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Abstract

The sources of knowledge that individuals use to make similarity judgments about words are thought to tap underlying phonological representations. This study addresses the issue of segmental representation by investigating bilingual deaf students' (a) awareness of American Sign Language (ASL) phonological structure; (b) the relationships between ASL phonological awareness (ASL-PA) and written English word recognition and reading comprehension skill, and (c) the question of whether age and/or reading ability would differentially affect performance on an ASL-PA task in fifty bilingual deaf children (ages 7–18) attending schools for deaf children in Western Canada. In the ASL-PA task, minimal contrasts between ASL parameters (handshape, movement, and location; H, M, and L, respectively) were systematically manipulated. The results show significant differences in deaf students' ASL phonological awareness, with discrimination accuracy improving with age and reading ability. Significant relationships between children's second language (L2) reading skills and first language (L1) phonological awareness skills were found. Evidence of rich metalinguistic knowledge that children with developing L1 phonological skills bring to the acquisition of L2 reading skills may have practical implications for the education of bilingual deaf children.

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*We often think that when we have completed the study of one, we know all about two, because two is one and one. We forget that we have still to make a study of the "and."*

Kilmister, *Sir Arthur Eddington: Selections*

Research that outlines the factors that contribute to successful reading acquisition for monolingual and bilingual hearing children is widely available (see reviews in Ehri 2005 and Grabe 2009). For example, the understanding that spoken words are made up of component parts, (i.e., phonological awareness) has been implicated in the development of reading for children who use spoken languages for communication (see review in Mody 2003). By contrast, we know very little about the specific language factors that contribute to the development of English reading skills for deaf-signing children who use American Sign Language (ASL) for communication. Historically, research on deaf individuals' reading skills has been limited to a monolingual spoken language perspective and has occurred without consideration for the role of visual language acquisition. Consequently, the evidence base available to inform the teaching of reading skills to users of visual languages remains limited. Learning to navigate different languages (e.g., ASL, English) that utilize different modalities (visual and aural, respectively) represents a unique bilingual circumstance (see review in Shook and Marian 2010). Although far more research has been done on bilingualism in deaf children and adults now than even ten years ago (e.g., Emmorey and McCullough 2009; Morford et al. 2011; Petitto 2009; Piñar, Dussias, and Morford 2011), the unique and complex processes involved in learning to negotiate the requirements of print-based literacy for deaf children remains poorly understood.

Most of the current theories of first- and second-language reading development stress the importance of spoken-language phonological skills (for reviews see Mody 2003; Koda 2007; Grabe 2009). Thus, the degree to which spoken-language phonological processing skills influence the course of reading development in deaf learners is a question that persists in the literature. Of note, in a recent review of past research on this question, meta-analysis results indicate that spoken-language phonological skills accounted for only 11 percent of the variance in reading ability among deaf learners (Mayberry, del Guidice, and Lieberman 2011). Overall language proficiency (either ASL or English) was found to be the best predictor of reading achievement. Moreover, no evidence of phonological coding and awareness abilities was found in half of the studies examined (i.e., fifty-seven studies met the meta-analysis criteria). Similarly, McQuarrie and Parrila (2009) found no evidence of spoken-language phonological awareness at the syllable, rhyme, or phoneme levels among deaf students (ages 8–18) despite reading skills ranging from poor to very skilled. These findings indicate that substantial, even average reading achievement is possible in the absence of spoken-language phonological awareness and suggest that skills other than spoken-language phonological abilities play critical roles in the reading achievement of signing deaf individuals. Importantly, conventional models of reading acquisition that are premised on the centrality of a spoken-language phonological code cannot easily account for the performance of these highly skilled bilingual deaf readers. Research on the degree to which sign language phonological processing skills influence the course of reading development for bilingual deaf readers could thus be a promising area and may shed light on "whether PA is a language-specific construct or a general competence shared across languages" (Koda 2007, 25).

