Does Age of Language Acquisition Affect the Relation Between American Sign Language and Mental Rotation?

A DISSERTATION
SUBMITTED TO THE FACULTY OF THE GRADUATE SCHOOL
OF THE UNIVERSITY OF MINNESOTA
BY

Amber J. Martin

IN PARTIAL FULFILLMENT OF THE REQUIREMENTS
FOR THE DEGREE OF
DOCTOR OF PHILOSOPHY

Maria D. Sera, Ph.D., Adviser

October 2009
Acknowledgements

This dissertation would not have been possible without the support of my adviser Maria Sera. I am grateful for the opportunity to have worked with her over my graduate school years, and for the patience she has doled out even when it was not deserved! She introduced me to the ideas that shaped the way I think about language-thought relations. Her guidance throughout my graduate school career has given me the tools and confidence I need to keep going. Thank you!

Thanks to Herb Pick whose sound research advice, thoughtful encouragement and winter camping trips kept me directed and motivated during graduate school.

I also want to expressly thank my parents for nurturing the scientific curiosity in me and for their confidence in my ability to achieve. I’d like to thank my husband Paul for many things including keeping me grounded in the scientific principles that govern both of our work despite being vastly different disciplines. Also, thank you for being abundantly supportive during the process of writing my dissertation and helping me to maintain an appearance of sanity. I look forward to many more years of sharing ideas and friendship and love. Thanks to my roommate Rania who was an essential and constant source of social support and valued friendship throughout my entire graduate school career, not to mention a great post-prelims travel companion! Thanks to Micah whose first four-and-a-half years of development were more fun than I could record. You have a truly special place in my heart. I also thank the other Deaf Ph.D. pioneers here at the U of M for their specialized support services.

Lastly I want to thank the people whose assistance made this possible: committee members Michael Maratsos and Apostolos Georgopoulos for their time and comments on the dissertation; the interpreters, especially Jules Lehto and Evonne Bilotta-Burke for being there throughout; Jim Williams who wrote the program that ran the mental rotation task and made the response button box; and the undergraduate research assistants who made the data collection for hearing participants possible- Kelly Batt, Rose Yep and Katy Swogger.
Dedication

This dissertation is dedicated to my parents Dennis and Vicki Martin and grandma Lois Beck (a.k.a the “gramma cop”). You have each been an instrumental part of my achievements by fostering my curiosity and my thinking about the lives of deaf children.
Abstract

Past research has shown a relation between knowledge of American Sign Language (ASL) and mental rotation. The goal of the current study was to examine factors related to American Sign Language use that contribute to mental rotation skills. In particular, the factors examined were age of acquisition of ASL, hearing status, gender, spatial language comprehension, spatial language production and amount of use of ASL. Many studies have examined the role of language on cognition, but few have examined which aspects of language knowledge (comprehension or production) contribute to those effects. Further, this study examines the role of age of acquisition of ASL on mental rotation. Participants were adults who had learned ASL at different ages across development. Participants completed a spatial language production task, spatial language comprehension task and a computerized-nonlinguistic mental rotation task that recorded participants’ accuracy and reaction times.

Results showed that native male signers were significantly faster on mental rotation compared to other groups based on the slope of change across degrees of rotation. Further, male native signers were also slightly more likely to interpret spatial relations in the comprehension task by rotating the signer’s description. There were no overall differences between the age of acquisition groups in mental rotation. Men and women did not differ overall in mental rotation nor did hearing and Deaf participants.

These results indicate that age of acquisition of ASL after infancy does not affect mental rotation. Implications are discussed for age of acquisition effects on language-cognition relations, for the effects of practice on male native signers’ speed of mental rotation, and implications for findings on the language tasks. Further research should
examine the effects of age of acquisition of a first language on general speed of processing.
# Table of Contents

List of Tables  
List of Figures  
Introduction  
Language and Cognition: Theories and Approaches  
Language Does Not Affect How We Think  
Language Affects Cognitive Content and Processes  
Language Refines Existing Universal Concepts  
Language Makes Some Thoughts More Accessible  
Language Experience Enhances Cognitive Processing  
Normal Language Acquisition is Necessary for Specific Cognitive Processes to Emerge  
Age of Acquisition Effects in Language Development  
Age of Acquisition Effects on Phonetic Processing  
Age of Acquisition Effects on Semantic Processing  
Age of Acquisition Effects on Neural Organization  
Age of Acquisition Effects on Second Language Learning  
Use of Space in American Sign Language  
Mental Rotation in Children and Adults  
Development of Spatial Language by English Speakers and ASL Signers  
ASL Use and Spatial Cognition  
Justification for the Current Study  
Methods
List of Tables

Table 1: Number of participants in each language group, hearing status and gender --- 57
Table 2: Slope Values for Men and Women in Each Group -------------------------------67
Table 3: Percentage of correct responses on language task not involving rotation -------68
Table 4: Percent of rotated responses on language task items involving rotation -------68
List of Figures

Figure 1: Reaction Time on “Same” and “Different” Trials as a Function of Degree of Rotation.----------------------------------------------------87

Figure 2: Untransformed Reaction Times for Across All Degrees of Rotation in Each Age of Acquisition Group.-------------------------------88
Introduction

Theories and Perspectives in Research on Language and Cognition

"Human beings do not live in the objective world alone, nor alone in the world of social activity as ordinarily understood, but are very much at the mercy of the particular language which has become the medium of expression in their society... The fact of the matter is that the "real world" is to a large extent unconsciously built up on the language habits of a particular group."

-Edward Sapir

"People do not think in English or Chinese or Apache; they think in a language of thought. This language of thought probably looks a bit like all these languages; presumably it has symbols for concepts and arrangements of symbols that correspond to who did what to whom... To get these languages of thought to subserve reasoning properly, they would have to look more like each other than either one does to its spoken counterpart, and it is likely that they are the same: a universal mentalese."

-Steven Pinker

The two quotes above represent two opposing viewpoints in the field of language-thought relations. These two views lie at opposite ends of a spectrum of beliefs about how language and thought interact. However, there are many other viewpoints that can be considered to lie somewhere between these two. As it stands now, the field of language and cognition has little in the way of a coherent framework for understanding the relations that exist between language and cognition. The research covers a wide array of topics and perspectives, and addresses multiple aspects of the questions, but disagreement still exists in how best to interpret findings. What the field needs is a better understanding of underlying mechanisms involved in language-cognition relations to help clarify the
nature of the effects that are seen. Additionally, a better understanding of underlying mechanisms would bring clarity to our definitions about what researchers mean by “effects” of language on cognition in the first place. Understanding these mechanisms is a needed step in bringing a more coherent framework within which to view language-cognition relations.

The current study’s focus is on factors associated with learning ASL spatial language and their association with mental rotation. In particular, I will examine the differential roles of: (1) age of acquisition; (2) spatial language production; (3) spatial language comprehension; (4) hearing status; (5) gender; (6) amount of current use of ASL; (7) length of time using ASL.

In this thesis, I will first provide an overview of the various perspectives in the field including those proposing no, or very few relations between language and thought, to those proposing broad and general effects of language on thought. Then, I will discuss the literature looking at age-of-acquisition effects in language acquisition as an important potential component of understanding effects in language-thought relations. Age of acquisition of language may be important to understanding mechanisms behind language and thought relations. If language-thought relations differ depending on the age of the learner it may indicate that mechanisms of language effects change over time depending on the cognitive maturational state of the learner. If age of acquisition of a language does not affect the patterns of language-thought relations, we may assume that the effects are constant and that language exerts a single influence regardless of the cognitive state of the learner.
I will then review the use of spatial language in American Sign Language. Spatial language use in ASL differs in important ways from spatial language use in English. The predominant difference is that in ASL mental rotation is much more frequently involved in ASL. I will discuss how ASL uses space to talk about space, and I will discuss the roles of the signer (i.e. the “speaker” in ASL) and the “addressee” (i.e. the “listener in ASL).

Finally, I will describe the study conducted for this dissertation. In the current study, ASL signers were tested in a mental rotation task and several language measures. Studying individuals who have learned ASL offers the unique advantage of comparing native and late first language learners. A very small percentage of deaf ASL signers are native users. Estimates say that about 5% of Deaf children are born to Deaf parents who can sign. For the remaining 95% of deaf children, age of first language acquisition varies considerably. Deaf children’s first language acquisition may begin any time from within the first year of life to adolescence and sometimes later depending on when interventions are begun. Also, because most children born to Deaf parents are hearing, studying this group offers the opportunity to study individuals who learned two languages simultaneously in two modalities (signed and spoken). Lastly, I describe the results and implications for better understanding language-thought relations.

**LANGUAGE AND COGNITION: THEORIES AND APPROACHES**

Over the last 100 years, answers to the questions of the relations between language and thought have emerged with different perspectives. Whorf (1956), for
example, posited that language could influence thought (called the Whorfian Hypothesis) and provided support for this idea in his analysis of Hopi and English languages (1956). In the Whorfian perspective, language has a large amount of influence on implicit thought and a speaker is unlikely to be aware of this influence. The influence of language varies from language to language, depending on the particular grammatical and semantic elements of each. The idea has been attractive in a variety of fields even outside of psychology. Researchers from diverse fields have been attracted to the idea of language effects on thought. Feminist scholars and anthropologists alike find the idea consistent with theories of their own (e.g. Spender (1985), and Barham (2002)). Feminists have argued for changing terminology that attaches maleness to English words referring to occupations like fireman, congressman, and the like not only because of the connotation that those occupations are reserved for men, but because repeated exposure to these terms may lead people to also hold such beliefs (Spender, 1985). However, the empirical evidence provided by Whorf himself was weak, at best, and scientific support for the concept was lacking.

During the 1960s, modularity of mind, and particularly of the language faculty became the predominant approach to the study and theory of cognitive functions. The cognitive faculties were thought to be independent of the language faculty and thus any one faculty had minimal effects on the function or development of another. In particular, modularity theory proposed that the development of grammar and syntax were not affected by extra-linguistic cognitive faculties. Several lines of evidence provided support for this position. First, children learn language seemingly effortlessly even though other
cognitive domains are underdeveloped (Chomsky, 1999). Second, children learn language without direct instruction; they do not need to be taught their language explicitly (Pinker, 1996). Third, even children with severe cognitive deficits such as William’s syndrome seem to acquire language despite very low general cognitive functioning (Bellugi, 1997).

Modularists differ in the degree of modularity they propose with some who argue for very closed systems, and others who argue for modularity particularly at input levels (Fodor, 1983). But, the consensus is that there are mechanisms in the human mind that are devoted specifically to language learning. Although modularists contend that extra-linguistic processes do not exert much effect on language learning, they do allow that language must at least interface with extra-linguistic cognitive processes (Hauser & Chomsky, 2002).

The extent of this interface and the ways that language and cognition might interact is the subject of much debate, however. Since the early 1970s there have been a number of studies that examine these potential relations. Some studies claim to show there are no effects, while others posit that there are clear effects of language on cognition. One of the difficulties in the field is that there is little consensus about the mechanisms that would underlie either observed effects of language on cognition, or non-effects. Overarching this difficulty is a lack of consensus as to what should be considered an effect and what an effect should entail. Can language influence content or organization of knowledge? Are language effects limited to cognitive processes? Must a language effect entail changes in development (i.e. a certain pattern observed is different before
and after language learning, or between speakers of different languages)? Can we be certain that effects are not better explained as simple practice effects, rather than specifically attributable to language? Without some understanding of the mechanisms that may be involved, it is difficult to interpret many of the findings. Below I provide a brief summary of the main arguments across the field and discuss the potential mechanisms that could be proposed for each of the arguments.

**Language Does Not Affect How We Think**

In classic studies of language-thought relations, researchers looked at the ways that languages varied in their naming of categories across the color space and how speakers of these languages perceived or recalled color categories. Heider (1972) studied a group of people in New Guinea called the Dani whose language lacked color terms beyond “light” and “dark.” She found that despite having no terms for focal colors such as “red”, “yellow” or “blue” the Dani people recalled these focal colors better than non-focal colors such as “reddish brown.” In a subsequent study, Rosch (1973), found that teaching categories of colors that were centered on the focal colors took fewer trials for Dani speakers to learn than terms for contrived categories centered on non-focal colors. She argued that taken together, these studies suggested that color learning was not influenced by color names used in one’s particular language, but entirely driven by an innate perceptual processing of specific color categories. These color categories have been proposed by Berlin and Kay (1969) to develop in a language along a specific set of stages whereby primitive languages contain only terms for *black* and *white*, then later
adding *red*, then *yellow* or *green*, then *blue*, then *brown* and finally *pink*, *purple* and *orange*. They proposed that the order and organization of these stages are universal across languages and indicate that these color names do not influence the color categories as they are perceived by the speakers. More recently, Pinker (1996) has made the same argument. He argued that the way humans think can affect how we develop languages we use to represent these thoughts. He pointed out that while there appears to be an infinite variation among language structures, in reality languages do not vary indefinitely. Languages that end up with only a few color terms, for example, show similar patterns in how those color terms divide up the world. A language with two terms will divide colors into *light* and *dark*, as the Dani language does. A language with three terms will be constrained to *light*, *dark* and *red*. A color with four terms will contain an additional term for either *yellow* or *green*. The human mind contains a set of constraints in structure and processes of cognition (a language of thought) and these constraints impose constraints on language in turn.

Other researchers also argue that there is no direct evidence for cognitive changes outside of those needed for language itself. For example, Munnich and Landau (2003) argue that there is only an effect of language on linguistic processing and only in this domain is there evidence for effects of a learning particular language. The most notable area, she argues where “thought” (i.e. speech processing) is affected by exposure to language is in phonemic processing of sounds. Before 10 months of age, infants are able to discriminate between most contrasts in phonemes. By 10 to 12 months, however, infants lose the ability to discriminate between sounds that do not carry a difference in
meaning in their native language (e.g. Werker, 1995). This appears to indicate a restructuring or reorganization of perception of phonemic contrasts. Other studies showed that adults, however, are able to discriminate between contrasts in these phonemes under some conditions, namely when they heard the two phonemes in a non-linguistic context in rapid succession (Werker and Logan, 1985). When adults are told that the sounds they are listening to are sounds of a language, they fail to hear the difference between the sounds. However, when they are told that the sounds are in a domain other than language, adults can detect the small differences between the sounds. Munnich and Landau suggest that when adults hear sounds in a linguistic context, sounds are processed in a linguistic mode, whereas if sounds are presented in a non-linguistic context (as in the rapid succession condition), adults can make the distinctions between phonemes because they are not processing the sounds linguistically. Thus, Munnich and Landau argue that while there are some instances in which language can affect “thought” (in this case, speech processing), these are limited to linguistic domains and only in linguistic contexts. The same stimuli presented in a nonlinguistic context will not show the same reorganization. In this conceptualization, no real effects of language on cognition occur, but different contexts may result in different observed effects merely because a linguistic context may trigger certain processes, although the underlying representations are not changed.

Munnich, Landau and Dosher (2001), examined whether differences in lexical categories between languages influence memory for items in those categories. They explored whether the lexical differences between English and Korean in representing spatial relations can lead to differences in speakers' memory for objects' location. In
English, the terms *above* and *on* are used differently to describe contact support of one object with another (*on*) or noncontact between two objects (*above*). In Korean, however, these two possible distinctions are collapsed into one term that does not distinguish between contact and non-contact relations. Munnich et al. hypothesized that after participants verbally described the location of a ball and table (e.g. "The ball is on the table," or "the ball is above the table.") English speaking adults, in contrast to Korean speakers, should recall with greater accuracy whether the ball made contact with the table or not. In fact, the researchers found no difference between the accuracy of recall between English and Korean speakers. They conclude that in the domain of spatial cognition, differences between languages' encoding of spatial properties did not evoke differences in speakers' representation of space.

