cognitive flexibility and seriation. The tests used in this study were the WAIS-III Block Design (BD) subtest as an estimate of general visual spatial ability across groups, the Knox's Cube Test—Revised (KCT—R) as an assessment of mental imagery, and the Color Trails Test, Parts 1 and 2, Form A (CTT) as an examination of cognitive flexibility and seriation. The Benton Test of Facial Recognition (BFT) was included to explore face processing abilities among the participants.

Connection to Previous Studies

A study conducted by Bettger, Emmorey, McCullough & Bellugi (1997), using the Benton Test of Facial Recognition, offers interesting insights into face processing skills by signers. Although not an exact replication of the study by Bettger and his colleagues, the present study included the Benton test to determine if a broader range of signers and non-signers would provide similar results. Therefore, with the exception of the Benton test, the tests in this study have not previously been used specifically to compare visual spatial abilities between signers and non-signers.
The present study offers further insights into an area of research that, while small, has prompted studies in the fields of linguistics, neuropsychology, education and psycholinguistics. Further, the present study raises questions about the results of previous research and the extent to which sign language experience really impacts visual spatial cognitive abilities.
Chapter Two

Literature Review

A number of studies in the last three decades have been conducted with Deaf\(^1\) children and with Deaf adults to explore the connection between sign language and various cognitive processes. Studies involving children investigated the possibility that, due to the use of a three-dimensional, visual spatial language, Deaf signing children may have an advantage over their non-signing hearing peers in visuospatial perception (Bellugi, O'Grady et al., 1990), seriation (Courtin, 2000), spatial memory span (Wilson et al., 1997), and other areas of cognitive development. Many studies that have been conducted with Deaf children have been replicated in studies with Deaf adults, indicating that enhanced visual spatial skills resulting from sign language use do carry over into adulthood.

It has been suggested in the literature that learning sign language as a first language can influence cognitive processes and perhaps enhance some skills, such as visual spatial perception. To demonstrate this, several studies utilized measures developed based on the visual and spatial characteristics of sign language and the skills that would be needed in order to comprehend the language. Some studies utilized standardized spatial measures, used in original or modified form to assess the influence of ASL (American Sign Language) on spatial skills. Results from these studies have, overall, fueled further research

---

\(^1\) The lower case “d” for deaf refers to the audiological classification for hearing loss. The upper case “D” for refers to a cultural and linguistic minority who have varying degrees of hearing loss and for whom sign language (for example, American Sign Language) is the primary mode of communication. Both the lower case “d” and the upper case “D” will be used here, depending on the characteristics of the population being discussed (deaf or Deaf).
on the linguistic structure of sign language, how sign language is processed, and how it may influence cognitive development.

**Visual Spatial Properties of Sign Language**

Signed languages, used by Deaf people the world over, historically have struggled to be recognized as real languages and as an accepted form of communication (Schein & Stewart, 1995). Using ASL as an example, much of the struggle arose from the heated and oppressive arguments on how to educate the deaf (Lane, 1984) and the view that sign language is primitive and not based on established linguistic principles. Armstrong, Stokoe, and Wilcox (1995), in examining the evolution of sign language studies, noted "...the thrust of much sign language research has been to demonstrate that currently accepted linguistic theories can be applied productively to the study of sign languages and that the observed structure of signed languages confirms the theories" (p. 11). It was William Stokoe's (1960) *Sign Language Structure* that initiated a shift in opinion regarding the linguistic validity of sign language and the understanding that it was not just "...a coding system for the manual representation of a spoken language" (Schein & Stewart, 1995, p. 23). Since then, cultural and linguistic studies of signed languages have been firmly established as respected areas of scholarly inquiry.

---

2 Lane's (1984) book provides a compelling history of the education of the Deaf. In theory and practice, education of the Deaf has historically been divided into two groups: those who support sign language as a language of instruction (and promote ASL/English bilingualism) and those who support an oral method, disallowing sign and emphasizing speech and lipreading. In the 1800s, many Deaf people were gainfully employed as teachers in schools for the Deaf, but after the 1880 Conference of Milan, in which the oral method gained widespread support and initiated changes in educational policy, most of these Deaf teachers were let go from their jobs, as they were unable to teach speech or conduct classes in spoken English.
The linguistic structure of sign language\(^3\), in many ways, is not that dissimilar from English. Sign language can be analyzed on various levels, such as phonology, morphology and syntax (Hickok, Bellugi, & Klima, 2001). The difference from spoken languages is the visual, three-dimensional and multi-layered properties of sign language (Poizner, Klima, & Bellugi, 1987). As well, the most obvious differences between spoken and signed languages are the receptive and expressive modalities that each uses: the ears and voice versus the eyes and hands. However, to say that sign language is expressed using only the hands would be erroneous. Although the hands are the primary tools of sign expression, their motion, shape, and location in space are crucial to the conveyance of meaning (Bonvillian & Siedlecki, 1996). As well, body posture, shifts of the shoulders, and cants of the head reinforce the location and proximity of objects. Facial expressions, especially the raising and lowering of the brows or the pursing of the mouth, for example, serve as important grammatical markers (Schein & Stewart, 1995). These are simplified examples of the complex interplay of hands, face, body and space in the linguistic foundation of sign language. In their simplicity, these examples downplay the enormous amount of attention that must be focused on a signer in order for the recipient to visually process and accurately comprehend all of the linguistic information and communicative intent. As well, to produce coherent sign communication, a signer must also be able to utilize motor skills, be able to recall the placement of objects in the conversation, and integrate these previously introduced mental images and their spatial locations in sign discourse (Emmorey, 2002).

\(^3\) Although sign languages around the world share essentially the same linguistic principles, for the purpose of this review, "sign language" refers to ASL unless otherwise noted.
Sign Language and Neurological Organization

Naturally, the unique visual spatial characteristics of sign language have attracted the attention of researchers from fields as diverse as linguistics, neuropsychology, education and psycholinguistics. The literature shows a diverse array of questions that have been considered regarding sign language and its differential effects on the people who use it. One of these questions asks: In what way does learning a spatial language from birth influence neurological organization and development? This question applies to individuals—Deaf or hearing—who are born to Deaf parents and subsequently learn sign language as a first language. Specifically, are the language centers of the brain altered by a visual spatial linguistic modality?

It must be noted here that subjects for most sign language research—brain-based or otherwise—generally tend to be from Deaf families. A Deaf family is defined as a family unit consisting of Deaf parents who sign and their Deaf children who learn sign as a first language. In some cases, hearing children of Deaf parents learn sign as their native language, and they are occasionally included in various research and comparative studies. Deaf subjects who were born to hearing parents vary greatly in the onset of their first exposure to sign language and the quality and duration of that exposure because they typically do not have parents who immediately and fluently begin to use sign language with them at birth. This variability makes them less ideal subjects than those from Deaf families. Unless otherwise noted, the subjects in the following studies were all from Deaf families and acquired sign language as their native language.
Brain-based studies have shown that the brain is wired for language in the same way for Deaf people using sign language as for hearing people using spoken language. Neurological bases for language function have been explored in Deaf adults who have suffered left-or right- hemisphere damage by comparing their sign language production and comprehension to the parallel speech and auditory comprehension abilities of brain-damaged hearing adults.

In terms of the left hemisphere, research has shown that for Deaf and hearing individuals, the functional organization is identical (Hickok, Kirk & Bellugi, 1998). Like hearing persons with left hemisphere lesions, Deaf signers with similar hemisphere damage will exhibit language dysfunction (Corina & McBurney, 2001). Further, Hickok, Love-Geffen, and Klima (2002) found that damage to the left temporal lobe significantly impairs subjects' ability to comprehend single signs and sentence-level simple and complex demands. Thus the role of the left hemisphere for language learning and comprehension appears to be the same for both spoken and signed languages.

The right hemisphere of the brain generally is considered to be responsible for visual spatial processing. Because sign language is visuospatially based, it would be logical to assume that right hemisphere-damaged signers would be linguistically impaired. An early study by Poizner and his colleagues (1987) found that while Deaf and hearing people with right hemisphere brain damage exhibited similar impairment on nonlanguage visuospatial tasks, the Deaf people exhibited no sign language aphasia. Current research, however, suggests that recruitment of the right brain for language
processing, especially in native signers, is greater than originally realized. For example, Newman and his colleagues (2002) noted that

R[ight] H[emisphere] damage in native signers leads to impairments in the processing of syntactic constructions that rely on spatial relationships and in the processing of classifiers, [which are] signs that convey visual-spatial information about their referent in a lateral or ‘iconic’ manner (p. 78).

