NON-LINGUISTIC COGNITIVE EFFECTS OF LEARNING AMERICAN SIGN LANGUAGE AS A SECOND LANGUAGE

by

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Submitted to the Graduate Faculty of

Arts and Sciences in partial fulfillment

of the requirements for the degree of

Master of Arts

University of Pittsburgh

2007

UNIVERSITY OF PITTSBURGH
ARTS AND SCIENCES

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This thesis reports the findings of four non-linguistic experiments with participants from three second language learning groups, students in second semester American Sign Language (ASL2), in fourth semester ASL (ASL4), and students learning Spanish as a point of comparison. These experiments provide evidence that the spatial-visual modality of ASL impacts the effects of language learning. Participants completed two face-processing tasks, the Benton Facial Recognition Test (BFRT) and the Mooney Faces Closure Test (MFCT), and two spatial relations tasks, a Mirror Reversal/Mental Rotation test (MR) and the Differential Aptitude Test-Space Relations (SR).

Previous research has found deaf native signers have increased facial recognition skills (McCullough & Emmorey, 1997; Bettger et al., 1997) and that hearing signers have increased face-processing skills (Arnold & Murray, 1998). Deaf late learners of ASL and hearing signers outperformed hearing non-signers on the BFRT (Bettger et al., 1997). However, on the MFCT, signers showed a slight disadvantage (McCullough & Emmorey, 1997). Existing research finds native signers have increased skills on mirror reversal tasks (Masataka, 1995) and mental rotation tasks (Emmorey, Kosslyn, & Bellugi, 1993). Some research has found that hearing ASL L2 participants outperform new ASL L2 participants and non-signers (Talbot & Haude, 1993). Research results are inconsistent about non-linguistic signing advantages. Research on ASL as an L2 is limited. This paper adjoins non-linguistic task results and begins to address when in the L2 progression effects are found.

Participants' scores on these four tests were analyzed using a series of one-way ANOVAs. When the language group was a significant ($p<.05$) factor, a post-hoc (Tukey's HSD) analysis determined which language groups significantly differed. ASL2 and ASL4 scores on the MR task were significantly different from the Spanish group. Moreover, Wilcoxon Signed Ranks Test confirmed significant, but not consistent, differences in accuracy between same and reversed test items in the higher rotation categories for each language group. These results suggest that mirror reversal and mental rotation may be separate skills that are both correlated with signing. Results also indicate that ASL may serve as spatial relations training, supporting a psycho-social response for gender differences on spatial relation tasks.

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1.0 INTRODUCTION

This quasi-experimental design looked for non-linguistic cognitive effects from learning American Sign Language (ASL) as a second language (L2) among hearing adults. The finding of cognitive benefits, outside of language skills, from learning another language may have implications in cognitive process theory, gender differences on spatial relations task, and education policy. We have accepted that bilingualism is an advantage for children (Bialystock, 2001; Li, 2003), that learning a second language strengthens the concepts used by both languages (Cummins, 1984), and that even cross-modal bilingualism (ASL-English) has linguistic benefits. Research has shown that learning ASL improves hearing children's English vocabulary (Daniels, 1993; Daniels, 1994; Daniels, 1996) and English reading skills (Bowen, Mattheiss and Wilson, 1993; Sydnor, 1994). Other cognitive benefits might occur as well. Experience with a visual-spatial language may influence cognitive processes (Keehner and Gathercole, 2007) and cognitive speed. Spoken language research has indicated that being bilingual strengthens children's ability to inhibit misleading data (Bialystok and Codd, 1997). With the modal difference and historical resistance to recognize signed languages as natural languages, signed languages have been linguistically analyzed only since the 1960's. ASL, even as the most studied sign language, is profoundly understudied. Cross-modal linguistic studies are recognized as an area to be further studied (Pavlenko, 2005). This proposed research addresses of the dearth of experiments with English/ASL bilinguals by testing for non-linguistic cognitive effects from learning ASL as a second language in hearing adults. In particular, participants will be asked to complete two face-processing tasks and two spatial relations tasks.

1.1 PREVIOUS RESEARCH ON THE NON-LINGUISTIC EFFECTS OF SIGNING

Some existing research has shown that deaf signers perform differently on some cognitive tasks than hearing non-signers. Emmorey, Kosslyn, and Bellugi (1993) did several related studies on mental image ability. One finding was that ASL signers are more successful than non-signers at generating a mental image of previously seen block letters after prompted by cursive lower case letters. Deaf ASL signers without knowledge of Chinese were more successful in reproducing "pseudo" Chinese characters that were written in the air using point light displays than hearing non-signers. (Klima, Tzeng, Flok, Bellugi, and Corina, 1996).

1.1.1 Face Processing and Signing

Research suggests that face processing and signing are related. During a signed conversation, the "listener" focuses on the face while the arms and hands are perceived through peripheral vision (Isenhath, 1990). The focus on the signer's face facilitates the perception of grammatical features of ASL which are encoded in facial expressions (Baker and Padden, 1978, Liddell, 1977, 1980, Stokoe, Casterline & Croneberg, 1965). Specifically, eyebrow lowering indicates a wh- questions and eyebrow raising indicates a yes/no question. Another example is that adverbial intensifiers like the adverb "very" are expressed by mouthing the "oo" shape. Since facial expressions are incorporated into the grammar of ASL and the face is the focus during communication, many studies have tried to determine if signers have an advantage in remembering faces, recognizing faces, or discriminating faces. Some studies have indicated that ASL does improve face-processing skills but seemingly has no effect on others.

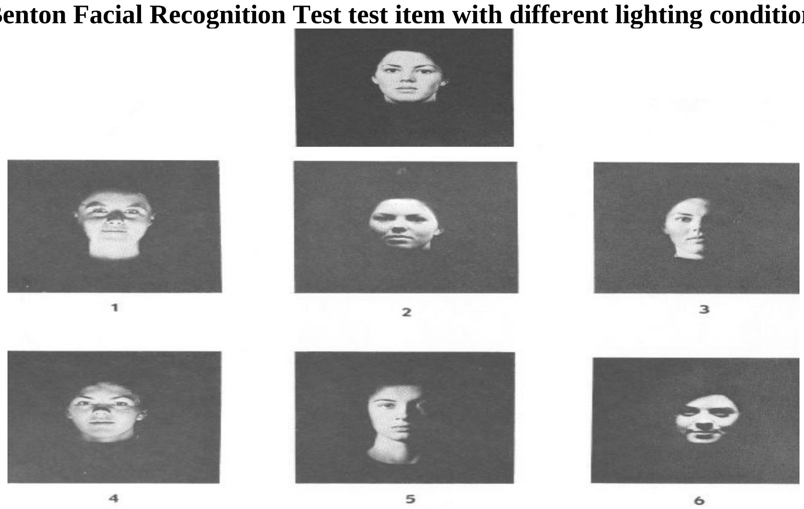
McCullough and Emmorey (1997) used Adobe Photoshop and the Warrington Recognition Test for Faces (Warrignton, 1984) to create three versions of each face, with altered eyes, noses, or mouths. Participants were shown a target face and then had to choose the matching face given two choices with only one facial feature alteration. They found that deaf signers were overall more accurate than hearing non-signers. Further, hearing signers outperformed hearing non-signers when noticing an alteration in the eyes, similar to the deaf signers. However, deaf signers outperformed hearing signers when the alteration was to the face's mouth. McCullough and Emmorey attribute the difference to the deaf participants' additional skill of lip-reading.

McCullough and Emmorey (1997), in a memory test again using the Warrington Recognition Test for Faces test, deaf signers and hearing non-signers were asked to rate faces as "pleasant" or "unpleasant". Then, participants were asked to choose as quickly as possible which one of the two displayed faces they had seen during the "pleasant/unpleasant" task. Neither group performed well on the task; answering accurately only about 71% of the time with similar speed. Since both groups performed close to chance (50%), McCullough and Emmorey repeated the memory test, removing the time pressure, with an additional group of deaf native or near-native signers. They found that this group increased to 81% accuracy; however the standard accuracy with hearing subjects is 87%. Thus, McCullough and Emmorey concluded that an ASL advantage does not exist for remembering or recognizing faces.

Conversely, Arnold and Murray (1998) found that deaf and hearing signers of British Sign Language (BSL) did have an advantage over non-signers for remembering location of specific faces during a game of Concentration using the stimuli from the Warrington test. Deaf signers were more successful than hearing signers; both signing groups were more successful than non-signers. Furthermore, the success on the faces task measured in number of attempts was negatively correlated with the hearing signers' amount of experience with BSL; i.e. the number of attempts needed for success decreased as the amount of experience with BSL increased. The test was also conducted using pictures of objects; without the face stimuli, signers and non-signers performed similarly. This finding indicates that signers did not have a task advantage but did, indeed, have a face remembering advantage. Arnold and Mills (2001) also supports a signing advantage for face memory in their study which replicated Arnold and Murray (1998) with hearing BSL L2 participants.

The Benton Facial Recognition Test (BFRT) has also been used to test for a signing advantage. The test, which is clinically used to test for prosopagnosia (the inability to recognize faces after brain injury) requires participants to match a target face given six test faces in three different conditions: the correct test face image is identical to the target face image, test images match the target image but from different camera angles, and test images match the target image but in different lighting conditions (Benton, Hamsher, Varney, and Spreen, 1983).

Figure 1 Sample Benton Facial Recognition Test test item with different lighting conditions.



Bettger, Emmorey, McCullough, and Bellugi (1997) conducted a series of experiments with the BFRT, noting that the task is discriminating between test faces, not recognizing a previously seen face. Both deaf native signers of ASL and hearing non-signers performed near 100% accuracy on the identical target test condition. Deaf native signers outperform hearing non-signers overall, however, and particularly in the challenging shadow condition.

In another experiment, Bettger et al. (1997) attempted to separate the effects of being deaf, lack of auditory perception, from the effects of learning a visual/spatial language, signing. This test had four groups of participants (N=8 for each group): deaf native ASL signing participants with deaf parents, hearing native signing participants with deaf parents, deaf participants who were late-learners of ASL, and hearing participants who had no signing skills. The researchers found statistically significant differences in the mean percentage correct for each group. First, since the hearing native signers performed like the deaf native signers, the lack of auditory perception did not seem to be the cause of enhanced facial discrimination. Further evidence comes from a study with deaf children who have not learned to sign; these children with the lack of auditory perception and the lack of signing perform like hearing non-signing children on the BFRT (Parasnis, Samar, Bettger, and Sathe, 1996). Therefore, deafness by itself does not seem to be the cause of enhanced facial processing. Second, since the deaf late learners of ASL performed like native signers, learning ASL in early childhood does not seem to be a requirement for cognitive effects (Bettger et al., 1997). To summarize, all three signing groups scored higher than the group of non-signers, and the three signing groups did not differ significantly from one another. In addition, the researchers tested, using a shortened form of the BFRT, three groups of children between the ages of 6 and 9: deaf children who are native signers with deaf parents, deaf children who are not considered native signers with hearing parents, and hearing children who are non-signers. The deaf native signers had the highest scores, matching Bellugi et al.'s (1990) results with native signing children from 3 to 10. However, in the Bettger et al. (1997) study, deaf children with hearing parents did not show a signing advantage over the like non-signing children. This last finding might be the most relevant to the current study because children with hearing parents usually begin learning ASL later and have less exposure to ASL, as are the target population of ASL L2 students beginning learning the language.

Although there seems to be a signing advantage on the BFRT, not all tasks involving face processing show such advantage. For example, the Mooney Faces Closure Test uses high contrast images that require participants to process the entire picture, not the individual facial features.

Figure 2 Sample test stimuli from the Mooney Faces Closure Test.

Participants are asked to view the image and label the face as a boy, a man, an old man, a girl, a woman, or an old woman. When McCullough and Emmorey (1997) gave this test to deaf signers and hearing non-signers, they did not find a sign advantage. In fact, they found a "marginally significant" difference between the groups in which the signers' mean score was lower. The authors suggested that an overreliance on local facial features rather than global explained the lower scores on the MFCT.

Table 1-1 Face Processing: Effects of Signing

Task	Participants	Reseacher(s)
Identifying altered facial features	Deaf signers>hearing non-signers	McCullough & Emmorey, 1997
Concentration-Face Matching	Deaf & hearing BSL signers>non	Arnold & Murray, 1998
Benton Facial Recognition Test	Deaf native signers>hearing non	Bettger et al., 1997
Benton Facial Recognition Test	Deaf very late learners, hearing signers > hearing non signers	Bettger, Emmorey, McCullough, & Bellugi, 1997
Warrington Test-Face Memory	Deaf signers = hearing non-signers	McCullough & Emmorey, 1997
Benton Facial Recognition Test	Deaf children with hearing parents= hearing children	Bettger, Emmorey, McCullough, & Bellugi, 1997
Mooney Faces Closure Test	Hearing non-signers > signers	McCullough & Emmorey, 1997

Although several populations were tested on the BFRT to determine if signing causes enhanced facial processing, several factors in the populations have not been addressed. Firstly, will hearing adults learning ASL as an L2, not as a primary or preferred communication method gain enhanced facial processing skills? If so, will the cognitive effects be seen after only 6 months exposure to ASL or after 18 months exposure, which is even less than the deaf non-native signing children who did not show any advantage. Also, the Bettger et al. (1997) study which showed that signing seemed to be the important factor had a small populations (N=8) in each comparison group. A larger scale study testing for facial processing effects of late-learning signing of a hearing population has yet to be done. Lastly, we do not know if there is any correlation with learning ASL as an L2 and success on the Mooney Faces Closure Test. If some relationship is found, it is unclear if the hearing ASL L2 students will perform like deaf signers, i.e. slightly worse than non-signers.

This face-processing research has implications for our understanding of models of the brain, the part-whole theory, and the possibility that the brain retains its plasticity into adulthood. Current models of bilingualism focus on how two languages are organized in relationship to each other, not to other cognitive skills (Kroll and Tokowicz, 2005). Some (Farah, Wilson, Drain, Tanaka, 1995; even argue that face processing is a separate system than object recognition based on participants with brain injury (Farah, 1996) or a domain specific skill (Nachson, 1995). If learning a second language as an adult offers facial processing advantages, might there be other non-linguistic cognitive effects?

1.2 VISUAL-SPATIAL ABILITIES

It is generally accepted that gender differences are found when testing visual-spatial ability with males outperforming females (Maccoby and Jacklin, 1974). However, it is debated whether the difference is biological (Bock and Kolakowski, 1973; Broverman, Klaiber, Kobayashi, and Vogel, 1968; Kommenich, Lane, Dickey, and Stone, 1978) or environmental, cultural, experience-based difference (Sherman, 1967, Maccoby and Jacklin, 1974). Men generally perform better on tasks requiring the mental rotation of images as if the images were three-dimensional, i.e. rotation on more than one axis (Vandenberg and Kuse, 1978; Linn and Petersen, 1985; Peters, 2005). Men outperform women whether the mental rotation task uses block figures or human figures (Alexander and Evardone, 2007). In a study comparing five different sets of stimuli (alphamumeric characters, PMA symbols, animal drawings, polygons and cube figures), Jansen-Osmann and Heil's (2007) results challenge the conventional generalization that men always outperform women in mental rotation tasks. In their study, only polygons produced male advantage in mental rotation speed and rotational uncertainty. Geiser, Lehmann, and Eid (2006) identified five solution strategies for solving the items on mental rotations test. Their results support that overall males perform mental rotation tasks more accurately and faster than females. They also found that females tended to choose a less successful analytic rather than rotation strategy, which accounted for some of the gender difference. Some research has indicated that training and practice effect mental rotation and mirror reversal tasks. Scores on a short (5 questions with a total of 10 possible points) mental rotation test rose after a single one-hour lecture on spatial abilities (McGee, 1978). Burnett and Lane (1980) treated spatially-related college courses as "training" and found that experience significantly improved women's scores more than men's scores on the test, even though women's scores did not significantly improve overall. Likewise, Johnson, Flinn, and Tyer (1979) considered a drafting course as training between a pre- and post-test of the Witkin's Embedded Figures Test (1971) which asks participants to find an embedded figure as quickly as possible within a complex figure, testing for the spatial relations skill of field independence. They found that all groups (male and female in the drafting course, in the mathematics course, and in the language course) improved but females in the drafting course had significant improvement compared to the other groups. Moe and Pazzaglia (2006) found that scores on a mental rotation test could be manipulated for better or for worse simply by telling participants that a gender was better on that test. Therefore, experience or confidence with spatial relation tasks seems to influence test scores despite any researched gender differences. Emmorey, Klima, and Bellugi (1993) found no gender effects or interaction with gender with the mental rotation and mirror reversal identification task with ASL signers and non-signers.

1.2.1 Visual Spatial Skills and Signing

In addition to the obvious visual aspect of ASL, visual-spatial ability as a cognitive skill is connected to signing because signing allows for space to be included in the language (Bellugi et al., 1990). The pronouns "you" and "me" are obvious examples of how the movement of the sign is dependent on the location of the signer and the referent whereas spoken language has a set phonological form for the concepts. Emmorey, Klima, and Hickok (1998) investigated if ASL affected the ability to reproduce scenes involving location in a space and orientation of the object, two skills necessary for sign language comprehension. They found an advantage for ASL signers for object orientation and for location of objects in scenes requiring mental rotation. A gender difference among the deaf participants was noted by the researchers: males (both hearing and deaf) outperformed females as a group, and deaf signing males outperform hearing males but do not outperform deaf signing females (Emmorey, Klima, and Hickok). Signing, in some way, may encourage the use of a mental rotation strategies rather than analytic strategies that were identified by Geiser et al. (2006). In addition to mental rotation practice, signing also requires mirror reversal detection in order to understand directions and movements given from the signer's perspective. Some signs include left to right movement, for example: a right-handed signer moves her hand from the left to the right, to produce the sign SUMMER. When the sign SUMMER is perceived by the "listener" facing the signer, the movement looks right to left from the listener's perspective. Such mirror reversal may be understood as a visual-spatial skill. For instance, Japanese native signing deaf children showed fewer mirror reversal errors on a tactile perception task requiring the participants to distinguish "p" from "q" (Masataka, 1995). Prior studies also indicate that deaf signers perform a mirror reversal and mental rotation task more quickly than hearing non-signers (McKee, 1987; Emmorey, Kosslyn, and Bellugi, 1993). Furthermore, hearing native signers show similar results to deaf signers in speed and accuracy, outperforming hearing non-signers on the mental rotation task/mirror reversal identification task. Emmorey, Kosslyn, and Bellugi (1993) concluded that signing improved detection of mirror reversals. When the researchers separated the results of the deaf native signers from the deaf non-native signers, they found that the native signers were more accurate than the deaf signers who had later exposure to ASL (Emmorey et al., 1993). Moreover, Talbot and Haude (1993) found that ASL skill level impacted success on a mental rotation task, but the female participants who had increased scores on the mental rotations test were hearing student interpreters with six years of experience. A limitation of the Talbot and Haude study is that the groups varied greatly, in that the beginning ASL L2 learners, as a group, who had a mean of less than one semester of signing experience compared to the successful signing group had a mean of six years. Keehner and Gathercole (2007) studied sign language interpreters who learned British Sign Language as adults with a Corsi blocks paradigm, in which the participants were required to identify blocks in a rotated display. They found that the signers outperformed hearing non-signers on spatial configurations rotated 90° and 180°, but that signers and non-signers were equally successful at configurations rotated 0° which indicates that the rotation, not the task in general, was difficult for the non-signers. Student interpreters (as in the Talbot and Haude study and the Keehner and Gathercole study) may not be representative of most L2 learners. Thus, more research is warranted within the ASL L2 population.

Table 1-2 Signing Effects on Visual-Spatial Abilities

Task	Participants	Reseacher(s)
Mirror Reversal "p" "q"	Native Japanese signers-children	Masataka, 1995
Mental Rotation & Mirror Reversal	Deaf signers, hearing native signers <hearing non-signers	Emmorey, Kosslyn, & Bellugi, 1993
Mental Rotation & Mirror Reversal	Deaf native signers < deaf non-native signers	Emmorey, Kosslyn, & Bellugi, 1993
Mental Rotation Test	Female Hearing ASL interpreters> hearing non-signers, beginning ASL L2 learners	Talbot & Haude, 1993
Corsi Blocks Paradigm	Non-native hearing BSL interpreters> hearing non signers	Keehner and Gathercole, 2007

1.3 THE CURRENT PROJECT

1.3.1 Introduction

The main goal of this work is to attempt to discover if cognitive effects are seen within two or four semesters of ASL L2 learning. It is unclear if exposure to ASL, without explicit training in 3-D mental rotation or mirror reversal will positively affect the mental rotation skills. A second goal is to discover when in the L2 progression (in two semesters or in four semesters) the cognitive effects can be found. If ASL enhances cognitive skills of mental rotation and mirror reversal perhaps ASL should be a preferred language in the school systems. The benefits would be more than greater communication skills, but also greater spatial skills that are used in a variety of situations. For example, spatial ability has been found to be positively correlated with the quantitative section of the Scholastic Aptitude Test (SAT) (Burnett, Lane, and Dratt, 1979). Moreover, gender differences in spatial relation skills can be neutralized if signing experience is correlated with higher spatial relations skills. From a pedagogical perspective, the results may guide ASL teachers to additional practice activities.

This is a cross-sectional study of two face-processing tests, the Benton Facial Recognition Test (which may be a labeled a face discrimination task) and the Mooney Faces Closure Test (which tests gestalt face processing), and two spatial relations tests, the Mirror Reversal/Mental Rotation Test and the Differential Aptitude Test-Space Relations. Specifically, I will determine if 6 months (ASL 2) or 18 months (ASL 4) exposure to ASL affect success on these tasks. I hypothesized that participants with 18 months exposure to ASL will show increased success because ASL 4 students may be able to focus on signers' faces rather than hands; but participants with 6 months experience will perform like non-signers on the BFRT. I predicted that all participants (signers at both levels and non-signing controls) will perform similarly on the MFCT because the signing experience will not be sufficient enough to cause an over-reliance on individual facial features. I made two predictions concerning the mental rotations tasks. First, participants with 18 months exposure of ASL will show increased success on both of the visual-spatial tasks, the Mirror Reversal Test and the Space Relations test, but participants with 6 months exposure will perform like control participants (non-signers) because they will not yet have mastery of the spatial aspects of ASL grammar, which would improve performance on the spatial relations test. Second, the scores on both of the visual-spatial of female participants will differ to a greater degree than the scores of male participants; more ASL experience will positively correspond with accuracy on the task for female participants; male participants generally will have higher scores which will show smaller gains from ASL exposure.

1.3.2 Structure of the Thesis

Chapter Two describes the face processing experiments. Chapter Three explains the spatial relations experiments. Chapter Four focuses on the comparison of the face-processing and spatial relations results. Chapter Five summarizes and concludes the thesis.

2.0 FACE-PROCESSING EXPERIMENTS

2.1 METHODOLOGY

2.1.1 Participants

This research tested for advantages from experience of ASL as an L2. Signing participants were recruited from students in second semester ASL classes (ASL 2) and fourth semester ASL classes (ASL 4) at the University of Pittsburgh during the spring semester 2007. The ASL L2 population is often overlooked in linguistic research because most ASL studies strongly favor native signers. I requested volunteers from seven (7) ASL 2 classes and from both ASL 4 classes.

Control groups of non-signers of similar age and education level were students in second semester Spanish classes (SPAN2) and in fourth semester Spanish classes (SPAN 4) to test if learning any second language effects scores on the tasks. I requested volunteers from seven (7) of the twelve SPAN2 classes and from four (4) of the seven SPAN4 classes.[1]

During the language classroom recruitments, students were given sign-up sheets that listed the data collection times. At this stage, 143 students had volunteered, but only 70 students participated, approximately 50% of those who initially volunteered. 38 participants reported being in ASL classes (21 in ASL 2 and 17 in ASL 4) with the remaining 32 participants being in the Spanish group. The participants were not compensated for their participation. All participants reported normal vision and hearing. Language experience data was collected. All participants were self-reported native English speakers. The complete participant survey is found in Appendix A.

