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Improving ASL fingerspelling comprehension in L2 learners with explicit phonetic instruction

Leah C Geer
California State University, Sacramento, CA, USA

Jonathan Keane
University of Chicago and Mattersight, Chicago, IL, USA

Abstract

Students acquiring American Sign Language (ASL) as a second language (L2) struggle with fingerspelling comprehension more than skilled signers. These L2 learners might be attempting to perceive and comprehend fingerspelling in a way that is different from native signers, which could negatively impact their ability to comprehend fingerspelling. This could be related to improper weighting of cues that skilled signers use to identify fingerspelled utterances. Improper cue-weighting in spoken language learners has been ameliorated through explicit phonetic instruction, but this method of teaching has yet to be applied to learners of a language in a new modality (M2 learners). The present study assesses this prospect. Eighteen university students in their third-semester of ASL were divided into two groups; one received explicit phonetic training, and the other received implicit training on fingerspelling. Data from a fingerspelling comprehension test, with two experimental conditions and a control, were submitted to a mixed effects logistic regression. This revealed a significant improvement from the pre-test to post-test by students who received the explicit training. Results indicate that even short exposure to explicit phonetic instruction significantly improves participants' ability to understand fingerspelling, suggesting that ASL curricula should include this type of instruction to improve students' fingerspelling comprehension abilities.

Keywords

ASL fingerspelling, second language acquisition, explicit phonetic instruction, phonetics

Corresponding author:
Leah C Geer, California State University, Sacramento, College of Education, 6000 J Street, Sacramento, CA 95819, USA.
Email: leah.geer@csus.edu

I Introduction

Fingerspelling is a loanword system for borrowing orthographic representations of English words into American Sign Language (ASL). It is very often used for proper names and brand names that do not have conventional lexical signs (Padden, 1998). It can also be used for emphasis or even to borrow the exact semantics of an English word into an ASL sentence where the closest translation equivalent is still slightly different. As with all linguistic systems, fingerspelling has multiple levels of linguistic structure. The phonology of signed languages generally includes specifications for handshape, movement, location, and orientation of the palm (Battison, 1978; Stokoe, Casterline & Croneburg, 1965; Valli, Lucas, Mulrooney, & Rankin, 2011). In fingerspelling, the phonological level – handshape and orientation specifications – consist of abstract units that are contrastive with one another (-A- versus -S-, -M- versus -N-, or -H- versus -U-). Most manual letters are produced with the wrist extended or slightly hyperextended, elbow flexed past 90 degrees, and the forearm rotated such that the palm is facing outward. Several letters are produced with a different orientation that does not conform to this default. The letters -G-, -H-, -P-, and -Q- face inward and -P- and -Q- also face downward.

Additionally, as with all parts of language, this phonological representation must be executed by the body through an interface between the abstract units (the phonology) and the physical reality (the phonetics). Again, as with all language, there can be, and often is, a divergence from phonological specification – or the citation form which is (more) closely tied to the phonological specification – and phonetic implementation due to a host of factors including coarticulatory effects, reduction, and effects of production rate. This article investigates how teaching explicit phonetic variation (rather than just the static citation forms of each letter) can help students better be able to perceive and understand fingerspelling.

There are many compelling reasons that make fingerspelling an appealing area of study; this investigation focuses on the puzzling fact that students and researchers report that fingerspelling is one of the hardest aspects, if not the very hardest aspect, of ASL acquisition (Patrie & Johnson, 2010; Quinto-Pozos, 2011; Wilcox, 1992). Despite this, there has been very little research on how to address this problem pedagogically. The present work aims to do just that through an integration of past work on fingerspelling comprehension in skilled deaf signers and hearing second language (L2) learners, as well as work on the use of explicit phonetic instruction in L2 teaching generally, all in an effort to improve classroom teaching practices.

1 *Fingerspelling comprehension in Deaf signers*

Again, fingerspelling is a loanword system used in ASL to borrow words of English through their written form used primarily for proper names – individuals generally spell their name when they introduce themselves – as well as for brand names and other place names that have no conventional sign (Padden, 1998). The ASL manual alphabet consists of 26 letters created through unique combinations of handshape and orientation of the palm. Most often, handshape is the crucial distinguishing feature of manual letters (see above), but there are also letter pairs that differ only in their palm orientation (-G- and -Q-, -H- and -U-, and -K- and -P-). This latter set of letters is considered to have non-default palm orientation. Fingerspelling is often taught first in ASL classes which, for the adult second-language (L2) learner, introduces an additional function of fingerspelling, namely, using it to ask for new signs (Smith, Lentz, & Mikos, 2008). While this skill is introduced early and practiced often from a production standpoint, students continue to struggle with fingerspelling comprehension, which is what this article addresses. The next section provides a brief summary of previous work on fingerspelling comprehension in Deaf adults, as well as in hearing L2 learners.