**Language Affects Cognitive Content and Processes**

Another stance holds that differences across languages cause differences in thinking. In this section, I examine some of the important work showing support for this hypothesis.

In response to the interpretations of Rosch-Heider’s findings that color perception and color naming are universal, Roberson, Davidoff, Davies and Shapiro (2004) examined the development of naming and comprehension of color terms and memory for colors in young children of two cultures each with different color categories. English has eleven basic color terms while Himba, a language spoken by a seminomadic tribe in Namibia, has only five color terms. The Himba color terms, moreover, do not correspond
well to the set that is proposed for languages containing five color terms (Berlin & Kay, 1969) which should be light, dark, red, green and yellow. For example, one category called zoozu encompasses purple, dark blue, dark green and brown.

Roberson argues that if there is indeed a basic universal color set, as Rosch claimed of natural categories, then examining the development of color terms and memory for colors should show predictable results. Before learning labels in their respective languages, all children should show not only similar memory performance, but also should show mistakes consistent with categorical perception along the English-named categories. For instance, children should more often mistake dark blue and lighter blue for each other (i.e. make mistakes within a color category) than mistake dark blue for black (i.e. make mistakes across color categories). If there is no universal set of colors, then young children should show mistakes in which they confuse two colors of equal perceptual distance along the color spectrum regardless of their positions within or across the English color category boundaries. Once children begin to learn color terms in their language, their error patterns should change so that children make mistakes more often within the color category boundaries of their own languages.

The researchers tested children's knowledge of color terms in both comprehension and production tasks. Children who passed both the comprehension and production tasks for a particular color in their language were considered to have knowledge of that color. In the production task, children were shown a set of colored tiles and asked to verbally identify the color names. In the comprehension task, children were shown the same tiles and asked to "show me the red (or serandu) tile." For the memory test, the experimenter
showed the child one tile and told the child to remember its color before the tile was removed. Then child saw a tray of the full set of colors and was told to choose which of the colors she just saw.

Their results showed that before children knew color terms in their respective languages, both English speaking and Himba speaking children tended to make similar mistakes on the color memory task. Children made mistakes of perceptual distance both within and across color boundaries. Children did not recall within category colors better than between categories for either language. This indicates that there is not a universal set of color categories that corresponds to English color terms. The researchers examined children's performance on four color groups in more detail: colors focal in English only, colors focal in Himba only, colors focal in both languages, and colors not focal in either language. For children who did not know any color terms, there was no memory advantage of any color that was focal in either language or for colors that were focal in both languages. However, there was a disadvantage for colors that were not focal in either language.

The researchers followed these same children as they learned the color terms in their language. Children's memory for focal colors in their own language became more accurate as they learned the words in their language. Moreover, when children had learned some but not all of the color terms in their language, there was an advantage in memory for the colors whose terms they had learned over those whose terms they had not yet learned. Both English and Himba children who passed either the naming task or the comprehension task (but not both) recalled more accurately than children who failed both
tasks, and children who passed both tasks recalled more accurately still. This work offers evidence that languages do indeed shape color perception in its speakers.

Perhaps the strongest contemporary view of the linguistic relativity hypothesis is held by Levinson. Levinson (2003) argues that language and culture co-evolved and thus we need to take both of them into account. Language needs to be thought of in terms of both biological and cultural variation and how those respond to create language in the child. He discusses three categories of frame of reference that all languages can use for describing space; (1) a relative system (egocentric) in which the speaker's own viewpoint is the frame of reference from which to describe space (e.g. the pen is on my right); (2) an absolute system in which the viewpoint remains the same regardless of speaker's position (e.g. the pen is to the north) and; (3) an intrinsic system in which the reference point centered on the object itself (e.g., the pen is at the tip of the spoon).

Levinson conducted multiple studies comparing speakers of relative, intrinsic and absolute framed languages on various spatial cognitive tasks (Majid et al., 2004). In one task, speakers of Tleztal (an absolute frame of reference language) and Dutch (a relative frame of reference language) sat at a table with several objects arranged on it. They were asked to examine the placement of the objects and then turn 180 degrees to another table. At the second table, participants were told to place identical objects on the table in the same arrangement as they had seen them on the first table. Speakers of Tleztal placed the objects on the second table so that the same object that was on the north side of the first table would be placed on the north side of the second table and an object that was on the south side of the first table would be placed on the south side of the second table.
Speakers of Dutch, in contrast, placed an object that was on her right side on the first table, on her right side on the second table and so on.

In another task, participants were asked to observe the path of a moving object on top of the table. The experimenter pushed a toy car along a path that included two 90-degree turns along a Z-shaped path. Participants were asked to re-trace the path on a second table after turning 180 degrees. A majority of the speakers of Tleztal performed this task using an absolute frame of reference and traced the Z along a path that traveled to the same real-world direction as the original path (e.g. to the east or west). Speakers of Dutch, on the other hand, performed this task using a relative frame of reference and traced the path to their own right or left. These results held up even when more stringent environmental controls (e.g. testing both populations indoors) were used. In another study, the researchers even drove people who speak these two languages to different unknown locations and asked them to point to different distant places. The speakers of absolute languages did this well, pointing in the correct general location, despite not being able to see the actual landmark at which they were to point. The speakers of relative languages, on the other hand, did not perform well on this task. An analysis of the groups' gestures found that absolute speakers' gestures are geographically accurate whereas the gestures of the relative language speakers were not.

To Levinson, these studies demonstrate that language structure and semantics play a direct role in the representation of thought. Levinson contends that language developed in humans along with culture. Phylogenetically, language is analogous to the development of tools. As the hands evolved, so did the tools that were made to fit them.
Likewise, language evolved along with culture as a way to fit the needs of the particular group of users among whom the language emerged. To Levinson, language affects both how concepts are represented (as seen by the performance on the tables task) and cognitive processes such as spatial updating while moving (as seen by the remote location pointing task).

**Language Refines Pre-Existing Universal Concepts**

Another line of research has sought to determine whether language effects are observable in changes in cognition as children acquire a first language. Choi and her colleagues (e.g. 1999, 2003) have argued that infants may begin with a "universal set" of spatial concepts that become refined or strengthened depending on the language they acquire. Their studies have examined the developing conceptual categories of space in children learning English and Korean. English and Korean have different category boundaries required for describing objects in space. English speakers employ the concepts of containment and support to determine whether an object is "in" or "on" another object. Korean speakers employ the concepts of loose fitting or tight fitting relations between objects. A tight fitting relation between two objects is marked by the word "kkita" while a loose fitting containment is marked by the word "nhetta" in Korean. For instance, to describe the location of a book being upheld by a table, English speakers employ the concept of support and would say "the book is on the table." Likewise, to describe the location of a red lego block interlocked with a yellow lego block, an English speaker would say "the yellow lego is on the red lego." Korean speakers, by contrast, use
two different words to refer to the locations of these objects. A book on a table is considered a loose fitting placement, whereas joining legos is tight-fitting.

Choi, McDonough, Bowerman and Mandler (1999) demonstrated that the way one's language encodes spatial relations shapes infants' discrimination of containment relations. Infants aged 18- to 23- months sat in front of two video screens which depicted two different relations (for example, putting a book into a cover and interconnecting legos together). Infants also heard, in their native language, the preposition or verb that corresponded with one of the actions on the video screen. Korean infants were expected to look longer at the picture "put rings on pole" after hearing the word "kkita" while the English infants were expected to look longer at the picture "put rings in the basket" after hearing the word "in." Infants looked reliably longer at the scene that matched the spoken phrase than to the scene that did not match the spoken phrase. The authors argue that infants are attending to the meaning of the words and are able to make the relevant semantic distinction.

In a subsequent study, McDonough, Choi and Mandler (2003) examined the very early spatial categories of pre-verbal infants and their development over time. The researchers tested 9- to 14- month-old infants on a looking paradigm task similar to Choi et al. (1999). Infants' looking time at a matching or non-matching picture while hearing the English prepositions (in or on) or the Korean verbs (kkita or nheta) was measured. Very young infants' discrimination of the relations of tight and loose fitting containment was the same regardless of language environment. At 9-months, infants of both languages were able to make the distinction between tight fitting and loose fitting. Infants were
shown a picture of a tight fitting containment relation until they habituated, after
habituating, infants were shown a picture of a loose fitting containment relation. Both
Korean and English infants dishabituated to the new stimuli, indicating that they
observed a difference between the two. By 14-months, however, infants who were
learning English no longer showed discrimination between the two types of containment.
They appeared to group both types of containment together, just as in English both types
of containment are considered *in*. Korean infants, on the other hand, showed continued
discrimination. This seems to indicate that infants are born with a larger set of
discriminations that disappear as they learn language. It is still unclear however, how
language achieves this restructuring of infant thought.

McDonough and Choi et al. see language as molding representations that are
present early. As language develops, these representations change along the boundaries
set by language. In the case of color categories, Roberson argues that there are no
pre-linguistic categories or representations of color, but that the language provides those.
For spatial cognition, we do not know all of the category boundaries that might exist
before language learning, but in these studies the researchers showed that when language
categories fall along the same lines as the pre-existing categories, then language helps
infants retain those categories. But, when the language categories are divided differently
than the pre-existing categories, those categories are re-shaped to match the language.

**Language Makes Some Thoughts More Accessible**
Clark (2003) and Slobin (2003) argue that language cannot represent all the thoughts and ideas we have, it merely brings certain ones to mind more often. Clark argues that language is an imperfect fit for the multitude of thoughts and representations one can have. Thoughts have to be expressed through the sieve of language but those thoughts may not be adequately represented by the language one uses. Because we need to think about some things more than others just to speak a language properly, then language might bring those things to the front of our minds more frequently and hence make them easier to access. For example, Slobin (2003) describes how motion events are encoded differently in different languages. In describing motion events, English does not require encoding of path, but typically requires encoding of manner (e.g. “the boy ran into the house,”). Other languages, like Spanish or Turkish typically require encoding of path only (e.g. “the boy entered the house,”). Yet when describing events, speakers conform to these conventions even when other descriptions are possible. In fact, when translators work between languages, the translations often bear the mark of the translator’s first language. A native English speaker is more likely to insert manner descriptions into a Spanish translation where a native Spanish speaker would not place one (Slobin, 1996 as reported in Slobin 2003).

This does not imply that other ideas are absent from the minds of speakers that do not have to talk about some particular aspect. Rather, we have multiple representations because we need different representations for different types of discourse, or for different cognitive activities, and we have one representation that will fit with the language constraints. Furthermore, language does not always convey a true or accurate
representation of the real event, we may have faulty memories and representations because we have to put them differently into our language categories. Clark may conceptualize language as a subset of cognition. Things we "know" are much more vivid and detailed than things we can say, so language doesn’t capture all that we know but it does bring certain thoughts to mind more readily.

Language Experience Enhances Cognitive Processing

Emmorey, Kilma and Hickock (1998) were interested in whether use of a visual-spatial language modality would make certain cognitive processes more efficient. In ASL, mental rotation is often elicited during everyday conversation. For example, when describing a spatial scene, a signer typically signs from his own perspective, requiring the addressee to perform a 180 degree mental rotation in order to correctly interpret the spatial arrangement of the scene and to understand the causality of events. Two experiments were conducted. In the first, a linguistic task was administered to Deaf native signers. Participants were asked to view a videotape of an experimenter signing the locations of objects in a room layout. These were signed in two conditions: with a mental rotation required (that is, signing from the perspective of the experimenter), and without a mental rotation required (that is, from the perspective of the participant). Participants sat in front of a room layout model and were asked to judge whether the signed description matched the room layout. Adult native signers were more accurate in their judgments when rotation was involved.
In a second experiment, a non-linguistic task, both hearing non-signers and Deaf native signers were asked to view a video of objects in a room. As in the first experiment, the participants sat in front of a model of a room layout. In half of the videos, the room was shown from the same viewpoint as the modeled layout (e.g. both shown from the view point at the door). In the other half of the videos, the room was shown from the opposite side (e.g. shown from the view point of the wall opposite the door). Participants were asked to judge whether the room in the video matched the model. Both hearing and Deaf participants were more accurate on the non-rotated trials than on the rotated trials. However, the Deaf native signers performed significantly more accurately than the hearing non-signers on the rotated trials. They also found sex differences between the two experiments. Deaf males and Deaf females performed similarly only in the linguistic condition (experiment 1), but Deaf males out-performed Deaf females in the non-linguistic condition (experiment 2).

The authors suggest several possible explanations for their results. First, they suggest that mental rotation becomes more facile in signers with increasing experience. Hearing signers with more years of experience with ASL performed slightly faster than those with one year or less of experience with ASL. If signers need to mentally rotate during sign discourse, then this experience with ASL leads to the enhanced mental rotation abilities. They also offer an alternative explanation. It may in fact be a mental reversal, rather than a mental rotation that occurs in interpreting spatial layouts. In fact, many Deaf signers report that they "just know" how to interpret a spatial relation, but deny that they experience any sort of mental rotation while doing so. A third possible
explanation they offer is that rather than being faster at mental rotation per se, deaf adults are faster at mental image formation. They postulate that the experience with a spatial language enhances image formation which in turn makes mental rotation faster as well. It may be that mental image formation is responsible for the appearance of mental rotation abilities. However, the gender differences found are consistent with gender differences in other mental rotation studies, which will be discussed later. In either case, though, Emmorey sees the effect of language, or perhaps the repeated exposure to a particular linguistic process, as facilitating this process which enhances performance on a cognitive task.

Normal Language Acquisition Is Necessary for Specific Cognitive Processes to Emerge

Other researchers' stance on the linguistic relativity hypothesis is that certain linguistic constructions are necessary for some forms of thought to emerge. For example, De Villiers and de Villers (2003) argue that for children to understand what others may know, they need to understand embedded clauses. Children may develop propositional attitudes (that is, the notion that someone has a belief, a hope, a desire, etc.) with an implicit understanding of the world because they could be shared by the two individuals. However, the ability to form an understanding of another's knowledge state, explain why a person acted in a certain way and make the adequate predictions of others’ behavior, requires more. The false belief task is one test of this ability. In false belief tasks, children must figure out that another person holds different- and erroneous- knowledge than their
own. For example, a child must understand that if Bobby saw a cookie placed in the drawer before he went out to play, but did not see Sally move the cookie to the cupboard, Bobby should still think the cookie is in the drawer. Knowledge of another’s false belief, they argue must be represented in some explicit way. They argue that this theory of mind is tied directly to the acquisition of a linguistic construct. Further, language is a critical tool that allows for a correct representation of any other's mental state. What the child needs specifically, is the understanding and use of a clause such as, "he thinks that" that contains a mental verb and an embedded complement such as, "the candle is an apple" which is false.

De Villers, de Villers, Schick and Hoffmeister (2001) tested deaf children, ages 4 through 7, on false belief tasks and language measures. Children were from either an oral-only education background (not learning sign language), or from an ASL intensive day school with Deaf teachers. Children were given three tests of false belief tasks, low-verbal, high-verbal and non-verbal. Deaf children's language acquisition was also assessed, including a measure that specifically tested for understanding and use of the embedded false-complement clause. They found that the child's performance on the false belief tasks was related significantly to two language measures: vocabulary and complements measures. They report that Deaf children of Deaf parents (who had natural language exposure from birth) performed better at all ages on all three false belief tasks than signing deaf children of hearing parents and oral deaf children. The assumption is made here that the language abilities of the Deaf children of Deaf parents is better than those of the other two groups and this group may account for the differences between the
measures. However, no language data broken down by group was reported (de Villers, 2003).

Similarly, Spelke (2003) has speculated that language's role in making humans "smart" is its unique combinatorial properties. Language, by its ability to combine knowledge we already have into a unique representational system, allows humans to learn new wholes by combining parts. As children develop language, they also develop the ability to combine knowledge sets. She argues that we are born with core knowledge about the physical world, and while we do not need to represent new concepts through language, we can use language to combine existing knowledge. Core knowledge is not unique to humans, nor is any "natural geometry" or understanding of physical space.