The precise role that the right hemisphere plays in sign language comprehension is still under investigation, but the Newman et al. (2002) study was unique in that the subjects were hearing ASL-English bilinguals. One group had learned sign language as a native language from their Deaf parents and the other had acquired sign language after puberty. The study, which used functional magnetic resonance imaging (fMRI), also found that

[t]he plasticity of ... R[ight] H[emisphere] regions may change with age, leading to an apparent ‘critical’ or ‘sensitive’ period of development such that only when ASL is learned early in life can [RH] regions [specifically the angular gyrus] be recruited for the processing of ASL (p. 76).

The extent, however, to which nonlinguistic visuospatial perception may be affected by the recruitment of specific right hemisphere regions such as the angular gyrus has not been shown.

Language Modality Effects versus Sensory Compensation

Because it has been shown that the brains of Deaf and hearing people are similarly wired for language, we can surmise that language modality and experience might account for differences between signers and non-signers on some visual spatial tasks. In other words, the spatial processing required of
signers to make sense of sign communication—on a daily basis, for social and educational purposes—may enhance their visuospatial cognitive abilities, specifically with tasks that have a linguistic connection to sign language. A linguistic connection might include recalling the location of objects in space, visual-sequential memory or mental rotation, all of which are an integral part of ASL.

It has been argued (e.g., Wolff et al., 1989) that differences between Deaf and hearing groups on spatial tasks could be attributed to sensory compensation, or, rather, the idea that simply being deaf leads to enhanced visuospatial awareness and ability. However, the literature on sensory compensation is not conclusive. Deafness and knowledge of sign language tend to confound each other. In general cognitive studies assessing the visual spatial abilities of deaf non-signing adults and children, the sensory compensation argument has not been supported. For example, Parasnis, Samar, Bettger, and Sathe (1996) effectively eliminated the confound of deafness and sign language use by conducting a study in India comparing 12 non-signing hearing children with 12 deaf children who had no exposure to any signed language. No significant differences were found between the groups on various commonly used cognitive and visuospatial tests, such as the WISC-R Mazes, the Visual Motor Integration test, and the Benton Test of Facial Recognition. This strongly suggests that sign language experience, rather than deafness and sensory compensation, may be responsible for some of the enhanced visuospatial cognitive performances found in Deaf signing children and adults. In a similar study with 8 non-signing deaf and 8 hearing adults, Chamberlain (1994) examined performance on several
visual spatial tasks and found no significant differences between the groups, again ruling out sensory compensation.

Attempts to clarify the issue of sensory compensation versus language modality effects have led to more complex research. For example, research focused on lower level cognitive skills, specifically spatial attention in motion processing (Bosworth & Dobkins, 2002a), visual field asymmetries (Bosworth & Dobkins, 2002b), and visual attention to the periphery (Bavelier et al., 2000) have been conducted. In two studies, Bosworth and Dobkins (2002a, 2002b) examined the effects of spatial attention on motion processing in hearing non-signers and in Deaf and hearing adults who had learned ASL as a first language. They compared the visual field asymmetries among their subjects and noted that only non-signers did not exhibit a right visual field advantage. Bosworth and Dobkins attributed this difference to sign language exposure. They also found enhanced abilities in the Deaf subjects for attentional orienting and selective attention, but this effect was not found in the hearing signers, suggesting sensory compensation. As well, they did attribute to sensory compensation the fact that Deaf signers, unlike the hearing signers and non-signers, showed different responses to the processing of stimuli in the peripheral and inferior visual fields. From this research, it appears that both sign language exposure and sensory compensation may have an influence on lower-level visual spatial processing and motion detection.

Bavelier and colleagues (2000) used fMRI (functional magnetic resonance imaging) to map attention to information located in the periphery of one's visual space. Their subjects were individuals with normal hearing who were non-
signers and congenitally Deaf signing adults whose parents were also Deaf. Deaf subjects showed greater attentional capacity for motion in the periphery. The researchers concluded that this was a result of sensory compensation and neural plasticity. However, to support that theory, two important groups of subjects should have been included in the study: non-signing deaf individuals and hearing native signers. Data collected from these additional subjects might have provided more conclusive information about sensory compensation versus sign language exposure as the reason for the presence or absence of enhanced attention to the periphery. As it stands, the researchers' sensory compensation conclusion is questionable, as sign language exposure provides a different and more practical reason for greater attention to the periphery. That is, Siple (1979, cf. Emmorey, 2002) emphasized the importance of awareness to motion in the periphery for sign language perception due to the fact that "signers look at the face, rather than track the hands, when they are conversing or watching a sign narrative" (p. 244). Because sign language discourse can be highly dependent on topographical layout within the signing space, it is understandable that a signer will rely on peripheral attention and awareness to monitor changes that may happen within that space during a conversation.

Although there is some support for the sensory compensation theory, the research is far from conclusive. It appears, to a variable extent, that both lack of hearing and the use of sign language can influence neural development and function. However, Wilson (2001) suggested that if the loss of a sense changes sensory experience, the loss alters how that experience is processed, rather than the acuity with which it is perceived. Wilson, therefore, posited that experience
with sign language, rather than sensory compensation, influences visual perception. Considering that “signers are faced with the dual task of spatial perception, spatial memory, and spatial transformation, on the one hand, and processing grammatical structure on the other—in one and the same visual event” (Emmorey, 1993, p. 178), it is logical to surmise that the brain would need to process sign language differently than it does spoken language. The wiring of the brain may be the same for those who use signed versus spoken languages, but the processing would, by necessity, be different. “Because the syntax of ASL relies so heavily on the abstract manipulation of points in space and on spatial representation, the processing of linguistic structures involves the processing of visuospatial relations” (Poizner, et al., 1987, p. 18), a much different cognitive process than hearing.

Emmorey (2002) noted that there is “no evidence for the hypothesis that the language one uses can qualitatively alter the very nature of cognitive processes or representations. However, the evidence does suggest that the language one uses can enhance certain cognitive processes through practice” (p. 269). This is supported by results from Talbot and Haude (1993) who conducted a study on mental rotation using a group of interpreters with six years of signing experience (n=18), a group of novice interpreters (n=17), and a group of non-signers (n=15) as subjects. Tested on a mental rotation task, the newer interpreters did not perform as well as the more experienced interpreters. This study points to practice effects in sign language as the reason for improved performance on the task. Comprehension of a spatial scene within a sign language dialogue will often require an addressee to mentally rotate the visual
information in order to understand the layout and to comment on it himself or herself in a manner that is consistent with the original layout. Given the results of the Talbot and Haude study, use of sign language for communication appears to translate into improved performance on the nonlinguistic mental rotations task.

In spite of design limitations in that study (e.g., subjects were not tested on the task prior to learning ASL), the results are interesting. Generally, very little is said about the performance of Deaf subjects who learned sign language later in childhood or in early adulthood. If hearing people who have recently acquired sign language show gains in visual spatial performance, would adult Deaf non-native signers—who learned sign language later in childhood—by virtue of longer use and exposure to the language, show ability equal to that of the Deaf native signers? If there is a positive or negative difference, would it be significant? In other words, when adulthood is reached, does the gap in performance close?

**Differential Performance by Deaf and Hearing Subjects On Visual Spatial Tasks**

To what extent does sign language influence performance on visual spatial tasks, and in which domains of spatial cognition? Emmorey (2002) compiled and reviewed a decade of research conducted by various scholars, including herself, on the influence of sign language on visual spatial cognition. There are numerous spatial skills that appear to be unaffected by sign language use, including drawing or copying (Bellugi et al., 1990; Parasnis & Kirk, 1998), and visual perception using block design (Bellugi et al., 1990; Parasnis et al., 1987). However, Emmorey (2002) noted that there is "strong evidence that experience with sign language enhances specific cognitive processes" (p. 243),
specifically within three domains of visual spatial cognition—motion processing, face processing, and mental imagery.