The results from several works have suggested that Deaf signers, both adults and children, do not read fingerspelling letter-by-letter, but rather appear to be sensitive to the shape of the word (Akamatsu, 1985; Hanson, 1981; Padden, 1998; Schwarz, 2000). Given this, researchers have asked what it is about the shape of the word that signers are sensitive to. Put differently, to what cues are signers attending in order to understand fingerspelled utterances?

Wilcox (1992) suggested that the most relevant cue for successful fingerspelling comprehension lies in the transition segments (those between statically held postures) because they are the most information rich portion of the signal. Using a masking technique, Schwarz (2000) examined this assertion by isolating certain sources of information within the fingerspelling stream to see how this impacts comprehension. Her results revealed that while transitions themselves are not always enough to understand a fingerspelled word, they do offer information about certain characteristics of a hold segment (where the hand is held statically) that had been masked. Specifically, signers are able to tell whether the masked letter is short like -A- and -S- or tall like -W- and -R- even if they are not able to identify the letter exactly. This leads them to guess words that, even if not an exact match to the target item, form the same shape or envelope (Akamatsu, 1985) when fingerspelled.

2 *Fingerspelling comprehension in hearing signers*

The studies referenced above demonstrate that skilled signers are sensitive to holistic fingerspelled forms and not their individual parts. In contrast, Geer and Keane (2014) found that student learners are most attuned to the individual letters in their static form and are unable to use information in transition segments to successfully identify words. In another study, Keane and Geer (2016) showed that errors are strongly predicted by the presence of letters produced with non-default palm orientation, and performance is significantly worse on these items.

Taken together, these studies suggest that different fingerspelling comprehension strategies are used depending on the language background of the perceiver. Skilled (Deaf) signers use a holistic approach that synthesizes cues from the entire fingerspelling signal, including the holds and, crucially, the transition segments also. Relatively new ASL learners can only make use of the static portions of fingerspelling. This type of error is not unlike learners of spoken languages who use different cues and/or weight various cues differently from native speakers (Flege & Hillenbrand, 1986; Giannakopoulou, Uther, & Ylinen, 2013; Holt & Lotto, 2006; McAllister, Flege & Piske, 2002; Ylinen et al., 2010).[1] Work on the use of explicit phonetic instruction to help students learn to re-weight cues is reviewed next.

3 Explicit phonetic instruction in second-language teaching

Speakers appropriately weight various cues such as segment length, tenseness, nasality, and pitch in their native languages such that they are highly successful in phoneme identification/discrimination. Language learners often have difficulty with this task, particularly when the relevant cues are different from those used in their native language. In the case of adults acquiring a signed language (M2 learners, or learners of a language in a new modality), the set of possible cues to which students can attend is completely different. Several studies have shown that, through training, learners can be taught to re-weight cues in their new language (Giannakopoulou et al., 2013; Ylinen et al., 2010).

How exactly to go about teaching learners to re-weight cues has been a matter of debate. Explicit instruction draws learners' attention to some aspect of the new language along with a rule that explains why particular forms are found in particular places (DeKeyser, 2003). This method of teaching has been shown to be more effective than implicit instruction (Couper, 2003; Derwing, Murray, & Wiebe, 1998; Macdonald, Yule, & Powers, 1994; and, for a meta-analysis of the subject, see Norris & Ortega, 2000) where learners are expected to arrive at grammatical rules on their own.

For example, Saito (2007, 2011) designed an experiment that divided participants into two groups, one of which received explicit instruction on English-specific phonemes. Results revealed that learners who received the explicit training performed significantly better on measures of comprehensibility compared to the control group. In these particular studies, the ultimate goal was to improve their English pronunciation, but the training also involved an identification task, as research has showed that language perception often precedes production (Flege, 1995, 2003; Kuhl, 2000).

These studies indicate that explicit instruction positively affects L2 outcomes, and thus might also be effective for ASL students. Students have to learn to weight the following cues: canonical handshape, transitions, the movement envelope (Schwarz, 2000). It is quite possible then, that the reason students struggle with fingerspelling comprehension is simply because they are erroneously giving too strong a weight to the wrong cues, suggested by Geer and Keane (2014) and Keane and Geer (2016). This project puts forth that, like Ylinen et al. (2010) and Giannakopoulou et al. (2013), students can be taught to adjust the weights they have assigned to various cues in fingerspelling to improve their comprehension abilities.[2]

An additional consideration is the method by which ASL learners are taught fingerspelling, which could impact how they learn to comprehend it. Li and Juffs (2015) noted that one factor affecting Japanese-accented English is the manner in which students are taught to read English characters. Instead of learning what sounds a particular letter can make individually as phonemes, consonants are always paired with vowels. Instead of learning something like 'the letter "r" says /ɹ/', students learn something like 'the letter "r" says /ɹa/'. This, Li and Juffs argue, trains English learners to always produce vowels after consonants because they do not have a mental representation of the phoneme itself. The case of fingerspelling may be similar. Because students learn manual representations

Table 1. Participant characteristics by group.