[1] A third control group of non-signers were to be students who enrolled in the first semester ASL classes for the upcoming Fall semester. This third control group was an attempt to determine if students who choose to take ASL are already better at face processing or visual-spatial abilities. The not-yet-signing ASL students were contacted by email from the enrollment list. Despite recruitment emails to over 160 students, no pre-ASL students participated in the quasi-experiment.

Data from three SPAN participants were excluded after the fact because they reported ASL experience that was not "minimal." Two of the three excluded Spanish students reported ASL experience but did not describe what experience they had. The third had ASL classes in middle school and in high school. Three additional SPAN students had minimal ASL experience, i.e. knowledge of the fingerspelling alphabet or random signs, and were not excluded. A total of seven participants (four ASL and three SPAN) were excluded from the analysis because they reported a higher proficiency in another language (German, Hebrew, etc.) than either ASL or Spanish, which would mean that the ASL or Spanish would not be the L2 of the participant. In sum, the data from ten participants (six from the SPAN group, two from each of the ASL groups) were excluded after the fact in an attempt to control for language experience.

A one-way ANOVA test revealed that the only significant demographic difference between the groups is age ($F[2,52] = 5.842$, $p = .005$). A post-hoc Tukey's analysis revealed that the ASL 4 group, with a mean age of 21.83 (SD 2.3), was significantly older than both the Spanish participants who had a mean age of 19.6 (SD 1.8) ($p = .004$) and the ASL 2 participants, who had a mean age of 20.0 (SD 1.8) ($p = .032$). The ASL 2 group did not differ from the Spanish group ($p = .773$). The age difference may be related to the number of classes offered in each language and the registration preference given to students with more credits. With fewer ASL classes offered by the university, maybe the ASL classes were filled before younger students were able to enroll. Note that one 27 year-old female in the ASL4 group is outside the rest of the population, skewing the mean.

2.1.2 Materials

The specific cognitive tests are described in detail in sections 2.2.1 and 2.3.1. In order to computerize the data collection process, the tests were scanned to PDF format at 400 pdi using CanoScan LiDE60. The test questions were presented using Revolution software program by

Runtime Revolution Limited. The tests were computerized with an effort to keep the computerized version as close to the paper version as possible. To this end, the test directions and practice items were maintained with only minor modifications. Participants used the computer's mouse to click on their answer choice rather than circling or marking an answer. One time limit was imposed from the original test, the Benton Facial Recognition Test. See description of the individual tests below for details. Participants could review the instructions for as much time as they wanted. The entire testing time was approximately one-half hour. The participants were required to answer each question before the next question was shown. The Revolution program recorded the participants' answers and response times in seconds.

2.1.3 Data collection

Data from the language students was collected in a two-week span in March at the University of Pittsburgh's Robert Henderson Language Media Center during six 1-hour time slots reserved for the experiment. The time slots were chosen by availability of the lab space and varied by day and time for the maximum participation opportunity. There were no noticeable differences in the environmental conditions during the different data collection sessions.

The participants were randomly given a non-identifying numeric code 1 - 200. Only the code was attached to the study data. Participants used the identifying code to enter the Revolution program. Since the program ran independently on each computer, the participants began the experiment program when ready and could continue at his/her own pace within the time limits imposed n the test (if any). Each participant took all four tests, but the order of the tests varied. Participants who were assigned numbers 1 - 100 inclusive completed the face processing tests, BFRT and MFCT, and then completed the space relations tests, Mirror Reversal, and DAT-Space Relations. Participants who were assigned numbers 101-200 inclusive completed the space relations tests, Mirror Reversal and DAT-Space Relations Test, and then the face processing tests, BFRT and MFCT. I chose limited counter-balanced ordering for practical reasons. The two test order groups' means were analyzed using independent sample t-test. Test order was not a factor for any of the tests ($p.>.10$). The individual test items for both forms appeared in the same order within each subtest. At the beginning of each subtest, instructions were displayed until the participant clicked the continue box prompt to continue. A summary of the directions (Appendix B) were also posted on the side of the computer. Participants were encouraged to try to answer correctly but to make the best guess if unsure. The Revolution software program recorded the participants' answers, tabulated the raw scores and response times, and stored the results under the participation code. The response times were collected to show possible increased speed effects if participants reach accuracy ceiling on one or all subtests.

After the completion of the experiment, the participants were asked to complete the demographic information survey, (see Appendix A). The demographic information from the survey was stored with the participant's answers and response times under the participants' code.

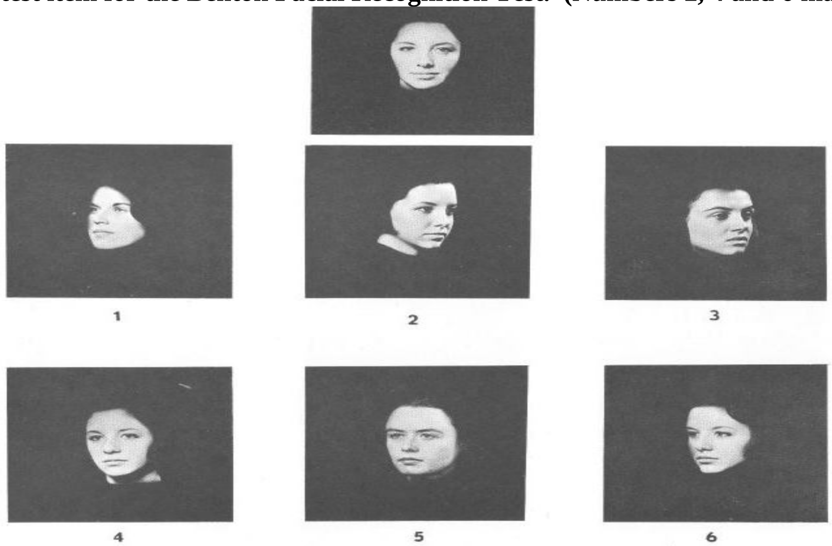
The raw scores of the two signing levels, ASL 2 and ASL 4, and SPAN, on each of the four subtests were imported into MicroSoft Excel and summarized. The Null Hypotheses for each test is that the scores of the three groups will not differ significantly ($p<.05$) because learning a second language, ASL or Spanish, will have no effect on the students' non-linguistic cognitive skills tested. Using SPSS software, participants' scores and total test times were compared using one-way ANOVA with language group as the independent variable. When language group was found to be a significant factor, I ran a post hoc test -Turkey's HSD to determine which language groups differed significantly. SPSS was also used to determine Pearson's bivariate correlation coefficients for reaction times on the face-processing tests and for accuracy scores between tests. The sample size did not allow for looking for an effect of handedness, ethnicity, other foreign language experience, or ASL teacher. A separate ANOVA analyzed the data based on the participants' proficiency as self-reported. Language proficiency was considered because proficiency may be a more important factor than age of acquisition (Abutalebi, Cappa, and Perani, 2005). Since the participants in this study are adult L2 learners, proficiency may be more relevant than age of acquisition.

2.2 BENTON FACIAL RECOGNITION TEST

2.2.1 BFRT Description

The researcher purchased the Benton Facial Recognition Test from the publisher, Psychological Assessment Resources, Inc. This face processing test was chosen to replicate previous research by Bettger, Emmorey, McCullough, & Bellugi, (1997) but focusing on ASL L2 learners. The test presents a target face, and participants have to recognize the target face in the six choices. The Benton Facial Recognition Test was altered to include a time constraint. This test included two sections. The first section, in which the target faces were well-lit frontal view, had one answer which exactly matched the target. For this first section of this test, each test item was shown, one at a time, for exactly 20 seconds. A time limit was added as a challenge because nearly all of the participants reached ceiling on this section of test items on a previous BTFR experiment (Bettger, Emmorey, McCullough, and Bellugi, 1997). The second part had three correct answers per test item asking participants to choose three faces in varied profile angles. On average, this test took less than five minutes to complete. See section *2.2.2 BRFT Results and Discussion* for details.

Figure 3 Sample test item for the Benton Facial Recognition Test. (Numbers 2, 4 and 6 match the target face.)

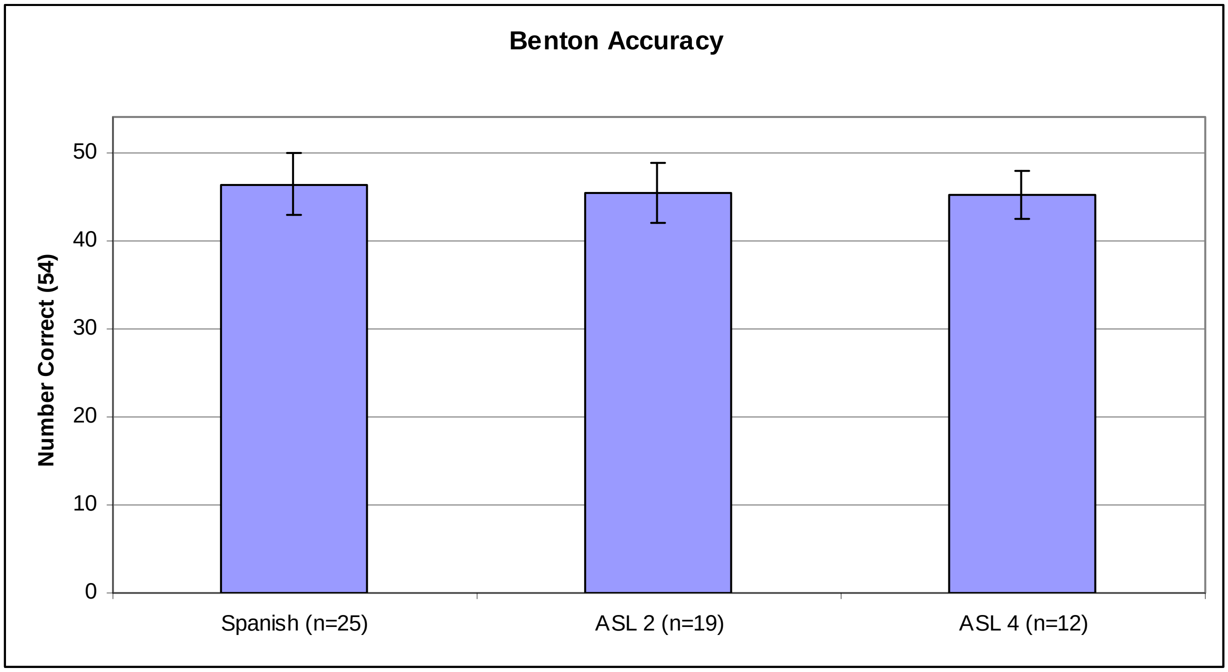


Every correct answer was counted; thus, when there were three right answers in one test item, three points can be earned. Having all correct answers for a single test item is not necessary to earn points. The raw scores were totaled per subtest and per section for the BTFR. Four participants had outlier scores (<27); those participants were excluded from the analysis for this subtest.

2.2.2 BFRT Results and Discussion

I hypothesized that participants with 18 months exposure to ASL will show increased success because ASL 4 students may be able to focus on signers' faces rather than hands; but participants with 6 months experience will perform like non-signers on the BFRT. The following figure shows the mean accuracy and standard deviations of the three language groups.

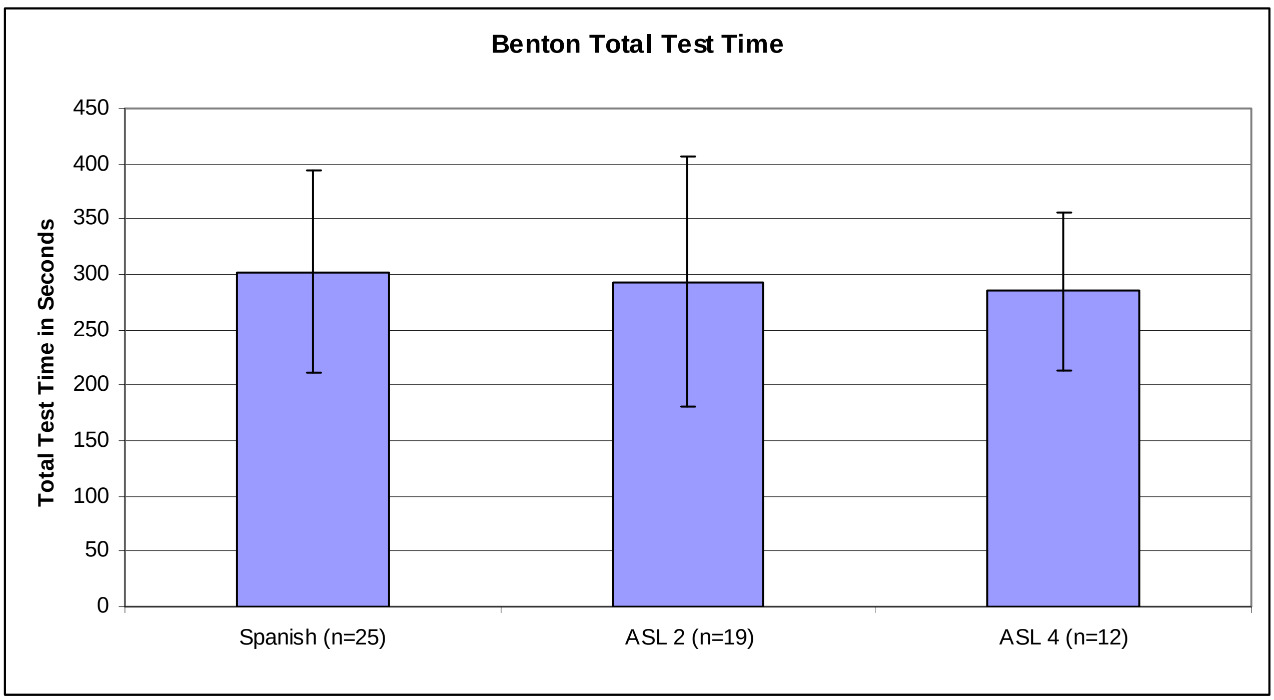
Figure 2- 1



The Benton Facial Recognition Test had a possible top score of 54, as noted on the y-axis. Scores on this test ranged from 35 – 52. No participant achieved a perfect score on the BFRT. Adding a twenty- second time limit for the first section of the task did not seem to have an impact, since all but two participants had a perfect score on the timed section. The mean of the participants enrolled in Spanish classes is 46.36 (SD 3.47). The mean of the participants enrolled in ASL 2 classes is 45.42 (SD 3.45), and in the ASL 4 classes is 45.17 (SD 2.76). Since the difference between groups is less than the differences within each group, it is clear that there is no meaningful difference between the accuracy of the three groups in the study (F [2, 53] =.693, p = .505). I had expected that the Spanish group's scores would be similar to Bettger et al.'s (1997) non-signing group and that the ASL L2 groups would score between deaf native signers and the non-signing groups. All three of the language groups in the current study scored between hearing non-signers and more successful deaf signers in a previous study (Bettger et al., 1997) using the original BFRT. It is unclear why the non-signing Spanish group in the current study (mean 86.7%) would score above hearing non-signers in the previous study (mean 81.7%.) One plausible explanation is that the current study drew participants from the college population, but the previous study drew participants from the community; and that difference makes comparisons of the results difficult.

In addition to the participants' accuracy on the BFRT, the participants' total test time was also recorded. By total test time, I mean the total time the participant took to complete one entire test. Total test time is comparable to reaction time because the participants' total test time is the sum of the individual test items' reaction times. Total test time does not include the time the participant spent reading the test directions. Although the accuracy is approximately the same for each group, the total time in which the groups took to complete the task may differ. Figure 2-2 shows the mean time in seconds to complete the BFRT.

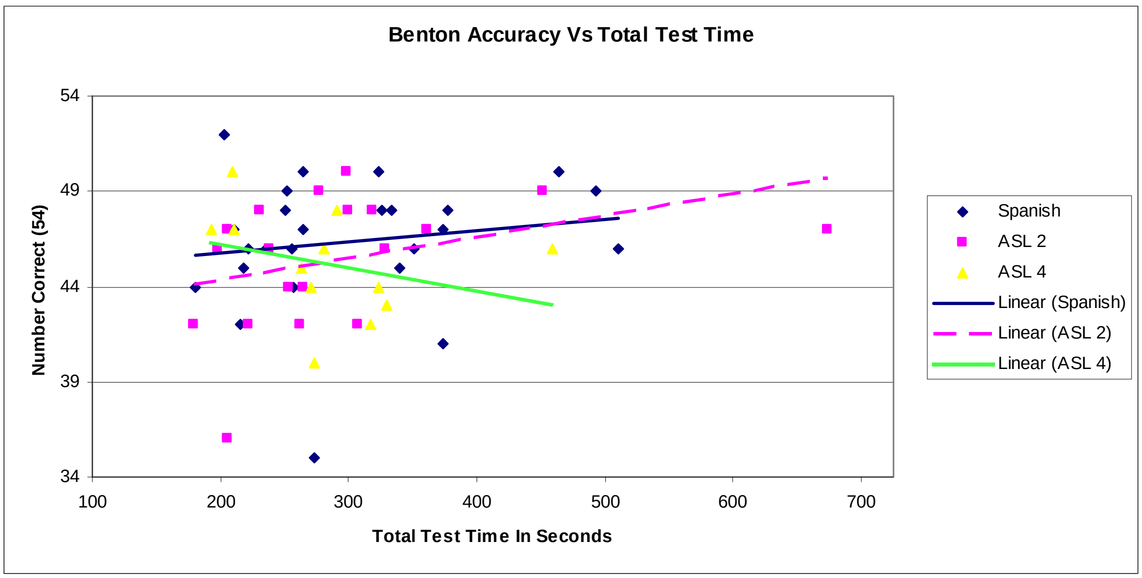
Figure 2- 2



Participants in the Spanish condition had a mean time of 303 seconds (SD 91.09); participants at the ASL 2 level had a mean time of 293 seconds (SD 112.94), and participants at the ASL 4 level took 285 seconds (SD 71.09). The difference between the ASL 4 group, which had the lowest mean time, and the Spanish group, which had the highest mean time, is only 19 seconds, yet the standard deviations are all over 70 seconds. Although the groups' means do lower with an increase in ASL experience, the difference in time the participants took in completing the test was insignificant based on the relatively large standard deviations ($F [2,53] = .146$, $p = .864$). Bettger et al. (1997) did not report total test time or reaction time.

One interesting trend did appear when the participants' accuracy was plotted against the participants' total test time when grouped by class. The following figure compares each participant's accuracy against total test time.

Figure 2- 3



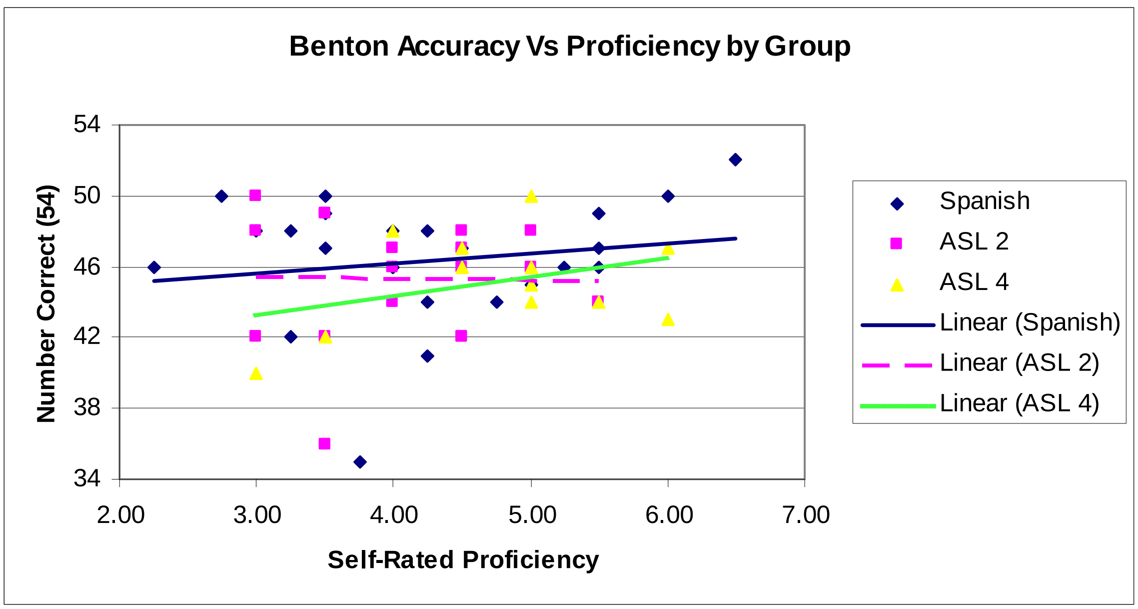
As the figure illustrates, more time to complete the task influenced the participants' accuracy. Extra time did not help nor hinder the Spanish students' accuracy. The Spanish groups' trend line was almost flat. The ASL 2 students responded similarly, but there is a slight tendency that taking more time may correlate with increased accuracy. It might be expected that an increase in time would correlate with an increase in accuracy, i.e., slowing reaction time may increase the likelihood of a correct answer. However, taking more time to complete the task was weakly correlated with lower scores in the ASL 4 group. None of the correlations reached significance. The following table summarizes each group's Pearson's correlation.

Table 2- 1 Benton Accuracy Vs Total Test Time

Language Group	Regression Equation	R^2	Sig. (2-tailed)
Spanish	y = 0.006x + 44.553	0.0245	.455
ASL 2	y = 0.0112x + 42.145	0.1335	.124
ASL 4	y = -0.0122x + 48.64	0.0986	.320

Proficiency level was also considered as a possible factor correlated with higher scores or with total test time. For this analysis, one additional participant's data was excluded in the proficiency analysis because proficiency was not given. In the following figure, proficiency is plotted against accuracy on the BFRT.

Figure 2- 4



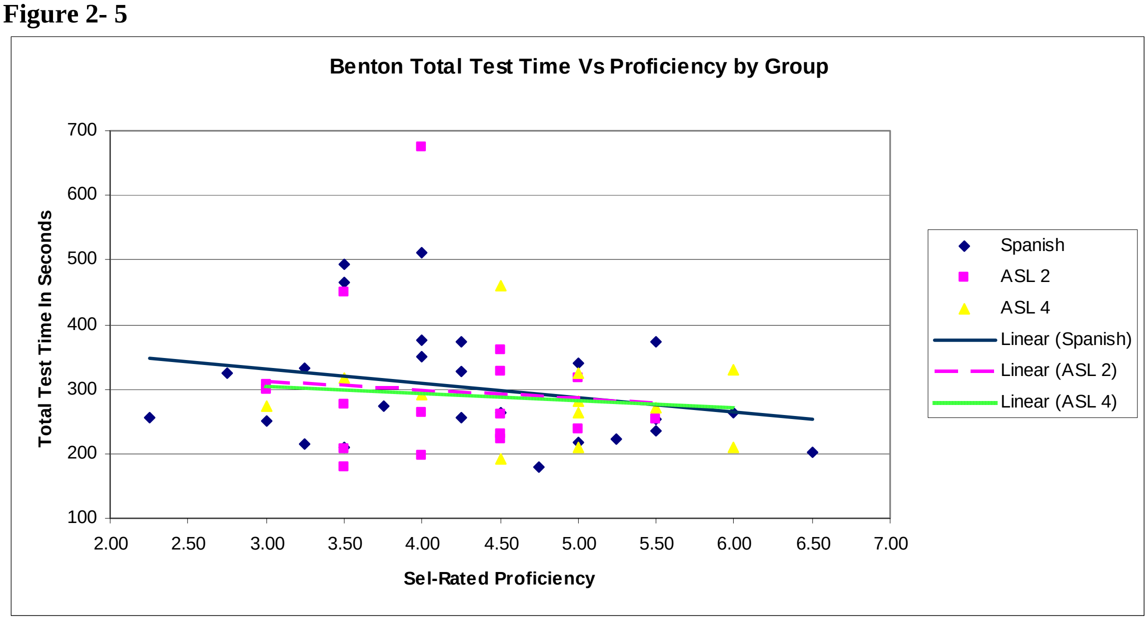
This figure maps, by language group, the participants' accuracy on the BFRT by self-rated proficiency. The participants' self-reported proficiency ranged from 2.25-6.5. Most scores were between 40 and 50. Overall the Spanish group's trend line is higher, i.e. at the same proficiency rating, Spanish students generally had a higher accuracy. For example at the 3.5 and the 5.5 rating levels, the participants in the Spanish classes at those levels had higher scores than the participants in the ASL classes. The trend line for the ASL 2 participants is generally lower than the Spanish group's trend line but higher than the ASL 4 group's trend line (except at proficiency levels above 5.0). The trend line representing the participants enrolled in Spanish is a slightly positively correlated slope, i.e. an increase in self-rated proficiency correlates with an increase in accuracy on the BFRT. The trend line representing the participants enrolled in ASL 4 also had a positively correlated slope, but the trend line representing the participants enrolled in ASL 2 is nearly flat. No distinct pattern emerged from the comparison. The following table summarizes each group's correlation of accuracy and self-reported proficiency.