Human infants, chickens and rats all show the ability to understand spatial properties. For example, rats and human infants can search correctly for an object hidden in one corner of a rectangular room. Where they both fail, however, is in using multiple spatial properties, such as geometric information and landmark information to find the correct corner where they previously saw an object hidden. Around age 6, children begin to make use of combined information (e.g., the sticker is to the left of the blue wall) to correctly interpret a spatial layout. According to Spelke, his combinatorial ability is a result of language learning which all normal children experience. This property exists in all languages and differences between languages may not create differences between ways of combining information. She argues that this area is still to be explored. But learning language, which offers the speaker the use of these combinatorial properties is the key difference between human and animal cognition.
Studying the same questions, Hermer-Vazquez, Moffet and Munkholm (2001) examined the development of the ability to use both geometric and landmark cues in a surrounding space to reorient oneself. Further, they were interested in the relation between the emergence of this ability and correlates with changes in language development. They measured the spatial cognitive changes as well as a host of other general cognitive changes between ages 3 to 6. The spatial reorientation task was designed to test which features of an environment are used to orient one's self after being disoriented. Children were shown into a rectangular room with three walls covered in identical-looking white cloth, and a fourth (one of the short side walls) covered in a blue cloth. While the child watched, a small toy was hidden behind the cloth at one of the four corners of the room and the cloth replaced so that no indication of the toy could be seen. The child was then blindfolded and disoriented by turning (either by being lifted by the experimenter and turned, or by turning himself in a circle). Once the child was disoriented, the blindfold was removed and the child searched for the hidden toy.

The researchers were interested in which corner the child searched for the toy first. If a child used the only geometric properties of the room (its rectangular shape) to reorient, he should search equally at the correct corner and the opposite rotationally equivalent corner. If a child, like an adult, was able to combine the information from the geometric properties and the landmark (the blue wall), he should search more often at the correct corner of the room. Children ages 3- and 4- years-old searched equally at the two geometrically equivalent corners of the room. Not until ages 5 and 6 did children begin to restrict their search to the correct corner of the room. Thus, it appears that the ability to
combine these two forms of spatial information to reorient one's self does not emerge until between 5 and 6 years of age.

Next, the authors examined possible cognitive correlates that could contribute to this change in spatial cognitive skills. They tested a new group of children on a range of standard cognitive tests including digit span, tests of non-verbal intelligence (TONI-II), spatial memory span, a test of spatial language comprehension of right, left, above, and behind, and production of spatial language of the same terms. Comprehension was tested by asking the child to describe the location of an object set in a display in front of them. The display grid stood upright in front of the child and contained six openings in which the experimenter could place the object. The experimenter first placed one red ball in to a fixed location, then placed the target object in one of the six openings. The child was asked to explain to his parent where the target object was located compared to the red ball. The comprehension task used the same objects and display grid. In this task, the experimenter stood behind the child and told the child where to place the object on the grid. Production and comprehension scores were computed as percent correct out of four trials of each relation.

The authors examined which of the cognitive tasks was most closely correlated with success on the reorientation task. The spatial language production score involving left and right spatial references was the strongest predictor of children's success on the reorientation task. Children who scored higher on this production task scored better on the reorientation task. Of the children who failed the spatial language production task, none scored above chance levels across the two geometrically equivalent corners of the
room. The authors suggest that the development of this particular aspect of language (the ability to produce spatial relations using *right* and *left*) allows children the ability to combine independent knowledge sets (knowledge of landmark information and knowledge of geometric information) for spatial orientation.

In a study with adults, Hermer-Vazquez, Spelke and Katsnelson (1999) presented participants with the same reorientation task in a larger room. The task was similar to the children's task in that participants were asked to locate an object in a rectangular room with one blue wall after being disoriented by turning. However, two additional interference tasks were also employed in addition to the normal condition. In one interference task, participants were asked to verbally shadow a rhythmical recording they heard through earphones while completing the task. In a second interference task, participants were asked to verbally shadow a spoken recording. The second interference task was designed to directly impede any verbal encoding strategies that participants might use. Participants in the rhythm shadowing condition performed more poorly than participants in the normal condition, but were still able to combine both the geometric and non-geometric properties. Participants in the spoken recording condition, on the other hand, were unable to combine these properties in order to find the target and in fact performed similarly to children and rats.

Hermer-Vazquez, Spelke and de Villiers may share a common conception of the relation between language and thought. They see the development of a specific linguistic construct as a necessary precursor of a specific cognitive skill. In de Villier's case, this is an emergence of a cognitive ability that does not exist prior to the development of the
required aspect of language. In Spelke and Hermer-Vazquez's case, the development of the very specific use of spatial terminology is necessary to combine already existing knowledge to be used in a new way.

Other research disputes the “strong” language claim that Spelke makes. Learmouth and Newcombe (2002) argue that language is not by itself the factor that allows children to succeed on the reorientation task. They tested 3- to 6- year old children in a reorientation task in both small and large rooms. One wall in the reorientation room was covered with a red fabric to serve as a landmark. Three- and 4- year old children were not able to use the landmark in either size room to successfully reorient themselves. Five-year-old children were able to use the landmark in the large room but not in the small room and 6-year-old children were able to use the landmark in both size rooms.

The authors suggest that landmark use is not a modular ability as claimed by other researchers and suggest that the use of language may contribute to children's landmark use in the reorientation task, but that other aspects of the environment, such as room size, are also essential to children’s success. It is not clear from this study why language should facilitate landmark use in 6-year-olds but not 5-year-olds. If a 5-year-old can use a landmark in large room but not in the small room, it does not seem likely that a factor such as language would contribute to landmark use. It seems that the question of the effect of language on some spatial cognition, such as reorientation, is not entirely understood.
AGE OF ACQUISITION EFFECTS IN LANGUAGE DEVELOPMENT

Age of acquisition effects on first- and second- language competencies have been well documented. As children age, second language learning seems to become more effortful, deliberate and error prone. Age of acquisition of language affects language processing, and in so far as aspects of language-thought relations depend on language processing, we may find that age of acquisition will affect the relationship. If language-thought relations are affected by age of acquisition, then even very small processing differences may be important indicators of mechanisms behind how those relations are established. There also seem to be different sensitive periods for different aspects of language acquisition, and age of acquisition effects can inform us about which aspects of language are responsible for the effects on cognition.

Age of Acquisition Effects on Phonetic Processing

Phonetic processing appears to have the shortest window for native-like attainment followed by grammar and morphemic processes, and semantics appears to allow more time before for age of acquisition effects are noticeable. Infants show relatively rapid changes in phonetic processing in infancy between birth and 12 months. In a classic study, Werker & Tees (1984) tested infants who were raised in either English speaking or Salish (a North American Native language) speaking environments on their ability to discriminate between sounds that occur in their native language as two distinct sounds and between sound that occur in their native language as the same sound. Infants who responded to the change in sounds by turning their head for a visual reward were
considered to discriminate the sounds. At six months all infants discriminated sounds, even sounds that adult speakers of their language could not discriminate. By 12 months, however infants’ performance was similar to that of adults in that they could no longer discriminate sounds that were not heard as two sounds by adult speakers. During this time infants’ phoneme categories become refined so that the vowel category boundaries in their language become adult-like. These studies of phoneme recognition show that there is a rapid development, and perhaps a small window of time during which infants learn these aspects of language.

**Age of Acquisition Effects on Semantic Processing**

At the word level, researchers have also demonstrated age of acquisition effects on language processing. Emmorey and Corina (1990) compared Deaf native signers with Deaf late childhood signers (mean age of first exposure: 11 years) on a lexical isolation task. Sign isolation was defined as the time it took for a participant to decide on the meaning of a sign and did not subsequently change his or her mind. Their results showed that Deaf native signers were faster to isolate a sign than Deaf late-childhood signers. Native signers were faster to isolate signs that were monomorphemic and faster to isolate the root sign of an inflected verb. However, for complex morphemic signs native signers and late childhood learners did not differ. For both groups these complex signs took longer to isolate. It appears that there are age of acquisition effects on some aspects of sign language processing, namely, isolating simple signs. When isolation can occur
quickly (as with the simpler monomorphemic signs) native signers are faster, but when isolation is more difficult and effortful, age of acquisition has no effect

**Age of Acquisition Effects on Neural Organization**

Research has also shown age of acquisition effects on neural organization and processing for language processing. Neville et al. (1997) studied the organization of neural systems involved in processing ASL and English in native signers and native English speakers. They found differences in ERP patterns among people learning ASL at different ages and, interestingly, between hearing and deaf *native* users of ASL. Using ERPs these researchers compared Deaf native signers, hearing native signers, hearing signers who learned ASL after age 18, and non-signers who had never learned ASL. Participants watched a series of signed sentences and were asked to indicate whether each sentence made sense. In half of the sentences, the final word was semantically correct and in the other half the final word was semantically incorrect. For example, one sentence read, "The winning candidate was preparing his acceptance wood." ERP responses to open and closed class words throughout the sentence were analyzed, as well as sentence final words. Deaf native signers and hearing non-signers displayed similar ERP patterns to open and closed class words. Closed class words elicited a more negative N250 over anterior regions than open class words. Open class words elicited a larger N400 response which was larger over the left hemisphere. A comparison of hearing and deaf native signers showed a greater N250 response in occipital areas for deaf but not for hearing native signers. Hearing late learners did not show the same distinction in response
between open and closed class words as the deaf and hearing native signers. Comparison of groups' responses to semantically appropriate and anomalous word endings indicated that all groups that knew ASL showed a more negative N400 response, but the Deaf native signers' N400 response to anomalous words began earlier. Results from both conditions indicate that there are processing differences in closed and open class words which interact with age of acquisition. Moreover, there are no significant age of acquisition effects for semantic processing as measured by detection of anomalous sentence final words. Thus, age of acquisition affects some but not all aspects of ASL processing.

Perani et al. (1998) found that both age of acquisition and proficiency in the language were important in establishing native-like neural circuitry. In this study proficiency covaried with age of acquisition in English and Italian speakers. Later learners of English who became highly proficient in the language had neural circuitry activation for English comprehension in fMRI identical to native English speakers. However, all of the participants in this study learned their second language before age 14. It is not clear whether the same effect for language proficiency could be found in adult learners of a second language. It is also not clear whether individuals reaching higher proficiency begin the late language acquisition process with a different capacity for learning, or whether they experience a more enriched language-learning environment than those who did not attain proficiency. We do not know the relative roles of native like neural circuitry and language proficiency. Does a general capacity for language drive neural circuitry in a particular way, or does native-like neural circuitry enhance
proficiency in a language? For adult learners of ASL (those learning after age 18) proficiency may be more important in establishing native like cortical representation for language than it is for early learners of ASL. Nevertheless, these results point to a potential role of language proficiency in processes of non-native language acquisition as opposed to age of acquisition.

**Age of Acquisition Effects on Second Language Learning**

A clear demonstration of the effect of age of acquisition on second language learning was conducted by Johnson and Newport (1989). In a study of late second language acquisition Johnson and Newport (1989) found clear age of acquisition effects in a group Chinese and Korean immigrants to the US who had learned English after arriving in the US. Participants arriving before age 7 were indistinguishable from native speakers of English on grammaticality judgments. Those arriving between the ages of 8 and 16 showed a clear correlation between age of arrival and scores on the language tests. Remarkably, there was no correlation between age of arrival and scores on the language tests for those arriving after age 17. These participants’ scores were highly variable with some scoring high and others scoring quite low.

Newport (1990) argues that the constraints on language learning are maturational constraints. That is, language learning abilities decline with age of the learner because human language learning is bound to a particular maturational state. If two learners at two different maturational states are given the same language input, they will not acquire the language in the same way. Moreover, there are other maturational processes occurring
which may also interfere with the maturational state of the language learning mechanism.

What accounts for age effects in language acquisition? One explanation for these observations is that there is a language faculty that is either present at birth or only emerges over a short time during early development. Newport (1990) argues, however, for a different hypothesis. She argues that it is actually the development and maturation of other cognitive processes that are the reason for the decline in language learning abilities in childhood. She calls this the "less is more" hypothesis. For example, late learning ASL signers seem to acquire unanalyzed whole morphemes, using them in "frozen forms" or similarly across usages where inflections are required. Late learners also are more variable in the use of appropriate structures than native signers. Young native learners, on the other hand, make errors of a different sort. Native learners' errors in early morphological production are such that they restrict their use of a morpheme to only the core morpheme in a complex sign while omitting any additional inflections. Newport argues that this indicates that younger learners do not perceive complex linguistic stimuli in the same way and thus are not able to store linguistic information as adults. This poorer ability to perceive and store linguistic information is, ironically, precisely the advantage that children have over adults. A young learner then, will have a less complex problem to solve in determining what morphemes mean and how to use them if they are only able to use a limited number of these complex pieces at a time.

Flege (1999) argues, on the other hand, that the current evidence does not support the idea that maturational changes account solely for the changes in second language performance after a sensitive period ends in late childhood. He argues that, several lines
of additional evidence are required. First, there should be a sharp discontinuity between performance measures and age of acquisition before and after a sensitive period has closed, not a slow linear decline around the end of the critical period. Second, there should be a correlation between performance and age of acquisition of the second language before the critical period closes, but no correlation for those beginning to learn after the critical period closes. Finally, there should also be no relation between performance on language measures and other “experiential” factors such as amount of schooling in the second language, or amount of use of the second language. Flege (1999) tested these three hypotheses and concluded that there was in fact, no support for a maturationally defined critical period in second language learning. Flege, like Johnson and Newport (1989) did find that individuals learning language later in life performed more poorly on English phonological and morphosyntactic tests. However, they also found that there was a non-linear relationship in age of acquisition and language performance before and after the critical period closed. They also found a correlation in performance and age of acquisition both before and after a critical period (this was true both when the critical period was defined as 12 years of age and when it was defined as 15 years of age). Flege also controlled for age of acquisition of English to examine the differing effects of amount of schooling in the US on phonetic and morphosyntactic structures in English. When age of acquisition was controlled for, amount of US schooling significantly related to performance on some tests of morphosyntax, but was not related to English phonological production. Flege, thus argues that the mechanism for a critical or sensitive period is not explained only by a closing of a maturational period
after which language learning is difficult. Rather, both age of acquisition and the language experiences in the second language together are required to understand second language learning and acquired competence.

Snow and Hoefangel-Hohle (1978) also found that a critical period did not explain second language acquisition well. They examined native English speakers’ acquisition of Dutch across their first year of learning the language. Older children (12 to 15 years old) and adults were found to learn much more quickly over the first year of language acquisition than younger children. Moreover, the youngest children (3- to 5-years old), who presumably should have had the easiest and fastest acquisition of second language, were the lowest performers on language measures after one year of language learning. Snow’s study did not track children’s acquisition beyond the first year, and subsequent studies would likely show that the youngest children caught up to and surpassed the older learners after more years of language learning, but they do make reference to the idea that second language learning may be subserved by different processes than first language learning. Moreover the mere fact that the youngest children did not learn Dutch as quickly as the older children over the first year does not necessarily indicate that there is no evidence for a critical period in this study. Infants also take longer than a year to begin using their native language. Hence the 3- to 5-year olds in Snow’s study may still be acquiring language the same way as first language learners, not like late second language learners. This study does not indicate how children of the same age learning a first language should fare.
Apart from Snow’s findings (1978), these studies share a common message that language learning is best in the earlier years of development. The studies differ remarkably in terms of the various “cut off” points at which we begin to see age effects in language acquisition. For some studies the cut off is relatively early. For example, phonetic processing has a relatively early cut off age, yet judgments of grammaticality seem to have later cut off ages. It seems likely that different maturational processes are involved in the development of these different linguistic skills. With this in mind it is reasonable to hypothesize that language-thought relations likewise will demonstrate disparate age of acquisition effects. It would be easy to assume that some relations will be relatively more affected by the age at which a language user acquires the language, and that different relations will occur with different “cut off” ages. As demonstrated here, different aspects of language learning have different sensitivities to age of learning. These distinctions are important because they may bear weight on the question of language-thought relations. Different age of acquisition effects are likely to also affect language-thought relations accordingly.