Although recent evidence documents a significant relationship between students' proficiency in ASL and their English literacy skills (see reviews in Chamberlain and Mayberry 2000; Piñar, Dussias, and Morford 2011), the exact nature of this relationship is not clear. Existing research has not determined whether the development of ASL phonological awareness (ASL-PA) is related to English word recognition, nor has it established whether ASL-PA is related to English reading comprehension for bilingual deaf children. These are important questions that, to our knowledge, have not been systematically investigated. Answers to these questions are essential for understanding reading-acquisition processes and developing optimal literacy instruction for children whose phonological foundation is based on the visual/formational patterns of signs rather than on the auditory/phonetic patterns of speech (see review in McQuarrie 2005). In this article we outline the present study, which investigates bilingual deaf students' awareness of the phonological structure of ASL and the relationships between ASL-PA, English written-word recognition, and English reading-comprehension skills.

## Method

### *Participants*

Fifty students (nineteen female and thirty-one male) between the ages of 7 and 18 ($M$ = 13 years, 5 months) participated in this study. The students attended dual-language (ASL-English) programs in specialized schools for deaf students in Western Canada, had begun learning ASL before the age of 6, and used it as their primary mode of communication in school. Of the fifty participants, thirty-eight (73 percent) were born profoundly deaf (> 90 dB), and six (13.5 percent) were born with a severe loss in the 75–89 dB range. Six students (13.5 percent) were prelingually deafened and had profound hearing losses diagnosed prior to 18 months of age. No participant had a cochlear implant. Seven students had families headed by Deaf parents, and forty-three students had families headed by hearing parents (eighteen of these students had some family history of deafness). All of the participants had normal or corrected-to-normal vision. None of the participants had been identified as having significant language or learning difficulties.

### *Measures*

Background measures were obtained for each participant: a pure-tone audiogram from the school, a nonverbal (performance) IQ measure, an ASL language-proficiency rating, and measures of word recognition and a reading comprehension level. A family-background questionnaire was also completed by the student's parent or guardian. Participants' awareness of ASL phonological structure was assessed by means of an ASL-PA experimental task: three, two and, one shared-parameter matching.

#### *Background Measures.*

ASL PROFICIENCY. The students' proficiency in ASL was rated by a Deaf ASL specialist who was familiar with the students. The students were rated from one to ten on their receptive and expressive use of

ASL. The scores on the receptive and expressive components were averaged to provide an overall language-proficiency score.

Background questionnaire. A detailed questionnaire was completed by a parent or guardian of the study participants. This information included the child's age, mother's and father's occupation and highest level of education, family hearing status, vision status, etiology, age of onset, age of diagnosis, amplification use, family communication practices, child's educational placement background, speech use, and speech comprehension.

Reading comprehension. The Reading Comprehension Subtest of the Revised/Normative Update of the Peabody Individual Achievement Test (PIAT-R/NU) (Markwardt 1997) was used to assess the students' reading comprehension skills. Standardized administration of the test was followed, with the stipulation that instructions be delivered in ASL rather than in spoken English. In this test, the participants were required to read a sentence silently and point to one of four pictures that best illustrated the sentence that was just read. The examiner recorded each student's response on an answer form.

Word recognition/reading vocabulary. A modified version of the Word Identification test from the Woodcock Reading Mastery Test-Revised/Normative Update (WRMT-R/NU; Woodcock 1998) was used to measure word recognition. Typical administration of the test requires hearing-speaking participants to read isolated words aloud. In a modification of test-administration procedures, deaf-signing participants read a printed stimulus word silently and pointed to one of four pictures that best illustrated the word they had just read. The examiner recorded each student's response on an answer form. Words were graded in difficulty from preprimer to adult level and presented one at a time. The participant's score was the number of correctly read words. A cutoff rule of six consecutive mistakes was applied.