Table 2- 2 Benton Accuracy Vs Proficiency

Language Group	Regression Equation	R^2	Sig. (2-tailed)
Spanish	y = 0.5699x + 43.921	0.0304	.404
ASL 2	y = -0.0882x + 45.691	0.0003	.942
ASL 4	y = 1.0811x + 40.032	0.1292	.251

The data do not indicate a difference in accuracy based on proficiency, but maybe the task was completed more quickly by the participants who described themselves as more proficient. The following Figure displays the participants' total test time to complete the BFRT in seconds vs. the participants' self-rated proficiency level.

Figure 2- 5



In this figure, the participants total test time was plotted against their self-rated proficiency levels. The figure illustrates that participants at the same proficiency had a wide range of total test time. For example, participants who rated themselves at 4.0 had, 198 seconds -674 seconds. Participants at the 5.0 rating seemed to complete the test at more compact time frame (218 seconds- 340). All three classes show a slight decrease in total test time with an increase in self-rated proficiency. The trend lines show a possible relationship-an increase in speed with an increase in proficiency, with approximately 60 seconds between the lowest proficiency participants and the highest. Referring back to Figure 2-4 Benton Accuracy by Proficiency, participants generally did not sacrifice accuracy for speed. Proficiency and total test time may be negatively correlated (i.e. with more proficiency less time is needed to complete the task). But, again, it may be that people who think they are proficient also confident to complete the task more quickly. However, the results do not reach significance. The following table summarizes each group's correlation of speed and self-reported proficiency. Language group does not seem to affect the interaction between total test time and proficiency.

Table 2- 3 Benton Total Test Time Vs Proficiency

Language Group	Regression Equation	R^2	Sig. (2-tailed)
Spanish	y = -22.777x + 400.12	0.0708	.199
ASL 2	y = -12.824x + 350.12	0.007	.741
ASL 4	y = -11.649x + 340.41	0.0226	.641

Overall, the first experiment did not yield significant results. I had predicted that participants with 18 months signing experience (ASL 4) would have an increase in success because ASL experience encourage more time focusing on faces, but no clear increase in accuracy or total test time was found. Bettger et al. (1997) found that signers had significantly higher mean percentage correct on the BFRT than the non-signers. Perhaps signing groups at this level of L2 experience (less than two years) do not differ from non-signing groups. Another possibility is that the addition of a time limit on the first section of the test obscured a difference in reaction time, i.e. without an imposed time limit, perhaps participants would have had varied total test times. Reviewing previous BFRT research with ASL participants, the ASL L2 groups in the current study did score between the non-signers and the native signers from the previous experiment, which is expected. However, the non-signing group in the current experiment outscored the non-signing group from the previous experiment, which is unexpected. Upon closer comparison, the previous experiment tested community members (without mention of education level) and the current study tested college students. It may be that college experience was a factor in the results.

2.3 MOONEY FACES CLOSURE TEST

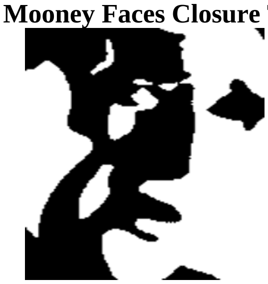
2.3.1 MFCT Description

The Mooney Faces Closure Test[2] (Mooney, 1956) requires participants to identify high contrast pictures as a girl, a boy, a young woman, a young man, an old woman, or an old man. The Mooney Faces Closure Test did not include a time constraint, but the participants were aware that the test was being timed. The average total test time was under three minutes, but one participant took over five minutes and another took over seven minutes to complete the MFCT. Thirty-five stimuli were presented, and the six possible answers were offered with each stimulus. All six answers were offered to limit guessing based on which choices were given for the stimulus. McCullough and Emmorey (1997) only offered four possible answers for each test question. Since the original photographs were not available to determine the correct answer, the correct answers were chosen by consensus between the principal investigator and faculty advisor. If the test item was ambiguous, two answers were accepted as correct. The stimuli were not evenly distributed between the possible answers. So, although a chance score would be 1 out of 6 or 16.67%, a participant who chose “adult man” for each test item would earn 37%, but no participant chose the

[2] I thank Marianne Latinus for supplying the test stimuli.

same answer throughout the test. The thirty-five stimuli and accepted answers are listed in Appendix C.

Figure 4 Sample test item from the Mooney Faces Closure Test. (This is an adult man.)

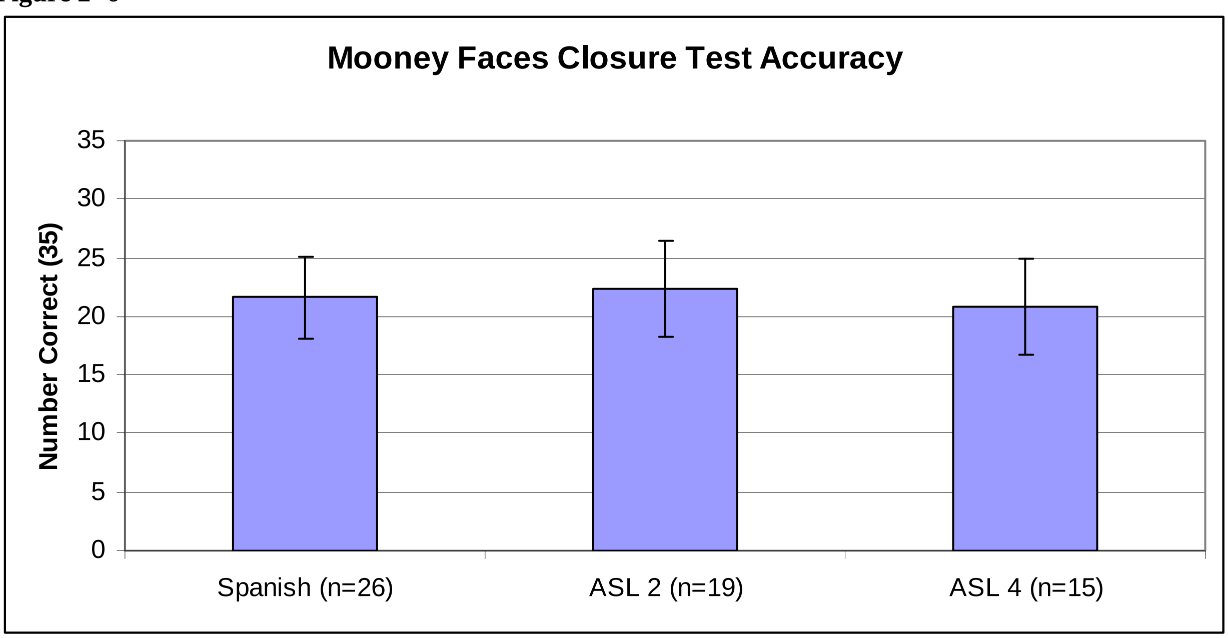


The participants are the same as the BFRT. The MFCT was conducted at the same time as the BFRT. The MFCT always followed the BFRT.

2.3.2 MFCT Results and Discussion

I predicted that all participants (signers at both levels and non-signing controls) will perform similarly on the MFCT because the signing experience will not be sufficient enough to cause an over-reliance on individual facial features, which McClullough and Emmorey (1997) suggested might have been a factor in the signing group scoring below the hearing group. The following figure gives each group's mean score.

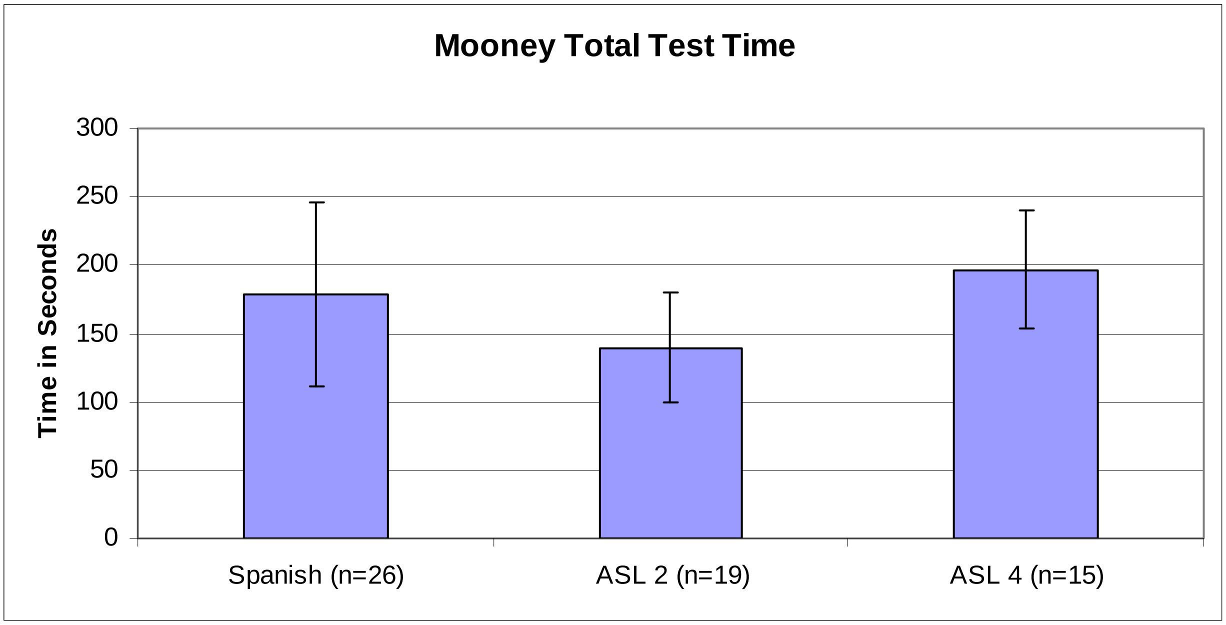
Figure 2- 6



The three groups' scores did not differ. The top score (from two participants) was 29 or approximately 82% accuracy. The lowest score was 13 which equates to 37% accuracy. The mean for all participants was 21.65 (nearly 62%), which nearly matches each groups' mean score. The participants taking Spanish as a foreign language had a mean of 21.65 (SD 3.47). The participants enrolled in ASL 2 had a mean of 22.31 (SD 4.06) and the participants enrolled in ASL 4 had a mean of 20.8 (SD 4.10) correct out of 35 test items. As the error bars illustrate, the difference in the scores within a group is greater than the difference between groups and was not found to be significant ($F[2,57]= .656$, $p = .523$). McCullough and Emmorey (1997) tested deaf ASL signers and hearing non-signers with the same task, but with a slightly different procedure. In this previous study, participants chose from only four choices, rather than six. Their results showed higher accuracy percentages, with hearing subjects outscoring deaf signers ($F[1, 46, 3.64]=3.64$, $p<.07$). All three language groups in the current experiment scored below both groups in the McCullough and Emmorey experiment. Perhaps the increase in answer choices resulted in an increase in difficulty in the current experiment. Regardless, the current experiment did not pattern with the previous experiment. One explanation is that the ASL L2 language groups do not have an "overreliance" on individual facial features that McCullough and Emmorey suggested might explain the deaf participants' poorer performance on this gestalt closure task.

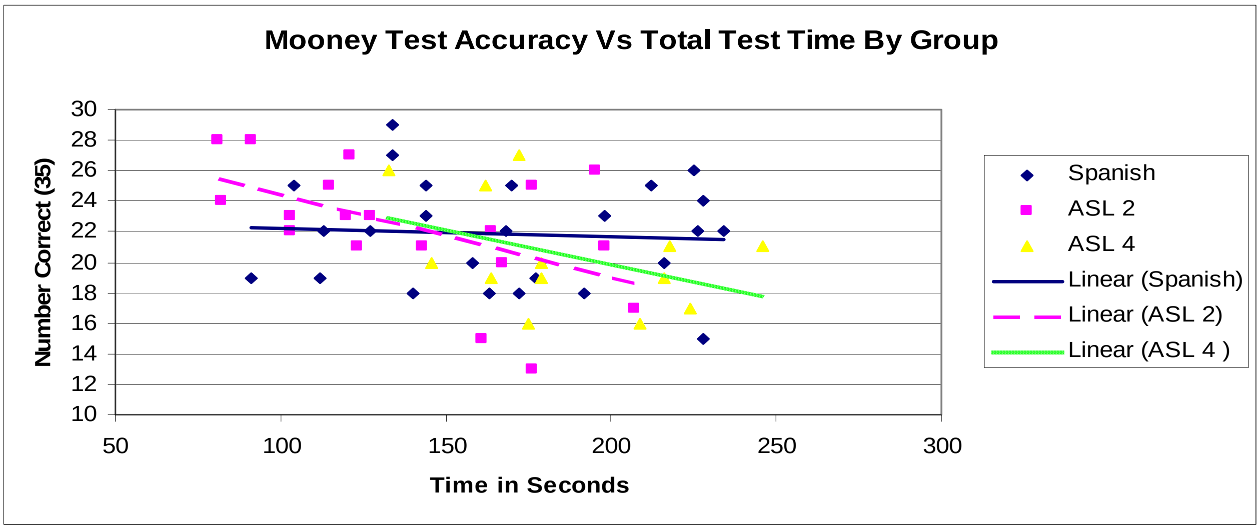
Perhaps language experience has an effect on the speed in which the participants performed this challenging test. This test had no time limit so the participants could take as much or as little time as they needed to choose and answer and move to the next item. The following figure shows the mean total test time for each group.

Figure 2- 7



The participants in the Spanish group took, on average, 178 seconds (SD 66.78) to complete the 35 test items. The participants in the ASL 2 group took, on average, 140 seconds (SD 40.17) to complete all of the test items. The participants in the ASL 4 group took, on average, 197 seconds (SD 43.58) to complete the test. The difference between the fastest group, ASL 2 and the slowest group, ASL 4 was 57 seconds. The one-way ANOVA test revealed significant difference based on language group ($F[2,57]=5.107$, $p = .009$). A post-hoc analysis (Tukey's HSD) revealed that the Spanish group did not differ significantly from the ASL 2 group ($p = .054$) although the difference approaches significance. The Spanish group did not differ significantly from the ASL 4 group ($p = .558$). The ASL 2 group did differ from the ASL 4 group ($p = .010$). I predicted no difference between the groups. It may be that signing experience helped the ASL 2 group complete the task because signers have more experience looking at faces. However, the increased experience with faces of the ASL 4 group may have acted as a hindrance in making a decision on the MFCT. This group may have had the longest total test times because ASL 4 participants may have the most experience with facial features processing and this task is more difficult when looking for individual facial features as this faces closure test requires whole image processing. McCullough and Emmorey (1997) did not report response times, even though their experiment also had no time limit. Figure 2-8 plots accuracy and total test time for the three language groups.

Figure 2- 8



This scatter plot shows a cluster of scores between 15 and 28 in the time range of 100-250 seconds. (I removed two outliers; a participant in the ASL 4 group took 302 seconds but only answered 17 items correctly and a participant in the Spanish group took 429 seconds with 17 correct items.) The trend lines indicate that the groups may differ. Participants in the Spanish group showed no interaction between accuracy and speed; that group scored approximately 22 regardless of how much time was taken to complete the task. Interestingly, as the ASL 2 participants took more time to complete the test, the accuracy decreased slightly. The following table shows the regression equation for the groups.

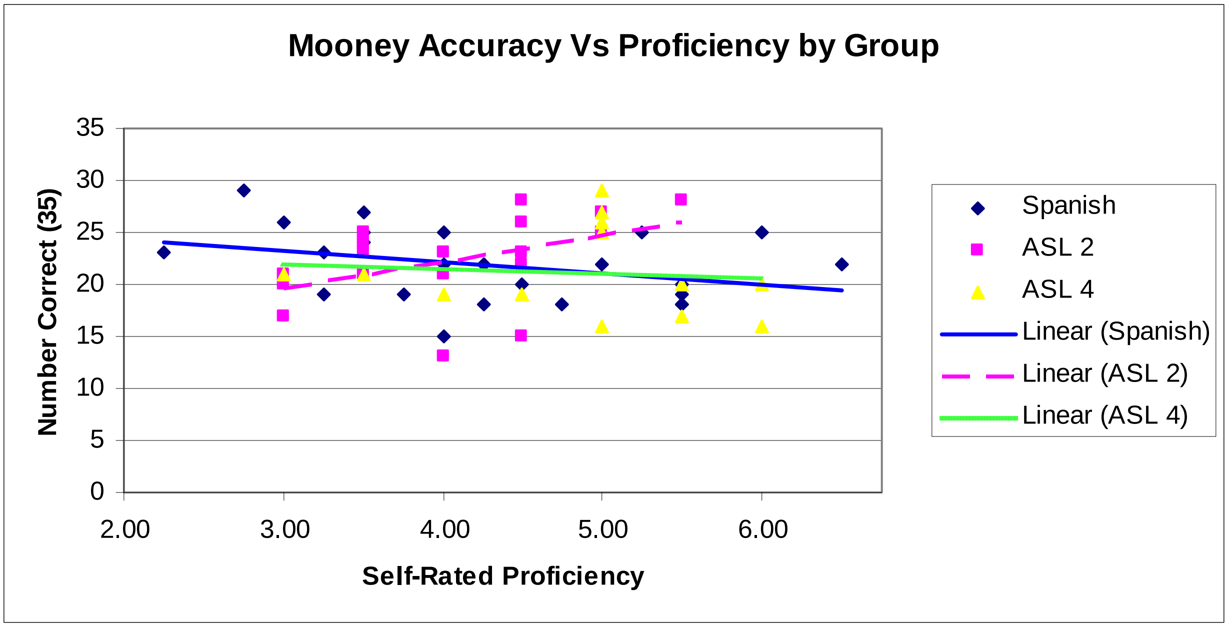
Table 2- 4 Mooney Accuracy Vs Total Test Time

Language Group	Regression Equation	R^2	Sig. (2-tailed)
Spanish	$y = -0.0061x + 22.869$	0.0062	.204
ASL 2	$y = -0.0543x + 29.899$	0.2875	.018
ASL 4	$y = -0.0455x + 28.95$	0.1811	.285

Although the results only reached significance for the ASL 2 group, the tendency does create questions. Causation can not be known by correlation, but there are at least two suppositions to consider. An increase in time might indicate that the participant was searching for individual facial features, which is an unreliable strategy on this task, which, in turn, may decrease accuracy. It may be that with more experience with face processing (as gained with experience with ASL because grammar is encoded into facial expressions), the participants relied more facial features or tried to see individual facial features, which were obscured by the high-contrast pictures. Another possibility is that the participants may have had difficulty seeing any design in the stimuli which explains the overall low accuracy for all of the participants (<62%) and the longer total test times for participants who had below average accuracy.

Figure 2-9 plots accuracy and proficiency by language group. One datum was not included in the MFCT analysis (likewise the other tests) because that participant did not report proficiency. Following the previous analysis, the two data that exceeded five minutes were excluded from this analysis and the remaining in this section.

Figure 2-9



The Spanish group and the ASL 4 group have a slight negative correlation, indicating that with an increase in self-rated proficiency, there is a decrease in accuracy on the MFCT. The ASL 2 group's accuracy seems to positively correlate with an increase in self-rated proficiency, i.e. with more proficiency the participant is more accurate. The ASL 2 and the SPAN groups' correlation approach statistical significance. The following table reports the correlation statistics.

Table 2- 5 Mooney Accuracy Vs Proficiency

Language Group	Regression Equation	R^2	p
Spanish	y = -1.0951x + 26.549	0.1207	.065
ASL 2	y = 2.5588x + 11.956	0.2075	.057
ASL 4	y = -0.4408x + 23.197	0.0086	.540

Both the Spanish and ASL 4 groups' accuracy seem to negatively correlate with self-rated proficiency, i.e. with more proficiency, the participant is less accurate, but the results are not significant and the ASL 4 correlation is extremely weak. In contrast, the ASL 2 group has a positive correlation which almost reaches significance, i.e. participants who rated themselves as more proficient scored higher on the MFRT. The cause of the trends is unclear.

Next, I compared the participants' total test time against the proficiency ratings. The following figure and table compare the total test time taken to complete the thirty-five test items based on the same proficiency categories separated by language group.

Figure 2- 10

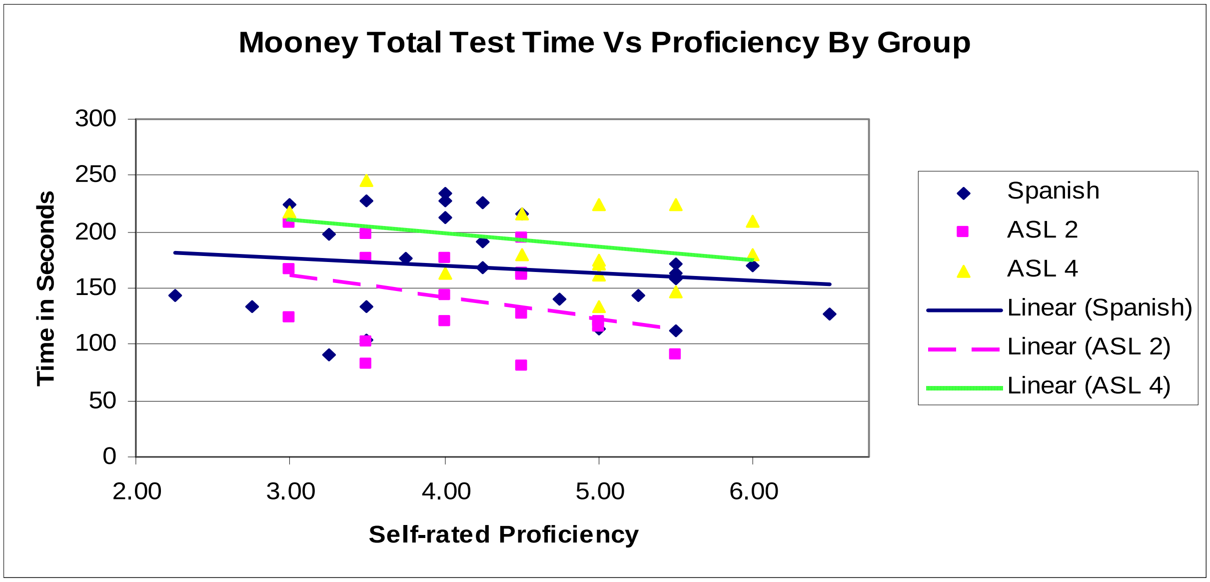


Table 2- 6 Mooney Total Test Time Vs Proficiency

Language	Regression Equation	R^2	Sig. (2-tailed)
Spanish	y = -6.5422x + 196.53	0.0260	.981
ASL 2	y = -19.235x + 219.68	0.1265	.148
ASL 4	y = -12.324x + 248.49	0.1013	.982

The results are not significant. ASL 4 participants generally have the highest times. The trend line corresponding to the ASL 4 group begins above the 200 second mark and decreases to approximately 175 seconds as proficiency increases. The Spanish group has a mostly flat trend line between 175 and 150 seconds, meaning that the participants total test time remained rather constant regardless of proficiency level. The ASL 2 group's trend line indicates that this group had the shortest total test time, with a slight decrease in total test time with an increase in proficiency. The

Spanish trend line is consistent with the expert hindrance theory in that there was no correlation with total test time and proficiency, but the ASL 4 trend line also shows no correlation.