**Motion Processing**

Given the importance of motion in sign language, it is not a surprise that Deaf children show superior ability for spatial analysis of dynamic point light displays (i.e., following a moving point of light that replicated shapes of Chinese kanji and then replicating the movements). That is, "Deaf children, even in the first grade, show a marked advantage in the ability to remember, attend to, and analyze ... spatial displays which involve movement patterns" (Bellugi et al., 1990, p. 297). The results with dynamic point light displays were replicated with Deaf adults by Klima, Tzeng, Fok, Bellugi, and Corina (1996; cf. Emmorey, 2002).

**Face Processing**

Bellugi and colleagues (1990) also showed that Deaf children had enhanced ability at earlier ages than their hearing counterparts on the Benton Test of Facial Recognition. As Bellugi and her colleagues noted, "[g]iven the important role that facial expression plays in ASL grammar, this suggests that linguistic experience may impact on nonlinguistic cognitive development" (p. 293).

Consistent with the results of Bellugi and her colleagues, Bettger et al. (1997) obtained similar results with adult subjects who were Deaf. Given that Deaf subjects appear more adept at discerning subtle changes in facial expressions, McCullough and Emmorey (1997) suggested that, in signers, facial processing involves the ability to generalize grammatical markers over a range of
faces rather than the ability to remember the individual faces. Both slight and obvious changes in facial features, especially around the eyes and mouth, have impact on the grammar of signed utterances. An addressee’s ability to detect changes in facial expression will have a significant impact on his or her understanding of the intent of the signed discourse.

Mental Imagery

Also linked to visual spatial cognition is mental rotation. In sign language discourse, mental rotation is connected to the need for the addressee to take on the signers’ perspective of the spatial layout of the concepts and objects set up in the signing space. Several researchers (i.e., Emmorey, Klima, & Hickok, 1998; Emmorey, Kosslyn, & Bellugi, 1993; Talbot & Haude, 1993) have found enhanced mental rotation abilities in signers. In addition, Bellugi et al. (1990) found enhanced abilities in young Deaf children (ages 3-10) for mental reorganization of parts into a whole (Hooper Visual Organization Test) compared to available junior high school norms.

As part of the domain of mental imagery, spatial memory span may also be influenced by sign language use. Wilson and her colleagues (1997) found that native signing Deaf children ages 8-10 (n= 16) demonstrated longer memory spans on the Corsi Blocks Test—a visual-spatial memory test—than non-signing hearing children (n=31) of the same mean age.

Cognitive Flexibility and Seriation

An additional domain of visuospatial cognition, cognitive flexibility and seriation, may also be enhanced by sign language usage. Courtin (2000) adapted the Trail Making Test to appeal to young Deaf and hearing children and
examined their cognitive flexibility and seriation skills. Courtin described flexibility in the adapted measure as “the ability to shift between ... two series of pictures” (p. 24). Seriation was defined as a sequential visual search process. Both flexibility and seriation are necessary skills in sign language comprehension because the “listener” is required to mentally map the location of objects in space and shift awareness of each in various frames of reference. Participants in this study consisted of 27 Deaf and 27 hearing children. The Deaf children, all of whom had Deaf signing parents, outperformed hearing children in both seriation and flexibility tasks. There appears to be no similar study with Deaf adult subjects. Would Deaf signing adults perform better on the Trail Making Test than their hearing signing or non-signing counterparts, or does this sign language advantage exist only in childhood?

Present Study

The purpose of the present study was to further examine whether sign language experience is positively related to performance on tests of face processing, mental imagery, and cognitive flexibility and seriation using adult Deaf signers, hearing signers, and hearing non-signers. Three commonly available and standardized tests were used: the Benton Test of Facial Recognition, the Knox’s Cube Test—Revised, and the Color Trails Test. These tests, which are generally considered to have little or no language base, were chosen for this study because they appear to have a linguistic connection to sign language.

The Benton Test of Facial Recognition (BFT; Benton & Van Allen, 1968) is described as a measure of the ability to match unfamiliar faces. In sign language
research, the BFT has been used to assess signers’ and non-signers’ facial discrimination ability, which is closely linked to the need for signers to detect facial changes that are of grammatical significance in sign language. Use of this test allowed comparison of the results from previous research to the results of the current research. The Color Trails Test (CTT; D'Elia, Satz, Uchiyama, & White, 1996) is a test of visual conceptual and visual motor tracking, both required for comprehension of sign language. Until now, the Color Trails Test has not been used in this kind of research, and it has the advantage of reducing general literacy requirements by replacing English letters with two colors (pink and yellow), which increases its utility with different groups. The Knox’s Cube Test—Revised (KCT-R; Stone, 2002) is a block tapping test that is used to assess spatial sequential memory which, in sign language reception, translates into knowing what has been referred to and when. Unlike the Corsi Blocks Test, which utilizes nine blocks arranged on a large square, the KCT-R consists of four blocks set up in a row, equidistant to each other. The KCT-R was first presented using its standardized administration and then in an experimental manner using a reverse rotated sequence. In the latter case, the examinee would repeat the tapping sequence presented by the examiner, but using a 180° rotation. This procedure mimics the need for signers to take on the perspective of the person who is addressing them in sign language.

**Research Questions**

The research questions for this study were as follows:
1. Would signers outperform non-signers on tasks of face processing, mental imagery, and cognitive flexibility and seriation? This would be an analysis of Group Performances.

2. Does being a native signer (Deaf or Hearing) provide gains in performance compared to those who learned sign as a second language? This would be an analysis of Subgroup Performances.

3. Would participant performance on the front, profile and shadow conditions of the Benton Test of Facial Recognition compare to previous research (Bettger, Emmorey, McCullough, & Bellugi, 1997)?

**Hypotheses**

It was hypothesized for the Color Trails Test, the Benton Test of Facial Recognition, and both the standard and experimental versions of the Knox's Cube Test—Revised that:

a. There would be a significant difference in performance in these tests between Deaf signers and hearing non-signers, with Deaf signers obtaining better scores.

b. Deaf signers would obtain better scores on these tests than hearing signers, although the differences would not be as large as that seen between Deaf signers and hearing non-signers and might not be statistically significant.

c. Hearing signers would achieve better scores on these tests than hearing non-signers, but the difference in scores would not be significant.
d. At the subgroup level, native signers would achieve better scores on the tests than non-native signers, though the difference in scores might not be statistically significant.

e. Results for the Benton Test of Facial Recognition would be comparable to previous research on scores for the front and profile conditions [no differences among groups] and the shadow view [signers would score significantly better than non-signers].
Chapter Three

Methodology

Overview of Participants

Participants in this study consisted of 30 Deaf adult signers, 28 hearing adult signers, and 30 adult non-signers. The 88 participants in this study were divided into three groups: Deaf signers, hearing signers, and hearing non-signers. Two of these groups, Deaf signers and hearing signers, were further divided into subgroups. The Deaf signers consisted of two subgroups: (1) individuals who were born to Deaf signing parents or had Deaf signing siblings (DD) and learned sign language as their first language (n=16), and (2) individuals who were born to hearing parents (DH) and were (a) deaf from birth or became deaf early in life, such as between the ages of one and four, and (b) began to learn sign language between one and six years of age from professionals such as teachers or from other deaf children (n=14).

The second group of participants consisted of hearing people who sign. Hearing signing participants were sub-categorized as those who had (1) Deaf signing parents (HD) and learned sign language as their first language while simultaneously learning spoken English from hearing people (e.g., family, friends, or teachers; (n=13),) and (2) those who had hearing, non-signing parents (HH) and who did not learn sign language until later in life for professional or personal reasons (e.g., employment as teachers of the deaf or as interpreters, or because they interacted with Deaf people on a personal level and needed a means of communication; n=15).
The third group of participants in this study was comprised of those who are hearing and have no sign skills or in-depth knowledge of ASL or Deaf people in general (HNS; n= 30). The HNS group was not sub-divided.

It would have been ideal here to also include a group of deaf people who do not know sign language; it is very difficult to obtain adequate numbers of such individuals in Canada and the United States. For that reason, non-signing deaf people were not included in this study.

Recruitment of Participants

Deaf and hearing signing participants were recruited from Deaf communities in Vancouver, British Columbia; London, Ontario; Bellingham and Seattle, Washington; and Fremont, California. Participants from the signing groups were recruited by email advertisements and by personal communication through the Deaf community by this researcher. Hearing non-signing participants were recruited in Vancouver, British Columbia, through advertisements placed throughout the community. Three hearing research assistants aided the researcher by fielding phone calls from non-signing volunteers and by conducting the testing sessions involving those participants.