Age of acquisition effects have also been implicated in language processing tasks such as word recognition and naming. Brown and Watson (1987) hypothesized that the reason for this effect is that earlier learned words are stored in a complete phonological form while later acquired words and later acquired words are stored in a way that requires more “reassembly” at a phonological level to retrieve. Gerhard and Barry (1998) examined age of acquisition effects in lexical processing and hypothesized that age of acquisition effects are primarily at the “output” or production level (as opposed to a
representational or storage level). Moore and Valentine (1999) argue, however, that instead of age of acquisition effects, order of acquisition is the important factor. They find that celebrity faces are named faster if they had been acquired between the ages of 6 to 12 than if they were acquired after age 18. They argue that the relatively late age of the “earlier” acquisition suggests that order, and not age, of acquisition is the key component because for any new class of stimuli, those learned first, set the stage for storage and retrieval of stimuli. Whatever the reason for the effects, much research has documented a age of acquisition effects on some aspects of language processing, particularly at the lexical level.

USES OF SPACE IN AMERICAN SIGN LANGUAGE

I next describe the multiple uses of space in American Sign Language in order to make it clear how ASL takes advantage of real space in its structure. According to Valli and Lucas (2002) space has several functions in ASL. First, space is used in articulation of all signs because location of articulation is a necessary component of every ASL sign, and is one of the four basic parameters that make up every ASL sign. Second, space is used referentially in cases where ASL requires marking a location in space to reference a noun. In conversation one may refer to a non-present person or object by establishing reference in the signing space and this is typically done by naming the referent and pointing to an arbitrary location in the signing space. The space used to establish reference has no inherent meaning (i.e. one would need to reestablish a space in a different conversation with a new addressee, or in a different conversation with the same
addressee). Winston (1995) describes different means available for marking a space for a referent. The signer can name the referent and then point to the space to mark it, use eye gaze directed to the space, move his body to the space, move a verb to the space, or switch hands from dominant to non-dominant near the space marked for that referent.

Third, space is used for inflection in spatially inflecting verbs. Some verbs in ASL are spatially modified to indicate who is the actor and who is the patient in a sentence. For example, in the sentence I GIVE YOU, the verb GIVE is inflected in the movement originating at the first person, and terminating in the location referenced for YOU (typically this is directly in front of the signer). Fourth, verbs can also be inflected to show aspect (repetition of behavior or on going behavior) (Valli & Lucas, 2002). The verb LOOK is modified with a circular movement to change the meaning to STARE.

Fifth, space can be used locatively to describe where in physical space an object is. If a person was standing on the right, a sign could be made on the signer’s right side signing space. Space is used in this way to indicate a frame of reference (Valli & Lucas, 2002). As mentioned previously, signers typically sign from their own perspective as they would see a spatial layout.

At the lexical level, each ASL sign consists of four parameters (akin to phonetic units), each of which has a spatial component. These include handshape, location, movement and palm orientation. Handshape refers to the shape of the fingers and palm that make up a particular sign. For example, a handshape may involve extending the index finger while leaving other fingers closed against the palm. There are about 40 distinct handshapes in ASL (Tennant, Brown, & Nelson-Metlay, 1998).
Location refers to the place within the signing space in which a sign originates or terminates. Valli and Lucas (2002) distinguished 25 separate location categories present in ASL. Signs are produced in a limited area called the signing space which is typically a box-shaped space directly in front of a signer with a height from about forehead level to mid-torso, and a width to about one foot on either side of the body. Signs are typically not produced outside of this area. For example, the sign for DRIVE is produced with both hands held 8 to 12 inches from the chest with the hands inside shoulder width. Signs can also be produced by making contact with another place on the body, including locations on the arms (e.g. POWER), forehead (e.g. FORGET), chin (e.g. MOTHER) and torso.

Stokoe (1960) classified the movement parameter into 24 different movements. Movements are classified according to their initial, duration and final positions. These movements can take place in neutral space, by contact with the non-active hand or contact with a location on the body (chest, forehead, chin etc.). Movements can take place by movement of the hand to change handshape (e.g. in the sign for NO) or movement of the entire hand while leaving handshape intact (e.g. in the sign for DRIVE). Finally, movements can be forward-back circular (e.g. LOOK A LONG TIME AT), can be unidirectional (e.g. ESCAPE), repetitive (e.g. PAPER) or consist of a single “beat” (e.g. STOP).

Finally, palm orientation refers to the position of the hand in the signing space. The palm can face upward, inward toward the body, downward toward the floor or outward from the body at any degree from the center of the body. Like other parameters, a change of the orientation of the hand can signal a change in meaning. A V-hand with
the palm facing toward the signer means STAND, while a V-hand with the palm facing down means LOSE.

Going beyond ASL phonology, Emmorey (1995) describes two functions of the use of space in ASL: semantic and syntactic. First, space can be used topographically to refer specifically to marked locations of objects. When space is used topographically, the use of space has semantic function. For example, if I were to explain the layout of an apartment, my use of space in language to describe where the kitchen is has a specific and direct relationship to its real world location. Thus, the use of space in this instance is not arbitrary. In the second type of function, space is used referentially. In this case, I would mark a location in the signing space to refer to a person or object that is the focus of conversation. The use of space for referencing an object is independent from the actual location of that object and thus it carries no semantic function. Marking a location on one’s left has no different semantic function than marking on one’s right, and thus this type of spatial use is arbitrary.

There is a small but growing body of research examining the exploitation of space in ASL discourse. This research covers areas such as semantics, syntax, pragmatics, acquisition patterns and neural-cognitive correlates of spatial language use in ASL. Emmorey, Corina and Bellugi (1995) demonstrated that this functional distinction of the use of space corresponds to a difference in linguistic processing between these two types of spatial use. In her study, Emmorey asked ASL signers to watch a series of video-taped signed sentences. The sentences contained semantic use of space (e.g. “The bathroom is on the left and the kitchen is straight ahead”) or referential use of space (e.g. “My brother
(point to left) is a dentist. My sister (point to right) is a nurse.”). After viewing the sentences signers watched a second set of test probe words that either matched the original sentence semantically (i.e. “bathroom (point to left)”) or was a semantic mismatch (“bathroom (point to right)”). For referential sentences, the test probe words contained a loci match (“My brother (point to left)”) or mis-match (“My brother (point to right)”). Participants were asked to indicate whether a probe word (BATHROOM or BROTHER) appeared in the original sentence. Participants took longer to recall whether a probe word appeared in the original sentence when the test probe was a spatial mismatch to the original word, but only for topographical use of space. For referential use of space, participants were equally fast to recall the word regardless of whether the probe was a spatial match or mismatch. This indicates that ASL signers process and recall spatial language differently depending on whether it has semantic or referential function.

Hence, American Sign Language uses space in every aspect of discourse at morphologic, semantic and syntactic levels of analysis. Naturally, because ASL relies on space in both iconic and in non-iconic signs, the role of non-linguistic spatial thinking in ASL learning and use has become an important question in the field of language-thought relations (e.g. Emmorey et al., 1993, 1998; Neville et al. 1997; Bavelier et al., 1998)

MENTAL ROTATION IN CHILDREN AND ADULTS

Research in the development of mental rotation shows two lines of evidence that mental rotation emerges as adult-like in late childhood. First, types of errors and patterns of reaction time become more like adults”. Increasing the degree of rotation required in a
mental rotation task is accompanied by more errors and increasing reaction times between ages 8 and 12 (Nelson, de Haan & Thomas, 2006). Second, imaging studies show that around this age, the superior parietal lobe becomes active during mental rotation tasks as it is for adults (Nelson et al. 2006). Moreover, mental rotation is an area of cognition with robust gender differences (e.g. Johnson & Meade, 1987) and much of the developmental literature focuses on this issue. Research consistently finds gender differences in mental rotation tasks with males outperforming females as early as preschool age on some tasks, and as early as infancy in other mental rotation-like tasks (Quinn & Leiben, 2008). Interestingly, even when men and women are matched on mental rotation ability, differences in cortical activation are observed. High-spatial skill women show more activation bilaterally than high-spatial skill men who show activation primarily in the right parietal regions (Roberts and Bell, 2000).

Ornkloo & Von Hofsten (2007) tested 14- to 26-month old infants in a task that required infants to mentally rotate. The researchers presented the infants with a set of elongated shaped blocks and a box with a lid containing an aperture into which the child could place the block upright. The blocks were presented to the infant on the table in different orientations so that the block was not aligned with the aperture directly and required a preadjustment to fit. The blocks and apertures were made so that infants could not fit the block in by force or trial and error; deliberate orientation of the block to the aperture was required. In essence, the infant was required to mentally rotate in order to insert the block. Younger infants (14 months) failed most of the trials requiring both raising the block from a lying position, and twisting the block to fit the opening. But by
26 months infants were largely successful the task. These older infants could orient the
block both by lifting the block to the right vertical orientation and twisting it to the right
horizontal orientation to fit the aperture. This study shows that some mental rotation skill
develops in late infancy.

In early and middle childhood, spatial skills in general improve with age. Children
show increasing accuracy, and decreasing reaction time on a variety of test measures.
Johnson and Meade (1987) conducted a battery of spatial tests in a cross-sectional study
of children in kindergarten through 12th grade. Correct responses increased with age, and
gender differences were not apparent at kindergarten, but emerged in middle childhood
and became pronounced by age 10. Other research has also found age differences in
qualitative changes in mental rotation strategies as well (Geiser, Lehman, Corth & Eid,
2008). Geiser conducted a latent class analysis to determine whether problem solution
strategies could classify participants into high and low classes of mental rotation
performance and whether children change the use of strategies over time. The study
found that children who were in the lowest performing category (they were performing at
chance and presumed to be using a guessing strategy) were least likely to become more
efficient mental rotators. They also found that the girls in their study were more likely
than boys to be using an inefficient strategy and to continue to use this strategy across
time. Children who were high performers were likely to remain high performers across
time.

Another recent study investigated the role of gesture in children’s spatial
reasoning in a spatial transformation task. In spatial transformation, participants see a
shape divided into sections and are asked to decide what the whole shape would look like if the sections were fit together. This task often involves mental rotation when the pieces are shown apart and turned away from each other. Ehrlich, Levine and Goldin-Meadow (2006) examined the role of gesture in boys’ and girls’ strategies for solving the Levine (1999) mental transformations task. The children were asked to solve mental transformation problems and also asked to explain their solution to the experimenter. The experimenters coded both children’s verbal strategy and their gestures while describing their strategy. The experimenters coded the verbal and gesture strategy explanations according to four classes of explanation: movement (children indicated a strategy which would involve imagining the pieces moving together), perceptual features (children used an explanation in which they described using the way the pieces looked, such as a curve or straight edge), perceptual whole (children described the way the whole figure looked when moved together- e.g. it looked like an arrow), and alignment (children described how the pieces fit together). Children often described the same strategy in both their verbal descriptions and in gestures. Both boys and girls were equally likely to indicate a movement strategy verbally, or in speech and gesture together. Using a verbal movement strategy explanation (without gesture) was related to both correct and incorrect responses on the task. Using a verbal and gesture movement strategy explanation was also related to both correct and incorrect responses. Only the gesture (without verbalizing) movement strategy explanation was related to success on the mental transformation task. Boys were more likely than girls to use gesture alone in their movement strategy explanations. What is interesting here is that children who succeed on the mental transformation task were
more likely to be using gesture alone- without accompanying speech- to solve the task. Although boys used this strategy more often than girls, it was equally helpful for both the boys and girls.

There is mounting evidence of mediation between language and other non-linguistic spatial cognitive tasks. Windsor, Kohnert, Loxtercamp and Kan (2008) studied 8-to-13-year-old children in three language groups: monolingual English speaking children with language impairment, Spanish-English bilingual children and English speaking monolingual typically developing children. These three participant groups were tested on a battery of non-linguistic tasks. Children completed several tasks that were designed to capture visual spatial cognition. Three of the tasks were a mental rotation task, a form completion task and a serial memory task. In the mental rotation task, children saw an odd shape on a computer screen and were asked to study its shape. When the child said they were “ready” the experimenter pressed a button causing the first shape to disappear from the screen and the second shape to be presented. Children were asked to determine if the second shape was the same or different from the first shape. The second shape was rotated at 45, 90, 135 or 180 degrees. The rotated shape was either a direct rotation of the first shape (these were “same” shapes), or was its mirror image (these were “different” shapes).

In the form completion task, children saw three shapes arranged on a board at the same time. One “broken” shape stood alone at the top edge of the board. Two choice shapes were presented at the bottom of the page. One of the choice shapes showed what the “broken” shape would look like if it was put together. The other shape was a
distracter. Children were asked to determine which of the two choices would create the form made by putting the “broken” shape together.

In a serial memory task, children saw five dots on a computer screen arranged in an X shape on the computer screen. Children watched as the dots illuminated in a sequence of two to five dots and were asked to recall the sequence. When the dot sequence was finished, children used the mouse to click on the sequence in the correct order that they illuminated. For all three tasks there were trials of increasing difficulty, and reaction time and accuracy were recorded.

Accuracy measures showed that the English-only monolingual children performed at 90% accuracy on all tasks. Bilingual children performed at 90% accuracy for form completion, but for the mental rotation and form completion they scored 85%. Children with language impairments scored at 90% in the form completion task but at 80% for mental rotation and slightly lower for serial memory. Across increasing difficulty levels, accuracy declined in the serial memory task and form completion task for all three participant groups, but not in the mental rotation task.

Reaction time showed that children with language impairments were reliably slower on mental rotation than the bilingual and monolingual groups who were not statistically different from each other. Moreover, the language impairment group was significantly slower than the monolingual group with increasing difficulty. Interestingly, although there was no statistical difference between the monolingual and bilingual groups, there was also no statistical difference between the bilingual group and the language impairment group.
DEVELOPMENT OF SPATIAL LANGUAGE BY ENGLISH SPEAKERS AND ASL SIGNERS

In all languages studied to date, communication about space begins very early and is seen in pre-language gestures. But, the completion of spatial language is a relatively late achievement. Understanding how children acquire spatial language, particularly relational constructions, will give us a better understanding of the ways that spatial language and spatial cognition interact.

Research on spatial language development has shown that there are clear patterns of spatial language acquisition across development. Even before they begin to speak, infants make use of joint attention and shared space to call attention to objects' location by pointing (Butterworth, 2001). Infants continue to use pointing even after they begin to acquire labels for things. However, use of spatial language such as proper use of prepositions is acquired much later. Studies in the acquisition of English spatial terms indicate that they are acquired in a consistent order depending on the reference points required, and characteristics of the objects referred to. For example, one study (Kuczaj and Maratsos, 1975) found that children acquire terms for the front and back of objects at the same time, and before they learn side. Children learn the front and back of themselves before they learn the front and back of other objects with intrinsic fronts and backs (e.g. a television or a refrigerator). However, children do not learn to use themselves as a reference point for identifying the front and back of non-fronted objects (e.g. a cup or a pencil) until after they learn to use other objects to indicate in front of or behind.
Johnston (1984) found that children typically learn the meanings of the terms *in*, *on*, *under* and *next to* first, and the terms *in front* and *behind* later. Moreover, learning the terms *in front* and *behind* was facilitated by the characteristic of the object serving as the reference point. If the object had an intrinsic front or back, children applied the terms *in front* and *behind* more readily.