In sum, the Mooney Faces Closure Test results did not show a difference in accuracy. This was expected, considering McCullough and Emmorey (1997) found that signers were not more accurate on this test; the hearing group had a higher mean than the deaf signing group. However, in the current experiment, the groups did differ in total test time. The ASL 2 group completed the test faster than the Spanish group ($p = .054$) and significantly faster than the ASL 4 group ($p = .010$). It may be that looking more at faces helped the ASL 2 participants, but the ASL 4's increased experience with individual facial features began to hinder the decision process on this task. The facial feature focus theory may be supported by the negative correlation between accuracy and total test time for both ASL groups, even though only the ASL 2 group's correlation reached significance ($p = .018$). There was no clear indication of a facial feature focus when looking at accuracy and proficiency ratings, which is plausible because language proficiency may not indicate decision strategy. The facial feature focus explanation, proposed by McCullough and Emmorey (1997), however, may be one explanation of the ASL 4's longest test times when sorted by self-rated proficiency.

2.4 COMPARISION OF FACE-PROCESSING TEST RESULTS

2.4.1 Introduction

It is not expected that the BFRT and the MFCT use the same skills, since the BFRT expect the participant to recognize (match) faces based on individual facial features and the MFCT's high contrast test items obscure facial features, but it is unclear if these face-processing skills are correlated.

2.4.2 Comparison Results and Discussion

I did not expect the scores on the two face-processing tests to be correlated because the two tests require different strategies. The following Figure plots the accuracy of each participant on both tests.

Figure 2-11

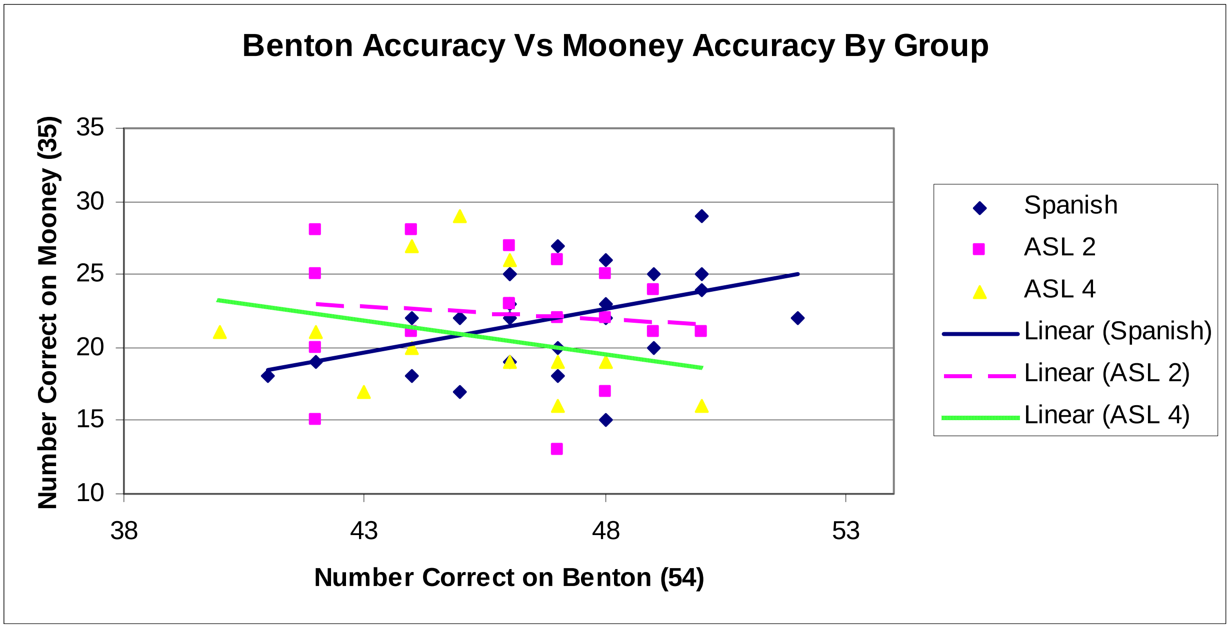


Table 2- 7 Benton Accuracy Vs Mooney Accuracy by Group

Language	Regression Equation	R^2	Sig. (2-tailed)
Spanish	y = 0.5966x – 6.0225	0.1976	.030
ASL 2	y = -0.163x + 29.77	0.0108	.669
ASL 4	y = -0.4622x + 41.707	0.0877	.350

The Spanish group's data create the only positively correlated trend line, meaning that students who answered more correctly on the Benton Facial Recognition Test also answered more correctly on the Mooney Faces Closure Test. The correlation was statistically significant. The two ASL groups have a slight negative correlation between tests, meaning that as the BFRT scores increases, the MFCT scores decreases. Overall, the ASL correlations are not strong, which is expected since the two tests seem to require different face processing skills. But the participants learning Spanish do have a statistically significant correlation between the face-processing tasks. Since only the non-signers showed this correlation, it may be that signing experience impacts performances on only one of the tasks. If signing affects one of the two skills, but not the other, the ASL groups' scores would not show a correlation. With the current study and results, it is not possible to ascertain what skills might be affected, but a possibility was found in Tanaka and Sengco (1997). They proposed that the features and the configuration (the spatial distances between the features) are both used for holistic face-processing. Facial features are best recognized when presented in the original configuration and worst in isolation (Tanaka and Sengco). The Mooney test stimuli obscure this configural information. Hence, it may be that the ASL groups use the configural information to complete the BFRT, but that skill could not transfer to the MFRT.

3.0 SPATIAL RELATION TESTS

3.1. METHODOLOGY

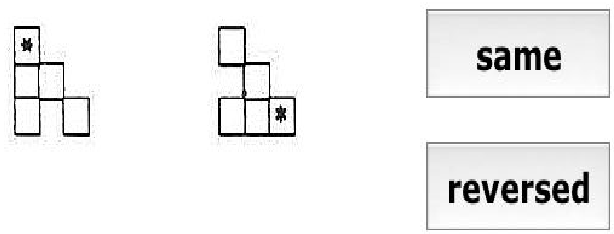
I used the same methodology as described in section 2.1. The same participants took the face-processing test described in Chapter 2 and the spatial relations test described here in Chapter 3.

3.2 MIRROR REVERSAL TEST

3.2.1 MR Description

The Mirror Reversal test[3] was included to replicate the Emmorey, Kosslyn, and Bellugi's (1993) experiment with similar stimuli. Participants had to determine if the test items were the same as the target stimuli or a mirror reversal of the target stimuli. The test items were rotated 0°, 45°, 90°, 135°, or 180°. The Mirror Reversal test included a two-minute time limit for all 50 test items, following the researchers who designed the test. The directions included a "same" sample test item and a "reversed" sample test item.

Figure 5 Sample test item for the Mirror Reversal test. (It is rotated 90° and mirror-reversed.)



The entire test is offered in Appendix D. Some participants completed all fifty items in the two minutes, and some did not answer every item. Three participants (one participant from each of the three language groups) scored below 60% and were excluded from analysis. Although chance

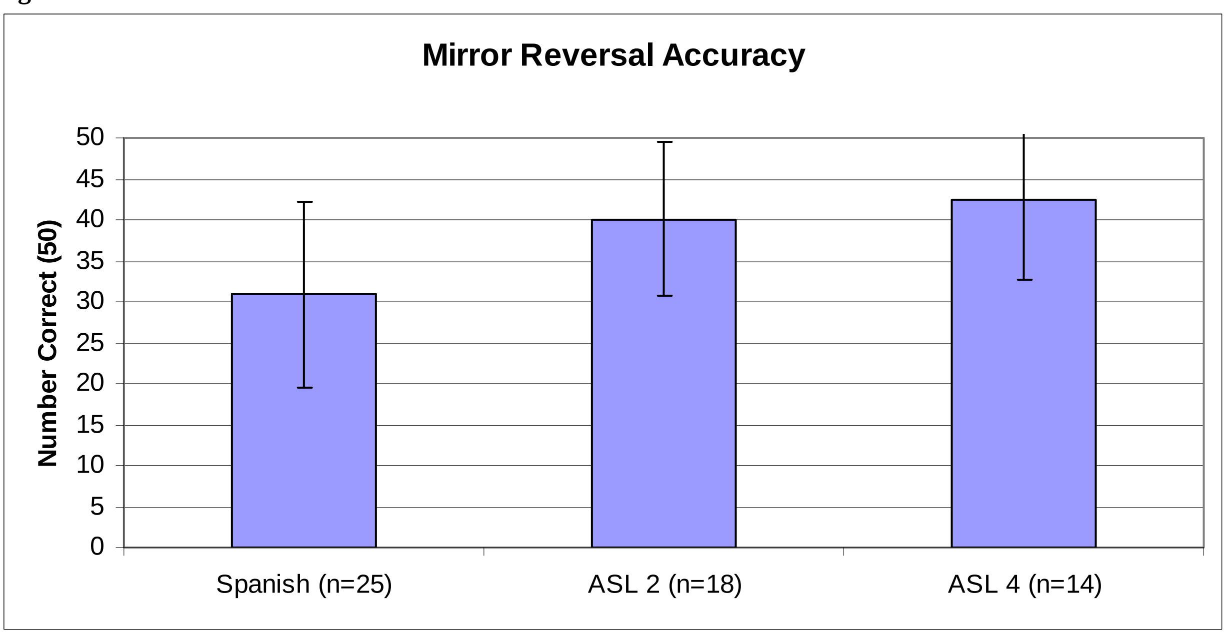
[3] I thank Dr. Karen Emmorey for sharing this test.

would be 50%, I chose a higher limit because 51%, 56% and 57% are close to random and these three scores are outliers from the rest of the data.[4]

3.2.2 MR Results and Discussion

I hypothesized that participants with 18 months exposure of ASL will show increased success on both of the Mirror Reversal Test, but participants with 6 months exposure will perform like control participants (non-signers) because they will not yet have mastery of the spatial aspects of ASL grammar, which would improve performance on the spatial relations test. Second, the scores on both of the visual-spatial of female participants will differ to a greater degree than the scores of male participants; more ASL experience will positively correspond with accuracy on the on the task for female participants; male participants generally will have higher scores which will show smaller gains from of ASL exposure. The following figure illustrates the participants' mean accuracy, as determined by number correct.

Figure 3- 1

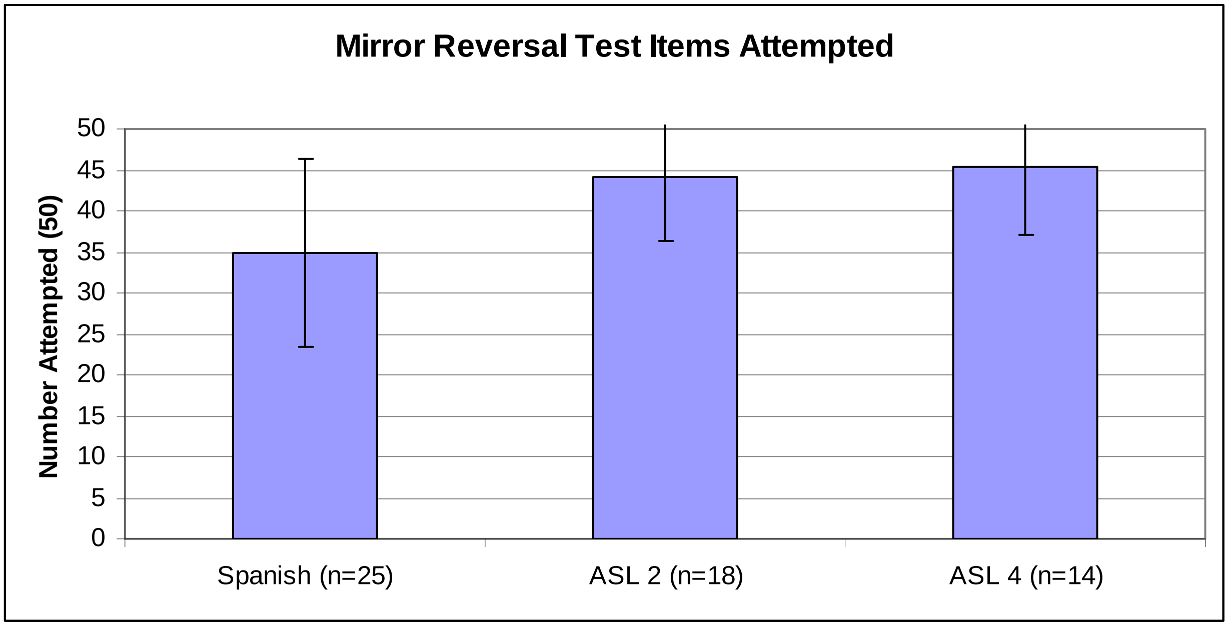


[4] In addition, four test items had zero rotation and were not reversed, i.e. exactly identical which means every participant should have answered these four test items correctly. The three excluded participants did not score even four items above chance.

The raw scores ranged from 13 (two participants) to 50 (seven participants). The participants in the Spanish classes had a mean of 30.92 (standard deviation 11.38). The participants in the ASL 2 classes had a higher mean of 40.06 (SD 9.36). The participants in the ASL 4 classes had the highest mean, 42.50 (SD 9.71). Language group was found as a significant factor for accuracy on the Mirror Reversal task ($F [2,54] = 6.996$, $p = .002$). The post-hoc analysis (Tukey's HSD) revealed that the Spanish group differed from the ASL 2 group ($p = .017$) and from the ASL 4 group ($p = .004$). The ASL 2 group and the ASL 4 group did not differ significantly ($p = .787$). I had predicted that the ASL 4 group would differ from the SPAN and ASL 2 group because I thought the ASL 2 group would not have had enough experience and success with the spatial aspect of ASL. This experiment can not conclude causation, but an assumption can be made that if a improvement is spatial relations skills are found with ASL experience, the improvement is found with limited (about 6 months) ASL experience.

As a point of comparison, using similar test items, Emmorey, Kosslyn, and Bellugi (1993) found deaf signers as accurate as hearing non-signers, but signers had significantly faster reaction times. As mentioned above, the total test time was constant for each participant, and the number attempted by each participant differed. In this experiment, the number of test items attempted is related to reaction time because participants who had faster reaction times answered more test items. The following figure compares the mean number attempted in each group.

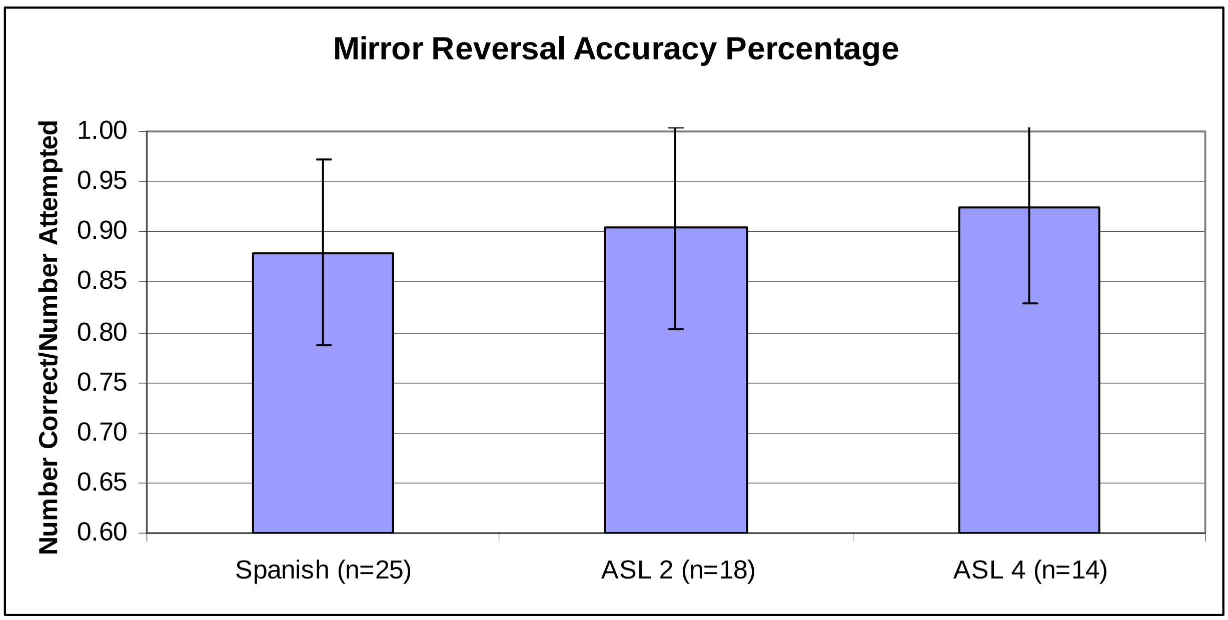
Figure 3- 2



Again, the Spanish group had the lowest mean, 34.88 (SD 11.42). The ASL 2 group attempted more items 44.06 (s.t. 7.70). The ASL 4 group had the highest mean number attempted 45.36 (SD 8.29). Overall, the scores ranged from 16 (one participant) to 50 (22 participants). Within the language groups, the number attempted by participants in the Spanish group ranged from 16 (one participant) to 50 (six participants). The test items attempted by ASL 2 participants ranged from 27 (one participant) to 50 (eight participants). The test items attempted by ASL 4 participants ranged from 20 (one participant) to 50 (eight participants). Even though the Spanish group had more participants (25) than either signing group (18 and 14), both signing groups had more participants who answered all 50 test items in two minutes. As the raw accuracy, the language groups difference in number attempted reached significance ($F [2,54] = 7.225$, $p =.002$). The Tukey's HSD analysis again found that the Spanish group differed from both the ASL 2 group ($p = .009$) and from the ASL 4 group ($p = .006$). Similar to the MR raw score results, the ASL 2 and ASL 4 groups did not differ in items attempted on the MR task ($p = .924$). As mentioned above, the number attempted is comparable to reaction time because participants who had faster reaction times were able to answer more test items in the two-minute time limit. In a similar experiment, deaf signers had significantly faster response times than hearing participants ($F [1, 64] = 4.16, p < .05$) (Emmorey, Kosslyn, and Bellugi, 1993). Therefore, both ASL L2 groups seem to pattern like deaf signers on this task.

Since not all participants completed all of the test items, perhaps the participants' accuracy percentage considering number attempted by the participant is a better indicator of the participants' success. A score based on the number correct/number attempted removes the factor of response time. The following figure shows the mean accuracy percentage of the three language groups.

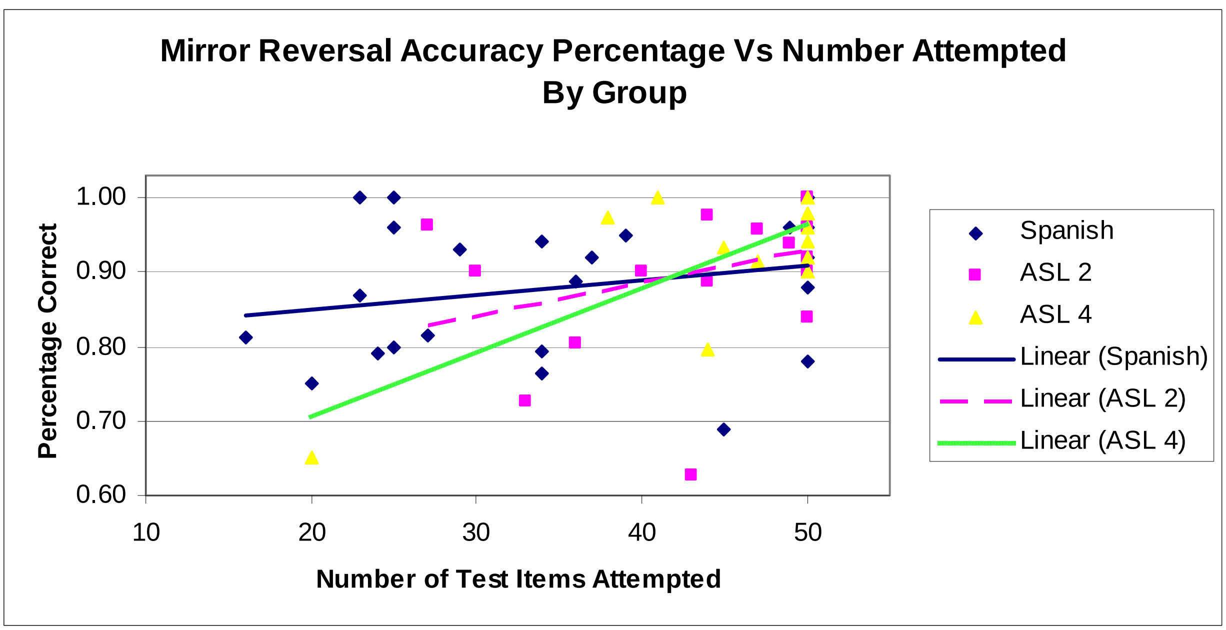
Figure 3- 3



Overall, the scores ranged from 63% (one participant) to 100% (ten participants). With a mean of 88% accuracy (SD 10%), the Spanish group had the lowest accuracy percentage. This group scores ranged from 75% (one participant) to 100% (four participants). The ASL 2 group had a mean percentage of 90% (SD10%), with a range from 63% (one participant) to 100% (three participants). The ASL 4 group had the highest mean, 92% (SD 10%) with a range of 65% (one participant) to 100% (three participants). As Figure 3-2 Mirror Reversal Test Items Attempted shows, the signing participants attempted more items. As Figure 3-3 Mirror Reversal Accuracy Percentage shows, the signing students answered better than or at least as well as non-signing participants. Thus, the signing participants did not seem to sacrifice accuracy to complete the test in the two minute time limit. Again, the tendency is that participants with more signing experience seem to be more successful, in raw score, number attempted in two minutes, and in accuracy percentage, but language was not found to be a significant factor (F [2, 54] = 1.081, p = .346).

It is expected that participants who attempted more test items would have more test items correct because, of course, the number correct is limited to no more than the number attempted. However, percentage is not limited to the number of attempted test items. A participant could answer few items but still score 100%. The following figure show the participants' success on the Mirror Reversal task by plotting the percentage correct (raw number correct/number attempted) to the number attempted by language group.

Figure 3- 4



The figure illustrates that several Spanish participants attempted less than thirty test items. The bulk of the Spanish participants attempted less than forty test items. Only eight of the twenty-five (32%) participants in the Spanish classes attempted over forty test items in the time allotted. The ASL2 group shows slightly more diffusion, but with a cluster of participants attempted over forty test items. Eight of the eighteen (44%) ASL 2 participants attempted all fifty test items. Other than a single outlier, the ASL 4 group cluster toward the top of the figure, over forty attempted and at or above 90% accuracy. Eight out of the fourteen ASL 4 (57%) participants attempted all fifty test items within the two-minute time limit. The trend lines all suggest that participants who attempted more items tended to have a higher percentage correct. (In contrast, it might have been expected that participants answering fewer items may have answered those items with more accurately.) The tendency for the faster participants being more accurate seems to increase with signing experience, and the ASL 4 group's correlation was significant. The following table details the correlation.