ASL phonological awareness (ASL-PA). The students' ASL-PA was measured using a seventy-six-item, receptive-based, phonological-similarity judgment task (picture matching-to-sample). The task required discrimination of similarity relations in signs sharing one, two, or all three of the specified parameters. A test item consisted of a four-picture quadruplet made up of a cue, a target response that matched the cue in one or more of the parameters being tested, and two additional distracters. The position of the target phonological item was randomized across the three serial-response choice positions. The tests items were arranged in three sets and were grouped as follows:

- Set 1 contained ten test items where cue and target shared three parameters (H + L+ M). Set 1 example: NAME-CHAIR.
- Set 2 consisted of thirty-six test items where cue and target shared two parameters (H + M; L + M; H + L). There were twelve test items for each two-parameter cue-target pairing. Set 2 examples: H + M (EAGLE-GLASS); L + M (FORK-COOKIE); and H + L (CHURCH-CHOCOLATE).
- Set 3 had thirty test items, ten for each single-parameter cue-target pairing (H, L, or M). Set 3 examples: H (GRASS-LION); L (DOLL-BUG); or M (APPLE-KEY).

Manipulation of phonological contrasts in sign formation was intended to clarify the extent to which the resolution of phonological similarity judgments may be differentially affected by formational complexity. Nameable pictures were used as the stimuli. Although nameable pictures are remembered in phonological rather than visual codes (see Schiano and Watkins 1981), phonological information is not present in picture stimuli. Importantly, in such tasks, participants are required to internally generate a phonological representation of the intended item labels before the name of the pictures can be held in short-term memory. In the ASL-PA task, the process being studied was that of encoding the picture stimuli and the labels activated by them and then deciding which item label was a better fit with the cue.

The picture stimuli were presented on a computer. The cue picture was outlined by a box with a red frame and was centered on the computer screen. The three picture-response choices, which were the same size as the cue, were bounded by yellow frames and aligned directly underneath the cue picture. The four pictures appeared at the same time on the computer screen. Participants were required to point to the picture on the computer screen whose sign was "most similar" to the cue from the three alternative pictures. The examiner recorded the participant's choice by pressing a number pad connected to the computer, which allowed for accuracy and response-choice data to be recorded. Cronbach's alpha reliability coefficient in our sample on this measure was 0.87.

## Design and Procedure

Descriptive statistics were calculated to identify students' knowledge of the phonological structure of ASL. Within-subjects repeated-measures ANOVAs were conducted to determine whether significant differences in difficulty occurred across single- and shared-parameter pairing combinations. Pearson product-moment correlations were used to identify relationships between students' ASL phonological awareness, English word recognition, and reading comprehension scores. Independent *t*-tests were performed to determine the effect of age and reading ability on ASL-PA.

Between February and April of the school year, a test battery of spoken-language and ASL experimental tasks was administered to all of the participants as part of a larger study. The total test battery took approximately 120 minutes to administer and was spread out over three or four sessions. The ASL-PA task reported on here was completed in one session of thirty to forty minutes. Administration of the reading measures (i.e., the PIAT-R/NU and a modified WRMT-R/NU) required an additional testing session of roughly 35 minutes. In their respective schools during school hours, all of the participants were tested individually in a private room free of distractions. All of the assessments were administered directly by a fluent signer, and all of the instructions were given in both ASL and print. Explicit instruction and a training session preceded the ASL-PA testing. No pictures from the experimental stimuli were used in the training session, and the participants received feedback on the correctness of their response. Before beginning the computerized trials, the participants' familiarity with the correct sign of all of the experimental picture stimuli was ensured through pretesting using a task-specific picture dictionary created for this purpose.

The nameable picture stimuli for the ASL-PA task was presented on a laptop computer using DirectRT precision-timing software. Each student sat facing the laptop, while the examiner sat to the right of the student. The experimental procedures for the task were outlined, and the examiner answered any questions the participant had. Understanding of the task requirements was further reinforced by computer practice trials, which included feedback on incorrect responses, preceding the ASL-PA task. No feedback was provided once the testing session began.