The participants' signing skills were determined through an initial screening interview, just as the adequacy of participants' English speaking skills was evaluated through an initial telephone conversation. Exclusionary criteria for this study included the following:

1. Any subject who scored higher than 16 on the Center for Epidemiological Studies Depression (CES-D) scale
2. Any subject who self-reported a history of neurological or psychiatric problems

3. Any subject who showed fine or gross motor impairments (e.g., tremor, paralysis) that would negatively influence scores on the Color Trails Test, which is timed and requires pencil use for completion

4. Any subject whose visual impairment was not corrected to 20/20 with prescription lenses, as the visual spatial tasks require adequate vision to be completed

5. Hearing subjects whose English language skills were recently acquired or were not sufficient for understanding instructions

6. Signing subjects whose ASL skills were newly acquired (less than 5 years) or their signs more closely resemble English than ASL, or their skills were not sufficient for understanding signed instructions

7. Deaf participants whose self-reported hearing loss was not severe enough to warrant an audiological classification of "deaf" (ideally, Deaf participants should have a bilateral loss of 80dB or greater, consistent with previous research)

8. Deaf participants who were not educated in a school for the deaf or signing program or whose educational background was primarily oral (i.e., no sign language used)

9. Participants who were trained to administer the tests used, or tests like the ones used in this study
Description of Participants

Deaf Signers: Subgroup Descriptions

Members of the DD group identified their first language as American Sign Language (ASL), and they were considered to be native signers. Participants in this subgroup had either Deaf signing parents, or Deaf signing siblings, or both. The age of this subgroup ranged from 22 to 71 years (M = 36.6, SD = 12.72). Causes of deafness were primarily hereditary or unknown. All DD participants had some type of post secondary education. Within this group, 31% had a Bachelor's degree, 37% had a Masters-level degree and 25% had taken post secondary courses without obtaining degrees. Seven percent had only a high school diploma.

The DH subgroup identified English as their first language but indicated that they began learning ASL by at least the age of 5 to 6 years of age, usually upon enrollment in schools for the deaf. Members of the DH subgroup were considered to be non-native signers. Here, sign language was learned through exposure to other children, teachers and other employees in the schools. The age of this group ranged from 25 to 61 years (M = 41.4, SD = 12.72). Causes of deafness in this group were listed as unknown, genetic, or resulting from spinal meningitis or maternal rubella. The DH participants had high school diplomas (14%), a few college courses (36%), Bachelor degrees (36%), and Masters-level degrees (14%).

Of the DD and DH participants, 67% were exclusively educated at schools for the Deaf prior to attending college, whereas others had a range of educational
placements, such as mainstreamed with an interpreter (17%), some oral immersion (3%), or a combination of the three (13%).

**Hearing Signers: Subgroup Descriptions**

The HD subgroup identified ASL as being their first language, as they were exposed from birth to sign language by their Deaf signing parents, and, therefore, are considered to be native users of the language. The age of this group ranged from 19 to 47 years (M = 30.7, SD = 8.90). This group of participants had primarily high school diplomas (31%) and some college education (54%), such as certificates or diplomas. Bachelor degrees were held by 15% of the participants in this group.

The HH subgroup of signers did not learn ASL until later in life. The majority of participants in this group were sign language interpreters, working in schools and the community. Others worked in settings requiring interaction with the Deaf, making sign skills essential. The age of this group ranged from 22 to 55 years (M = 38.2, SD = 8.40). The average age that this group began to learn sign language was 19.6 years. This group of participants had some college education (40%) such as certificates or diplomas, Bachelor degrees (47%) and Masters degrees (13%).

**Hearing Non-signers**

The hearing non-signing group (HNS) had neither Deaf relatives nor a working knowledge of ASL. The age range of this group was 21 to 71 years (M = 39.0, SD = 15.00). Among the HNS, 23% had only high school diplomas, 37% had some college experience, 27% had Bachelors degrees, and 13% had Masters degrees.
Measures

The measures used in the present study are described below. They are listed in general order of administration.

Demographic Sheet

A personal demographic sheet was administered that inquired about each subject’s age, gender, level and place of education, occupation, family background, and etiology of deafness, where applicable. This information was used to sort and describe the sample.

Center for Epidemiological Studies Depression Scale (CES-D)

The CES-D (Radloff, 1977) consists of 20 items designed to identify signs of depression in the general population. The CES-D was utilized in this study to rule out depressive symptoms that might influence performance. Six areas of affect are addressed: loss of appetite, sleep disturbance, feelings of helplessness and hopelessness, depressed mood, feelings of guilt or worthlessness, and psychomotor retardation (Shaver & Brennan, 1991). Frequency of these feelings are rated on a 4-point scale, ranging from “0 = rarely or never (less than 1 day)” to “3 = most or all of the time (5-7 days)”. Scores range from 0-60 with higher scores indicating higher levels of depressive symptomatology. Most studies use a cut-off of 16+ (Hubley & Low, 2003). In the present study, Cronbach’s alpha for the entire sample was .67. For the Deaf signers, hearing signers and hearing non-signers, coefficient alphas were .70, .80, and .51, respectively.
**WAIS-III Block Design**

The WAIS-III Block Design subtest (Wechsler, 1997) is a measure of perceptual organization, spatial visualization, and abstract conceptualization. This test requires the person to arrange red, white, and half red/half white blocks so that the pattern seen on the top of the blocks would match patterns presented in a booklet. The Block Design test was included in this study as an estimate of Performance IQ.

**Knox’s Cube Test—Revised (KCT-R)**

The KCT-R (Stone, 2002) is a measure of attention span and short-term memory. The basic materials consist of a horizontal line of four black one-inch cubes attached, two inches apart, to a wood base and a fifth black unattached cube. Using this fifth cube, participants are asked to tap a series of cubes in the same order as modeled by the examiner. This particular version of the test consists of a 26-item cube tapping series arranged in order of difficulty. The tapping series ranges from two to eight taps. For example, if the examiner touches the cubes in the following order: 1-3-2, then the participant does the same: 1-3-2 (see Figure 3.1; actual blocks are not numbered).
Figure 3.1

Knox's Cube Test-Revised, Layout

Participant

| 4 | 3 | 2 | 1 |

Examiner

Items are scored as right or wrong; scores range from 0 to 26. Reliability estimates using KR-20 are high (.99). Very little validity evidence is available for this new version, but previous research with the KCT and other types of tapping tests seem to support inferences that the test is measuring attention span and working memory. The KCT has been used in studies with Deaf individuals dating back to the 1930s (e.g., Amoss, 1936).

In addition to the traditional administration of the KCT-R, a new experimental procedure was used in this study in an attempt to measure attention span and short-term memory under the condition of requiring the participant to complete the task from the examiner's point of view. This task attempted to mimic a skill used by signed language users when they are retelling information provided to them by another person and, therefore, must shift their perspective visuospatially from that of listener to speaker. To do this, the same 26-item cube tapping series arranged in order of difficulty was used. However, if the examiner touched the cubes (starting at the far 'right') in the following order: 1-3-2, then the participant tapped the cubes as though from the examiner's
perspective (i.e., starting from the far 'right') as follows: 4-2-3 (see Figure 1.3).
Practice effects from the standard to experimental versions of the test were not
considered to be an issue given the complexity of this test (Stone, 2002).

Color Trails Test (CTT)
The CTT (Form A) (D'Elia et al., 1996) assesses perceptual tracking,
susceptibility to interference (attention), perceptual sequencing, and impulsivity.
The CTT reduces the language bias of the commonly used Trail Making Test by
eliminating the English alphabet and replacing it with two colors (i.e., pink and
yellow). In the first CTT task (CTT1), the examinee must connect the numbers in
the circles without regard to the color of the circle. In the second CTT task
(CTT2), the examinee must alternate from pink to yellow circles connecting
numbers in sequence from 1-25. The CTT was normed on 1,528 healthy
individuals ages 18-89 years who were free of any neuropsychological
challenges. Test-retest reliability estimates of the CTT1 and CTT2 over 14 days
were .64 and .79, respectively (D'Elia et al., 1996).