Table 3- 1 Mirror Reversal Accuracy Percentage Vs Number Attempted

Language	Regression Equation	R^2	Sig. (2-tailed)
Spanish	y = 0.0019x + 0.8124	0.0573	.239
ASL 2	y = 0.0045x + 0.707	0.1190	.158
ASL 4	y = 0.0087x + 0.5315	0.5597	.002

Raw accuracy, number of test items completed, and accuracy percentage all point to an increased success correlated with an increase in signing experience.

As with the previous experiments, I also compared the participants' results with their self-rated proficiency. The following figure shows the raw score accuracy plotted against proficiency.

Figure 3- 5

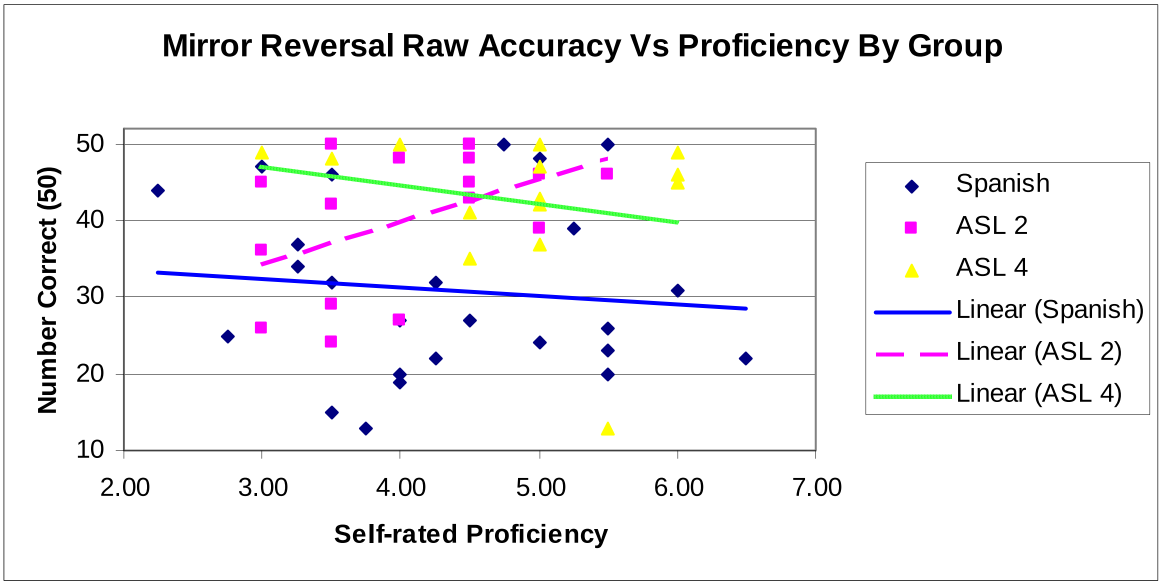


Table 3- 2 Mirror Reversal Raw Accuracy Vs Proficiency by Group

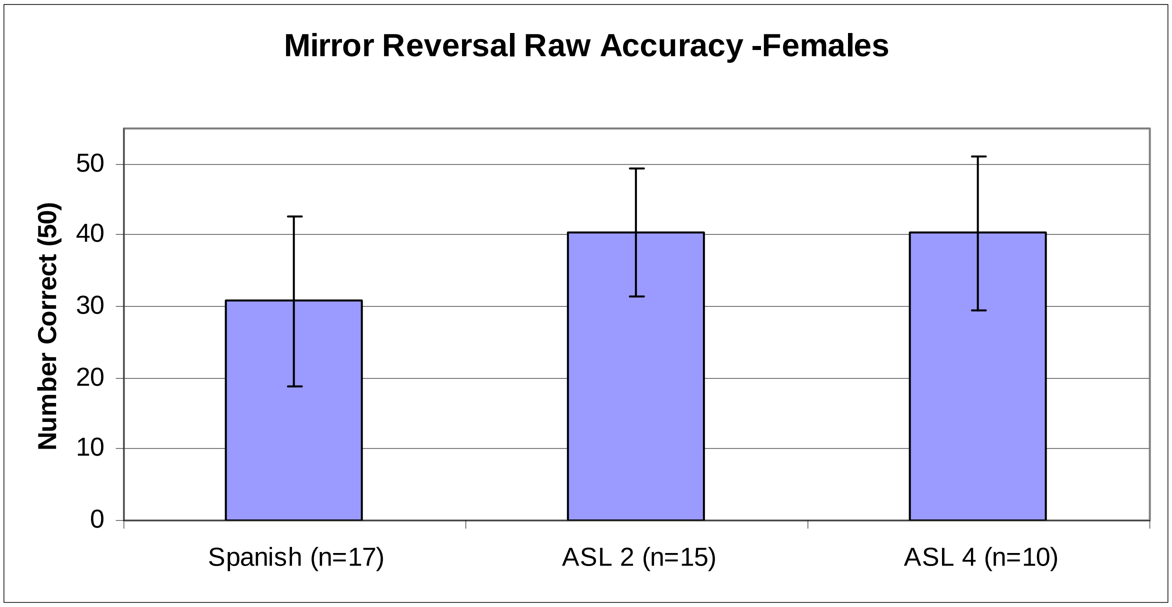
Language	Regression Equation	R^2	Sig. (2-tailed)
Spanish	y = -1.1399x + 35.856	0.0120	.603
ASL 2	y = 5.5529x + 17.535	0.1953	.066
ASL 4	y = -2.4733x + 54.513	0.0535	.426

Only the ASL 2 group shows an increase in raw accuracy with an increase in self-rated proficiency. The Spanish group showed almost no relationship but there is a slight decline in raw number correct with an increase in proficiency, and the ASL 4 group also has a decrease in raw number correct with an increase in proficiency. MR raw score and self-rated proficiency was not significantly correlated. In order to consider the difference in reaction time shown in Figure 3-2 Mirror Reversal Test Items Attempted, I also plotted the number of test items attempted against the self-rated proficiency by language group; no correlation was significant ($p>.05$). The Spanish group shows no relation between the number of completed test items and self-rated proficiency, which may be expected because Spanish ability would not seem to be related to speed during a mirror reversal task. It is unclear why the ASL 2 group has a trend toward an increase in the number of test items attempted with an increase in proficiency. (When the accuracy percentage is plotted against proficiency, the trend lines for each language group are recreated, but the correlations are not significant.) Since it may be expected that an increase in proficiency would be correlated with an increase in accuracy or that no relationship exists between mirror reversal accuracy and self-rated language proficiency, it is unexpected that the ASL group has a positive correlation, although the trend did not reach significance. Since all other measures of success on the mirror reversal task indicates that signing experience and success are positively correlated, it is unexpected and unexplained why ASL 4 does not have a positive correlation. One possible explanation is that some participants over-estimate their proficiency. Perhaps the validity of the self-rating proficiency scores should be questioned. Since the correlations are not statistically significant, the pattern might be random.

3.2.3 MR Results and Discussion - Females

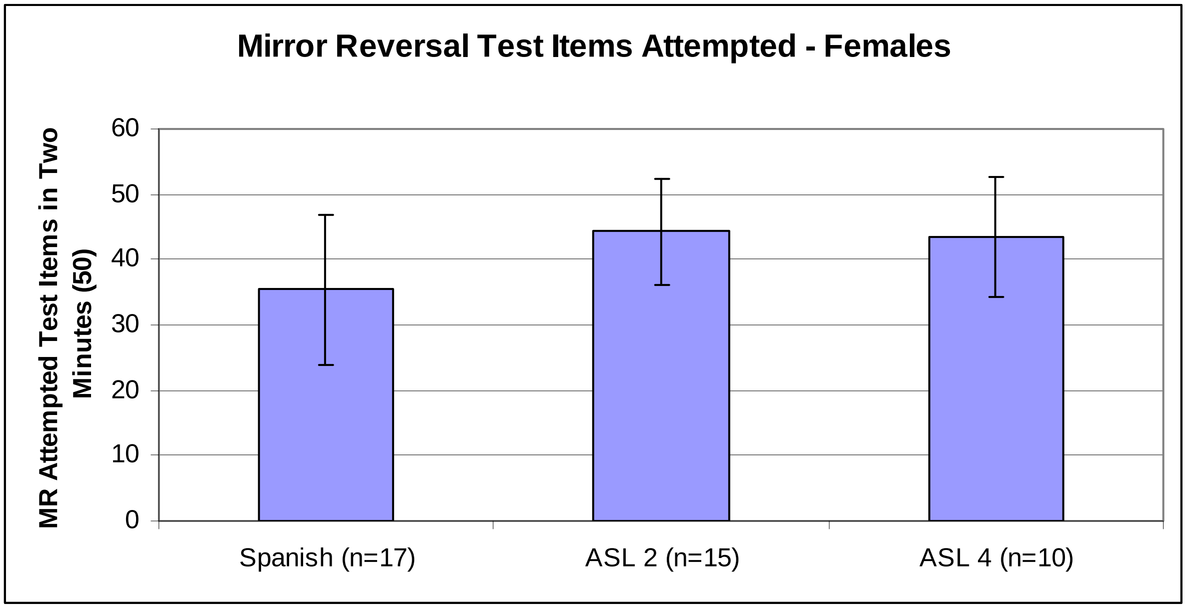
Since previous studies have considered gender as a factor on spatial relations tasks (but not face-processing tasks), I separated the participants by gender. It was extremely difficult to get more males to participant because of the lack of males enrolled in ASL 2 and ASL 4 at the University of Pittsburgh. There were too few males in the experiments (Spanish n=8, ASL 2 n= 3, ASL 4 n= 4) to fully analyze the males as a group. I did analyze the females in the three language groups. The following figure shows the raw scores on the MR task for the female participants only.

Figure 3- 6



As with the mixed gender population, Spanish participants, with a mean of 30.8 (SD 11.8) had the lowest scores on the MR test. Female ASL 2 participants with a mean of 40.5 (SD 8.9) scored similarly to female ASL 4 participants who had a mean of 40.3 (SD 10.8) Language was a significant factor on the MR raw score ($F[2, 39] = 4.530$, $p = .017$). As expected, a post-hoc analysis (Tukey's HSD) showed that the ASL 2 and ASL 4 groups did not differ ($p = .980$), but the Spanish group did differ from the ASL 2 group ($p = .024$). The difference between the female Spanish group and the female ASL 4 group did not reach ($p<.05$) significance on this measure ($p = .075$), but the difference did reach ($p < .10$) which can be justified with the decrease of ASL 4's in sample size. As described above, the number of attempted test items is similar to reaction time because the test had a set time limit. Participants who made quicker decisions would be able to view and answer more test items. The following Figure compares the number of test items attempted for the female participants.

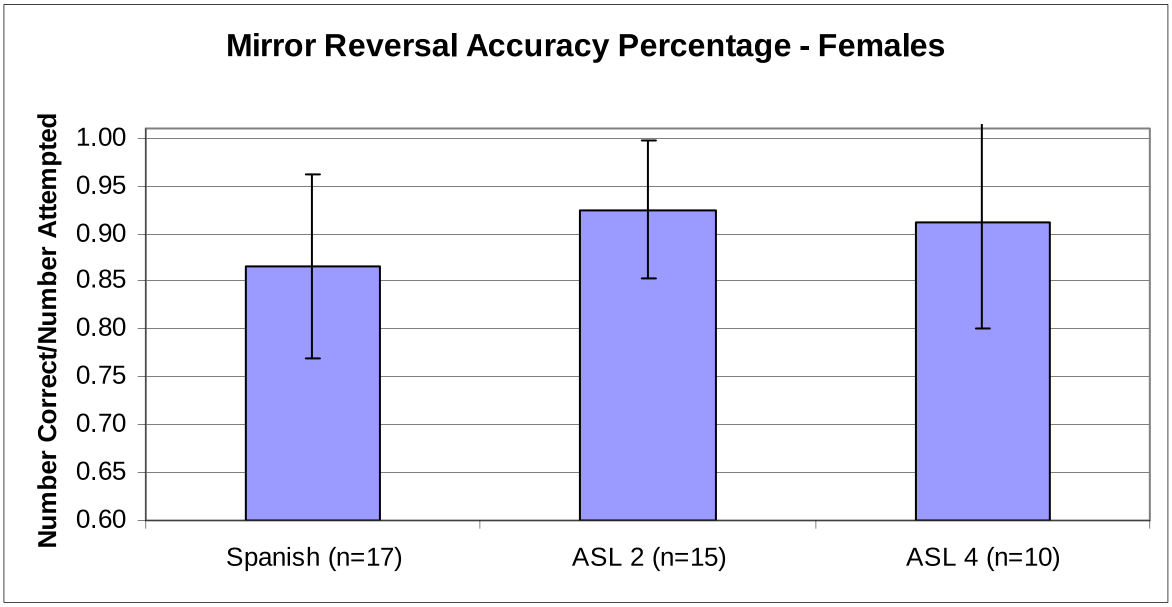
Figure 3- 7



As with Figure 3-6 Mirror Reversal Raw Accuracy-Females, the ASL 2 and ASL 4 groups had similar means on the number of test items attempted, 44.3 (SD 8.0) and 43.5 (SD 9.3), and the Spanish group had a lower mean score, 35.4 (SD 11.4). The difference was significant (F [2, 39] = 3.839, p = .030). The post hoc analysis (Tukey's HSD) found that the female Spanish group differed significantly from the female ASL 2 group (p = .039). The Spanish and ASL 4 groups' difference did not reach significance, but considering the smaller sample size of the female groups, it nearly reaches p<.10 significance (p = .111). Of course, the ASL 2 group did not differ from the ASL 4 group (p = .980).

I also compared the groups without penalty for slow reaction times. The following figure shows the accuracy of the female participants in percentage of the number of test items attempted.

Figure 3- 8



Similar to the entire populations, the Spanish group had the lowest accuracy percentage, 87% (SD 10%). ASL 2 and ASL 4 had higher scores than the Spanish group, 92% (SD 7%) and 91% (SD 10%) respectfully. As with the mixed gender population, language group was not a statistically significant factor when using MR accuracy percentage ($F\ [2, 39] = 2.396$, $p = .104$).[5]

In sum, signing experience was correlated with more success on the mirror reversal task, whether success is measured by raw number correct, number attempted (reaction time), or accuracy percentage (raw number correct/number attempted). Raw accuracy and test items completed in the two minutes time limit showed significant results by language ($p = .002$). Both ASL L2 groups outperformed the Spanish group in raw accuracy ($p < .01$) and number attempted ($p < .02$). The same pattern existed in the female population analysis.

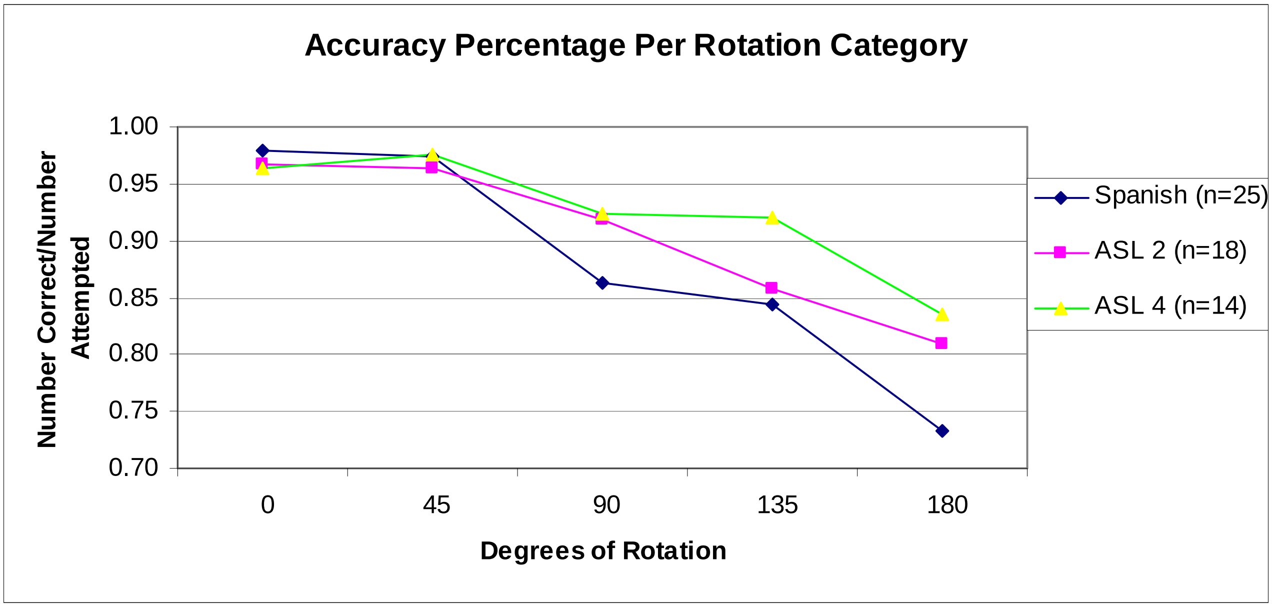
3.2.4 MR Test Item Analysis

Since results on the MR test were promising, I also reviewed accuracy for individual test items. I expected a negative correlation between rotation and accuracy, i.e. test items that were

[5] As a point of comparison, the males had means of 93% (SD 6%) for the Spanish group (n=8), 80% (SD 16%) for the ASL 2 group (n=3), and 98% (SD 2%) for the ASL 4 group (n=3).

more rotated from upright would be more difficult. The following Figure shows the accuracy percentage of the MR test at each rotation category for each group.

Figure 3- 9



Since the participants' accuracy percentages were not normally distributed (many students had 100% accuracy), I analyzed the data using the non-parametric Kruskal-Wallis Test. The language group results did not reach significance at any rotation level, but the trends at the 90° and 135° categories suggest that language group is a factor. Each language group is extremely accurate at the 0° (H = .810 [2], p = .667) and 45° (H = .717 [2], p = .699). At 90° rotation, the two signing groups performed similarly and outperformed the Spanish group (H = 3.780 [2], p = .151). When the test stimuli were rotated 135°, the ASL 4 group remained accurate (92%), but the ASL 2 and Spanish groups declined to about 85% accuracy (H = .3.536 [2], p = .171). When the test stimuli were completely rotated 180°, all language groups had a decrease in accuracy, but the results were not statistically significant (H = .308 [2], p = .857). In this most rotated category, ASL 4 was most accurate, followed by ASL 2, and Spanish was least successful, dropping to 73%. Reviewing the ASL 2 pattern, there is a consistent decrease in accuracy from 45° to 180°. Although the most accurate at the 180° category, the ASL 4 group shows a steep decline in accuracy. This decrease for the ASL 4 group is somewhat misleading in that the last five test items had two 180° reversals, the most difficult category. Since more ASL 4 participants completed all fifty test items, they had a higher number of errors which many of the SPAN group did not attempt. If every participant finished all fifty test items, I would expect the means to be lower at the 180° category, and the Spanish group's mean would separate farther from the signing groups.

Previous studies with a similar test design compared deaf native signers, hearing native signers, and hearing non-signers (Emmorey et al., 1993). The accuracy percentage by rotation category in the current study patterns with the results from the Emmorey et al. study[6]. Most noteworthy is that the ASL 4 group is most similar to the deaf native signers. The deaf native signers had slightly higher accuracy, noticeably at 180° rotation. The results of the Emmorey et al. study also indicated that signers and non-signers rotated the test items at a similar speed, which suggested to the authors that signers did not have an increase in mental rotation skills, but only in mirror reversal judgments. However, Hamm et al. (2004) concluded that mirror reversal detection and mental rotation skills are separate but related skills because their results found that neither rate of rotation nor mirror detection were correlated to general processing speed as measured by upright "same" stimuli decision times. The current data may indicate that signing experience has an effect on both mental rotation task and mirror reversal detection task.

The mirror reversals and normal presentation test items were combined for each rotation category in the previous figures. The mirror-reversal of test items might have been more or less difficult when rotation increased. The following figure and table offers the accuracy percentage by rotation category by normal or reversed presentation.

[6] The previous research description did not include the 45° rotation category.

Figure 3- 10

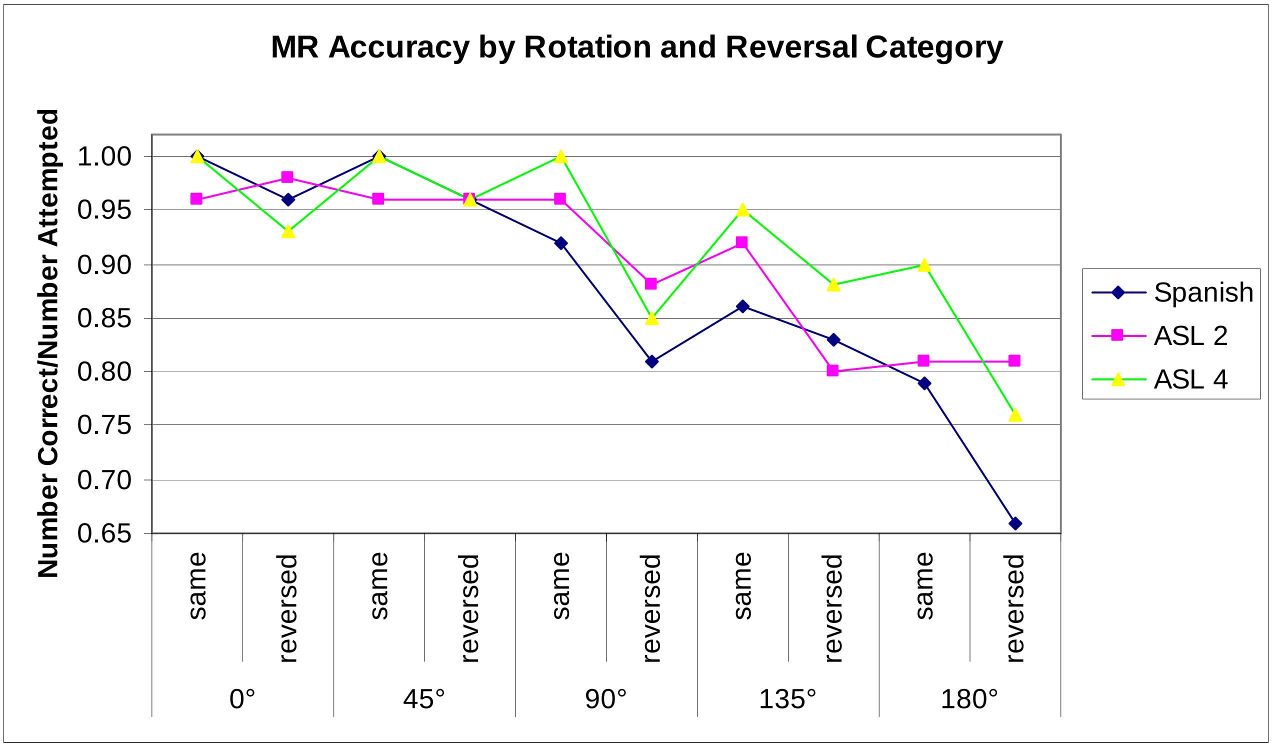


Table 3- 3 MR Accuracy by Rotation and Reversal Category

	0°		45°		90°		135°		180°	
	same	reversed	same	reversed	same	reversed	same	Reversed	same	reversed
Spanish	1.00	.96	1.00	.96	.92	.81	.86	.83	.79	.66
ASL 2	.96	.98	.96	.96	.96	.88	.92	.80	.81	.81
ASL 4	1.00	.93	1.00	.96	1.00	.85	.95	.88	.90	.76

The ASL 4 group generally is more successful in both presentations at all rotations, with the exceptions of the 90° and the 180° reversed conditions, in which the ASL 2 group minimally outscores ASL 4. The ASL 4 group had higher accuracy in the more rotated 180° same condition (90%) than in the less rotated 90° reversed condition (85%) and 135° reversed condition (88%). This finding might indicate that determining mirror reversal is a more difficult task than mental rotation. Another possible explanation is the when mirror reversal and rotation are both present, the task is more challenging.