## Results

The performance data are reported here in percentage correct, as percentages allow for clearer comparisons of the test-score means. Descriptive statistics for all of the measures are shown in tables 1 and 2. Data distributions were examined for outliers and violations of assumptions. Normality tests were met for all measures except for the ASL-PA handshape- and location-parameter scores. These two measures had slight negative skews, which may have been caused by a possible ceiling effect of the tasks. The handshape- and location-parameter scores were not transformed, however, because in practice, the statistical analysis used to examine the differences in difficulty

Table 1. Descriptive Statistics for ASL-PA Total, Shared, and Individual Item Parameters in Percentage Correct ($n$ = 50).

| | *M* | *SD* | *Range* |
|---|---|---|---|
| ASL-PA Total Score | 84.71 | 7.40 | 52.6–97.4 |
| *Parameters* | | | |
| 3 Shared | | | |
| H + M + L | 88.60 | 13.09 | 50.00–100 |
| 2 Shared | | | |
| H + L | 89.83 | 14.51 | 25.00–100 |
| L + M | 85.17 | 13.91 | 41.67–100 |
| H + M | 82.17 | 12.71 | 41.67–100 |
| Individual | | | |
| Location (L) | 89.60 | 11.60 | 40.00–100 |
| Handshape (H) | 89.40 | 14.34 | 40.00–100 |
| Movement (M) | 67.60 | 18.02 | 30.00–100 |

Table 2. Descriptive Statistics for ASL Phonological Awareness and English Reading Measures in Percentage Correct ($n$ = 50).

| | *M* | *SD* | *Range* |
|---|---|---|---|
| ASL phonological awareness | 84.71 | 7.40 | 52.6 – 97.4 |
| Word recognition (modified WRMT-R/NU) | 74.02 | 13.11 | 38.0 – 93.0 |
| Comprehension (PIAT-R/NU) | 52.84 | 16.91 | 22.0 – 100 |
| Reading grade equivalent | 3.92 | 2.74 | 1.2 – 12.9 |

between the ASL-PA parameters (i.e., ANOVA) is robust to minor violations of normality. Scatterplots were also visually inspected to ensure linear relationships between ASL-PA, word recognition, and reading-comprehension scores.

### Research Question 1

The first question posed in this study was whether deaf children have an awareness of signs as segmentable forms. This was determined by examining the means on the total task and across the three sets of parameter sharing (see table 1). For comparison purposes, all scores were converted to percentages.

The mean total task score ($M$ = 84.71) and shared and individual condition means (with the exception of the individual movement parameter) indicated that the deaf children in this study did not have difficulty discriminating phonological similarity. The mean for the shared-parameter combination where movement was the parameter of contrast (i.e., H + L) was higher than the means for the other parameter combinations: H + L ($M$ = 89.8), H + M + L ($M$ = 88.6), L + M ($M$ = 85.2), H + M ($M$ = 82.2). At the individual level (H, L, M) the mean for the movement subscale ($M$ = 67.6) was lower than the means for the handshape and location subscales ($M$ = 89.4 and 89.6, respectively). In addition, the range and the SD of scores for the movement subscale (range = 30–100, SD = 18.02) were greater than the ranges and the SDs of scores for the handshape and location subscales (range for H and L = 40–100, SD = 14.34 and 11.59, respectively). Research question 2 addressed whether these differences in means were statistically significant.

*Research Question 2*

A within-subjects, repeated-measures ANOVA design was used to determine whether particular combinations of shared ASL-PA parameters were significantly more difficult than the other parameter combinations for the deaf children in the study. Because the sphericity assumption was met (i.e., Mauchly's *W* was not significant, $W(2) = 0.976$, $p = .947$), no correction was applied. The effect for parameter combination was significant and of medium effect size [$F(3, 147) = 6.14$, $p < .001$, $\eta_p^2 = .111$]. Therefore, the null hypothesis that the means for the ASL-PA shared parameter combinations were equal was rejected.