Benton Test of Facial Recognition
The Benton Test of Facial Recognition (Benton & Van Allen, 1968) is
designed to assess recognition of unfamiliar faces. The long form version of this
test, developed by Levin, Hamsher, and Benton (1975), was used in the present
study, and consists of 22 items. This version correlated .88 to .93 with the
original version (Levin et al., 1975). In each trial, subjects are presented with a
stimulus face and are asked to locate it among six possible faces presented in
three separate conditions: front view, in profile, or partially in shadow. There are
22 trials, with a total possible score of 54.
Procedure

All testing was done on an individual basis. Initially, a basic screening questionnaire was administered to determine a participant's suitability for the study. Once suitability had been established, a session was scheduled in a location determined by the researcher and subject (e.g., University lab, subject's home). The session started with completion of the informed consent and demographic questionnaire. Following this, the Center for Epidemiological Studies Depression Scale (CES-D) was administered and scored. If the results of the CES-D were above the established cut-off (16), participants with high scores would be told that the CES-D is a screening tool and would be advised that their score was too high to rule out depressive symptoms that might have a negative effect on the memory tasks. These participants would be thanked for their time and offered a list of community agencies to contact if they were concerned that they might be depressed. However, if the results from the CES-D were within acceptable levels, testing continued, using the standardized procedures established for the administration of these tests. Testing began with the WAIS-III Block Design, followed by the KCT-R standard procedure, the CTT, the KCT-R experimental procedure, and finally the Benton Test of Facial Recognition. After testing concluded, participants were asked informally how they felt about both versions of the KCT—R, and were asked what strategies, if any, were used to aid them in completing the task. With the exception of the experimental KCT-R, no other modifications were made to the administration of the tests except that language of administration was ASL for the Deaf participants and spoken English for the hearing people. Care was taken to ensure that the instructions given in
ASL did not invalidate the results or reveal the purpose of, or answers to, the
tests.

**Analyses**

Analyses for each test were relatively straight-forward: participants' tests
scores were calculated according to the criteria for each of the tests. Raw scores
were used for the CES-D and Block Design. Total number of correct answers
were used for the Knox's Cube Test-Revised, standard and experimental
versions, and completion time (in seconds) was used for the Color Trails Test,
Parts 1 and 2. Percentiles were also calculated for the Color Trails Tests but are
not included here because they provided the same information and results as the
completion time statistics. The overall total score on the Benton Test of Facial
Recognition was considered, with further analysis done by calculating each
group's and subgroup's mean percentage correct in each of the three conditions:
front view, profile view and shadow. These latter calculations were done using
the statistical program R 2.3.1 (2006) and Excel (Microsoft, 2000).

Descriptive and statistical analyses on the data were done using the
SPSS statistical program, version 10.0 (SPSS, 2000). Descriptive statistics were
run on each group and subgroup for age, gender and education to determine
means, standard deviations and frequencies for these characteristics. One-way
analysis of variance was utilized for statistical analysis of the group and subgroup
scores, and Tukey's b test was used for post hoc analytic purposes. A
confidence interval of 95% was used in all cases.
Chapter Four

Results

This chapter will present the results of the performance of Deaf and hearing signers and hearing non-signers on visual spatial tasks measuring mental imagery, cognitive flexibility and seriation, and face processing. To review, the purpose of this study was:

1. To determine if signers would outperform non-signers on tasks of face processing, mental imagery, and cognitive flexibility and seriation (Group Performances);

2. To determine if being a native signer (Deaf or Hearing) would provide gains in performance compared to those who learned sign as a second language (Subgroup Performances);

3. To examine participant performance on the front, profile and shadow conditions of the Benton Test of Facial Recognition and compare these results with previous research (Bettger, Emmorey, McCullough, & Bellugi, 1997).

Analysis of screening measures will be presented first, followed by statistical data covering group and subgroup performances and the results of the Benton test.

*Groups and Subgroups: Comparison of Estimates of Depressive Symptomatology and Performance IQ*

As previously mentioned, the CES-D was used to screen participants for depressive symptomatology, and those who scored at or above the cut off were excluded from testing. This provided an important safeguard against possible
negative influence of depression on performance. Fortunately, there were no significant differences on scores between the groups, \( F (2, 84)= .731, p=.484, \) ensuring that whatever differences might exist could not specifically be attributed to depression.

Given that this study examined visual spatial abilities, the Block Design test was used to provide a fair estimate of the visual spatial skills of the groups, and that those skills would be relatively equal. However, the Deaf signers as a whole performed significantly better than the hearing signers and non-signers, \( F (2,85)= 3.93, p=.023, \) suggesting that they might be at a greater advantage than others for completing the tasks. This was not the case, however, and this issue will be discussed further in Chapter 5.

**Group Performances on Tasks**

Statistical results are listed beginning with the most significant differences and are presented in Table 4.1. Scores for each group on the Block Design, the CTT, the KCT—R, standard and experimental versions, the BFT, as well as the and depression scale were calculated according to the guidelines established for each. The mean score differences between groups were calculated using analysis of variance.
Table 4.1
Task Means and Standard Deviations for Deaf signers (DS), Hearing signers (HS) and Hearing non-signers (HNS).

<table>
<thead>
<tr>
<th>Subject Groups</th>
<th>DS</th>
<th>HS</th>
<th>HNS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(M) (SD)</td>
<td>(M) (SD)</td>
<td>(M) (SD)</td>
</tr>
<tr>
<td>BD</td>
<td>52.9</td>
<td>8.61</td>
<td>50.1</td>
</tr>
<tr>
<td>CTT 1</td>
<td>30.4</td>
<td>6.92</td>
<td>28.8</td>
</tr>
<tr>
<td>CTT 2</td>
<td>60.9</td>
<td>14.29</td>
<td>56.9</td>
</tr>
<tr>
<td>KCT-RE</td>
<td>8.6</td>
<td>3.05</td>
<td>10.0</td>
</tr>
<tr>
<td>KCT-RS</td>
<td>13.8</td>
<td>2.51</td>
<td>14.5</td>
</tr>
<tr>
<td>BFT</td>
<td>49.0</td>
<td>3.40</td>
<td>49.0</td>
</tr>
<tr>
<td>CES-D</td>
<td>5.7</td>
<td>4.12</td>
<td>5.6</td>
</tr>
</tbody>
</table>

Note. Task abbreviations: BD=Block Design; CTT 1, 2=Color Trails Test 1 or 2; KCT-R (S/E)=Knox’s Cube Test—Revised, Standard or Experimental version; BFT=Benton Test of Facial Recognition; CES-D= Center for Epidemiological Studies Depression Scale

A one-way analysis of variance conducted on the Block Design total scores from the three groups—Deaf signers (DS), Hearing signers (HS), and Hearing non-signers (HNS)—showed a statistically significant difference, $F$ (2, 85) = 3.93, $p = .023$. Post hoc analyses, using Tukey’s b test, showed that HNS (M=46.0, SD= 12.01) differed statistically significantly from DS (M= 52.9, SD= 8.61), but neither the HNS or DS groups were statistically significantly different than the HS (M= 50.1, SD= 7.23) group.

One-way analysis of variance conducted on the three groups’ raw scores (in seconds) on the Color Trails Test 1 showed a statistically significant
difference, $F(2, 85) = 9.94, p < .001$. Post hoc analyses, using Tukey’s b test, indicated that HNS (M=39.9, SD=14.50) differed statistically significantly from both DS (M=30.4, SD=6.92) and HS (M=28.8, SD=6.60), but the DS and HS did not differ statistically significantly from each other.

One-way analysis of variance conducted on the three groups’ raw scores (in seconds) on the Color Trails Test 2 showed a statistically significant difference, $F(2, 85) = 4.40, p < .015$. Post hoc analysis, using Tukey’s b test, showed that HNS (M=69.9, SD=24.52) differed statistically significantly from HS (M=56.9, SD=8.25), but neither the HNS nor the HS were statistically significantly different than the DS (M=60.9, SD=14.29) group.

One-way analysis of variance conducted for the Experimental version of the Knox’s Cube Test—Revised total scores, showed a trend toward statistically significant difference among the three groups, $F(2, 85) = 3.06, p < .052$. Post hoc analysis, using Tukey’s b test, showed that HS (M=10.0, SD=3.53) differed statistically significantly from HNS (M=8.0, SD=2.80), but neither HS nor HNS were statistically significantly different from the DS (M=8.6, SD=3.05). The differences between the total scores for all three groups are so slight that the results are not conclusive.

One-way analysis of variance tests conducted on scores obtained by the three groups showed no statistically significant difference on the Knox’s Cube Test—Revised, standard version total scores $F(2, 85) = .901, p = .410$, the Benton Test of Facial Recognition Test, total score, $F(2, 85) = .908, p = .407$, or CES-D, $F(2, 84) = .731, p = .484$. 