I compared each groups' accuracy within each rotation category, i.e. the accuracy of the same test items was compared to the accuracy of the reversed test items in each rotation category. Since many participants scored 100% in each category, the results were not normally distributed. Therefore, I used the non-parametric Wilcoxon Signed Ranks Test, which allows for skewed distribution, to test if the accuracy for reversals is significantly different from the accuracy for the "same"s within each rotation category. At the 0° rotation, none of the language groups had different accuracy between the test items which were the same orientation and the test items which were reversed (SPAN Z=-1.633, p = 0.102; ASL 2 Z=.000, p = 1.000; ASL 4 Z=-1.633, p = 0.102). Likewise, each language groups' accuracy was not significantly different in the 45° rotation category (SPAN Z=-1.633, p = 0.102); ASL 2 Z=-.368, p = 0.713; ASL 4 Z=-1.342, p = 0.108).

The Spanish participants had lower accuracy percentage beginning at the 90° rotation. All three language groups decline in accuracy at the 90° and reversed condition. In the 90° category, the SPAN group's accuracy (Z=-1801, p = .072)[7] and the ASL 4 group's accuracy (Z=-2.032, p = .042) were significantly different in the same and reversed conditions. In each case with a significant difference, the language group had a lower accuracy percentage with the reversals in the rotation category. The ASL 2 group did not show a difference in accuracy at this rotation category (Z=-1234, p = .217).

All three groups increase accuracy when the test items are at normal presentation but have the increase rotation to 135°. However, the Spanish group has the lowest mean, 86%. The means for each language group decreased at 135°. The Wilcoxon tests revealed that the Spanish group's difference was not significant, indicating that at 135° rotation, the "same" were equally difficult as the reversals (Z=-386, p = .700). Both ASL groups were significantly more accurate with test items that were not reversed. The ASL 2 group dropped from 92% to 80% which is statistically

[7] For the Wilcoxon Signed Ranks Test, significance is adjusted to p = < .10 for the small sample sizes in these with-in group analysis.

significant (Z=-1.807, p = 0.071). The ASL 4 group dropped somewhat less dramatically, but still significantly, from 95% to 88% (Z=-1841, p = 0.066).

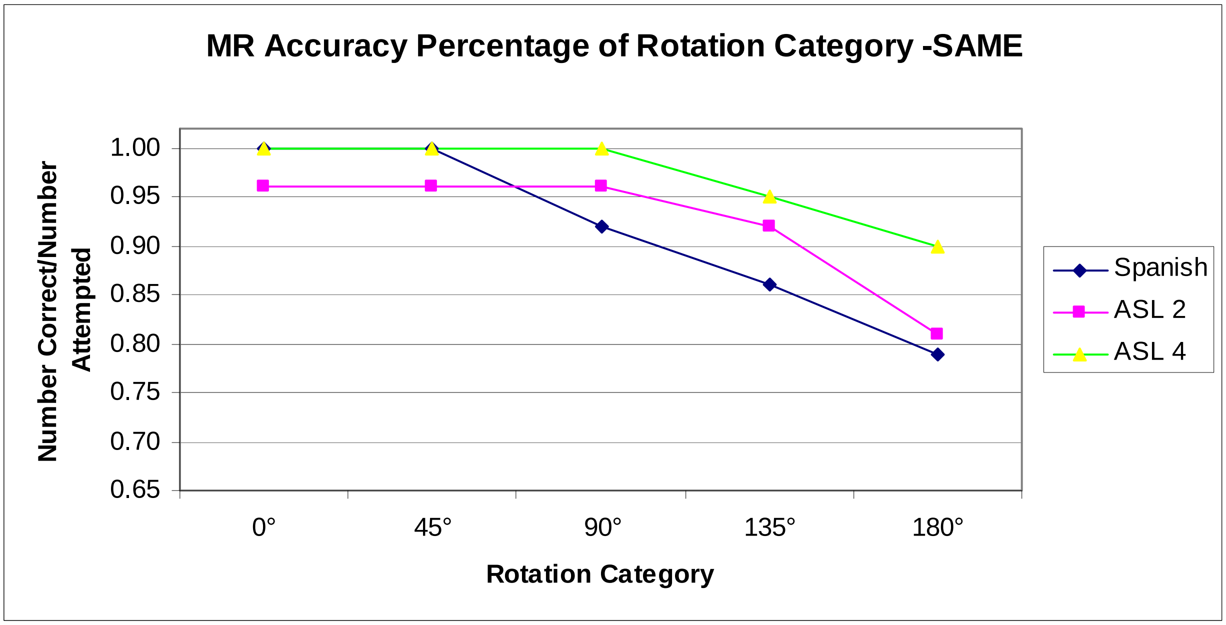
In the most rotated 180° category, the SPAN and the ASL 4 groups differed in accuracy between the same presentation and the reversals. The Spanish group's mean dropped from 79% to 66% (Z=-1.868, p = .062) and the ASL 4 group's mean dropped from 90% to 76% (Z=-1.854, p = .064). The same-reversal comparison revealed no difference for the ASL 2 group (Z=-.562, p = .574). The following table summarizes the Wilcoxon results, comparing accuracy of the normally presented test items and the mirror reversed test items. In each case with a significant difference, the language group had a lower accuracy percentage with the reversals in the rotation category. Significant (p< .10) findings are bolded.

Table 3- 4 Wilcoxon Test Results

	0°	45°	90°	135°	180°
Spanish	p = .102	p = .102	**p = .072**	p = .700	**p = .062**
ASL 2	p = 1.00	p = .713	p = .217	**p = .071**	p = .574
ASL 4	p = .102	p = .108	**p = .042**	**p = .066**	**p = .064**

The Wilcoxon Signed Ranks test results illustrate that the differences in accuracy were not consistently significant, even within language groups. The Spanish group had significantly different accuracy for non-reversed items rotated 90° and 180°, but this group found reversed test items rotated 135° equally as difficult as non-reversed items (only 83% and 86% accuracy). In contrast, the ASL 2 group only had a significant difference between the reversed and "same" test items in the 135° category. The ASL 4 group had significantly better accuracy for non-reversed test items at 90°, 135°, and 180°. Overall, the results indicate that the combination of rotation and reversal affects accuracy. In order to see the participants accuracy by rotation category only, the following figures maps the accuracy of the three groups for normal presentation test items (Figure 3-11) and for mirror reversed test items (Figure 3-12).

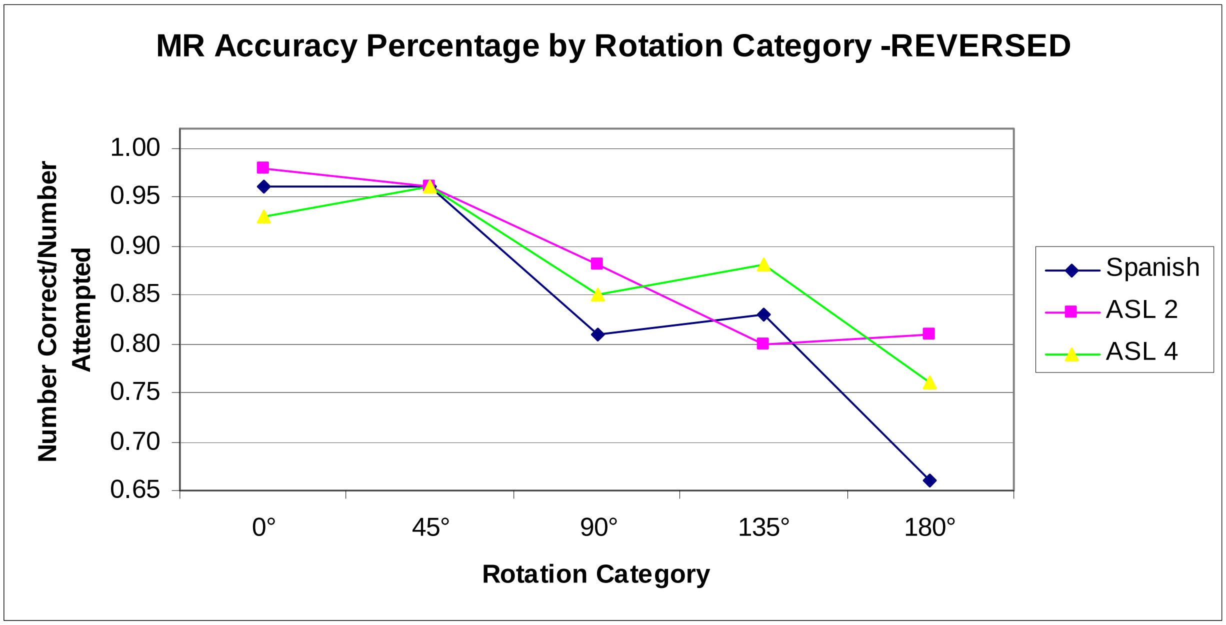
Figure 3- 11



As mentioned above, the Spanish participants have a decrease in accuracy at a lesser degree of rotation (90°) than the signing participants. The difference did not reach significance (H = 3.539 [2], p = .170), but the trend indicates that language group may be a factor. Again, the ASL2 and ASL4 have similar accuracy with normally presented test items which were rotated 135°, with SPAN have lower accuracy (H = 3.856 [2], p = .145) This difference in accuracy approaches significance. At 180° rotation, all groups see a decrease in accuracy and the Kruskal-Wallis test indicates that there is not a statistical difference between the groups (H = 1.077 [2], p = .584).

The effect of rotation is rather uniform. The Spanish group's rate of decline is nearly constant, beginning at 100% accuracy and dropping approximately 7% with each rotation. The ASL 4 group's rate of decline also seems constant, yet it began at 100% accuracy at 90°, dropping approximately 5% with each rotation. The ASL 2 group's rate of decline begins at 90°, drops only 5% at 135° and 11% at 180° rotation. The three groups all decreased in accuracy with rotation, with the Spanish group being challenged with less rotation. The following Figure show illustrates the effect of mirror reversal presentation at each rotation category.

Figure 3- 12



The overall pattern indicates the mirror reversal does not affect accuracy consistently with increased rotation, as was indicated in Figure 3-12 MR Accuracy Percentage by Rotation Category-SAME. All three language groups were equally accurate at 45° of rotation (H = .226 [2], p = .893). With mirror-reversed test items with 90° rotation, all three groups decrease in accuracy, and no significance difference is found (H = 2.088 [2], p = .352). However, with mirrored-reversed test items rotated 135°, the Spanish and ASL 4 accuracy rebounds, but the ASL 2 continues to decrease. The three groups' accuracy in this category, however, does not differ statistically (H = 1.631 [2], p = .442). The ASL 2 group's accuracy is maintained at 180°, but the Spanish and ASL 4 groups decrease in accuracy by 17% and 12%, respectfully. Nevertheless, the accuracy between the groups is not statistically different (H = 1.332 [2], p = .514.

It is unclear why the ASL2 group seemed to respond differently at the 135° and 180° rotation category. A possible explanation is that members of that group used a different strategy for test items which were near 180° of rotation. Murray (1997) designed an experiment to test the strategies of mentally rotating or mentally flipping. She found that participants instructed to mentally “flip” the test figure out of the picture plane were faster than when “spinning” the test figures to upright orientation, and the difference was even greater with mirror reversed test items. In a related experiment, Murray showed that “flippers” are faster at 180° than at 120° or 240°, but “spinners” are the slowest at 180°. It is unclear if ASL 2 participants used a mental flip to answer more accurately at 180° rotation, and if so, it is unclear why that group might use a different strategy.

In sum, the three language groups had lower accuracy rates at higher rotations. Generally, ASL 4 was more accurate at each rotation category, and Spanish was the least accurate at each rotation category. The performance of the ASL 4 group matched the native signers from previous research. Test items that were mirror-reversed tended to be more difficult than test items with normal presentation. Language group was not found to be statistically significant for any specific reversal and rotation category, but the trends indicate that language group may be a factor. Reversal and rotation did not consistently decrease the three groups’ accuracy. Whereas, rotation seemed to uniformly lower accuracy for each language group, mirror reversal did not seem to be equally difficult. These results may indicate that the ASL groups have an increased skill with the mirror reversal task over the non-signing Spanish participants because the signing groups have higher accuracy of the mirror reversed test items overall. Emmorey et al. (1993) conclude that signing participants are better able to evaluate mirror reversals, and these results support their argument. The results illustrated in Figure 3-13 and the results of the Wilcoxon Signed Ranks Tests, however, do not indicate that mirror reversal is equally challenging at every rotation category. Hamm, Johnson, and Corballis (2004) studied processing time for mirror detection of rotated objects and concluded that mirror reversal stimuli seem to be “flipped” to normal presentation after being mentally rotated. They propose that mental rotation and mirror detection skills are correlated, yet separate skills, not related to general processing speed. Therefore, it is possible that signing experience affects both mirror reversal detection and mental rotation skills, which may account for the different patterns for the mirror reversed and normal presentation test items and the overall better accuracy (and speed) of the ASL groups.

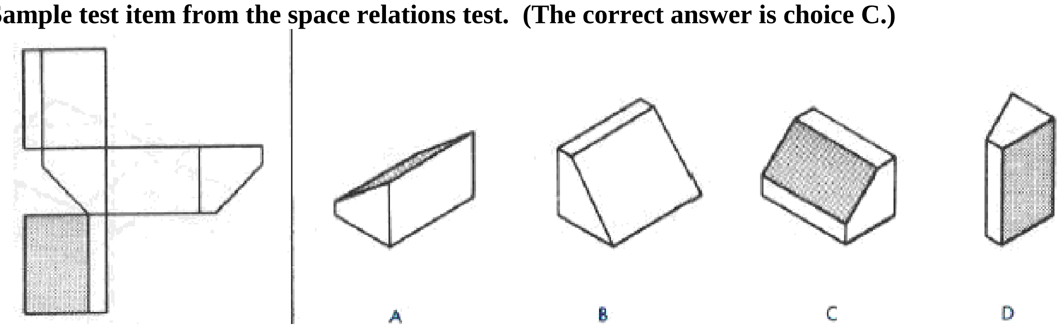
Some previous research has questioned if a third decision, rotational uncertainty, may also be a factor in reaction time (Ilan and Miller, 1994; Jansen-Osmann and Heil, 2007). A rotational uncertainty, which participants take extra time for upright stimuli in experiments with some rotated stimuli than for upright stimuli in experiments with no rotated stimuli, might also be a factor in accuracy at different rotation categories.

3.3 SPACE RELATIONS TEST

3.3.1 SR Test Description

I purchased the commercially available Differential Abilities Test-Spatial Relations from The Psychological Corporation. Often given as part of a standardized intelligence test, the Differential Aptitude Test's Spatial Relations subtest requires participants to mentally fold two-dimensional geometric figures into three-dimensional figures. The answer choices include similar figures which may be rotated. The Space Relation Test had a fifteen minute time limit, as required by the Directions for Administration and Scoring. The standardized directions include a sample test item and an explanation of why the distracter choices are incorrect and why the correct answer is the only possible correct choice.

Figure 6 Sample test item from the space relations test. (The correct answer is choice C.)

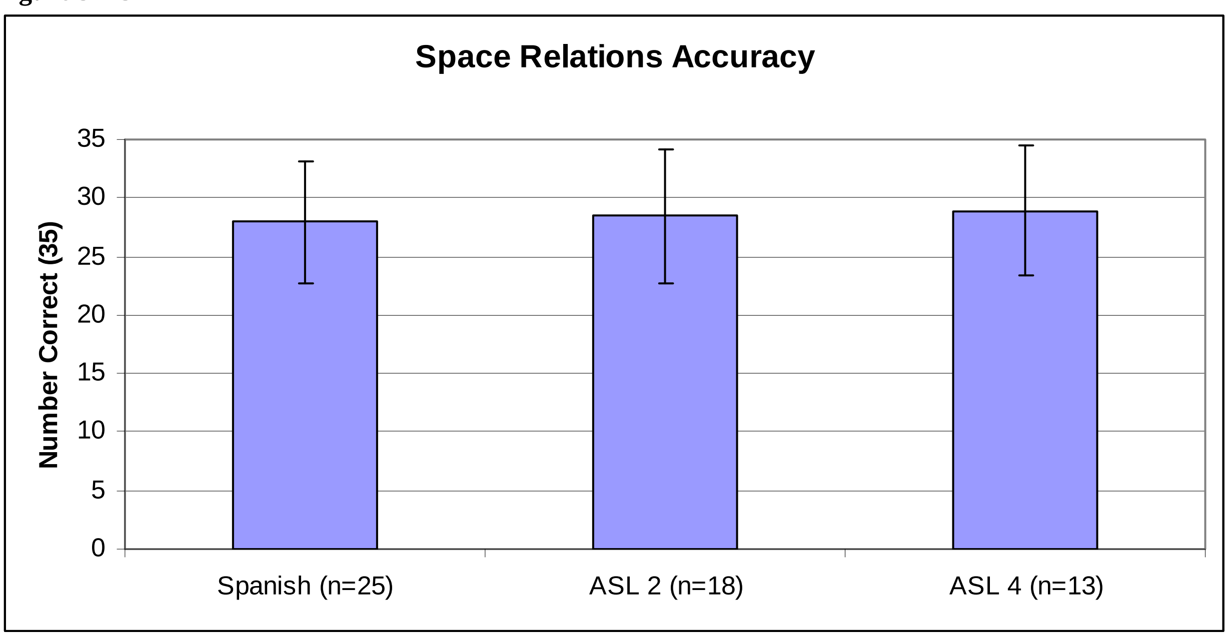


The test was administered as recommended, with the sole alteration of computerization of the test. One excluded ASL 4 participant scored 8/35, which is below random, since participants chose between four possible answers for each question.

3.3.2 SR Results and Discussion

I hypothesized that participants with 18 months exposure of ASL will show increased success on both of the Space Relations test, but participants with 6 months exposure will perform like control participants (non-signers) because they will not yet have mastery of the spatial aspects of ASL grammar, which would improve performance on the spatial relations test. Second, the scores on both of the visual-spatial of female participants will differ to a greater degree than the scores of male participants; more ASL experience will positively correspond with accuracy on the on the task for female participants; male participants generally will have higher scores which will show smaller gains from of ASL exposure. The following Figure shows the means and standard deviations of the three groups.

Figure 3- 13



The top score on this test is 35. Four participants scored all 35 questions correctly. The lowest score (two participants) was 17. The Spanish group's mean is 27.92 (SD 5.27). The ASL 2 group's mean is 28.44 (SD 5.70), and the ASL 4 group's mean is 28.92 (SD 5.48). The three language groups show no significant difference (F [2, 53] = .151, p = .860). Rounded to the nearest whole number, all three groups' means are in the 6^{th} stanine norm for combined sex groups according to the technical manual of the DAT. Only one participant did not complete the thirty-five test items in the fifteen minute time limit. That participant answered thirty-four items, so there was no noticeable difference when using percentage correct to measure accuracy. The rest of the analysis will be with raw scores except when comparing accuracy percentage between the two spatial relations tests.

As with the other experiments, accuracy on this space relations task was plotted against the participants' self-reported proficiency. The following figure shows the participants' raw accuracy against proficiency.

Figure 3- 14

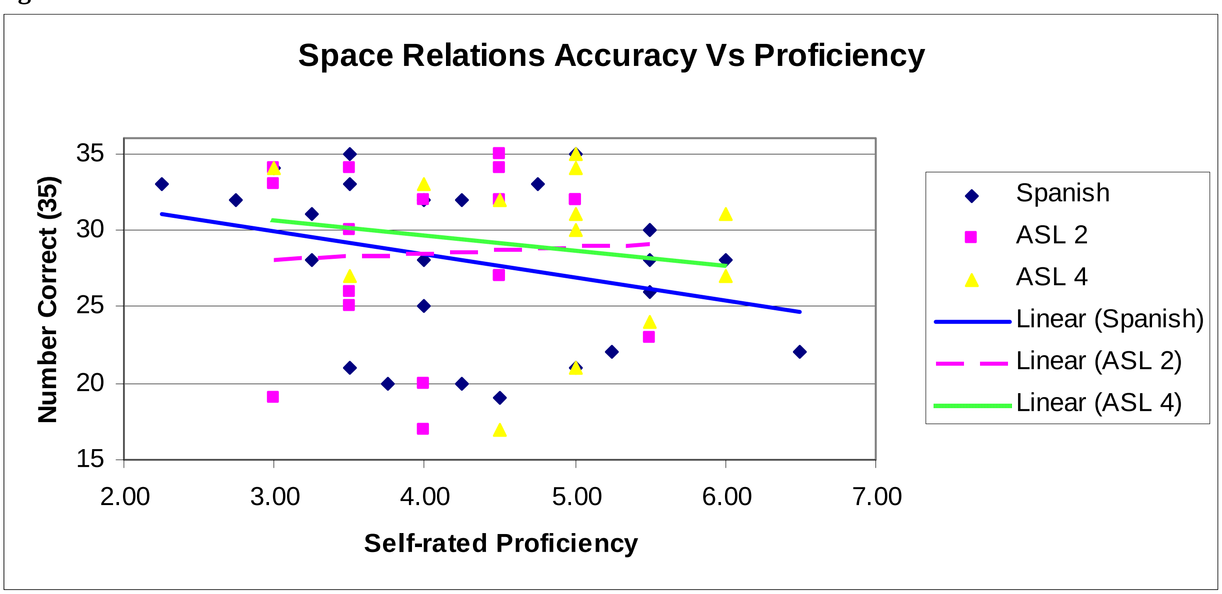


Table 3- 5 Space Relations Accuracy Vs Proficiency

Language	Regression Equation	R^2	Sig. (2-tailed)
Spanish	y = -1.5072 + 34.446	0.0975	.129
ASL 2	y = 0.4294x + 26.703	0.0032	.825
ASL 4	y = -0.9917x + 33.653	0.0254	.603

These results indicate that language proficiency is not positively correlated with space relations task. The ASL 2 group has almost no relationship. The Spanish and ASL 4 group has a slight negative correlation, meaning an increase in self-rated proficiency is correlated with a decrease in accuracy on the space relations task. None of the correlations are significant.

Since both the mirror reversal task and the space relations task required the participants to mentally rotate figures, it may be expected that scores on two space tests are positively correlated. The following figure plots the accuracy percentage on space relations task and the mirror reversal task by language group. For this comparison, I used accuracy percentage for both measures because then both measures would show the participants' accuracy, regardless of time limits.