Other research has shown that children's use of spatial terms does not become adult-like until around age 6. Sowden and Blades (1996) asked children 3- to 6- years old, and adults to place objects *next to* or *near* another object. Both 3- and 6- year olds who were told to place an object *next to* the other typically placed the two in contact with each other. However, when asked to place an object *near* the other 3-year-olds placed the object in contact with the other whereas 6- year-olds and adults typically did not place objects in contact. While children can correctly use spatial terms such as *next to* as young as 3 years of age other terms such as *near* do not seem to become adult like until around age 6.

There is less work that examines children acquiring ASL as a first language, and even fewer studies directly examining spatial language acquisition in ASL. A few studies have looked at children’s acquisition of grammatical use of space and spatial constructions. When referencing an object or person in ASL, one designates a location in the signing space and refers to the same space to indicate that referent throughout the conversation. If two referents are needed, another location is designated for the other referent and both locations are kept constant throughout the conversation. Hoffmeister (1985) found that until the age of 5, children do not use spatial referents correctly or
consistently. Children are likely to use the same location for several referents, and to change locations of referents throughout a conversation.

Schick, Marshark and Spencer (2005) report that use of spatial grammatical properties of ASL also develop gradually over the early years of language use. In ASL, transitive verbs require spatial agreement between a subject and object. If Sally gives Bobby a book, this is indicated by directing the verb GIVE from Sally's space to Bobby's space. Meir (1987) showed that children acquire this type of verb agreement in a U-shaped pattern between 2-years and 3-years of age. Early use of these verbs are done correctly, followed by a decrease in percentage of correct use of directional verbs, followed by an increase again nearing 3 years of age. Meir suggests that early use might be based on rote memory (as seen with irregular verb use in English speaking children). Other studies have reported a slightly different pattern of acquisition. One study reported that very young children acquiring ASL use uninflected forms of verbs when they first begin to acquire them. Adult-like use of inflection appears to be complete around age 6 (reported in Emmorey, 2002). Regardless, it is clear that young children need time to acquire this spatial component of inflecting verbs.

Martin and Sera (2006) found that spatial constructions in ASL that involve mental rotation, require longer to learn than spatial constructions that do not involve mental rotation. Martin and Sera examined the development of spatial relations in English speakers and ASL signers ages 4 through adults. In this study, the child was shown a set of two pictures, each depicting opposite relations (e.g. a car in front of a tree and a car behind a tree). The experimenter held a card that matched one of the child's two
pictures. The experimenter described the picture to the child and asked the child to indicate which of their two pictures matched. Eight spatial relations were examined: *in front, behind, towards, away, left, right, above* and *below*.

Because spatial discourse in ASL is typically signed from the perspective of the signer, the addressee (or "listener") must perform a 180 degree mental rotation in order to correctly interpret some spatial relations. In the Martin & Sera study, six of the spatial relations (*in front, behind, towards, away, left* and *right*) involved this type of mental rotation. Two relations (*above* and *below*) did not. In English, by contrast, spatial relations are not typically view-dependent. That is, the viewpoint is arbitrary and the listener does not need to perform a mental rotation in order to understand the relations.

We found that the relations that involved mental rotation took longer for children to acquire than those that did not. For the relations *above* and *below*, we observed no differences in understanding between the English speakers and ASL signers. For the other relations, however, we found clear differences between the ASL and English speakers in their interpretations of the rotated spatial constructions.

One clear pattern that emerges in the literature examining use of spatial language in both children learning English and children learning ASL is that while the process of using spatial language (e.g. pointing) begins very early, full use of adult-like spatial language does not seem to be complete until relatively late in language acquisition. In fact, it may well be the last aspect of language (apart from ongoing vocabulary development) to become adult-like. I discuss this in relation to the development of spatial cognition in the next section.
ASL USE AND SPATIAL COGNITION

As I have mentioned, questions about language-cognition relations can be examined in signers by comparing spatial language use and spatial cognition. Several studies have shown that different types of spatial language in ASL are associated with different mental tasks in the user. Additional research also examines the relation between ASL use in general and specific spatial cognitive tasks. Bandurski and Galkowski (2004) examined the differences in several cognitive domains between three population groups with different language-learning backgrounds. The three groups were: 1) Deaf children learning ASL as a first language from Deaf parents (DCDP), 2) deaf children who are late learners of sign language who have hearing parents (DCHP), 3) and hearing children of hearing parents (HCHP). DCDP and HCHP were judged to have early and consistent language exposure from parents from birth, while the DCHP began learning sign later in childhood.

One cognitive assessment was a spatial analogy task which consisted of two sections: an opposite relation analogy and a part-whole analogy. In the opposite relations analogy task, children saw a geometric figure (e.g. a diamond with a dot in the left side corner). They were asked to choose from a set of possible answers of which one was a 180 degree rotation of the figure. The scores for DCDP were significantly higher than both other groups (DCHP and HCHP) and HCHP scored the lowest of all three groups. An inspection of the errors made by children, there were no overall differences in the
errors between the DCDP and DCHP. However the most frequent type of error made by the HCHP choosing an answer which did not involve making a mental rotation at all.

These results provide some evidence for improved spatial skills in children learning a spatial language. What is most striking, however is the finding that hearing children were less likely to perform a 180 degree rotation of the stimuli in the opposite relations task, when they made errors, they most often preferred not to make any rotations at all. There were no differences found in the types of errors made by the DCHP and the DCDP. While they DCHP were not exposed to sign language early and consistently, they were using it at school on a daily basis. Thus the spatial experience provided by the sign language they learned late may have been sufficient to produce the same pattern of results as seen in native signing deaf children. It should be noted, that deafness and ASL use were confounded in this study. It is not possible to determine whether the pattern of results was from ASL use or from deafness.

Emmorey, Kosslyn and Bellugi (1993) looked at three different types of mental imagery abilities in adults. They tested five groups of participants for differences in mental image generation, mental image maintenance and mental rotation. They tested Deaf native signers, Deaf early signers who learned to sign between the ages of 2 and 8, Deaf late signers who learned to sign between the ages of 12 and 16, hearing native signers, and hearing non-signers. In the mental image generation task, participants were asked to decide whether an X on a screen was "on" or "off" the area made by a letter shown just before the X appeared. Results showed no effect of gender or age of sign language acquisition. Signers were faster at this image generation than non-signers and
there was an insignificant trend toward Deaf signers performing faster than hearing signers. In the image maintenance task, nonsense shapes were shown to participants. Once the participants learned the shape, the letter disappeared and an X appeared on the screen. Participants performed two image maintenance tasks. As in the image generation task, participants were asked to determine if the letter was 'on' or 'off' the shape they had just seen. In a second image maintenance task participants first saw and studied a shape, then pressed a key and the shape disappeared and a new shape appeared. In this task, participants were asked to indicate whether the two shapes were the same or different. There were no differences between the signers and non-signers. That is, learning ASL, at any age, did not affect participants' ability to maintain an image in mind, or to remember its shape.

The final task was a mental rotation task. Participants were asked to examine a shape made up of four (simple) or five (complex) adjacent darkened boxes on a grid. Participants saw two shapes on the screen at the same time. One shape was rotated at 0, 90, 135 or 180 around a central axis. Participants were to decide if the shapes were the same or mirror images of each other. In this task, the researchers did not find a difference in accuracy between hearing and deaf participants. However among the deaf participants, they found that the native signers were more accurate than early learners (mean age of acquisition was 4.9) and more accurate than late learners (mean age of acquisition was 14.5). For reaction time, the researchers found that native signers (both hearing and deaf) were faster than hearing non-signers. However, a closer inspection of the differences at 0 degrees of rotation revealed that Deaf participants were also faster at 0 degrees which
does not involve mental rotation. The authors argue that this finding indicates the signers are not mentally rotating faster, but are detecting mirror images faster than non-signers. The patterns of errors were the same for all groups. There were more errors at higher degrees of rotation for all five groups. However, the Deaf native signers made fewer errors on complex images than early or later learners.

Other research studying ASL signers’ visual attention allocation has demonstrated that deaf adults who use ASL have enhanced attention allocation in the peripheral visual areas compared to non-signers (e.g., Loke and Song, 1991). In these studies, the researchers showed that deaf signers allocated attention to the entire peripheral visual area. Moreover, the research also demonstrates less allocation compared to hearing participants in the central visual areas for both children and adults (Mitchell and Quittner, 1996; Quittner et al. 1994 etc.). Children who had a cochlear implant appeared to perform better on central attention allocation than children who only signed (Smith, Quittner, Osberger & Miyamoto 1998). Hearing adults who had learned ASL from birth but also acquired spoken language, also did not allocate attention in their peripheral visual areas as well as the deaf signing adults (Bavelier et al., 2000, Neville & Lawson 1987).

Proksch and Bavelier (2002) found that deaf native signers were more distracted than hearing non-signers by a peripheral distracter, and less distracted by a central distracter. This difference between deaf and hearing subjects in peripheral attention has also been linked to differences in visual cortical activation between the two groups. Greater activation in the medial superior temporal area has been observed in deaf adults compared to hearing controls (Brozinsky & Bavelier, 2004).
This evidence suggests that it may be the experience of deafness rather than the language itself accounts for the difference in attention allocation between deaf and hearing signers. This may be the case, however, additional controls can be used to further explore the effect that acquiring a particular language would have on attention allocation. Were the hearing native signers given both a receptive and expressive proficiency test? Were the deaf participants given a test of language proficiency? Perhaps it is an interaction between the language learning and deafness (i.e. deaf signers participants are less likely to develop an over-riding attention allocation strategy that is facilitated by hearing). Differences between deaf signers and hearing non-signers are limited to those tasks that capture allocation of attention to the periphery. Other tasks such as motion detection, or detection of lightness change do not show these same differences between groups.

The current study furthers the investigation of ASL and spatial cognition. In particular, the aim of this study was to determine whether ASL spatial relations production or comprehension contributed to the observed effects found in mental rotation. The current study compared mental rotation in signers who have learned ASL at different ages across development. Unlike previous studies, however, the current study included two spatial language measures to determine whether comprehension or production of ASL accounted for effects on mental rotation. Additional variables were also examined. The roles of hearing status, gender, current amount of use, years of signing and attitudinal measures were included to investigate the relations of these factors on ASL users’ mental rotation skills as well.
JUSTIFICATION FOR THE CURRENT STUDY

The question of whether, like language acquisition in general, there is an age of acquisition effect on language-cognition relations and which aspects of language knowledge contribute to these effects have not been specifically addressed in the literature. Although many studies consider production or comprehension in language-thought relations, none has directly compared the contributions of each to the other. Furthermore, the literature has also found consistent age of acquisition effects in both first and second language learning. But no studies have addressed the question of whether age of acquisition of first or second language may contribute differently to language-thought relations. Age of acquisition effects will give us a better understanding of the nature of the relations between language and thought because, as previous research has found, age of acquisition of language affects language processing, and in so far as aspects of language-thought relations depend on language processing, we may find that age of acquisition will affect the relationship. Where age of acquisition effects differ across various aspects of language, we can identify which aspects of language may be implicated. This study is the first of its kind to address these two questions specifically.
Methods

Participants

Sixty-six adults (ages 18-61) participated (31 males, 35 females). Forty-eight participants were ASL signers, and 18 were non-signers. Participants were divided into four age of acquisition groups according to self-reported age of learning American Sign Language. Nineteen participants (six males, ages 23-61, mean age 34.5) were native signers who reported to have learned ASL from family members beginning at birth. Of the native signers, 13 were deaf and 6 were hearing. Thirteen participants (seven males, age 24-57, mean age 34.5) were early signers who reported to begin learning ASL between the ages of 1 year and 11 years. The early signers’ average age of first exposure to ASL was 4;7. Of the early signers, 11 were deaf and 2 were hearing. Sixteen participants (seven males, age 25-61, mean age 39) were signers who reported to have begun learning sign after the age of 14. The average age of first exposure to ASL in the late signer group was 20;7. Of the late signers, 8 were deaf and 8 were hearing. Deaf participants in the late-signer group were adults who either were born deaf or became deaf before entering school and had been taught orally and did not learn to sign until adulthood. Many of the deaf participants began learning to sign when they entered college with other deaf students. Eighteen participants (ten males, ages 18-61, mean age 32) were participants who were non-signers and had never learned ASL. Table 1 shows the breakdown of participants by language learning group, hearing status and gender.

An additional sixteen participants were tested but eliminated from analysis. Fourteen participants were eliminated from analysis due to experimenter error. One
participant was eliminated for failing to follow the directions. One non-signer was eliminated because they indicated they were a native speaker of a language other than English.

Table 1: Number of participants in each language group, hearing status and gender

<table>
<thead>
<tr>
<th>Group</th>
<th>Male</th>
<th>Female</th>
<th>Male</th>
<th>Female</th>
</tr>
</thead>
<tbody>
<tr>
<td>Native Signers</td>
<td>5</td>
<td>8</td>
<td>1</td>
<td>5</td>
</tr>
<tr>
<td>Early Signers</td>
<td>7</td>
<td>4</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>Late Signers</td>
<td>6</td>
<td>2</td>
<td>2</td>
<td>6</td>
</tr>
<tr>
<td>Non-Signers</td>
<td>--</td>
<td>--</td>
<td>10</td>
<td>8</td>
</tr>
</tbody>
</table>

Language Production and Comprehension Tasks

These two tasks were designed to assess whether ASL users sign from their own perspective (production) and mentally rotate the signs they see (comprehension). Recall that in ASL, spatial descriptions are typically signed from the signer’s own perspective. Hence, when the addressee (or “listener”) interprets spatial relations they see, they must mentally rotate the signs the see in order to correctly interpret them. The production and comprehension tasks in the current study were designed to capture these processes. The spatial relations tested included two that do not involve mental rotation in ASL (above and below), and six relations that involve mental rotation (in front, behind, towards, away, right, and left). ASL signers were tested in ASL by a fluent ASL signer and English speakers were tested in English by a native English-speaker. The two language
tasks were always given consecutively either before or after the mental rotation task. Half of the participants received the production task before the comprehension task, and half of the participants received the comprehension task before the production task. All trials used in the language production and comprehension tasks are shown in Appendix A.

**Spatial Relations Production Task**

In the production task, the participant was asked to describe a picture to the experimenter so that the experimenter could choose a picture that matched the participant’s picture. The goal was to see whether participants described the pictures from their own perspective or the addressee’s perspective. The participant sat across the table from and facing the experimenter. The experimenter handed the participant one card, and took two cards for herself. The experimenter’s two cards depicted opposite relations. For example, if one of the cards showed a girl on the right and a boy on the left, then the other card showed the girl on the left and the boy on the right. The participant’s card matched only one of the experimenter’s cards. The cards were arranged prior to each session so that the experimenter could not see the face of the participant’s card, and the experimenter did not show her two cards to the participant. The participant described his picture and the experimenter chose which of her cards matched the participant’s. The chosen card was marked with a removable sticker and the three cards in the set were turned face-down, and then removed from the table before the next trial began. No feedback was given during the test, except for one warm-up trial (using either *above* or *below*) to demonstrate the task to the participant. There were 24 trials (three sets of trials
depicting each relation with people, animals and vehicles). There were two additional control trials depicting above and below which involved two shapes that were not included in scoring. ASL signers produced the relations in ASL and English speakers gave the relations in spoken English.

**Spatial Relations Comprehension Task**

In the comprehension task, the participant watched or heard the experimenter describe a picture and chose which of two pictures matched the description. The goal of this task was to see whether signers performed a mental rotation when interpreting the descriptions. The experimenter showed the participant two cards, placing them face up on the table in front of the participant. Each of the two cards showed opposite relations. The experimenter had one card that matched one of the participant’s two cards. Without showing the card to the participant, the experimenter described her picture. The participant then chose which of his or her cards matched the card the experimenter described. There were 24 trials testing each of the eight relations with three trials. These trials are shown in Appendix A. For each relation, one trial set depicted two people, one set depicted two animals and the third depicted two vehicles. There were four additional control trials depicting above and below which involved two shapes these were used to demonstrate the task and to ensure the participant understood the task but were not scored.