36
Strategies for Block Tapping

All the groups were asked informally what strategies they were utilizing to assist them with the block-tapping test, as noted in the Procedures section of Chapter 3. A variety of strategies were mentioned, and these will be discussed further in Chapter 5, but it appears from the results that most of the strategies were not necessarily effective, as performance on either version of the KCT-R was not outstanding.

Subgroup Performances on Tasks

In order to detect differences among the subgroups related to age of acquisition of sign language, further analysis was done using subgroup mean scores. Statistical results are listed beginning with the most significant differences; means and standard deviations are presented in Table 4.2.

A one-way analysis of variance conducted on the Color Trails Test 1 raw score (in seconds) showed that there was a statistically significant difference among the four signing sub-groups (DD, DH, HD, HH) and the non-signers, $F(4, 87)= 4.96$, $p< .001$. Post-hoc analysis, using Tukey's b test, indicated that there was a statistically significant difference only between the non-signers ($M = 39.6$, $SD = 14.49$) and the four groups of signers (DD: $M =30.9$, $SD =7.64$; DH: $M =29.9$, $SD =6.23$; HD: $M =29.9$, $SD =7.57$; HH: $M =27.8$, $SD = 5.74$). The subgroups did not differ statistically significantly from each other.

One-way analysis of variance tests conducted on scores obtained by the four signing subgroups and the hearing non-signers showed no statistically significant differences between the subgroups, nor between the subgroups and the non-signers on the Color Trails Test 2, $F(4, 87)= 2.19$, $p= .079$, CES-D, $F(4,
$86)= 1.50, \ p= .211,$ WAIS-III Block Design total scores, $F (4, 87) = 2.22, \ p= .074,$

Knox's Cube Test—Revised, standard version total scores, $F (4, 87)= 1.13, \ p= .350,$ or Experimental version total scores, $F (4, 87)= 1.52, \ p= .203,$ or the

Benton Test of Facial Recognition Test total score, $F (4, 87) = 0.58, \ p= .681.$

Means and standard deviations are presented in table 4.2

Table 4.2

| Task Means and Standard Deviations for Signing Subgroups and Hearing non-signers |
|---------------------------------|----------------|----------------|----------------|----------------|----------------|----------------|
| Subject Subgroups               | DD (M) (SD)    | DH (M) (SD)    | HD (M) (SD)    | HS (M) (SD)    | HNS (M) (SD)   |
| Tasks                           |                |                |                |                |                |
| BD                              | 54.6 (8.09)    | 50.9 (9.06)    | 50.4 (9.37)    | 49.9 (5.05)    | 46.0 (12.01)   |
| CTT 1                           | 30.9 (7.64)    | 29.9 (6.23)    | 29.9 (7.57)    | 27.8 (5.74)    | 39.6 (14.49)   |
| CTT 2                           | 60.3 (15.94)   | 61.6 (12.71)   | 58.1 (8.72)    | 55.8 (7.96)    | 69.9 (24.52)   |
| KCT-RE                          | 8.8 (3.04)     | 8.4 (3.16)     | 9.9 (4.83)     | 10.1 (2.02)    | 8.0 (2.80)     |
| KCT-RS                          | 14.0 (2.66)    | 13.5 (2.41)    | 13.7 (2.87)    | 15.3 (2.49)    | 13.7 (2.78)    |
| BFT                             | 48.6 (4.06)    | 49.4 (2.53)    | 49.0 (2.57)    | 49.0 (2.70)    | 48.1 (3.01)    |
| CES-D                           | 6.8 (4.41)     | 4.4 (3.46)     | 6.6 (4.39)     | 4.6 (4.11)     | 6.7 (3.74)     |

*Note. Subject Abbreviations: DD=Deaf of Deaf Parents; DH=Deaf of Hearing Parents; HD=hearing of Deaf parents; HS=hearing signers [non-signing parents]; HNS=hearing non-signers. Task abbreviations: BD=Block Design; CTT 1, 2=Color Trails Test 1 or 2; KCT-R (S/E)= Knox's Cube Test—Revised, Standard or Experimental version; BFT=Benton Test of Facial Recognition; CES—D= Center for Epidemiological Studies Depression Scale*

The analysis done at the subgroup level indicates that none of the subgroups differ statistically significantly from each other on any of the tasks. Differences arise only at the group level.
Beyond the Total Score: Front, Profile and Shadow Results on the Benton Test of Facial Recognition

The total score for each group on the BFT did not produce any statistically significant differences, $F(2, 85) = .908, p = .407$. To more closely analyze the performance of the participants on facial processing, the BFT was divided into three conditions of recognition for the stimulus faces: front view, profile view and partially in shadow. There were six items of one correct response each for the front view condition. For the profile and shadow conditions there were eight items each, with three correct responses for each item. Group and subgroup mean scores were tallied for each condition: front (6), profile (24), and shadow (24), and these scores were further converted to mean percentage correct. One-way analysis of variance conducted on the mean percentages uncovered no statistically significant differences between the signers and non-signers in the front view condition, $F(4, 83) = .412, p > .7989$; or the profile view, $F(4, 83) = .673, p > .612$; or the shadow view, $F(4, 83) = .268, p > .8978$. At the subgroup level, no significant differences were detected among the signing subgroups in the front view condition, $F(2, 85) = .737, p > .4815$; or the profile view, $F(2, 85) = .963, p > .3856$; or the shadow view, $F(2, 85) = .283, p > .7542$. The mean percentages correct are presented in Tables 4.3 and 4.4.
### Table 4.3

**Benton Test of Facial Recognition: Mean percentage correct for Deaf Signers, Hearing Signers and Hearing non-signers**

<table>
<thead>
<tr>
<th>Conditions</th>
<th>DS</th>
<th>HS</th>
<th>HNS</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>By view</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Front</td>
<td>100.0</td>
<td>99.4</td>
<td>97.7</td>
</tr>
<tr>
<td>Profile</td>
<td>95.1</td>
<td>95.2</td>
<td>93.6</td>
</tr>
<tr>
<td>Shadow</td>
<td>83.6</td>
<td>84.0</td>
<td>82.4</td>
</tr>
</tbody>
</table>

**Note.** Subject Abbreviations: DS=Deaf signers, HS=hearing signers, HNS=hearing non-signers

### Table 4.4

**Benton Test of Facial Recognition: Mean percentage correct for subgroup signers [and non-signers]**

<table>
<thead>
<tr>
<th>Conditions</th>
<th>DD</th>
<th>DH</th>
<th>HD</th>
<th>HS</th>
<th>HNS</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>By view</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Front</td>
<td>100.0</td>
<td>100.0</td>
<td>98.7</td>
<td>100.0</td>
<td>97.8</td>
</tr>
<tr>
<td>Profile</td>
<td>95.1</td>
<td>95.2</td>
<td>96.1</td>
<td>94.4</td>
<td>93.6</td>
</tr>
<tr>
<td>Shadow</td>
<td>82.6</td>
<td>84.8</td>
<td>83.7</td>
<td>84.4</td>
<td>82.4</td>
</tr>
</tbody>
</table>

**Note.** Subject Abbreviations: DD=Deaf of Deaf Parents; DH=Deaf of Hearing Parents; HD=hearing of Deaf parents; HS=hearing signers [non-signing parents]; HNS=hearing non-signers.
Chapter Five

Discussion

Evidence from the literature has supported the idea that sign language experience may enrich visual spatial cognition, and this has been found in both children and adults. The purpose of the present study was to further explore this concept by comparing the performance of Deaf signers, hearing signers and hearing non-signers on several visual spatial tasks. All the participants were adults. Research reported in the literature review tended to focus on one type of test or task per study, whereas the present study examined multiple tasks. The tasks administered included block tapping (Knox's Cube Test—Revised), trail making (Color Trails Test, Form A), and identifying a target face among stimulus faces (Benton Test of Facial Recognition). These tasks reflected the skills found in the literature to be enhanced by sign language experience: mental imagery, cognitive flexibility and seriation, and face processing.

For the present study, the hypotheses favoring signers, especially Deaf signers, were established based on evidence from the literature. The final results were somewhat surprising and here the effects of sign language experience are not as clear as they appear in other studies.