Figure 3- 15

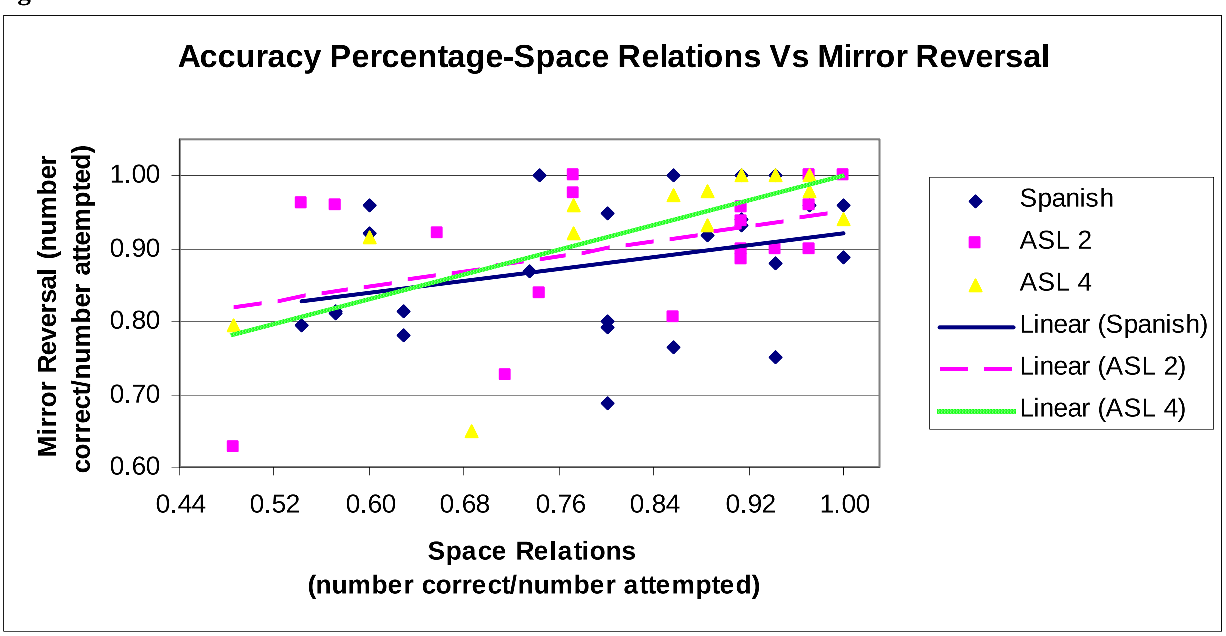


Table 3- 6 Accuracy Percentage-Space Relations Vs Mirror Reversal

Language	Regression Equation	R^2	Sig. (2-tailed)
Spanish	y = 0.2046 + 0.7161	0.1118	.097
ASL 2	y = 0.2585x + 0.6934	0.1787	.078
ASL 4	y = 0.426x + 0.5747	0.448	.065

As expected, all three groups show a positive correlation between accuracy percentage on the Space Relations task and accuracy percentage on the Mirror Reversal task. Participants who are more successful on the SR task tend to be more successful on the MR task, but none of the correlations reached significance. But the trends indicate that the two skills may have at least one underlying skill. It is also interesting to note that the correlation is closer to significance with an increase in ASL experience. Perhaps an ASL L2 group with more experience would have a significant correlation.

Figure 3-15 shows that the two spatial relations tasks are positively correlated for all three language groups, if the students are judged only on the percent correct, which does not penalize participants for being slow to complete the task. The following figure plots the accuracy in raw score on space relations task and the mirror reversal task by language group. By using the raw score, the comparison includes the factor of the time constraint.

Figure 3- 16

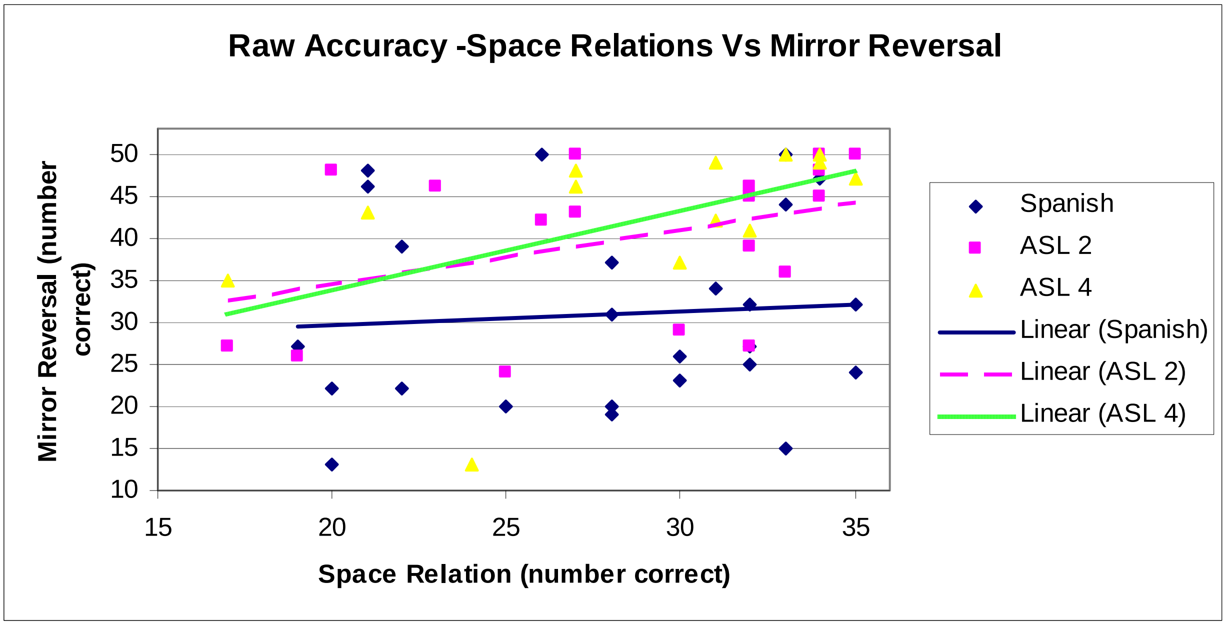


Table 3- 7 Raw Accuracy – Space Relations Vs Mirror Reversal

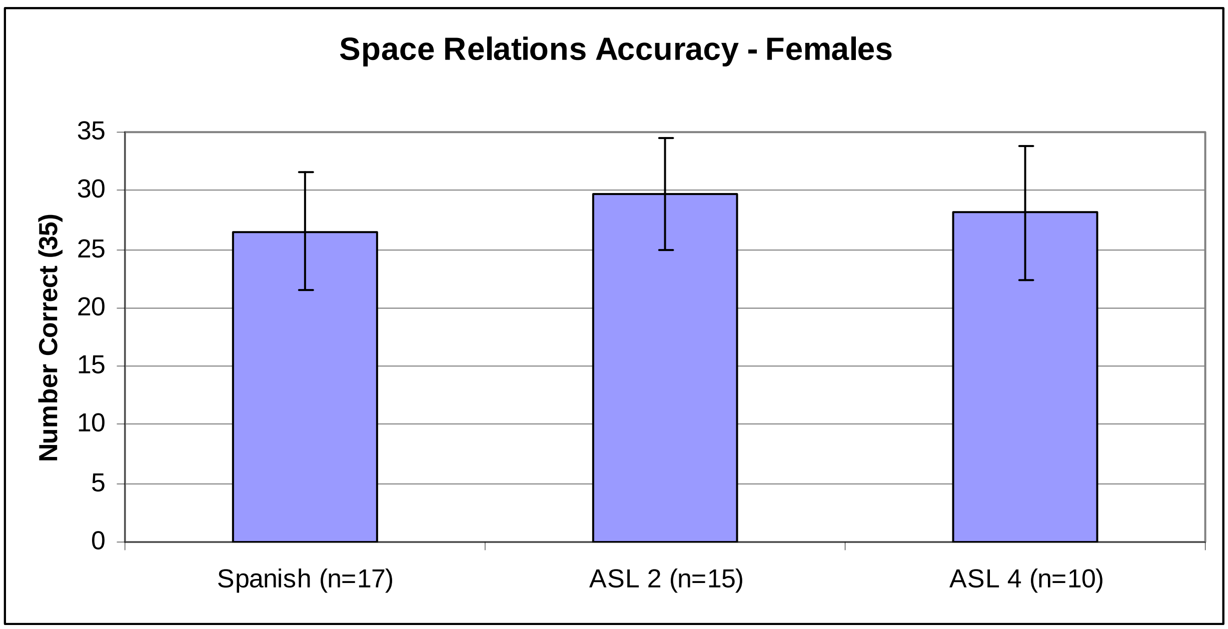
Language	Regression Equation	R^2	Sig. (2-tailed)
Spanish	y = 0.165 + 26.314	0.0058	.717
ASL 2	y = 0.6508x + 21.543	0.157	.104
ASL 4	y = 0.954x + 14.716	0.02695	.296

When considering the increased difficulty introduced with the two minute time constraint, the two ASL groups maintain the positive correlation, but the Spanish group's Space Relation and Mirror Reversal scores show much less correlation. No groups' correlation reached significance. But the trend suggests that the non-signing Spanish group has less relationship between the two scores. For the Spanish group, doing well on the SR task did not predict begin able to correctly answer many more MR test items. Referring to the Spanish group's trend line on Figure 3-16, an increase of only three more mirror reverse test item correct would be expected with an increase of nearly fifteen more space relations test items correct. Being able to solve the space relations test items does not necessarily facilitate being able to make quick and accurate decisions about the mirror reversal test items for the Spanish participants. The two signing groups showed a trend toward a positive correlation between the SR and the MR raw scores. Perhaps signing strengthens a skill needed for both tasks, but the participants in the current study have not had enough signing experience for the correlations to reach significance.

3.3.3 SR Results - Females

Although the groups scores did not differ significantly, I also hypothesized that ASL experience might serve as training for space relation tasks for females. The following figure compares female participants from the Spanish class to female participants from ASL classes.

Figure 3- 17

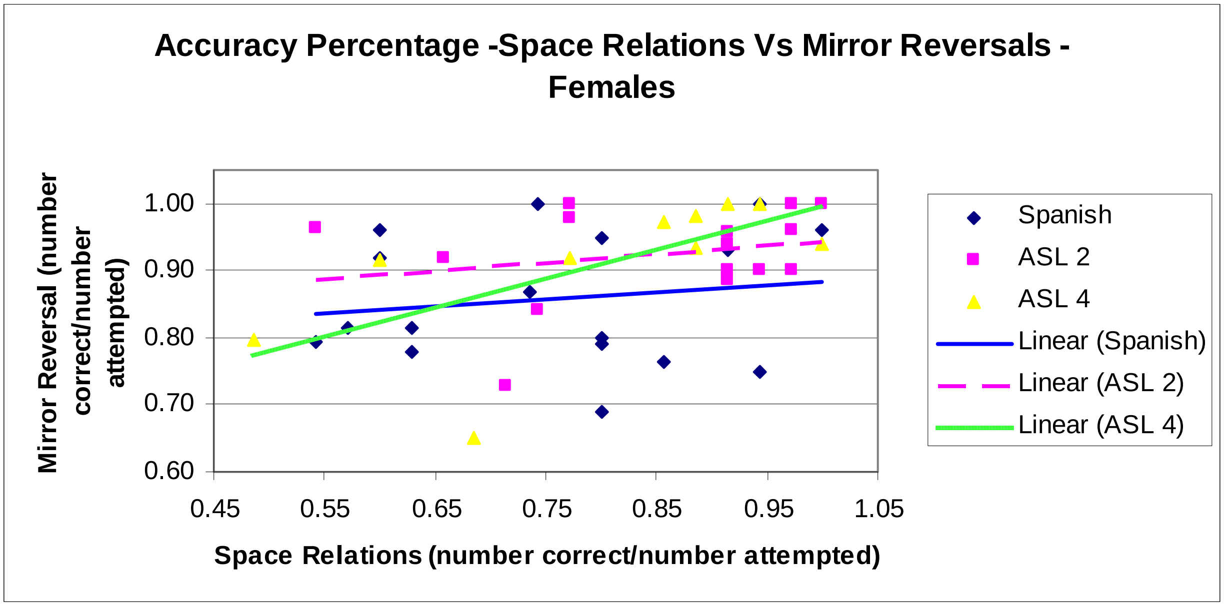


The total range of scores is 17 (one participant) to 35 (three participants). One participant in each language group had a perfect score on the Spatial Relations test. The females in the Spanish classes had the lowest mean of 26.53 (SD 5.06). The female participants in the ASL 2 classes had the highest mean of 29.67 (SD 4.82). The female participants in the ASL 4 classes had a mean of

28.1 (SD 5.76). Although the means excluding the males[8] did not change dramatically, and although the differences between the groups was not statistically significant (F[2, 39]= 1.480, p = .260), it is noteworthy that the Spanish groups mean decreased from 27.92 to 26.53 when males were excluded. The ASL 4 group's mean dropped less than one point when the males were excluded. Given that the gap between the Spanish and ASL scores for both spatial relations tests widened in the female population, it may be that signing experience does serve as some form of spatial relations training which has been shown more helpful to females than to males while in childhood (Connor, Serbin, and Schackman, 1977) and while in college (Burnett and Lane, 1980).

Since the results of the Space Relations task indicates that females might be more affected by the possible spatial relation training of ASL, I questioned if the female population within the language groups would have a different correlation between the two spatial relation tasks. The following figure is again a comparison of Accuracy Percentage of the Space Relation test to the Mirror Reversal test, but Figure 3-18 only compares the female participants.

Figure 3- 18



[8] As a point of comparison, the males had the following means: Spanish 30.88 (4.67), ASL 2 22.33 (6.81), ASL 4 31.67 (4.04).

Table 3- 8 Accuracy Percentage Space Relations Vs Mirror Reversals – Females

Language	Regression Equation	R^2	Sig. (2-tailed)
Spanish	y = 0.1013x + 0.7812	0.0229	.554
ASL 2	y = 0.1256x + 0.8182	0.0572	.363
ASL 4	y = 0.4312x + 0.5646	0.4222	.045

Comparing Figure 3-15, which is the total population to Figure 3-18 which is the female population, we see that the three language groups separate when the males are excluded. ASL 2 and Spanish form nearly parallel trend lines, with the ASL 2 female participants having overall higher scores, but those language groups' correlations between SR accuracy percentage and MR accuracy percentage were not significant. The ASL 4 group had a statistically significant correlation of accuracy percentage on the two spatial relations tests. This result may indicate that a skill required for both MR and SR, or two or more separate skills required for the two tests, are acquired by ASL 4 but not by ASL 2 or in Spanish.

In sum, there is a no difference between the three language groups on the space relations task. However, there is a trend that indicates that ASL experience might act as training for spatial relations tasks because female ASL 2 participants tended to be more accurate than female Spanish participants. Previous research also using college courses as training or controls, found that all groups (male and female) improved on the post-test, but females who received the spatial relations training in a drafting course completed the task significantly faster on an embedded figure test (Johnson, Flinn, and Tyer, 1979). Performance on the two spatial relations tasks are positively correlated when the measurement excludes the time constraint. When raw scores are used, which are affected by the time constraints and can be understood as a measure of reaction time, only the signing students scores are positively correlated. The only significant correlation was the female ASL 4 group's correlation accuracy percentage between SR and MR. The correlations may also be influenced by the participants' own expectations of success on spatial relations tasks (Moe and

Pazzaglia, 2006). For example, female ASL 4 participants might think that they are good at spatial relations tasks (because of signing experience or for unknown reasons). Overall, the results indicate that ASL may serve as spatial relations training, supporting a psycho-social response for gender differences on spatial relation tasks.

4.0 COMPARISION OF FACE-PROCESSING AND SPATIAL RELATIONS RESULTS

4.1 INTRODUCTION

All participants were in four experiments, two face-processing tasks and two space relations tasks. As discussed in Chapter 2, the two face processing tasks are thought to tap separate skills, even though they both involve processing faces. The two space relations experiments, although different tasks, may use some of the same skills, namely mental rotation; and those two test results were compared. In this section, I explore the possibility of correlations between the scores of the spatial relations tasks and the face-processing tasks. Face-processing skills have been described to operate in anatomically distinct system (Farah et al., 1995; Farah, 1996) or domain specific system (Nachson, 1995), so correlations between face-processing tasks and spatial relations tasks are not expected.

4.2 RESULTS AND DISCUSSION

4.2.1 BFRT and Spatial Relations Tests

The following figure compares the Benton Facial Recognition Test and the Mirror Reversal scores in raw accuracy.

Figure 4- 1

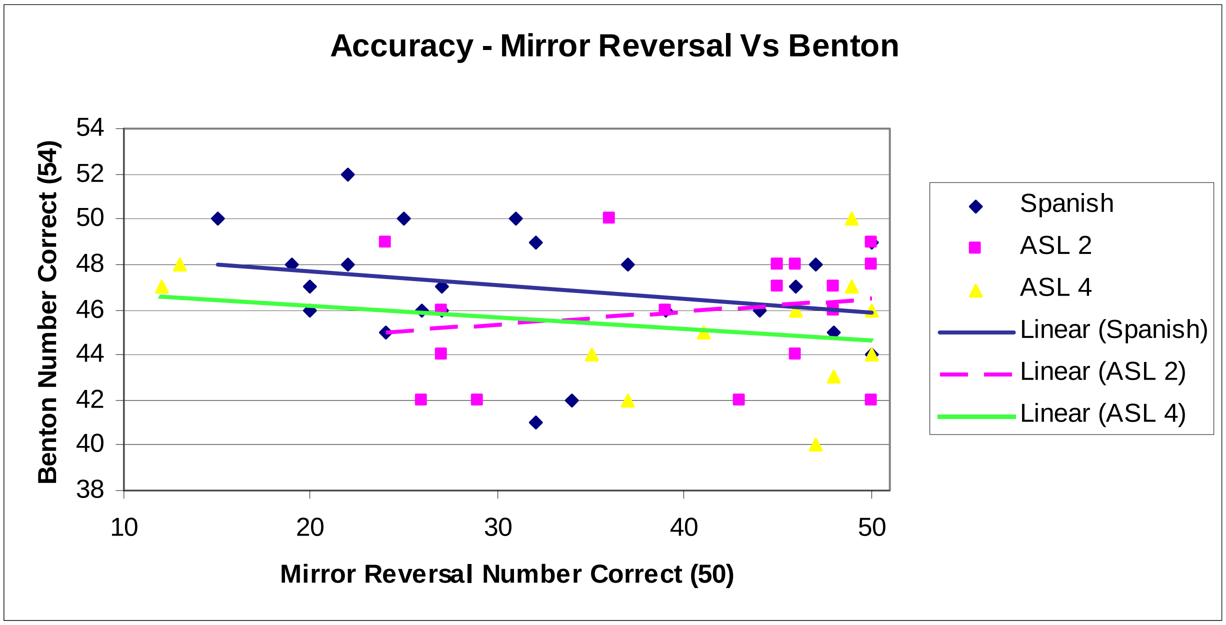


Table 4- 1 Accuracy –Mirror Reversal Vs Benton

Language	Regression Equation	R^2	Sig. (2-tailed)
Spanish	y = -0.024x + 49.955	0.0713	.802
ASL 2	y = 0.0557x + 43.656	0.0386	.655
ASL 4	y = -0.0508x + 47.185	0.0634	.972

As expected, scores on the MR and BFRT tests are not correlated for any language group. This figure compares the accuracy based on raw scores for both tests; a comparison MR accuracy percentage and BFRT raw score also showed no significant correlations.

The following figure compares the accuracy of the BFRT and the Space Relations test.

Figure 4- 2

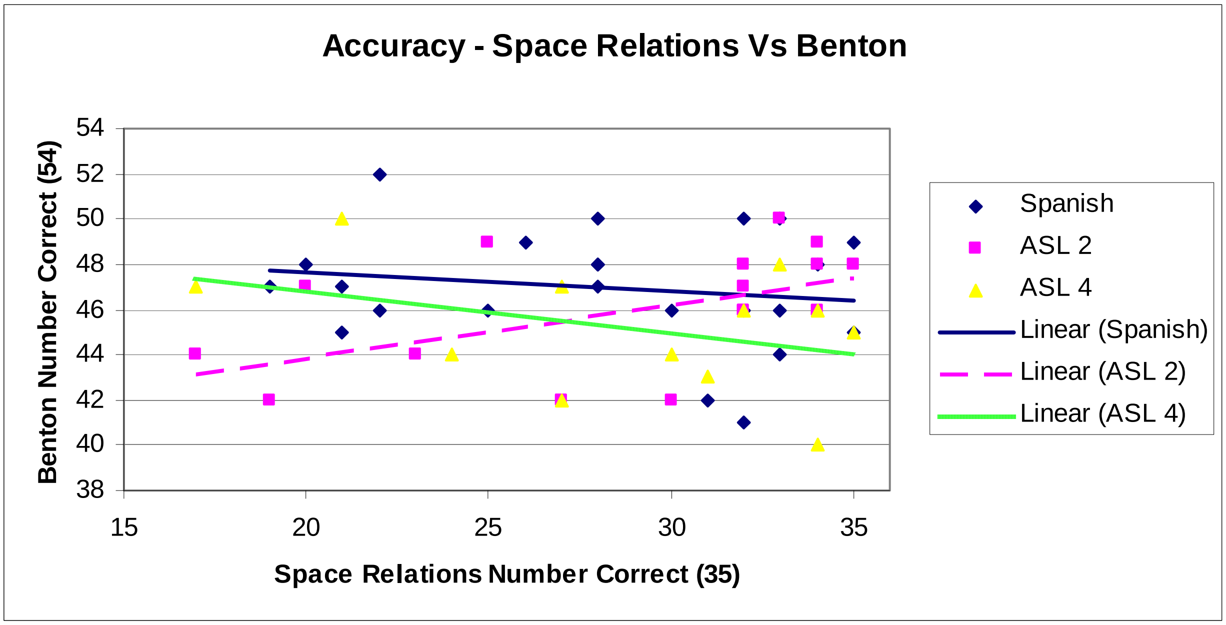


Table 4- 2 Accuracy – Space Relations Vs Benton

Language	Regression Equation	R^2	Sig. (2-tailed)
Spanish	y = -0.0851x + 49.354	0.0294	.646
ASL 2	y = 0.2347x + 39.173	0.2512	.064
ASL 4	y = -0.1867x + 50.533	0.1484	.216

Although the Spanish and ASL 4 groups do not seem to have a relationship between accuracy on the space relations task and the BFRT, the ASL 2 group does show a trend toward a positive correlation ($p = .064$). It is unclear why this result approaches significance.

4.2.2 MFCT and Spatial Relations Tests

The Mooney Faces Closure Test results are not expected to be correlated with either of the spatial relations tests because the tasks do not seem to be related. The following figure correlates the participants' accuracy in raw score on the MFCT and the Mirror Reversal task.

Figure 4- 3

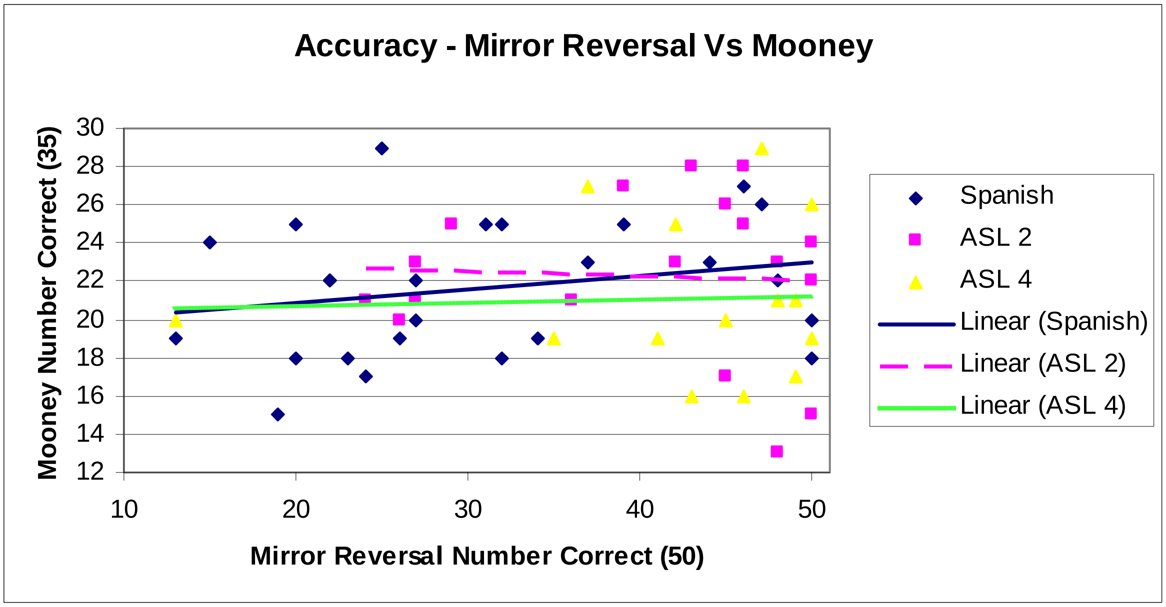


Table 4- 3 Accuracy – Mirror Reversal Vs Mooney Faces Closure Test

Language	Regression Equation	R^2	Sig. (2-tailed)
Spanish	y = 0716x + 19.427	0.0527	.270
ASL 2	y = -0.0237x + 23.283	0.0028	.835
ASL 4	y = 0.0184x + 20.291	0.0019	.883

The nearly flat trend lines indicate that the two tasks are not correlated for any language group, and no correlation was significant. As expected, analysis shows that the tests are, in fact, not correlated.