Characteristic	Explicit training	Implicit training
Gender	f = 8, m = 1	f = 6, m = 3
ASL 2 grade	A = 3, A– = 2, B+ = 3, B = 1	A = 3, A– = 2, B+ = 3, B = 1
ASL required for major	2	1
Average age of ASL acquisition (years)	22	21
Average age at time of study (years)	24	24

of letters in isolation, they become too focused on seeing those specific forms without regard for how they can be influenced by the context in which they appear, namely, the letters that precede or follow them. Just as Japanese students of English have to un-learn this CV pattern for correct English pronunciation, ASL students have to learn to focus on aspects of fingerspelling other than just the static portions of the signal. That is what this training program aims to remedy.

The goal of this study is to answer the following research questions.

1. Will students who receive explicit training improve more on a comprehension measure than students receiving implicit fingerspelling training?
2. Will the efficacy explicit training interact with the experimental conditions? Specifically, will the training result in more or less improvement on fingerspelling comprehension when holds are masked, when transitions are masked, or in the control conditions where nothing is masked?

II Methods

1 Participants

Eighteen students in their third semester of language learning participated in this experiment in exchange for course credit. The class was split into two groups; one received the explicit fingerspelling training, while the other received the implicit training. Groups were balanced for grades received in students' highest completed level of ASL at the time of study as a proxy for language proficiency. Table 1 presents additional characteristics demonstrating that groups were also balanced with respect to age, age of acquisition, and gender.

2 Delivery and timeline

Using the survey delivery system *Qualtrics* (Qualtrics, 2016), participants entered a unique study identification number to complete a pre-test and post-test. These tests included the same content and basic design as those used in Keane and Geer (2016). Data were collected over a three-week period during a summer semester. Participants had one week to complete the pre-test, during which time they did not have access to the explicit training or implicit training (which they knew as Training A and Training B, respectively). In the following week they gained access to their training. In the week after the training, they completed the post-test, again, during which time they could not access the training. Participants were naive to the purpose of the study and to the differences in training design.

3 Stimuli

Video stimuli for this project consisted of fingerspelling video clips from the corpus collected and annotated by Keane and colleagues (Keane, 2014; Keane, Brentari, & Riggle, 2013a, 2015, Keane, Riggle, & Brentari, 2013a). In their corpus, researchers identified stable hand configurations, which they termed apogees, as periods in which the velocity of the hand was zero or approached zero (see §3.2.2 of Keane, 2014, for more detailed information about segment identification in this corpus). In other words, the portion of the signal where the hand is as still as possible is the hold portion. The portions in between held postures are transition segments. Raw video footage was modified in the following ways for this experiment:

- slowed to half-speed (all);
- black screen masks inserted into the transition portions of each of the clips to create the holds-only condition (30 items); and
- black screen masks inserted into the hold portions of each of the clips to create the transitions-only condition (30 items).

The stimuli were all slowed to half speed to avoid a floor effect. Before data collection for the study reported in Geer and Keane (2014) began in earnest, several students volunteered to test project stimuli. At normal speed, students were unable to comprehend fingerspelled stimuli, even without masking. To combat this issue but still examine relevant cues in the fingerspelling stream, video clips were slowed to facilitate student testing. Crucially, half-speed stimuli retain their timing properties. For example, consider Figure 1. In this particular token, the hold portions are longer than the transition portions. Even when the item is slowed to half speed, this remains true. Instead of -C- lasting 149 ms, its duration would be double that, or 298 ms. This is important because previous work asserted that the reason transitions were most important for fingerspelling comprehension is because they are temporally longer (Wilcox, 1992). Keane et al. (2013b; 2015) have shown this is not always the case and, in fact, as this token exemplifies, sometimes the duration of the holds is greater than that of the transitions (see also Keane, 2014, Chapter 3).