Two sets of trials testing the same relations were made for the production and comprehension tasks. The two sets were counterbalanced so that half of the participants
saw set one for the production and set two for the comprehension while the other half of the participants saw set two for production and set one for comprehension.

**Mental Rotation Task**

A computerized program was developed for the purpose of the mental rotation task in this study. During this task, participants were seated in front of a computer with a response button box made for this experiment. Participants saw two bears side-by-side on the screen at the same time. Both bears had one arm raised (either the right or left). The bear that appeared on the left side of the screen was shown right side up (0 degrees rotation) the bear appearing on the right was rotated at 0, 30, 60, 90, 120, 150 or 180 degrees. Appendix B shows the mental rotation stimuli used in this task. Participants saw a total of 56 trials. The participant was asked to judge whether the two bears are the “same” (both have the same arm raised) or “different” (each has a different arm raised) as quickly and accurately as possible. The participant pressed a green button on the button box if he judged the two bears to be the same, and a red button if he judged them to be different. The participant kept one hand over the green button and one hand over the red button during the task. There were a total of 56 trials, 8 trials at each of the seven degrees of rotation (four “same” and four “different). Three randomized sets of the mental rotation task were made so that each of the three sets contained all 56 stimuli in different orders. Each participant received one of the three sets during this task.

Participants’ accuracy and reaction times were recorded by the computer. Accuracy was recorded for each trial according to whether the participant correctly
indicated “same” for the same trials and “different” for the different trials. A score of 1 was recorded for each trial if the participant answered correctly and a score of 0 was recorded if the participant answered incorrectly. Percent correct was determined in two ways. First, overall percent correct was the percentage of all 56 trials that were answered correctly. Second, percent correct was determined at each degree of rotation for the four “same” trials and separately for the four “different” trials. This yielded 14 accuracy scores for each participant by determining the percent correct out of the four trials at each of the seven degrees of rotation on “same” and “different” trials. Hence each accuracy score was either, 0%, 25%, 50%, 75% or 100%.

Reaction times were recorded to the millisecond starting at the moment the pictures appeared on the screen until the moment an answer key was pressed. In the analysis of reaction time all reaction times from incorrect responses were omitted. Thus, all of the reaction times included in the analysis were from correct responses only. Participants’ scores across the four “same” trials (or fewer if any responses were incorrect) were averaged into one composite score for “same” at each of the seven degrees of rotation. Likewise, the four “different” trials from each degree of rotation were averaged into one composite score for “different” at that degree. This resulted in fourteen reaction time scores for each participant that were used in the analyses.

**Language Background**

To gather information about both signers’ and non-signers’ language use each participant also completed a language background form.
Language Use

The intention of these questions was to determine whether the participant was currently a frequent or infrequent user of ASL (shown in Appendix C). Participants who used ASL indicated age at which they were first exposed to ASL. Signers also indicated how often they currently use ASL each day either by number of hours each week, or indicating they always or rarely use ASL. Some adult native signing hearing participants may no longer be exposed to ASL on a regular basis as they were in childhood. Responses were then categorized on a scale of 1-5 whereby 1 indicated they never or rarely used, and 5 indicated they constantly used ASL. Early and native signers were also asked to indicate when they began using English by indicating the age at which they were first exposed to English, and whether they were exposed to signed English, written English or oral English.

Non-signers were asked to indicate whether they were a native English speaker, whether they knew or had become fluent in any other languages, whether they knew sign language and whether they knew any deaf people. None of the non-signers tested indicated that they had learned more than a few individual signs, although three indicated they knew a deaf person (this is shown in Appendix D).

Attitudinal Ratings

Signers’ attitudes toward Deaf culture and ASL use were also assessed in three questions. Previous research (e.g. Johnson & Newport, 1989) also included attitudinal measures to determine whether there may be motivational factors related to language
acquisition in later learners. For the purposes of this study, attitudinal ratings were used to determine whether higher affiliation with the Deaf community or higher regard for the importance of signing well was related to language use and mental rotation. First, participants rated the strength of their identification with Deaf Culture on a 5-point scale with 1 indicating no affiliation, and 5 indicating they strongly identified with the Deaf Culture. Second, attitude toward signing proficiency was rated by indicating how important it was to sign ASL well with 1 indicating no importance and 5 indicating very important. Third, participants indicated how often they ask other deaf people questions about appropriate ASL use with 1 indicating they rarely or never asked other Deaf users about ASL signs, and 5 indicating they often ask other Deaf users about ASL signs.
Results

LANGUAGE PRODUCTION AND COMPREHENSION

Production Task Scoring

The production task was scored from the video recording of the sessions. Each of the 24 trials were scored as 0 or 1. A score of 0 indicated that the participant signed from his or her own perspective and did not produce a rotation. A score of 1 indicated that the participant produced a rotation by signing from the addressee’s perspective. There were six trials that did not involve mental rotation (testing above and below) and the scores of these trials were used to ensure that the participant understood the task. Responses on these trials neared 100% correct. The scores of the remaining 18 trials (involving rotation) were tallied and a percentage of rotated productions was determined.

Comprehension Task Scoring

The comprehension task was scored by hand from the marked responses on the cards. Each of the 24 trials was also scored with either a 0 or 1. A score of 0 indicated that the participant interpreted the spatial relations from their own perspective and did not rotate them. A score of 1 indicated that the participant interpreted the spatial relation from the signer’s perspective by rotating. There were six trials that did not involve mental rotation (testing above and below) and the scores of these trials were used to ensure that the participant understood the task. Responses on these trials neared 100% correct. The scores of the remaining 18 trials (involving rotation) were tallied and a percentage of trials on which the participant rotated was determined.
MENTAL ROTATION

Accuracy Scores

For each participant, the computer recorded the response time in milliseconds at each of the 56 trials, and accuracy at each trial. Because accuracy was high across all participants (97% of the trials were answered correctly), and there was little variability among participants, accuracy was not included in any additional analyses.

Transformation of Reaction Time Scores

Participants’ response times on each of the 56 trials included eight responses from seven different degrees of rotation. Reaction times on “same” trials and “different” trials did not differ significantly from each other. Figure 1 shows the reaction times for all participants for “same” and “different” trials across degrees of rotation. These were combined and analyzed without distinction between the two types of trials. Figure 2 shows the reaction times in milliseconds across all degrees of rotation for each of the four groups. Mental rotation is typically measured as a slope of the change in reaction time across increasing degrees of rotation, rather than only average reaction times at each degree. To create a slope to best fit a line, transformations were performed on response times by computing the log of each response time divided by the square of the degrees of rotation in order to find a function that best fit a line. A higher slope value indicates a greater increase in the speed of mental rotation with increasing degrees of rotation, this is referred to as “slower” mental rotation. In contrast, a smaller slope value indicates that
reaction times are less affected by the increasing degrees of rotation and is referred to as “faster” mental rotation.

**Age of Acquisition Group**

An ANOVA comparing the slope of change in reaction time across groups found no significant differences among the four groups (F= .378 (3, 62) p=.77). All groups’ reaction times became slower at the same rate with increasing degrees of rotation.

**Hearing Status**

Deaf and hearing participants’ slopes were compared. No significant difference was found between deaf (.18) and hearing (.16) (t=.931 (64), p=.355). Comparisons within each group also revealed no significant differences between deaf and hearing participants. Hearing and deaf participants’ reaction times changed at the same rate across increasing degrees of rotation.

**Gender**

Within each age-of-acquisition group, a t-test was conducted to compare the slopes of the men and women in the group. Among the native signers, a large and significant difference was found between men (.11) and women’s (.20) slopes (t=-2.4, p<.05). Native signing women’s mental rotation became slower more quickly than men’s with increasing degrees of rotation. No significant difference was found between men and women in early signers, late signers and non-signers.

To explore whether the difference between native signing men and native signing women was due to men being especially fast, or to the women being especially slow,
follow-up tests were conducted for all men together (excluding women), and for all women together (excluding men). T-tests for men only showed that native signers were faster than early signers ($t=-3.02 (11) p=.01$), and non-signers ($t=-2.41 (14), p=.03$) but not late signers. For women only, no difference was found between native signing women and early signers ($p=.27$), or late signers ($p=.95$) or non-signers ($p=.58$). Thus, the gender difference among native signers seems to be due to native signing men being especially fast. Table 2 shows the slope values for men and women across all four groups.

Table 2: Slope Values for Men and Women in Each Group

<table>
<thead>
<tr>
<th>Group</th>
<th>Men</th>
<th>Women</th>
</tr>
</thead>
<tbody>
<tr>
<td>Native Signers</td>
<td>.11</td>
<td>.20</td>
</tr>
<tr>
<td>Early Signers</td>
<td>.17</td>
<td>.14</td>
</tr>
<tr>
<td>Late Signers</td>
<td>.18</td>
<td>.19</td>
</tr>
<tr>
<td>Non-Signers</td>
<td>.16</td>
<td>.17</td>
</tr>
</tbody>
</table>

**LANGUAGE TASKS**

An arc sine transformation was conducted on the percent correct for each participant on the comprehension and production tasks. For the trials that did not involve rotation (**above** and **below**), there was no variability in responses (all participants signed and interpreted them in the same way) so these were not included in further analyses. Table 3 shows the mean scores of each signing group on the comprehension trials and production trials that did not involve mental rotation. The remaining 18 trials that involved mental rotation were used in further analyses of the language tasks. Table 4
shows the percentage of responses in the comprehension and production tasks in which the participant made a rotation. Recall that typically, spatial relations are signed from the perspective of the signer. The production scores reflect that participants are signing more often from their own perspective, but are also occasionally making the rotations in production. The comprehension scores indicate that participants are largely making the appropriate mental rotation to interpret the signs. Performance on the comprehension and production tasks were correlated (r = .327, p = .02). This indicated that overall, participants who rotated on the comprehension trials tended to not rotate on the production trials.

Table 3: Percentage of correct responses on language task not involving rotation

<table>
<thead>
<tr>
<th></th>
<th>Comprehension</th>
<th>Production</th>
</tr>
</thead>
<tbody>
<tr>
<td>Native Signers</td>
<td>99%</td>
<td>99%</td>
</tr>
<tr>
<td>Early Signers</td>
<td>100%</td>
<td>92%</td>
</tr>
<tr>
<td>Late Signers</td>
<td>100%</td>
<td>99%</td>
</tr>
<tr>
<td>TOTAL</td>
<td>100%</td>
<td>97%</td>
</tr>
</tbody>
</table>

Table 4: Percent of rotated responses on language task items involving rotation

<table>
<thead>
<tr>
<th></th>
<th>Comprehension</th>
<th>Production</th>
</tr>
</thead>
<tbody>
<tr>
<td>Native Signers</td>
<td>75%</td>
<td>23%</td>
</tr>
<tr>
<td>Early Signers</td>
<td>82%</td>
<td>21%</td>
</tr>
<tr>
<td>Late Signers</td>
<td>74%</td>
<td>18%</td>
</tr>
<tr>
<td>TOTAL</td>
<td>76%</td>
<td>21%</td>
</tr>
</tbody>
</table>

**Comprehension**

There were no significant differences between groups on the transformed comprehension scores on the trials that involved rotation (F = .726 (2,45) p = .489). There
were also no differences between hearing and deaf participants \(t = .499 \ (46), p = .628\), or between men and women \(t = -.444 \ (46) p = .659\) in their consistency in rotating on the comprehension task.

**Gender Difference Within Native Signers**

Within native signers, a marginally significant gender difference emerged. Men were the interpreting spatial relations by more consistently rotating them to the signer’s perspective (80%) compared to women (73%) \(p< .08\).

**Production**

For the production trials that involved mental rotation, analyses determined that there were no differences between age-of-acquisition groups \(F=.438 \ (2,45) p = .648\), between men and women \(F=1.76 \ (1,44) p=.191\) or between Deaf and hearing participants \(F=.072 \ (1,44) p=.790\). Within each of the three signing groups, there were also no differences between men and women or between hearing and Deaf participants.

All groups performed similarly on the language tasks. However, native signing men tended to interpret spatial relations more often by making a mental rotation than native signing women. There were no differences between deaf and hearing participants for either the comprehension or production tasks.

**Amount of Current Use and Number of Years of Signing**

To determine whether amount use and years of signing differed significantly among signing groups, two ANOVAs were conducted. First, an ANOVA was performed
with age of acquisition group and hearing status as between subjects variables, and amount of signing as the dependent variables. This showed that amount of use differed significantly among age of acquisition groups and between hearing status (F(2, 42)= 3.51, p=.03). Among the deaf participants, native and early signers reported the most frequent use of ASL on a scale of 1 to 5 (4.6 and 5) whereas late deaf signers reported slightly less (4.0). Among hearing signers, native signers reported the least amount of current use (1.6) and hearing early signers reported the most use (5) and hearing late signers reported an intermediate amount (3). For years of signing, an ANOVA revealed that native and early signers had significantly more years of signing (33 years and 26 years) compared to late signers (18 years) (F(2, 47)= 11.08, p <.001). So, age of acquisition is associated with number of years of use of ASL.

**Relation Between Language Tasks and Mental Rotation**

There was no correlation between performance on the language tasks and the slope on the mental rotation task across all groups (correlation between comprehension scores and slope r=.066 (p=.65); correlation between production scores and slope, r=.007 (p=.961).) Conducting a separate analysis for each group revealed that for native signers, there was a positive correlation (r= .378, p=.11) between the comprehension task and their slope on the mental rotation. That is, a greater tendency to rotate on the comprehension task was correlated with increasingly slow performance across increasing degrees of rotation on the mental rotation task. For early (r=.143, p=.64) and late signers (r=-.170, p=.53), the correlation was reversed. More rotation on the comprehension task
was correlated with faster performance on the mental rotation task. In sum, for native signers better performance on the comprehension task was correlated with slower performance on the mental rotation, and for early and late signers, better performance on the comprehension task was correlated with faster performance on the mental rotation. However, these were not reliable correlations.

**Correlations Among Age and Attitudinal Measures**

Slope on the mental rotation task was not correlated with age at the time of testing ($r = .096, p = .44$), age at time of learning ASL ($r = .086, p = .56$), number of years of signing experience ($r = .07, p = .57$) or amount of current use ($r = .015, p = .90$). Several correlations between attitudinal variables and other measures were found. Importance of signing well and age were negatively correlated ($r = -.299, p = .04$). Participants who felt that it was important to them to sign well tended to be younger. Cultural affiliation was also correlated with number of years of signing ($r = .296, p = .04$) showing that with more years of experience in signing, participants also felt a stronger affiliation with the deaf culture. Number of years of signing was negatively correlated with asking questions about ASL ($r = -.320, p = .02$) in that the more years of signing experience one had, the less likely they were to ask other ASL users about using ASL signs or structure. Cultural affiliation was also correlated with the desire to sign well ($r = .588, p < .001$). Participants who felt strongly affiliated with Deaf culture expressed that it was important to them to sign well.
Age of learning ASL was correlated with age at the time of testing ($r=.297$, $p=.04$) indicating that as participants’ age at the time of testing increased, they were more likely to have learned ASL at a later age. Age was also correlated with years of signing ($r=.452$, $p=.01$) indicating that older participants had more years of signing experience.