To determine which differences among the shared parameters were significant, post-hoc comparisons using the Bonferroni adjustment for multiple comparisons were performed. Tests of within-subject comparisons across components revealed significant differences between H + M + L and H + M ($M = 88.6$ versus $M = 82.2$, $p < .001$) and between H + M and H + L ($M = 82.2$ versus $M = 89.8$, $p < .001$). However, no significant differences were found between the means for the following parameter combinations: H + M + L and L + M, H + M and L + M, and L + M and H + L.

Although the differences between individual parameters suggested that the movement parameter of ASL-PA was more difficult than the other two parameters, this hypothesis needed to be tested statistically. Therefore, a within-subjects, repeated-measures ANOVA design was used to determine which single-parameter pairings were significantly more difficult for the deaf children in the study. The sphericity assumption was met (i.e., Mauchly's *W* was not significant, $W(2) = 0.989$, $p < .001$), so no correction was applied. The effect for parameter was large and significant [$F(2, 98) = 49.55$, $p < .001$, $\eta_p^2 = .503$]. Therefore, the null hypothesis that the means for the three individual ASL-PA components (H, L, M) were equal was rejected.

To determine which differences among single-parameter pairings were significant, post-hoc comparisons using the Bonferroni adjustment for multiple comparisons were performed. Tests of within-subject comparisons across these parameters revealed significant differences between handshape and movement ($M = 89.4$ versus $M = 67.6$,

$p < .001$) and between location and movement ($M = 89.6$ versus $M = 67.6$, $p < .001$). However, there was no significant difference between the means for handshape and location.

### *Research Question 3*

The third question posed in this study was whether relationships existed between bilingual deaf students' ASL-PA, English word recognition, and reading comprehension scores. Descriptive statistics for the ASL-PA total score and the measures of word recognition (modified WRMT-R/NU) and reading comprehension (PIAT-R/NU) are presented in table 2.

The means for these measures were 84.7 for ASL-PA, 74.0 for word recognition, and 52.8 for reading comprehension. Pearson product-moment correlations were calculated to determine the relationships between the three scores. As table 3 shows, a significant moderately positive correlation was found between overall ASL-PA and word recognition scores ($r = .47$, $p < .01$). The slope of +0.84 indicates that for an increase of 1 score point in ASL-PA, there was an increase of almost 1 score point in word-recognition scores. The $r^2$ of .23 between total ASL-PA and word recognition means that 23 percent of the variance can be explained by the relationships between the two variables rather than by chance or some other cause(s).

A significant moderately positive correlation was also found between total ASL-PA and reading comprehension ($r = .48$, $p < .01$). The slope of +1.09 indicates that for an increase of 1 score point in ASL-PA, there was an increase of a little more than 1 score point

Table 3. Correlations between ASL Phonological Awareness (ASL-PA) and Two English Reading Measures: Word Recognition (Modified WRMT-R/NU) and Comprehension (PIAT-R/NU) ($n = 50$).

| | ASL-PA | Modified WRMT-R/NU | PIAT-R/NU |
|---|---|---|---|
| ASL-PA | — | | |
| Modified WRMT-R/NU | .47* | — | |
| PIAT-R/NU | .48* | .76* | — |

*$p < .01$.

in PIAT-R scores. The $r^2$ of .23 between total ASL-PA and reading comprehension indicates that 23 percent of the variability in reading comprehension is consistently associated with ASL-PA scores. In addition, word recognition was found to be a significant predictor of reading comprehension ($r = .76$, $p < .01$).

*Research Question 4*

The fourth question posed in this study had to do with whether participants' performance on the ASL-PA task would vary as a function of age and/or reading ability. Age and reading ability were only moderately correlated ($r = .49$, $p < .01$); thus separate analyses were conducted in order to better discriminate between the effect of age and the effect of reading ability.