Similarity of Groups on Block Design and Depressive Symptomatology

WAIS-III Block Design

As mentioned in Chapter 4, the WAIS-III Block Design was included in the present study as an estimate of Performance IQ, a means of determining if participants were of the same basic ability to manipulate objects to copy a visual design. It was not intended to be a part of the exploration of sign language
experience and visual spatial skills, and significant differences between the groups were not wanted nor expected. Ideally, there would have been no significant differences among the groups on the Block Design task in order to assume participants all had relatively equal skill in terms of visual organization and visual-motor coordination. The expertise shown by the Deaf group on this task leads one to expect that they would also show greater skill on subsequent tasks, but this was not the case. Given that the Deaf signers as a group were performing statistically significantly better than the non-signers—although not the hearing signers—the BD task may be tapping a visual spatial skill that Deaf signers have a stronger grasp of, such as mental manipulation. The skills measured by the Block Design test may not be as strongly connected to the other tasks that comprised the study. As it is, the term “Performance IQ” may be too broad to be used here.

Although at this point there is no way to know, it is possible that the Deaf participants in general were utilizing a different and more effective strategy to complete the task than the other participants. Regardless, given that the hearing signers also showed better results—albeit not statistically significant—on the Block Design than the non-signers, there is no evidence that sign language experience was not an influencing factor here. Deafness is not a logical contributing factor to these results either. What factors may have influenced the Deaf signers’ performance on the Block Design? At the beginning of the Block Design test session, this researcher asked all the signing participants—Deaf and hearing—if they had previously seen the test. Most of the Deaf participants recalled seeing something similar early in their school years, of having been
tested with blocks, probably some version of the Weschler Intelligence Scale for Children (WISC). However, hearing signing subjects were also not unfamiliar with the blocks, as many of these participants were interpreters who had been present in a professional capacity at psycho-educational test sessions and had seen the test administered [either a WISC or WAIS Block design]. Did this prior knowledge have an effect on performance? If so, both signing groups, not just one, should have performed significantly better than the non-signers. Still, previous experience may have given the signers an edge over the non-signers.

**CES-D**

There is no evidence that other studies exploring the connection between sign language and visuospatial cognition used a depression screener. Given that the CES-D covers a wide range of depressive symptomatology that might negatively influence performance, and the fact that no significant differences existed among the participants in the present study, we can rule out depression in our analysis and discussion of results.

**Comparison of Age Range and Education Levels**

Of the demographic characteristics of the sample, age and education may have had some influence on the results. A demographic overview appears in Table 5.1.
Table 5.1

Age Range in Years and Education Levels (%) Across Participants

<table>
<thead>
<tr>
<th>Subjects</th>
<th>DD</th>
<th>DH</th>
<th>HD</th>
<th>HH</th>
<th>HNS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age Range</td>
<td>22-71</td>
<td>25-61</td>
<td>19-47</td>
<td>22-55</td>
<td>21-71</td>
</tr>
<tr>
<td>Mean</td>
<td>36.6</td>
<td>41.1</td>
<td>30.7</td>
<td>38.2</td>
<td>39.0</td>
</tr>
<tr>
<td>Standard Deviation</td>
<td>12.72</td>
<td>12.72</td>
<td>8.90</td>
<td>8.40</td>
<td>15.00</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Education</th>
<th>HS Diploma Only</th>
<th>Some College</th>
<th>Bachelors degree</th>
<th>Masters degree</th>
</tr>
</thead>
<tbody>
<tr>
<td>DD</td>
<td>7%</td>
<td>25%</td>
<td>31%</td>
<td>37%</td>
</tr>
<tr>
<td>DH</td>
<td>14%</td>
<td>36%</td>
<td>15%</td>
<td>14%</td>
</tr>
<tr>
<td>HD</td>
<td>31%</td>
<td>54%</td>
<td>47%</td>
<td>--</td>
</tr>
<tr>
<td>HH</td>
<td>--</td>
<td>40%</td>
<td>13%</td>
<td>--</td>
</tr>
<tr>
<td>HNS</td>
<td>23%</td>
<td>37%</td>
<td>27%</td>
<td>13%</td>
</tr>
</tbody>
</table>

Note. Subject Abbreviations: DD=Deaf of Deaf Parents; DH=Deaf of Hearing Parents; HD=hearing of Deaf parents; HS=hearing signers [non-signing parents]; HNS=hearing non-signers.

The youngest participant was 19 and the oldest was 71. Although every effort was made to match participants on the age variable, the oldest hearing signer was only 55. The HNS group and the DD subgroup had the closest match in terms of age range. In terms of the results, the hearing signing group may have had an advantage over the Deaf signers and the hearing non-signers because no participant was older than 55. Older participants may have had decreased abilities in terms of memory, which would have influenced recall of block tapping in the KCT-R, and may also have had trouble with visual-motor tracking ability on the CTT, causing them to perform less swiftly. The hearing signers, overall a younger group, likely did not have these difficulties. Of the
demographic characteristics, age is possibly the most significant variable in interpreting the results. Had the research excluded older participants, those over 45, for example, the results may have been much different.

However, one of the most important points of this study concerns the age of sign language acquisition. No differences emerged between the subgroups of Deaf signers, who were separated by their native or non-native status as signers. Early language learning is an important stepping-stone to future success, but it would appear that in terms of visual spatial cognitive development, a delay of a few years does not greatly affect Deaf people's performance on visual spatial tasks. Whatever gaps were evident in studies with children, those gaps are closed as both native and non-native signers grow and become proficient in sign communication.

In terms of education, level of education may or may not be a contributing factor to the results, but area of education appears to be. In the area of college experience, the majority of hearing signers were enrolled in professional interpreting courses which would enable them to find employment in the field of interpreting. In fact, of the 28 participants in this group, 14 were interpreters, and of the interpreters, all but 3 were second-language learners. None of the other groups engaged in intensive sign language studies at a college or university level. In light of the overall results, where hearing signers were out-performing the Deaf signers and the hearing non-signers, it is important to consider the idea that perhaps focused study of sign language made the most difference. Just knowing and using the language might not be enough. An analogy to this would be the rules of the English language... most speakers of the language know the
basic rules but might not be able to explain the reasons behind those rules, nor would they be consciously thinking about them when speaking. For signers who have grown up using the language, sign conversation is automatic; they may not be as familiar with the rules governing their language, whereas interpreters—the majority being second-language learners—are constantly evaluating and questioning how sign language is used, what meaning is being conveyed, and how signs must be accurately translated into spoken English and vice versa. These are complex skills constantly utilized by the interpreting profession, and should not be overlooked when considering the results of this study.

**Signs of Enhancement?**

*KCT-R: Standard and Experimental versions*

Even though age and education may have played a role in the performance outcomes in this study, it does also appear to some extent that sign language may enhance performance. To begin with, the Knox's Cube Tests, Standard and the Experimental versions, were considered to be key tests in the examination of sign language experience effects on nonlinguistic tasks. In the case of the KCT-R standard administration, in both the group and subgroup conditions, no significant differences were found, suggesting that there are no grammatical, syntactic or other features of ASL that would transfer to enhance performance on this task. In terms of the KCT-E, however, although no statistically significant differences were found among the *subgroups*, there were differences among the *groups* that approached significance. Perhaps the larger sample size that came from combining the subgroups helped to show this. It had been hypothesized that Deaf signers would perform better than hearing signers...
and significantly better than non-signers, but this was not found. Rather, it was the hearing signers who were demonstrating a better grasp of this task than non-signers. Hearing signers were also doing better on this task than the Deaf, although not significantly so. All the participants were asked what strategies, if any, were used to help them to recall the sequence of taps on the blocks and reverse them. Answers were varied. The Deaf made mention of memorizing visual patterns, watching the rhythm of the taps and counting sequences, and hearing signers and non-signers alike mentioned listening to the taps and/or counting. A few could not describe their strategies at all. Overall, these strategies did not seem to be effective and did not stand out as being a factor to consider in performance for any group or subgroup, and other possibilities need to be explored.

One possible explanation for the fact that hearing signers did better in general on the KCT-R experimental test than the Deaf and the non-signers may be that most of the signers work as interpreters, and since their livelihood depends on quick recall and replay of what has been said [or done], their skills for this receive more frequent practice. In this case, only indirectly could sign language be considered an influencing factor. In exploring this, we must also consider why the non-signers were not performing at the same level as the signers. One possibility lies in the administration of the KCT-R; all signers were tested by this researcher, who had plenty of time to develop fluency and consistency in the tapping sequences, while the non-signers were tested by three research assistants who had considerably less time to practice and hone their skills prior to administering the test. As well, three research assistants create
more variability than just one researcher. This was an unfortunate but unavoidable aspect of the present study.