**Summary of Results**

In sum, the results of the current study show that while there are no overall differences in mental rotation among those who learned ASL at different ages across development, native signing men were significantly faster than men who learned ASL early, or not at all. For women, learning ASL at any age was not associated with faster mental rotation. Results from the language tasks also did not show a difference among the groups. However, one gender difference emerged in the comprehension task showing that native signing men tended to rotate in the comprehension task more often than native signing women. There was no overall correlation between performance on the language tasks and the slope of response times between degrees of rotation on the mental rotation task. However, there was a trend for native signers who were consistent rotators on the comprehension task to also be slower mental rotators, and for the opposite to be true (more rotation on the comprehension task and faster mental rotation) for early and late signers.
Discussion

This study began by asking whether age of acquisition of ASL was related to mental rotation in adult signers and non-signers. Also examined was whether spatial language production was related to mental rotation performance in adult signers. Gender, number of years of signing experience and attitudinal measures were also explored in relation to language and mental rotation tasks.

No overall age of acquisition effects were found. However, male native signers performed the fastest on mental rotation. The results of the current study are similar to Emmorey’s (1993) results in that no overall difference was found between hearing non-signers and deaf signers in the slope of mental rotation speed across degrees of rotation. However, Emmorey did not report comparisons of slopes of mental rotation speed between native signers and signers who learned ASL later in life. The current study included these groups and did not find an overall difference in slopes of mental rotation speed between them. Moreover, spatial language performance was related to mental rotation for native signers, but no relation was found for early and late learners. I next discuss several implications of these results including 1) native signing men’s better mental rotation is related to their spatial language use; 2) native signing men’s better mental rotation is not related to more years of experience with ASL; 3) some language-cognition relations are unaffected by delayed first language acquisition; 4) ASL does not improve mental rotation in non-native learners and; 5) results of the language production
and comprehension tasks indicate that there is more variability in ASL signers’ perspective taking than is typically assumed.

**Learning ASL Improves Mental Rotation in Native Signing Males Only**

The results of the current study show that learning ASL appears to improve mental rotation only in native signing men. Native signing women, people learning ASL at older ages, and non-signers did not differ from each other in mental rotation. Thus, learning ASL from birth appears to enhance mental rotation in men, but does not affect mental rotation in other ASL learners. More importantly, there was also a trend toward native signing men to be more likely than women to interpret spatial relations from the perspective of the signer. This finding is important for uncovering mechanisms mediating language and cognition.

The important finding from this group showed a trend within native signers for men, more often than women, to interpret spatial relations from the perspective of the signer. This suggests that for people learning ASL from birth, there is a relation between understanding spatial relations and mental rotation. It suggests a possible mechanism for the relation between ASL knowledge and mental rotation in this group whereby rotations made during spatial language comprehension facilitate mental rotation. Male native signers appeared to engage in mental rotation in ASL more often than native signing women and this tendency to rotate signs during comprehension may be driving their superior performance on mental rotation. Production of spatial relations was not related to mental rotation performance in native male signers, so these results specifically
implicate the process of comprehension in enhancing mental rotation in adult male native signers. To my knowledge, this is the first demonstration of a more specific mechanism mediating language and cognition. It is an important finding for the field that has so far demonstrated an effect of language on a variety of cognitive processes, but has not yet determined how these relations may be established.

There are two additional results that are important for understanding male native signers’ mental rotation performance. First, when cognitive changes are effected by language it is most likely to be pushed in the same general direction as previously existing biases. Second, some research suggests that native language learning exerts a stronger effect on cognitive changes than learning at later ages.

There is a wealth of research demonstrating men and boys’ superior performance on mental rotation tasks. As discussed earlier, gender differences in mental rotation may emerge as early as infancy (Quinn & Leiben, 2008), although the results of studies with preschoolers are mixed in terms of finding gender differences (Johnson and Meade 1987). Erlich et al. (2006) found that children who used a movement gesture strategy in describing how to solve a mental transformations task (that is, their explanation of solving the task included a gesture that described moving pieces together to form a whole) performed better on the task itself. Notably, success was related to using a gesture only, and not using accompanying verbal explanation. Furthermore, although both boys and girls who used this strategy were successful on the task, boys used the strategy more often.
If ASL signers’ verbal strategies relate to success like hearing children’s gestures, this would demonstrate that the physical aspect of describing the strategies contributes to their mental transformation success. Although ASL signers cannot gesture and “talk” at the same time, a “verbal” description in ASL inherently includes a physical movement as does gesture. Also, Deaf boys may also be using movement strategies more often than Deaf girls, these two experiences together could be what gives ASL signing males an advantage over other groups. Their language creates more opportunities to use physical movement in spatial discourse, and they do so more often than girls. Although for adults in the current study, language production was not related to mental rotation, language production as children may contribute to more consistent rotation in comprehension as adults.

Language learning may also emphasize differences that already exist between groups. With much work showing that men are faster than women at mental rotation tasks (indeed, gender differences have been found in young children as well) it is clear that there are already established patterns in performance between males and females in mental rotation. Thus, learning ASL natively might contribute to a gender difference in mental rotation for this group only. In the same vein, we might also expect to see a similar difference favoring native signing women for facial recognition given that previous research has found women to consistently perform better in facial recognition tasks (Lewin and Herlitz, 2002).

Findings from Kurisnki and Sera (under review) suggest that cognitive changes as a result of language learning are stronger for native speakers than for adult second
language learners. In their study, Spanish native speakers assigned male and female voices concordantly with the grammatical gender of the Spanish word for the object significantly more often than adult second language learners. Native Spanish speakers assigned grammatical gender-congruent voices to objects 77% of the time, whereas adult second language learners only assigned congruent voices around 61% of the time. Interestingly, most of the native speakers of Spanish were not aware of this bias even when explicitly asked to explain their choices of voice assignment. This suggests that native speakers are more strongly influenced by the language effect than later learners. Kurinski also suggests that original biases (such as being biased to categorize artifacts with masculine qualities) can be pushed further along the same direction by learning a language that has some aspect that is consistent with the bias. This might explain the current finding that only native signing men were better mental rotators. Men and boys tend to perform better on mental rotation, and boys tend to also use certain gesture strategies more than girls. Native ASL language learning may push boys further along the path to better mental rotation that they are already on.

One last result is important for interpreting the results of male native signers. The finding that amount of use of ASL and number years of signing were not related to performance on the mental rotation task implies that more experience with ASL did not contribute to better mental rotation. Native signers had an average of 34.5 years of experience with ASL, early signers had slightly fewer years of experience 29.8 years and late learners had 18.4 years of experience using ASL. The number of years of experience differed significantly between the groups. Moreover, if it were simply the case that more
experience with ASL should contribute to faster mental rotation, then the same effect should be found for native signing women as well.

**Implications For Language-Cognition Relations in Late First Language Learners**

The current study included a group of participants who began learning ASL early in life but later than is typical for first language acquisition. Most children who are born deaf are born to hearing parents who do not sign. For this reason, and because age of diagnosis of deafness is still relatively late for native language learning, many deaf children acquire their first language later than most children. The inclusion of this group in the current study makes it possible to compare late first language learners with native ASL signers, native mono-lingual English speakers and late second language learners. The results of comparisons on slope on the mental rotation task show that late first language learners are not different in speed of mental rotation compared to late ASL learners (ASL/English bilinguals) or non-signers (English speaking monolinguals). This finding has two important implications. First, it indicates that some cognitive processes, such as mental rotation, are not affected by delayed language acquisition. Processes other than mental rotation may be affected by delaying first language acquisition, but mental rotation apparently is not. From a theoretical perspective, this is important because it suggests that some language-cognition relations may be resilient to non-normative language experiences. Second, it is important to know which aspects of cognition may be threatened by late language learning and which ones are not so that appropriate interventions can be planned. Mental rotation appears to be unaffected.
It should be noted however, the average age of first language exposure in the early signing group was 4;7. This age is still younger than the age at which children typically master complex spatial relations (Sowden & Blades, 1996) and earlier than the age at which children learning ASL begin to use spatial referents consistently (Hoffmeister, 1985). Further, children at this age are not yet efficient mental rotators. At this age, most children learning ASL may not be ready to learn spatial relations and so the children who are just beginning to learn ASL at this age may not be much delayed in acquiring this aspect of ASL. Moreover, Martin and Sera (2006) suggest that learning ASL spatial relations is difficult and slow for young ASL learners. Children were found to have more difficulty on ASL spatial relations that involved mental rotation compared to English speaking children whose language does not require rotation. Children’s language might have been waiting on their mental rotation skills to develop. Furthermore, Martin and Sera did not separate native learners from late first language learners. Where native signers might have an advantage may be in the age at which they acquire spatial relations in ASL. So, even though spatial relations may take longer to develop in ASL signers than English speakers, native signers may still acquire them sufficiently earlier than children who start learning ASL late and this may be enough to enhance mental rotation in the males.

**ASL Does Not Improve Mental Rotation in Non-Native Learners**

This study did not find an overall difference between signers and non-signers in mental rotation although an effect of native signing emerged in an interaction with
gender. It seems that for women, learning ASL does not improve mental rotation and for men, learning ASL after infancy does not affect mental rotation.

Emmorey (1993) suggested that ASL may not recruit mental rotation at all. Her study did not find differences between native signers and non-signers on mental rotation which lead her to question whether ASL in fact recruits mental rotation or whether it requires a mirror image reversal type of process instead. Specifically, she found that native signers were faster at 0 degrees of rotation where no mental rotation is required. For this reason, she suggested that mental rotation might not be employed in ASL. However, Emmorey (1993) did not break down her native signers by gender, and did not report mental rotation slopes for signers who were non-native learners of ASL.

Regardless of whether ASL recruits mental rotation or mirror image reversals, the results of both studies indicate that effects of language on cognition are limited to very specific cognitive skills and do not generalize within a cognitive domain. Despite extensive experience with a spatial language, not all aspects of spatial cognition are enhanced, only those specifically recruited by that language.

However, it is possible that mental rotation is, in fact, recruited in ASL use but most adults are sufficiently good mental rotators and ASL use does not enhance mental rotation further. So, mental rotation might indeed be necessary for understanding ASL, but knowledge of the language does not offer any more benefit than normal adults typically obtain. In this study, none of the signing groups who used ASL were better at mental rotation than the non-signers who never did. However, the current study only
addressed the question of whether ASL knowledge leads to better mental rotation, and the results here suggest that they do not.

Implications of the Variability in Language Task Findings

ASL spatial relations are typically signed from the perspective of the person who is signing and standard teaching practices for adult ASL learners explicitly teach this (Valli and Lucas, 2000). However, in the current study, adoption of one’s own perspective (indicated by signing the relative locations of the objects in the picture as the participant viewed it in the same relative locations in the signing space) did not near 100 percent of the production trials. Around 20% of the descriptions were signed from the viewpoint of the addressee rather than from the signer. Why was there not more consistency in the signers’ perspective taking during signing? This may be explained in one of several ways. First, it may be that some participants intentionally signed from the opposite perspective to facilitate communication. Participants might have felt that it was more important for the addressee to select the correct picture than for the signer to sign as they naturally would. Second, it is possible that signing from one’s own perspective is less conventional than is commonly thought. This may be an example of where proscriptive language and descriptive language differ. Even though formal ASL may call for signing from one’s own perspective, in the real world, the formal rules may be broken some of the time.

A third possibility is that the type of space depicted in the pictures may have been ambiguous or open to multiple interpretations. Emmorey, Tversky and Taylor (2000)
described two types of spatial description formats used by ASL signers when describing an open space. Signers may use “diagrammatic space” in which a scene is described as though from a fixed viewpoint, usually above the scene. Another type of description signers may use is “viewer space” in which the signer imagines themselves as though physically in the space and describes it from their own view. ASL signers are also more likely to take a diagrammatic viewpoint than viewer space when describing spatial layouts whereas English speakers were more likely to take the viewer’s perspective (Emmorey et al., 2000). Although the stimuli in the current study were not designed to resemble spatial layouts or to elicit diagrammatic spatial descriptions, it is possible that pictures used in this study were ambiguous in terms of spatial perspective required. This might have allowed multiple possible spatial perspectives. Indeed, research with English speakers (Tversky, 1996) has shown that various factors inherent in a spatial task including type of stimuli or even the directions given before the task can elicit different types of perspective taking in spatial descriptions.

**LIMITATIONS OF THE CURRENT STUDY AND FUTURE DIRECTIONS**

One limitation of the current study is that the task used for mental rotation was too simple as shown by the high accuracy rates. The task used in this study involved analyzing the difference between two figures on one dimension to determine whether they were the same or not. This simple task could have created a ceiling effect that made it difficult to find differences among some of the groups. A more complex mental
rotation task, such as those used by Emmorey, might make these differences more apparent.

Secondly, the plane of rotation used in the mental rotation task in this study was a frontal vertical plane. Because in ASL much of the rotation occurs on the horizontal plane, a mental rotation task that rotates on this plane instead should be added. We might find this type of mental rotation to be more sensitive to age of acquisition effects or relate differently to the language tasks. If ASL signers performed better on a task of mental rotation in which objects rotate only horizontally but not better on tasks such as the one used here where object move vertically, it would support the idea I discussed earlier that language recruits only very specific cognitive skills without transferring to other skills even within the same domain.

A third limitation may be that general ASL proficiency was not tested here, only comprehension and production of spatial relations. It would be important to know whether spatial language specifically or ASL proficiency generally is a better predictor of mental rotation skills. Language may recruit very specific aspects of cognition, but this does not necessarily imply that only specific aspects of language do the recruiting. A future study could also include a more general measure of ASL proficiency. We might find that there is a relation between general ASL proficiency and mental rotation only for one of the groups, for example late second language learners. If this is the case, it would imply that the relations between language and cognition differ depending on age of acquisition, and that specific cognitive skills are recruited by general language ability.
A fourth limitation may be in the small number of participants in some sub-groups. Although 66 participants were tested in this study, some sub-groups became quite small when the groups were broken down based on gender and hearing status. For example, one of the groups in the current study (hearing early signers) consisted of only two participants. So, results involving hearing early signers could not be generalized and larger sizes in this group might clarify some of those findings.

There are important questions left for future research. Still unsettled is the whether young children learning ASL must develop mental rotation skills to a certain proficiency level before they are able to comprehend ASL spatial relations. If this is so, we might expect that children who are better mental rotators acquire ASL spatial relations earlier than other children who are not as efficient at mental rotation. It would also be important to compare signers and non-signers in mental rotation before and after spatial language learning (in late infancy, toddlerhood and preschool years). Importantly, this would allow us to determine whether individual differences before learning language relate to rate of acquisition or use of spatial relations, and to observe changes in mental rotation that may occur simultaneously along with language acquisition. Furthermore, comparing these observations in native sign language users with those in children learning sign language at a later age in childhood (e.g. whose first exposure to sign language is at school entry) would help us better understand whether native sign language acquisition recruits cognitive processes in a different way than later first language acquisition does. Similarly, observing adult second language learners before, during and
after they acquire proficiency in ASL would allow us to compare adult late second
language learning with child late language learning.

Future studies will answer these additional questions about language and thought
relations. Do young infants in signing environments and those in spoken language
environments show similarities mental rotation before their spatial language emerges? Do
differences between native signing and other groups emerge simultaneously with spatial
language? Do individual differences in mental rotation or general spatial skills relate to
the acquisition of a spatial language like ASL? Several patterns of results could be found.
First, prior to language production ASL signers who are better mental rotators acquire
spatial relations earlier than ASL signers who are less efficient at mental rotation.
Second, ASL signers who were better mental rotators prior to learning spatial relations,
continue to be better after learning than poorer mental rotators. Third, no relation is found
for English speakers between mental rotation and spatial relations acquisition. Fourth,
both signers and non-signers show the same mental rotation early in infancy before either
acquires productive spatial relations, then they diverge after spatial language is acquired.