To determine whether performance on the ASL-PA task was differentially related to age, the 50 participants were sorted into younger (7–12 years) and older (13–18years) age categories: 16 participants were in the younger group, and 34 were in the older group. Mean ages for the two groups were as follows: younger = 9.5 years, SD = 1.46; older = 15.3 years, SD = 1.62. An independent samples *t*-test was conducted to determine whether the older students performed significantly better on the ASL-PA items than the younger students. The results indicate that the older group had significantly higher ASL-PA scores ($M = 66.26$, SD = 6.60) than the younger students ($M = 60.38$, SD = 7.61; $t(48) = -2.80$, $p < .01$).

To determine whether performance on the ASL-PA task was differentially related to reading, the participants were divided into two groups based on reading age (RA), those reading above and below the age 9 level because 9 years of age corresponds to the third- and fourth-grade median level of reading achievement of the deaf school-aged population (Allen 1986). There were 29 participants in the RA < 9 group and 21 participants in the RA > 9 group. Mean reading ages for the two groups were as follows: RA < 9, $M = 7.75$ years, SD = 0.72; RA > 9, $M = 11.75$ years, SD = 3.0. An independent samples *t*-test was conducted to determine whether the students who had higher reading ages performed significantly better on the ASL-PA items than students who had lower reading ages. The results indicate that the more advanced readers (RA > 9) had significantly higher ASL-PA scores ($M$ = 67.33, SD = 4.86) than the less advanced readers (RA < 9) ($M$ = 62.24, SD = 8.23; $t$ (48) = − 2.53, $p$ < .05).

## Discussion

The purpose of our study was to investigate the ASL-PA skills of deaf children and adolescents whose first language is ASL and who are second-language readers of English. We examined students' performance on a phonological similarity judgment task designed to tap their awareness of the phonological structure of ASL. The task required discrimination of minimal contrasts in signs across three comparison conditions: signs that shared three parameters, signs that shared two parameters, and signs that were differentiated by a single parameter. In addition to our question about the extent of phonological elaboration in the underlying representations of deaf children, we were interested in identifying the relationships between ASL-PA and English word-level reading and comprehension measures. The results contribute to our current understanding of differences in difficulty among various phonological parameters and the relationships between ASL-PA and measures of English word recognition and reading comprehension.

### *Effect of Parameter on Accuracy*

A novel goal of this study was to determine the extent to which deaf bilingual children and adolescents had an awareness of signs as segmentable forms and whether the resolution of phonological similarity judgments would be differentially affected by formational complexity. An examination of the performance data on the ASL-PA task indicates that bilingual deaf students are indeed sensitive to ASL phonological structure and are able to accurately discriminate phonological contrasts between signs that share one, two, or all three sign parameters. However, student success varies across the parameters. Although we anticipated that similarity judgments for the three-shared-parameter sets might be the most salient and thus easier to identify, we found no clear trend of significant differences between the subset scores throughout the two- and three-shared-parameter comparisons. The only significant differences among the parameter combinations were found between H + M + L and H + M and between H + M and H + L. A visual examination of the trends across the means of the shared-parameter combinations, however, indicates that the addition of movement to a subset complicates the similarity judgment task and as a result reduces students' identification accuracy; the highest combined subset mean score was 89.8 on the H + L two-shared-parameter set; the second highest mean was 88.6 on the H + M + L three-shared-parameter set; the next highest mean score was 85.2 on the L + M set; and the lowest mean, 82.2, was found on the H + M set. On the single-sign-parameter sets, the students' handshape and location mean scores were very similar ($M$ = 89.4 and 89.6, respectively). This suggests that these two parameters were relatively distinctive, making it easy for students to make form-based similarity judgments. In contrast, the significantly lower mean on the single-sign-movement parameter indicates that similarity judgments based on perception of shared movements are more difficult than handshape and location judgments. Taken together, these results are in line with models of ASL phonology that posit that handshape and location parameters, like consonants in spoken languages, carry more potential for lexical contrast. Movement, however, is analyzed as more vowel-like and, like vowels in spoken languages, does not carry much contrastive power (see Brentari 2002). The differences in difficulty between the parameters also suggest that, like the construct of spoken-language phonological awareness (see review in Goswami 2002), the construct and underlying components of ASL phonological awareness are multifaceted.