The memory demands of the KCT-R, most especially in the experimental version, may have had an influence on results for the older participants, and should be considered when examining the results. The KCT-R, standard administration, requires the examinee to memorize and tap out progressively larger sequences, concluding with one 8-tap sequence. It is moderately difficult, and no differences between any of the groups and subgroups were found. On the other hand, the experimental version required the examinee to mentally rotate the taps and respond as if from the examiner's perspective. This directive added considerably to the memory load for this task. The older participants in the Deaf group and the non-signing group may have found this more challenging and were less able to recall and rotate as sequences grew larger.

Color Trails Test

Group and subgroup performance on the CTT 1 and 2 produced interesting results. There are several reasons why the CTT 1 and 2 were used in this study: first, it offered a reliable and readily available alternative to the popular Trail Making Test (TMT), which is often used with both Deaf and hearing adults and children; second, the CTT has so far not been used in previous sign language studies; third, the CTT controls for literacy and numeracy aspects that are present in the TMT; fourth, it provided an opportunity to specifically test Deaf adults, rather than children, as done by Courtin (2000). Using a modified, child-appealing version of the Trail Making Test, Courtin's (2000) study did not strictly adhere to the administration guidelines of the standard TMT: in Part B of the test,
he used the number of errors made by the children as the basis for analysis, feeling that "the main goal of the research was to measure the children's cognitive flexibility irrespective of their seriation abilities" (p. 24). In the present study, the administration guidelines for the CTT 1 and 2 were followed, and results were based on completion time, not number of errors (which were few). In terms of the performances of the subgroups on the CTT 1, which addresses sustained visual attention, perceptual tracking and simple sequencing, all the signers—Deaf and hearing—performed statistically significantly better than the non-signers. These results are consistent with what is required for receptive understanding of sign communication. As well, Courtin (2000) had similar results, although he did not have hearing signers in his study. It would appear that signers do better on the CTT 1 than non-signers, and whether the signers are Deaf or hearing, or when they learned sign language, makes no difference.

Part 2 of the CTT addresses more complex visual motor scanning and cognitive flexibility in alternating between colors while sequencing numbers. The results of the CTT 2 tell a slightly different story than the CTT 1. Here, the hearing signers as a group did statistically significantly better than the non-signers. There was a difference between signing groups, although it was not significant. If sign language experience was truly influencing performance, we could expect both signing groups to have significantly different scores than the non-signers. The higher score on the Block Design exhibited by the Deaf signers raises the question of why they did not perform as well as or better than the hearing signers. One possibility for the results, as previously mentioned, is that the mean age ranges for the Deaf signers and the non-signers were very similar,
with a larger number of older participants who may have performed less swiftly on the task. Other than that, there seems to be no other explanation for the results.

Of the tests used in this study, the CTT has shown to be a good measure for highlighting differences among the different groups in this study. Sign language does appear to enhance performance on Part 1 of the test, while age might be more of an influencing factor on Part 2. It would also appear that there are positive effects from learning sign language, even in later life, which supports the findings of Talbot and Haude (1993). No significant differences in visual spatial abilities were found between hearing native and non-native signers on the tasks, and as a combined group they tended to perform statistically significantly better than non-signers.

**Face Processing: Truly influenced by Sign Language?**

The Benton Test of Facial Recognition has been studied by other researchers (i.e., studies with adults: Bettger, Emmorey, McCullough, & Bellugi, 1997; studies with children: Bellugi, O'Grady, Lillo-Martin, O'Grady Hynes, van Hoek, & Corina, 1990) who have found that signers are more proficient on some aspects of face processing due to the grammatical markers of sign language that tend to appear on the face. The BFT was included in this study to see if results found by others could be replicated, specifically the results found by Bettger and his colleagues (1997). It is important to note that this was not an exact replication, due to differences in sample population and size. Bettger and his colleagues reported data from experiments using different sets of subjects. One study used hearing non-signers (n=16) and DD signers (n=16), and then used a
new set of participants in another study broadening the range of classification: DD (n=8), DH (n=8), HD (n=8), HH (n=8). The DH group, unlike the present study, consisted of late learners of ASL.

The present study found no significant differences in the face and profile test conditions, consistent with the results of Bettger and his colleagues. However, in the shadow condition no significant differences were found between the groups or subgroups, which was not expected and which contradicts the findings of Bettger et al. Overall, at both the group and the subgroup level, scores were similar across conditions, differing only by a percentage or two.

It is not readily apparent why the results of this study were not consistent with previous research. However, all subject backgrounds and experiences cannot fully be accounted for, nor can we assume that there was consistency across administrations of the test. There was no time limit for this test, and it may be that all the subjects made use of that, studied their choices carefully and made more accurate decisions than had subjects in other studies.

Limitations of this Study

Ideally, the subgroup sample size should have been much larger than 15 people. A larger sample size would likely have improved the chances of identifying significant differences. However, given that the sample population was so unique, it was difficult to recruit more subjects who met the criteria set forth.

Age may or may not be considered a limitation in this study. It may have been better to have excluded older adults, such as those over 55, or to separate subjects in to age categories and compared their performance. However, the
sample was not large enough to do that, and, therefore, we cannot say for sure if age has negatively influenced the results here.

All the participants in this study could be considered well educated. Education itself did not seem to adversely influence the results, but had the sample included those who were less educated, more differences may have been noted. It also appears that those who have undertaken intense training in sign language for professional reasons were at a greater advantage in this study.

This study would have benefited from the inclusion of a subgroup of Deaf subjects who were late learners of sign language, such as at the post secondary level. This would have provided a greater range of comparison on the age of language acquisition issue.

The testing of the non-signers may have produced different results if there had been just one researcher or just one research assistant doing the testing.

**Strengths of this Study**

The size of this sample (88) was much larger than many other sample populations used in this kind of research, which strengthens statistical analysis. Participants came from diverse geographical areas of Canada and United States and, therefore, it could not be said, for example, that the results may only apply to signers and non-signers from the British Columbia area. Further, the tests used in this study are standardized and readily available, so anyone interested in trying to replicate the results could easily undertake the task. Finally, while this study broke new ground by incorporating tests not previously used, older research was revisited. Key results of past research were not replicated here and this raises questions about the robustness of past findings.
Future Research

The results from the Knox's Cube Test-Revised, experimental version, were interesting but did not achieve the significance between signers and non-signers as expected. However, the mental imagery requirements for this task were challenging for signers and non-signers alike, and future research might produce more significant results and further insights into how this skill is connected to sign language fluency.

As previously noted, the subjects in this study were well educated. Future research may want to broaden the range of education levels to include those less educated.

In the future, it may also be important to compare performance on the tasks in terms of age-ranges. The age span in the present study may have balanced out what strengths and weaknesses existed in each group, hiding the effects of sign language enhancement that might otherwise have been apparent.

The high score on the Block Design demonstrated by the Deaf subjects in this study may warrant a closer look. Perhaps future studies may want to attempt replication of these results by Deaf subjects on the Block Design subtest of the WAIS-III.

Implications for School Psychology Practice

School psychologists who work with adult learners may find some of the information presented in this study useful. For example, they may want to use caution when interpreting the block design scores of Deaf clients, especially if using norms from the hearing population. Those who administer aptitude tests and encounter someone interested in becoming a sign language interpreter
might utilize the CTT and consider speed, errors and near misses in terms of visual tracking and how important it is for sign language reception and comprehension. Tasks with a heavy memory component, such as the KCT-R, would be helpful, as retaining and repeating chunks of information that can and do become increasingly more complex is a necessary skill for interpreters.

While this study has very little to do with the everyday practice of school psychology, some may find the unique application of these tests interesting and/or may find a need to administer them when working with signers or the Deaf population. At the very least, this study may serve to remind psychologists that regardless of the tests being used, unique characteristics in examinees such as Deafness, use of a visual spatial language, or having had Deaf signing parents may change how the examinees approach a task, and, therefore, interpretation of test results should take this into account.
References


R Development Core Team (2006). R 2.3.1—A Language and Environment [Computer software].


Appendix
Research Ethics Board Certificate of Approval