The next figure illustrates the correlation between the Mooney Faces Closure Test and the Space Relations Test.

Figure 4- 4

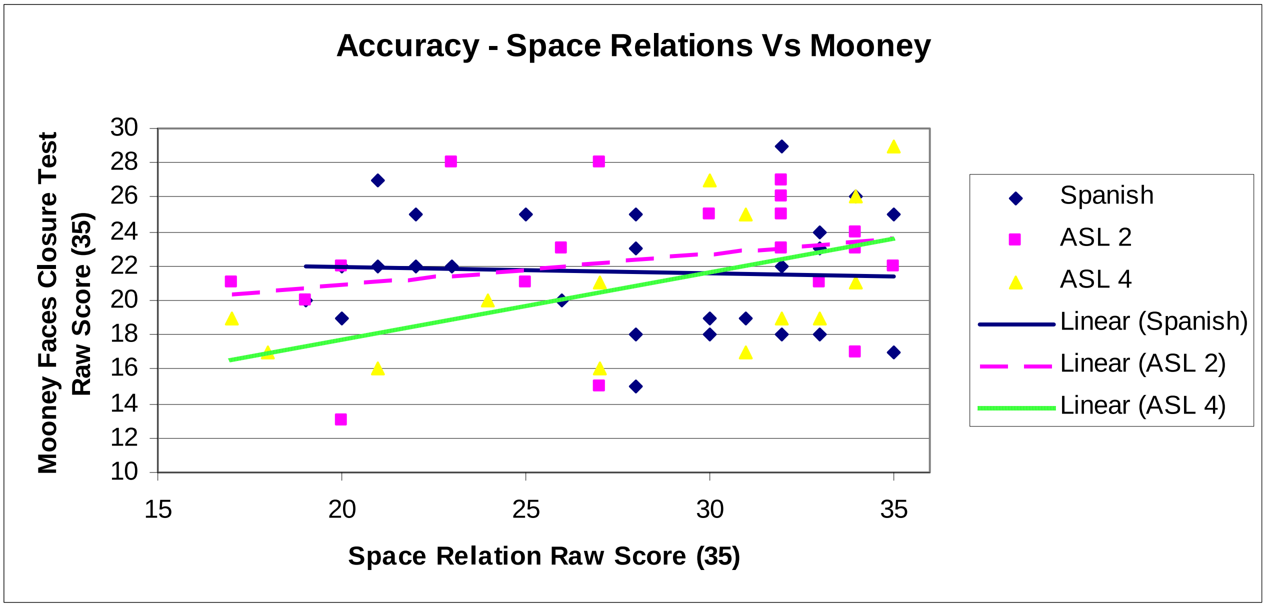


Table 4- 4 Accuracy – Space Relations Vs Mooney

Language	Regression Equation	R^2	Sig. (2-tailed)
Spanish	y = -0.0354x + 22.637	0.0029	.810
ASL 2	y = 0.1839x + 17.167	0.0703	.271
ASL 4	y = 0.3949x + 9.7432	0.3121	.074

Again, no correlation between the MFCT and the SR test was expected, and none was found. There is trend toward a positive correlation for the ASL 4 group. This trend might be driven by three outlier ASL 4 participants whose SR score were lower (<21) than the rest of the ASL 4 scores.

5.0 DISCUSSION AND CONCLUSIONS

5.1 SUMMARY OF RESULTS

The four experiments did reveal some significant findings based on language group. The three groups did not differ in accuracy on either the Benton Facial Recognition Test or the Mooney Faces Closure Test. The Spanish group had a positive correlation between accuracy on the BFRT and on the MFCT. Neither of the ASL groups, however, had correlated scores on the face-processing tests which suggests that ASL experience may affect performance on one of the two tests. I would postulate that ASL would be more likely to affect the BFRT because those stimuli include individual facial features, which is encoded in ASL grammar.

The ASL 2 group's total test time for the MFCT was significantly lower from the ASL 4 group's total test time, and almost significantly lower than the SPAN group's total test time. Also, the ASL 2 group's accuracy and total test time was correlated on the MFCT.

Both of the ASL groups had significantly higher accuracy scores than the Spanish group on the Mirror Reversal test providing further evidence that the spatial-visual modality of ASL effects cognitive processes, such as mirror reversal detection and mental rotation. Since students within a single year of signing experience differed significantly from the non-signing control group, it may be the effects of signing on this task are seen early in the L2 process. In addition, both ASL groups completed significantly more test items within the two-minute time constraint than the Spanish group. Another measure of the ASL 4 success on the MR task, accuracy percentage, was significantly positively correlated with number of completed test items.

The increased success of the signing groups on the MR task could be attributed to an increase in ability to mentally rotate the figure in order to compare the test figures at the same orientation or an increase in detecting mirror reversals. These results suggest maybe both mirror reversal detection and mental rotation skills are affected.

Mental rotation is a cognitive process that is considered analog with the physical process. The results indicate that the signing participants have an increased success on this task which requires some mental rotation. Consequently, the results suggest that experience with signing gives practice for this cognitive process. At least two sources of the practice may be involved. ASL may give opportunity for the students to physically experience receiving information at different rotations, which encourages the students to mentally rotate the information. This practice may then increase the speed with which participants can mentally rotate objects. If so, only limited experience (six months of ASL) impacts this skill because the ASL2 as well as the ASL4 participants significantly outperformed the non-signing SPAN participants in the number of MR test items completed. It could be that this practice explains why the signing students maintained their accuracy levels though 90° rotation while the SPAN participants' accuracy began to decrease after 45° rotation. Perhaps the mental rotation practice from ASL experience enabled the signing participants to regard 45° and 90° rotated items as upright test items. Processing time was then available to detect mirror reversals whereas perhaps the SPAN participants spent more effort on rotation leaving less for mirror reversal detection. Another possibility is that ASL students become more familiar with receiving information from different rotations because of the visual-spatial modality of ASL. In this case, the ASL participants may not mentally rotate the scene, but learn to process the scene at the rotation. This explanation is supported by anecdotal evidence from native signers who claim that they do not mentally rotate scenes but just understand them (Emmorey, Klima, and Hickok, 1998). In addition, Murray's (1997) results in which participants could be taught to "flip" objects rather than "spin" (rotate) them in order to determine mirror reversal. ASL experience might encourage this faster (per Murray) strategy.

The Wilcoxon same-reversal comparison revealed that accuracy was significantly decreased in the reversal condition in certain rotation categories. However, the reversals were not consistently more difficult in every rotation category for any of the language groups. At 90° rotation, for both the SPAN and ASL 4 groups accuracy significantly decreased for reversed test items, but the ASL 2 group had similar accuracy for reversals at the rotation. Both ASL groups had significantly decreased accuracy for the reversed items at 135°, but the SPAN group was similarly accurate at that rotation. At 180° rotation, the SPAN and ASL4 groups were significantly less accurate with reversals than "same's," but the ASL2 group had similar accuracy at this rotation. The accuracy percentages were not consistently significant, even within language groups, which supports that the mirror reversal task is not just another mental flip on a different axis. The results indicate that mirror reversal detection is more difficult when the figures are at rotations closer to 180°.

The Space Relations task did not reveal significant differences based on language group. Although the language groups did not differ significantly on the SR test, a slight gender difference was gleaned from comparing the combined sex means and the female population means on the spatial relations tasks. The SR test seems to be at least two skills: the mental construction of the test figure and the rotation of the constructed three-dimensional figure. It is plausible that ASL experience does not affect the mental construction skill, which explains why language group was not found to be a significant factor. Overall, the significant MR results and, to a lesser extend, the SR results indicate that ASL may serve as spatial relations training, supporting a psycho-social response for gender differences on spatial relation tasks.

5.2 LIMITATIONS AND FUTURE RESEARCH

5.2.1 Mirror Reversal and Mental Rotation

The Mirror Reversal Test combined mental rotation and mirror reversal detection. Perhaps the two skills, mirror reversal detection and mental rotation, could be separated in a future experiment so that the two processes can be analyzed in isolation. The future experiment could include trials in which the participants would not have to consider any rotation, thus removing rotational uncertainty from the participants' processing of the stimuli.

5.2.2 MR Individual Test Item Reaction Times

Future testing could include analysis of reaction times to the millisecond for each MR test item to try to assign reaction time for the mental rotation of the figure and for the mirror reversal decision. Shepard and Metzler (1971) found that reaction time (of correct answers) is a linear function of the rotation of the test figures, configurations of ten connected cubes. In that experiment the figures were either the same or different three-dimensional block figures, which was ascertained by mentally rotating the figures (as per the participants' post experiment interview). However, Hamm et al. (2004) found that participants have longer response times for mirrored test items, regardless of rotation. Therefore, recording and analyzing response times per test item for the language groups might reveal how ASL learning is correlated with mirror reversal detection, mental rotation skills, and general processing speed.

5.2.3 Stimuli

It would also be relevant to test the same participants with the 2-dimensional MR stimuli and the Shephard and Metzler (1971) three dimensional stimuli. Jansen-Osmann and Heil (2007) also found that type of stimulus (for example, animal drawings or polygons) interacted with gender; sometimes females outperformed males, males outperformed females, and sometimes no gender differences were found. Accordingly, future ASL L2 experiments could test rotation and reversal skills with different stimuli. Detailed analysis of incorrect test items may indicate whether participants are using an analytic strategy, which would make mirror reversal detection difficult, or rotation strategy (Geiser, Lehmann, and Eid, 2006). This research's results merit further testing of ASL L2 participants on mirror reversal and mental rotation tasks.

5.2.4 Amount of ASL L2 Experience

Significant results were found on the MR test rather soon in ASL learning. It may be enlightening to test ASL1 students for effects. Moreover, an experiment could be designed in which mental rotation and/or mirror reversal practice was stressed with some classes and the regular curriculum would serve as the control participants. Mental rotation practice could include activities where signs were given at angles (for example, 45° angles) and paper and pencil worksheets asking students to identify signs or objects that have been rotated. Mirror reversal activities include having to mirror a partner's movements and also producing the movement without mirror despite being face-to-face.

It may be that not all significant effects are found with only 6 or 18 months of experience using ASL as an L2, not as a primary language used everyday for basic communication. A future longitudinal experiment could include ASL L2 with over two years of continued signing experience, such as ASL interpreters. It may be possible to determine a timeline for non-linguistic effects. A longitudinal study could also address if accuracy increases linearly or has a curvilinear increase, i.e. that accuracy increases with ASL experience to an accuracy plateau.

5.2.5 Sample Size

The sample sizes of each group did not reach the goal for the study (n=30); larger groups may have produced more statistically significant results. Convenience samples are challenging, but participation incentives could increase sample sizes. An increase in sample sizes would also make analysis of factors such as gender more informative.

5.2.6 Spatial Relations Training

A pre- and post-test design could attempt to answer if signing experience does act as training for spatial relations skills particularly for the female signers. This question is relevant as the DAT-

Space Relations test is used an IQ test. If the results are driven in part by experience, then the test is questionable as an intelligent quotient. Moreover, if spatial relation skills are improved by learning ASL as an L2, people may be more motivated to choose ASL as an L2. And more schools may want to offer ASL as a foreign language. Furthermore, ASL teachers could use the testing and results to improve instruction. For example, perhaps some students need additional practice in mental rotation or mirror reversal detection which would then improve their ASL learning.

5.2.7 Demographic Information

For any future experiments, I would improve the requested demographic information screen. The participants could have chosen language class and then language level. This improvement would have created four language groups, SPAN 2, SPAN 4, ASL 2 and ASL 4. Separating the two levels of Spanish participants might have revealed if the language level groups (level 2 and level 4) were more alike than language groups (Spanish and ASL).

It might also be interesting to recruit control group participants from another less-commonly-taught language, for example, Arabic.

5.2.8 Proficiency Ratings

The separate ANOVA analysis for proficiency did not yield significant results. It may be that proficiency is not relevant to the tasks, or conversely, the proficiency ratings were not accurate. Proficiency was not determined by any administered language proficiency test. No standard ASL proficiency test is in use. Proficiency can be based on instruction level (Carrell, 1991; Brisbois, 1995), and so the language levels included could be considered a type of proficiency. Nonetheless, as described above, proficiency was solely self-rated. However, the proficiency rating used in this experiment was superficial. An improvement would be administering a more thorough questionnaire about the participants' language skills, like Clarke's three-point scale which asks "can do" questions (Clarke, 1981). Rather than a language production proficiency rating like Clarke's, a receptive ASL proficiency test might be a more valid measure to use with non-linguistic tests. Participants could be asked to answer questions after watching video clips of ASL. The questions could be designed to ascertain proficiency in the spatially related grammar of ASL. The designed proficiency test could then be used by the ASL teacher as an assessment tool for material mastery or student placement into levels.

In summary, language group was only found to be a significant factor on the Mirror Reversal Test ($p = .002$). Both ASL groups were significantly more successful on this task than the Spanish group ($p < .02$). The signing groups were able to attempt more test items in the challenging two-minute time limit which enabled the signing groups to answer more correctly. The results indicate that experience with ASL, even adult L2 with less than a year experience, is correlated with an increase skill on the Mirror Reversal Test. All groups had a decrease in accuracy with test items at higher rotations. Mirror reversal detection was generally more difficult at higher rotations. Wilcoxon analysis revealed that each groups' accuracy on reversed test items sometimes differed significantly within each rotation category, but reversal was not consistently more difficult. Taking together, these results support that mental rotation and mirror reversal detection are separate skills.

With focus on spatial relations tasks for future experiments, improvements in test design would include increased sample sizes, additional language groups, recording participants' reaction times for individual test items, and separating mirror reversal detection from mental rotation tasks.

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APPENDIX A

Age ________ Gender Male Female

Major ____

African-American Asian Caucasian Hawaiian/Pacific Islander

Hispanic/Latino Native American Other ________________________

Do you have normal hearing? Yes No

Do you have normal vision (with or without corrective lenses)? Yes No

Are you Right-Handed Left-Handed Ambidextrous

Is English your native and preferred language? Yes No

List all foreign/second languages you know in order of most proficient to least proficient.

Rate your language ability on the following aspects.

(1-very poor, 2-poor, 3-fair, 4-functional, 5-goood, 6- very good, 7-native like, n/a-not applicable)

	Language	speaking/signing	listening/receptive	reading	writing
1.	__________________	_______	_______	_______	______
2.	__________________	_______	_______	_______	______
3.	__________________	_______	_______	_______	______

Do you have experience with American Sign Language (ASL)? Yes No

If yes, are you currently taking ASL 2 ASL 4

If yes, did you have signing experience before taking classes at Pitt? Yes No

Please describe your signing experience, including length of experience.

ASL students:

Who is (has been) your teacher(s)

ASL 1 ____

ASL 2 ____

ASL 3 ____

ASL 4 ____

APPENDIX B

NLCE

Enter the CODE Number that you were assigned. Enter only the number. It will take a few seconds for the program to load; please wait. You should not enter the code twice.

This experiment is in five (5) sections. Before each section, there will instructions for that section. If you have any questions about what you are to do, please ask on the instruction pages. Before a testing section, the continue button will read, "Continue to test." Since the program records response time, please do not wait to ask questions during the testing sections.

Below are summaries of the instructions for each section. In each section, make a choice (your best guess), even if you are unsure. The program may present the sections in a different order than presented below.

Face 1 part 1

Choose the single matching face from the choices (1-6) to the target face.

Face 1 part 2

Choose the <u>three</u> (3) matching faces from the choices (1-6) to the target face.

Face 2

Label each image as either
-a boy
-a girl
-a man
-a woman
-an old man
-an old woman

Space 1

Decide if the figure to the right is the same or mirror-reversed image of the figure on the left, regardless of the figure's rotation.

Space 2

Decide which one of the choices (A-D) could be made from the pattern shown.

APPENDIX C

Mooney Faces Closure Test items and answers


old man


adult woman


woman/girl


adult woman


adult man


old man


man/old man


adult man


adult woman

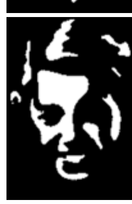

man/old man


adult woman


girl


adult woman


woman/old woman


woman


old man


boy/girl


adult man


adult man


girl


adult man


adult woman


old man


adult man


adult man


man/old man/old woman


old man/old woman


old man/old woman


old man


adult man


adult man


adult man


old man


adult woman

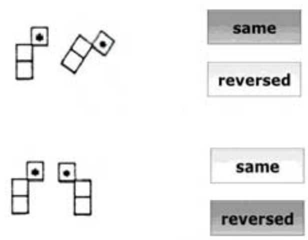

boy/girl

APPENDIX D

Space 1 Test

On the following screens, you will see pairs of forms, each having an asterisk at the top. The leftmost form will always be upright, and the rightmost one will be tilted.

Your task is to decide whether the rightmost form faces the same way as the leftmost one, irrespective of orientation. That is, if they were both upright, would they be identical ("same") or mirror-reversed ("reversed")?



Continue

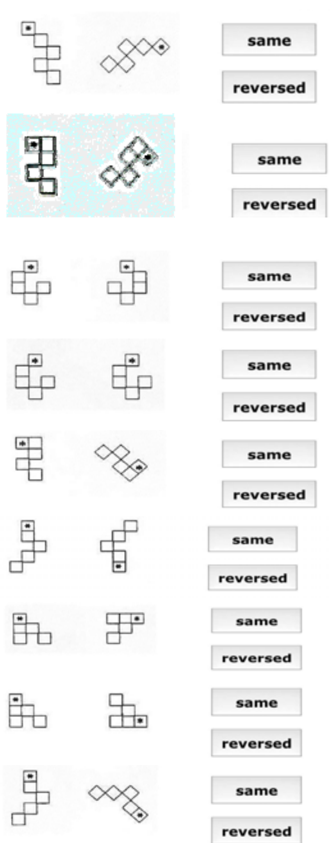
Space 1 Test

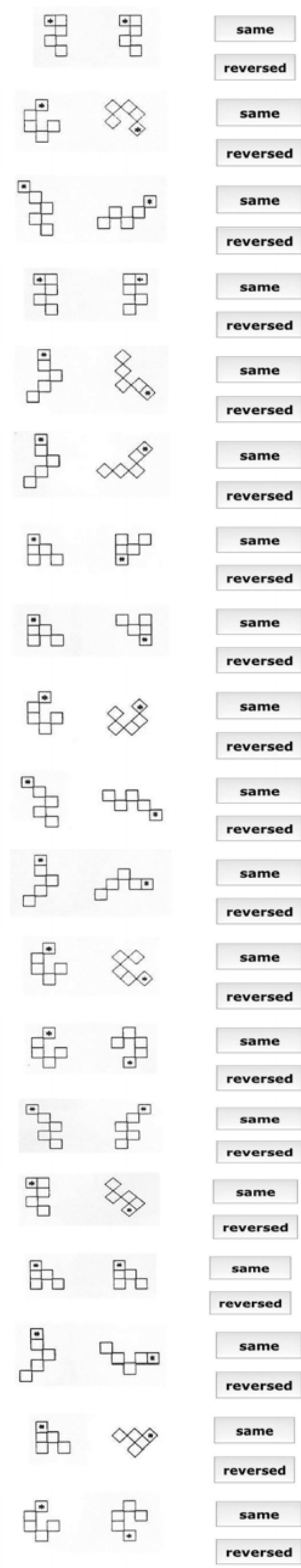
After you decide whether a given pair contains same or reversed forms, please click the appropriate word to its right, and go on to the next pair. There are a total of 50 pairs in this section.

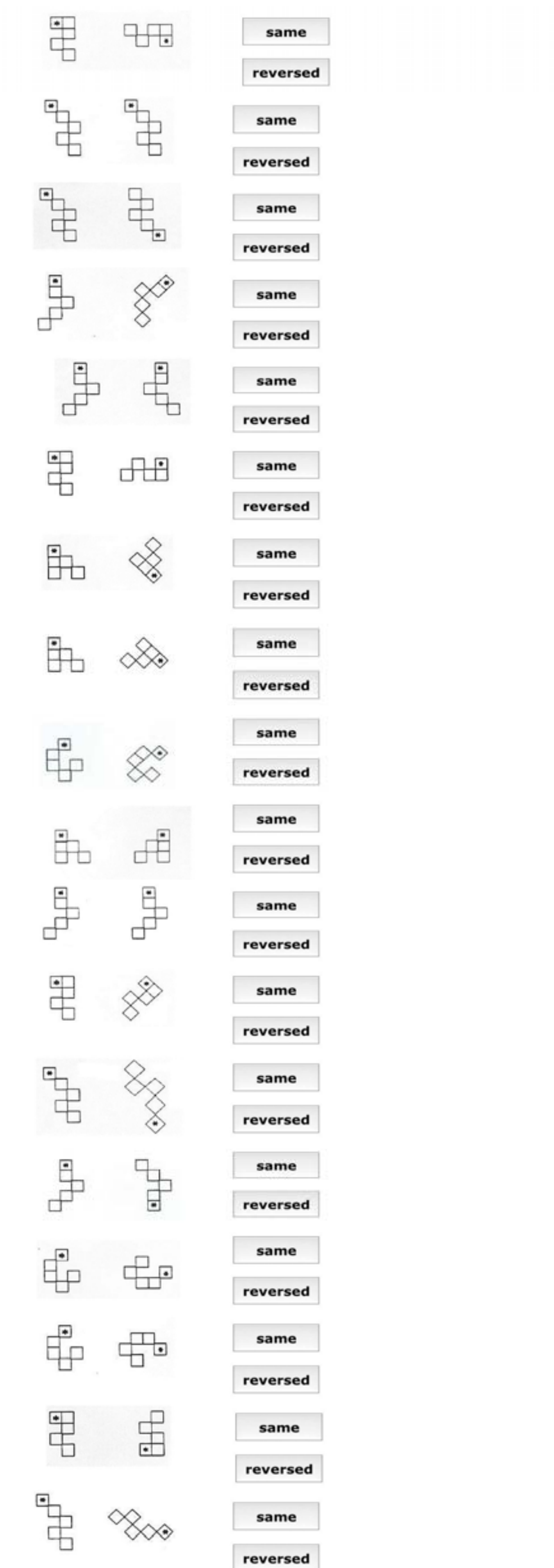
You will have two minutes to work through the test; please work as quickly and accurately as possible.

There is no "Continue" button for the items in the next subtest. The next item will appear as soon as you click on your choice.

Continue to test






same
reversed
same
reversed
same
reversed
same
reversed
same
reversed
same
reversed
same
reversed
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same
reversed
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