CONCLUDING REMARKS

In this dissertation I described the various stances across the field in the studies of
language-cognition relations. I then described the current study and its results that
demonstrated that male native signers were fastest at mental rotation. Further, results
from this group suggest a possible mechanism through which ASL affected mental
rotation in native signing men. Native signing men were more likely to make a mental
rotation during language comprehension than women. However, no overall relation emerged between mental rotation and age of acquisition of ASL. Late first language acquisition does not affect all aspects of cognition and more years of practice in ASL does not improve mental rotation. Furthermore, the results of the language task demonstrate the need to look more closely at prescriptive and descriptive spatial language of ASL. Finally, by studying cognitive changes in children across time as they acquire language, and by including children acquiring sign language for the first time at various ages future studies can bring more to the understanding of language-cognition relations.
Figure 1: Reaction Time on “Same” and “Different” Trials as a Function of Degree of Rotation.
Figure 2: Untransformed Reaction Times for Across All Degrees of Rotation in Each Age of Acquisition Group.
References


Kurinskui, E., Sera. M.D. (under review). Does learning Spanish Grammatical Gender Change English Speaking Adults’ Categorization of Inanimate Objects?


Appendix A
Stimuli Used in Production and Comprehension Tasks

English sentences indicate what the participant heard the experimenter say in the comprehension task or the sentence elicited from the participant in production.

Top picture is the target “correct” picture in each set.

<table>
<thead>
<tr>
<th>Above</th>
<th>Set 1</th>
<th>Set 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>My picture shows the cowboy above the girl.</td>
<td>![Image]</td>
<td>![Image]</td>
</tr>
<tr>
<td>My picture shows the peacock above the penguin.</td>
<td>![Image]</td>
<td>![Image]</td>
</tr>
<tr>
<td>My picture shows the fire truck above the jeep.</td>
<td>![Image]</td>
<td>![Image]</td>
</tr>
<tr>
<td>My picture shows the ballerina above the man.</td>
<td>![Image]</td>
<td>![Image]</td>
</tr>
<tr>
<td>My picture shows the turtle above the duck.</td>
<td>![Image]</td>
<td>![Image]</td>
</tr>
<tr>
<td>My picture shows the bicycle above the car.</td>
<td>![Image]</td>
<td>![Image]</td>
</tr>
<tr>
<td></td>
<td>Set 1</td>
<td>Set 2</td>
</tr>
<tr>
<td>---------------------------</td>
<td>--------------------------------------------</td>
<td>--------------------------------------------</td>
</tr>
<tr>
<td>My picture shows the woman below the man.</td>
<td><img src="#" alt="Image 1" /> <img src="#" alt="Image 2" /></td>
<td><img src="#" alt="Image 3" /> <img src="#" alt="Image 4" /></td>
</tr>
<tr>
<td></td>
<td>My picture shows the pirate below the cowgirl.</td>
<td><img src="#" alt="Image 5" /> <img src="#" alt="Image 6" /></td>
</tr>
<tr>
<td>My picture shows the deer below the goat.</td>
<td><img src="#" alt="Image 7" /> <img src="#" alt="Image 8" /></td>
<td><img src="#" alt="Image 9" /> <img src="#" alt="Image 10" /></td>
</tr>
<tr>
<td></td>
<td>My picture shows the fox below the pig.</td>
<td><img src="#" alt="Image 11" /> <img src="#" alt="Image 12" /></td>
</tr>
<tr>
<td>My picture shows the red bus below the green bus.</td>
<td><img src="#" alt="Image 13" /> <img src="#" alt="Image 14" /></td>
<td><img src="#" alt="Image 15" /> <img src="#" alt="Image 16" /></td>
</tr>
<tr>
<td></td>
<td>My picture shows purple car below the green truck.</td>
<td><img src="#" alt="Image 17" /> <img src="#" alt="Image 18" /></td>
</tr>
<tr>
<td></td>
<td>Set 1</td>
<td>Set 2</td>
</tr>
<tr>
<td>---------------------</td>
<td>----------------------------------------------------------------------</td>
<td>----------------------------------------------------------------------</td>
</tr>
<tr>
<td>My picture shows the girl in front of the boy.</td>
<td><img src="image1.png" alt="Image" /> <img src="image2.png" alt="Image" /></td>
<td><img src="image3.png" alt="Image" /> <img src="image4.png" alt="Image" /></td>
</tr>
<tr>
<td>My picture shows the raccoon in front of the rabbit.</td>
<td><img src="image5.png" alt="Image" /> <img src="image6.png" alt="Image" /></td>
<td><img src="image7.png" alt="Image" /> <img src="image8.png" alt="Image" /></td>
</tr>
<tr>
<td>My picture shows the red car in front of the blue car.</td>
<td><img src="image9.png" alt="Image" /> <img src="image10.png" alt="Image" /></td>
<td><img src="image11.png" alt="Image" /> <img src="image12.png" alt="Image" /></td>
</tr>
<tr>
<td>Behind</td>
<td>Set 1</td>
<td>Set 2</td>
</tr>
<tr>
<td>--------------</td>
<td>-------</td>
<td>-------</td>
</tr>
<tr>
<td>My picture</td>
<td></td>
<td></td>
</tr>
<tr>
<td>shows the</td>
<td></td>
<td></td>
</tr>
<tr>
<td>woman in the</td>
<td></td>
<td></td>
</tr>
<tr>
<td>orange dress</td>
<td></td>
<td></td>
</tr>
<tr>
<td>in front of the woman in the green dress</td>
<td><img src="image1.png" alt="Image" /></td>
<td><img src="image2.png" alt="Image" /></td>
</tr>
<tr>
<td>My picture</td>
<td></td>
<td></td>
</tr>
<tr>
<td>shows brown</td>
<td></td>
<td></td>
</tr>
<tr>
<td>duck in front of the yellow duck.</td>
<td><img src="image3.png" alt="Image" /></td>
<td><img src="image4.png" alt="Image" /></td>
</tr>
<tr>
<td>My picture</td>
<td></td>
<td></td>
</tr>
<tr>
<td>shows the</td>
<td></td>
<td></td>
</tr>
<tr>
<td>blue motor-cycle in front of the red tractor.</td>
<td><img src="image5.png" alt="Image" /></td>
<td><img src="image6.png" alt="Image" /></td>
</tr>
</tbody>
</table>
### Towards

<table>
<thead>
<tr>
<th>My picture shows the boy walking towards me.</th>
<th>Set 1</th>
<th>Set 2</th>
<th>My picture shows the boy walking towards me.</th>
</tr>
</thead>
<tbody>
<tr>
<td>My picture shows the cat walking towards me.</td>
<td></td>
<td></td>
<td>My picture shows tigger coming towards me.</td>
</tr>
<tr>
<td>My picture shows the car driving towards me.</td>
<td></td>
<td></td>
<td>My picture shows the car driving towards me.</td>
</tr>
<tr>
<td>Away</td>
<td>Set 1</td>
<td>Set 2</td>
<td></td>
</tr>
<tr>
<td>------</td>
<td>------</td>
<td>------</td>
<td></td>
</tr>
<tr>
<td>My picture shows the boy walking away.</td>
<td>![Set 1]</td>
<td>![Set 2]</td>
<td></td>
</tr>
<tr>
<td>My picture shows the cat walking away.</td>
<td>![Set 1]</td>
<td>![Set 2]</td>
<td></td>
</tr>
<tr>
<td>My picture shows the car driving away.</td>
<td>![Set 1]</td>
<td>![Set 2]</td>
<td></td>
</tr>
<tr>
<td>My picture shows the plane flying away.</td>
<td>![Set 1]</td>
<td>![Set 2]</td>
<td></td>
</tr>
<tr>
<td>Left</td>
<td>Set 1</td>
<td>Set 2</td>
<td></td>
</tr>
<tr>
<td>-------------------------------------------</td>
<td>--------------------------------------------</td>
<td>--------------------------------------------</td>
<td></td>
</tr>
<tr>
<td>My picture shows the girl on the left.</td>
<td><img src="image1.png" alt="Image" /></td>
<td><img src="image2.png" alt="Image" /></td>
<td></td>
</tr>
<tr>
<td></td>
<td><img src="image3.png" alt="Image" /></td>
<td><img src="image4.png" alt="Image" /></td>
<td></td>
</tr>
<tr>
<td>My picture shows the black dog on the left.</td>
<td><img src="image5.png" alt="Image" /></td>
<td><img src="image6.png" alt="Image" /></td>
<td></td>
</tr>
<tr>
<td></td>
<td><img src="image7.png" alt="Image" /></td>
<td><img src="image8.png" alt="Image" /></td>
<td></td>
</tr>
<tr>
<td>My picture shows the yellow boat on the left.</td>
<td><img src="image9.png" alt="Image" /></td>
<td><img src="image10.png" alt="Image" /></td>
<td></td>
</tr>
<tr>
<td></td>
<td><img src="image11.png" alt="Image" /></td>
<td><img src="image12.png" alt="Image" /></td>
<td></td>
</tr>
<tr>
<td>My picture shows the grey cat on the left.</td>
<td><img src="image13.png" alt="Image" /></td>
<td><img src="image14.png" alt="Image" /></td>
<td></td>
</tr>
<tr>
<td></td>
<td><img src="image15.png" alt="Image" /></td>
<td><img src="image16.png" alt="Image" /></td>
<td></td>
</tr>
<tr>
<td>My picture shows the blue train on the left.</td>
<td><img src="image17.png" alt="Image" /></td>
<td><img src="image18.png" alt="Image" /></td>
<td></td>
</tr>
<tr>
<td></td>
<td><img src="image19.png" alt="Image" /></td>
<td><img src="image20.png" alt="Image" /></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Set 1</td>
<td>Set 2</td>
<td></td>
</tr>
<tr>
<td>----------------------</td>
<td>-----------------------------------------------------------------------</td>
<td>-----------------------------------------------------------------------</td>
<td></td>
</tr>
<tr>
<td>My picture shows the boy on the right.</td>
<td><img src="image1" alt="Set 1: Boy" /> <img src="image2" alt="Set 1: Girl" /></td>
<td><img src="image3" alt="Set 2: Boy" /> <img src="image4" alt="Set 2: Girl" /></td>
<td></td>
</tr>
<tr>
<td>My picture shows cat on the right.</td>
<td><img src="image5" alt="Set 1: Cat" /> <img src="image6" alt="Set 1: Turtle" /></td>
<td><img src="image7" alt="Set 2: Cat" /> <img src="image8" alt="Set 2: Turtle" /></td>
<td></td>
</tr>
<tr>
<td>My picture shows the yellow car on the right.</td>
<td><img src="image9" alt="Set 1: Car" /> <img src="image10" alt="Set 1: Plane" /></td>
<td><img src="image11" alt="Set 2: Car" /> <img src="image12" alt="Set 2: Plane" /></td>
<td></td>
</tr>
<tr>
<td>Control Sets</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>--------------</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Set 1</td>
<td>Set 2</td>
<td></td>
</tr>
<tr>
<td>My picture</td>
<td>![Image of Set 1]</td>
<td>![Image of Set 2]</td>
<td></td>
</tr>
<tr>
<td>shows the</td>
<td>My picture shows the circle above the</td>
<td>My picture shows the circle above the</td>
<td></td>
</tr>
<tr>
<td>star above</td>
<td>circle.</td>
<td>triangle.</td>
<td></td>
</tr>
<tr>
<td>the circle.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>My picture</td>
<td>![Image of Set 1]</td>
<td>![Image of Set 2]</td>
<td></td>
</tr>
<tr>
<td>shows the</td>
<td>My picture shows the rectangle below the</td>
<td>My picture shows the star below the</td>
<td></td>
</tr>
<tr>
<td>rectangle</td>
<td>diamond.</td>
<td>square.</td>
<td></td>
</tr>
<tr>
<td>below the</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>diamond.</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

My picture shows the star above the circle.
My picture shows the circle above the triangle.
My picture shows the rectangle below the diamond.
My picture shows the star below the square.
Appendix B
Stimuli Used in Mental Rotation Task

<table>
<thead>
<tr>
<th>Degree</th>
<th>Same</th>
<th>Different</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td><img src="image" alt="Panda" /></td>
<td><img src="image" alt="Panda" /></td>
</tr>
<tr>
<td>60</td>
<td><img src="image" alt="Panda" /></td>
<td><img src="image" alt="Panda" /></td>
</tr>
<tr>
<td>90</td>
<td><img src="image" alt="Panda" /></td>
<td><img src="image" alt="Panda" /></td>
</tr>
<tr>
<td>120</td>
<td><img src="image" alt="Panda" /></td>
<td><img src="image" alt="Panda" /></td>
</tr>
<tr>
<td>150</td>
<td><img src="image" alt="Panda" /></td>
<td><img src="image" alt="Panda" /></td>
</tr>
<tr>
<td>180</td>
<td><img src="image" alt="Panda" /></td>
<td><img src="image" alt="Panda" /></td>
</tr>
</tbody>
</table>
Appendix C

**Language Background form for Signers**

**Developing Relations Between Spatial Language and Spatial Cognition**

Institute of Child Development
University of Minnesota

Name: ________________________________

Birthdate: ____________________________

Highest education attained:  
High School 
Some college  
AA degree  
BA/ BS degree  
MA/MS degree  
Ph.D. degree

**American Sign Language Background:**

How long have you been exposed to ASL?  
Since birth  
OR  
Since:  
1 month old- 6 months old  
6 months old – 1 year old  
1 year old – 1.5 years old  
1.5 years old – 2.0 years old  
2.0 years old – 2.5 years old  
2.5 years old – 3.0 years old  
3.0 years old – 3.5 years old  
3.5 years old – 4.0 years old  
4.0 years old – 4.5 years old  
4.5 years old – 5 years old

OTHER: ____________________________

Do you have Deaf parents?  Yes  No

Do you have Deaf siblings?  Yes  No

Do you have other Deaf family members?  Yes  No
How many hours a week do you use and see ASL?

Never
Rarely
Occasionally
1-3 hours
3-6 hours
6-9 hours
Constantly

Who do you sign with? (e.g. family, co-workers, friends)

Circle which signing style you consider yourself to use most:

ASL
PSE
Signed English
Other

English Background:

Please circle the language(s) you used most when you first learned English:

Pidgin Signed English
Signed Exact English
Oral spoken English
Written English only
ASL

When did you first start learning English?

Since birth
OR
Since I was:
1 month old - 6 months old
6 months old – 1 year old
1 year old – 1.5 years old
1.5 years old – 2.0 years old
2.0 years old – 2.5 years old
2.5 years old – 3.0 years old
3.0 years old – 3.5 years old
3.5 years old – 4.0 years old
4.0 years old – 4.5 years old
4.5 years old – 5 years old

OTHER: ____________________

Did you first learn English when you entered school?  
Yes  
No

**Cultural Background**

How strongly would you say you identify with the Deaf culture?  
5= Completely identify with Deaf culture  
1= Do not at all identify with Deaf culture

5 4 3 2 1

Is it important to you to be able to sign ASL well?  
5= very important  
1= not at all important

5 4 3 2 1

Do you ever ask questions to other Deaf ASL users about how best to sign words and sentences in ASL?  
5= I frequently ask Deaf ASL users about signs  
1= I rarely or never ask Deaf ASL users about signs

5 4 3 2 1
Appendix D

Language Background for English Speakers
Developing Relations Between Spatial Language and Spatial Cognition
Institute of Child Development
University of Minnesota

Name: ___________________________

Birthdate: _______________________

Age: ______________

Gender: _______________________

Highest education attained: High School
Some college
AA degree
BA/BS degree
MA/MS degree
Ph.D. degree

Are you a native English speaker?  Yes  No

If no, what is your native language? _____________________

Are you fluent in any other languages?  Yes  No

If yes, which language(s)? _____________________________

At what age did you start learning the other languages? ______________

____________________________

Are you currently learning any other languages but not yet fluent?  Yes  No

If yes, which language(s) _____________________________

Have you ever learned any sign language?  Yes  No

If yes, how old were you? _____________________________
Do you have Deaf friends or family members?
   Yes     No

If yes, what is their relation to you? ________________