### *ASL-PA, Word Reading, and Reading Comprehension*

Significant positive correlations were found between deaf students' L1 phonological awareness and L2 reading skills; deaf students with higher ASL-PA scores had stronger reading skills, as reflected in their word recognition and reading comprehension scores. These correlations are consistent with the relationships found in the research literature on phonological awareness in monolingual English-speaking children (see Ehri et al. 2001). Gray and McCutchen (2006) find correlations between spoken-language phonological awareness and word reading ranging from 0.37 to 0.70. The correlation of 0.47 between ASL-PA and written-word recognition in our study is similar to Muter et al.'s

(2004) results, where a significant moderate positive correlation of 0.41 was found between phonological awareness (rhyme detection) and reading vocabulary for children who use spoken language in the United Kingdom. When effect sizes are expressed in terms of predicted success rates, as described by Rosenthal and Rubin (1982), the $r^2$ found between ASL-PA and word recognition may be interpreted as follows: Children who scored above the mean in ASL-PA were approximately twice as likely than their peers scoring below the mean in ASL-PA to score above the mean in word recognition. On a practical level, these results imply that deaf children who are better able to discriminate the phonological parameters of ASL have stronger associations between L1 ASL-PA and L2 English word recognition. The correlation of 0.48 between total ASL-PA and reading comprehension shows that students who scored above the mean in ASL-PA were again, slightly more than twice as likely than their peers scoring below the mean in ASL-PA to score above the mean in reading comprehension. These results support the argument that a strong phonological foundation in sign language may facilitate Deaf students' acquisition of English as a second language.

Spoken-language PA explains 11 percent of the variance in reading achievement in studies reviewed for the meta-analysis (Mayberry, del Giudice, and Lieberman, 2011). In contrast, our findings indicate that sign language PA accounts for 23 percent of the variance in both word reading and reading comprehension. The spoken-language phonological awareness data for the participants in this study are reported in McQuarrie and Parrila (2009): Good and poor readers alike demonstrated a similar insensitivity to spoken-language phonological awareness, and their performance across task levels could not be attributed to phonological facilitation. The findings of this study indicate that, although these students were not proficient in spoken English and spoken-language PA, L1 ASL phonological awareness is related to L2 word-level reading and comprehension measure in this population. This finding is consistent with research conducted on spoken-language L2 learners of English that indicates that L2 word-level skills can be assessed independently of English oral-language proficiency (e.g., Gottardo et al. 2001; Lesaux and Siegel 2003). In the spoken-language L2 literature, correlational studies have demonstrated that phonological processing is related across languages and is correlated with word recognition across languages (e.g., Durgunoglu et al. 1993; Gottardo et al. 2001; Lesaux and Siegel 2003). Therefore, it may be the case that our findings reflect cross-linguistic transfer of PA.

Finally, in our study, word reading and reading comprehension were strongly related ($r = 0.76$). Similar findings have been reported in studies conducted with monolingual hearing children, indicating that word reading and reading comprehension are highly related; correlations fall with the range of 0.35 to 0.83 (Cain 2006, 65).

### *Effects of Age and Reading Ability*

According to our results, the effects of both age and reading ability on ASL-PA task performance are straightforward. Older participants did better on the task than younger participants, and more advanced readers did better than less advanced readers. Given the surprising lack of variability in the age of sign language acquisition by the participants in our study (i.e., birth to age 5), these results suggest that awareness of L1 phonological structures may be developmental. These results are also similar to those found in the L2 literature that indicate that L1 PA skills differentiate between low- and high-achieving readers (see review in Koda 2007)

## Limitations and Suggestions for Further Research

Some limitations of this investigation deserve attention and represent areas for further research. First, knowledge of the phonology of sign language is, in comparative terms, relatively new. Consequently, ASL-PA is not yet a well-defined construct, and in this area, research with children is exploratory. Because there are currently no standardized or commercial measures of ASL phonological awareness, it is possible that the ASL-PA task used in this study may not be inclusive of all factors related to ASL phonological structure and therefore may not reflect the scope of lexical elaboration (i.e., precision of phonological representation) in the sign lexicon. In addition, the correlational nature of the study prevents the drawing of causal conclusions based on the data collected. Further investigations of the components of ASL-PA and reading development in bilingual deaf children are necessary to clarify relationships between ASL-PA and English reading proficiency.

Although the correlations found in our study are substantial, other factors may influence signing deaf children's reading development (e.g., early home literacy experiences, print exposure, L1 proficiency). Unfortunately, these factors, which are assumed to contribute to reading comprehension, were outside the scope of the current study.

Finally, attempts to collect complete participant records on our ASL language-proficiency rating measure were unsuccessful. Future studies should include comparisons between late and early learners of sign language and include standardized ASL language-proficiency measures to better understand how language experience and language knowledge may shape perception performance on ASL-PA tasks.

## Conclusions

This research serves as an important early step in exploring the extent to which deaf signing children are able to discriminate sublexical properties of signs. Our results indicate that significant relationships exist between ASL phonological awareness, written word recognition, and reading comprehension. This suggests that ASL phonological awareness might be an important ingredient in the lexical development of deaf children. The results of our study provide additional support for the argument that having a strong phonological foundation in any language may be more important than the modality through which it is realized (e.g., Petitto 2000; MacSweeney et al. 2008; Mayberry 2007; Mayberry and Lock 2003). If ASL phonological awareness does indeed discriminate between nonachieving and achieving deaf readers, these aspects should constitute a critical consideration in future investigations. In this sense, our research lays part of the initial groundwork for continued investigations of ASL phonological awareness and English reading skills.

As a language, ASL is independent of English and reflects neither the structure nor the orthography of English. Thus, the evaluation of ASL as a support to reading has historically been based on the ease with which it can be "mapped" to English format (see review in Wilbur 2000). We argue that reading acquisition entails various trade-offs among the relative advantages of having a code that derives from a visual language (ASL) and one that directly corresponds to print. The development of a robust internal organizational framework based on visual (rather than auditory) patterns may provide a scaffold for bilingual deaf learners in accessing text-based literacy skills. That little evidence exists in support of this hypothesis is not surprising. Simply, efficiency in accessing the lexicon is a learned process. The acquired sets of relations (i.e., grapheme-phoneme links) demonstrated by successful L1 and L2 spoken-language users are cultivated. Given that deaf learners have not been taught to read using a code other than spoken phonology, evidence of young deaf bilingual readers discovering associative links between sign and print seems all the more significant. While the associative relations between the two languages are not obvious, what is obvious is that signing deaf children are making those links. As Grabe (2009) observes, "L2 reading is not just someone learning to read in another language; rather, L2 reading is a case of learning to read with languages" (129).

Increased knowledge with respect to the contributions of L1 sign language phonological awareness to L2 reading, particularly as it may vary in terms of its developmental importance and/or its contribution to specific aspects of L2 reading-skill development, has substantive pedagogical implications: It may lead to instructional methods that are more "sensitive" to the strategies and competencies that are available to bilingual deaf readers who acquire their primary language by eye rather than by ear. It thus seems both pragmatic and practical to research alternate strategies for reading instruction with signing deaf learners—strategies that will capitalize on developing analytic links to orthography in the sign language phonological base from which the child is working. In this way, instructional paradigms for deaf learners will better parallel best-practice paradigms for hearing learners that focus teaching on how to accomplish the integration of print language with the child's mental representation of language. A longitudinal intervention study incorporating explicit ASL phonological-awareness training would be a first step in this direction.

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