The pre- and post-tests consist of 94 video clips. To generate this list, common four- to six-letter words were extracted from the CELEX database (Baayan, Piepenbrock, & Gulikers, 1995). CELEX is a database that provides information about English, German, and Dutch with respect to their orthography, phonology, morphology, syntax, and word frequency. For the purposes of this study, the most important characteristic of this database is information about word frequency. Of these 94 words, four served as practice items for participants to familiarize themselves with the task before it actually began. The first full block of 15 tokens had no masking. These served as control items. The

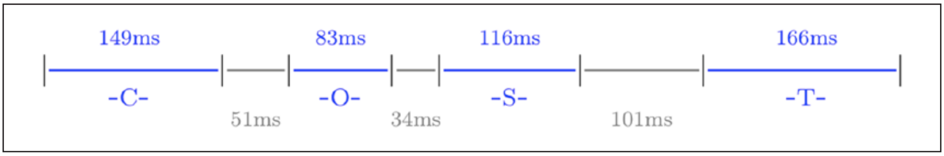

Figure 1. Timeline depicting the proportion of time spent in transition and hold segments of the fingerspelled utterance C-O-S-T. The segments indicated with a letter label represent holds, and the segments without a letter label represent transitions. For this particular token, holds are appreciably longer than transition segments. The average duration of hold segments in this token is 128.5 ms, and the average duration for transition segments is 62 ms.

second full block consisted of 30 hold-only items, and the third full block had 30 transition-only items. The final block consisted of another 15 control items.

4 The training programs

This section details the two training programs that participants received. Recall that DeKeyser (2003) stipulates that training is explicit when students are made aware of a rule for some aspect of their L2, or given information that would allow them to infer the rule on their own. In the study described here, the explicit training is one in which rules are stated for students, who can then consider them consciously, which has been shown to positively impact language learning (Schmidt, 2001). The implicit training, while still focused on fingerspelling, does not allow students to even infer rules about the structure of fingerspelling or the environments which condition certain types of phonetic variation.

a The explicit training program: Experimental group. In between their pre- and post-tests, participants in this training group received an explicit fingerspelling training. There are two main sections. The first includes information about the structure of fingerspelling. For example, consider the images in Figure 2. These images draw participants' attention to the differences between hold and transition segments. In hold portions of the signal, the video is clear and little-to-no movement, identified by blurring, is visible. Transition segments do exhibit blurring, and the configuration of the hand shows features of the previous and subsequent letters. This means one could potentially use transition information to predict subsequent letters, leading to faster lexical recognition. In Figure 2b the letters -S-, -O-, -R-, and -T- can be identified, while in Figure 2c the first image is slightly blurry and looks to have features of both -S- and -O-, the second with features of -O- and -R-, and the final one with -R- and -T-. These images are described in detail in the explicit training.

The second part of the training focused on describing the types of phonetic variation that students might encounter when they see fingerspelling. Consider the two words in Figure 3. Both include a U-R bigram (two-letter sequence). To make this otherwise hard-to-differentiate letter combination more distinguishable, this signer adds ulnar deviation (sideways flexing of the wrist toward the pinky) and supination (upward rotation) of the

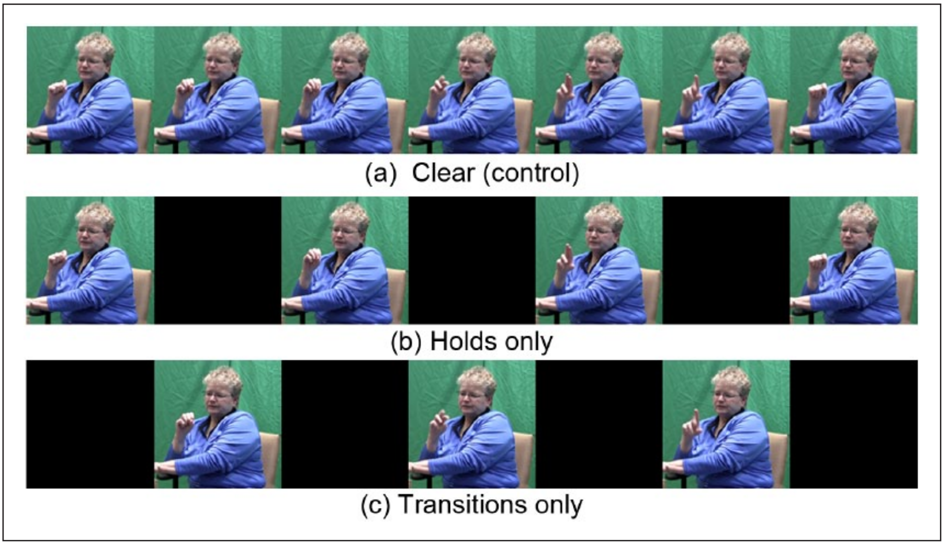

Figure 2. Example token in still images, extracted from videos, of the word S-O-R-T. The clear video (a) presents participants with unmodified stimuli: all portions of the signal are present. The holds only condition (b) presents stimuli in which the frames of transition are masked, and the transitions only condition (c) provides the opposite: the frames in which a posture is held are masked.

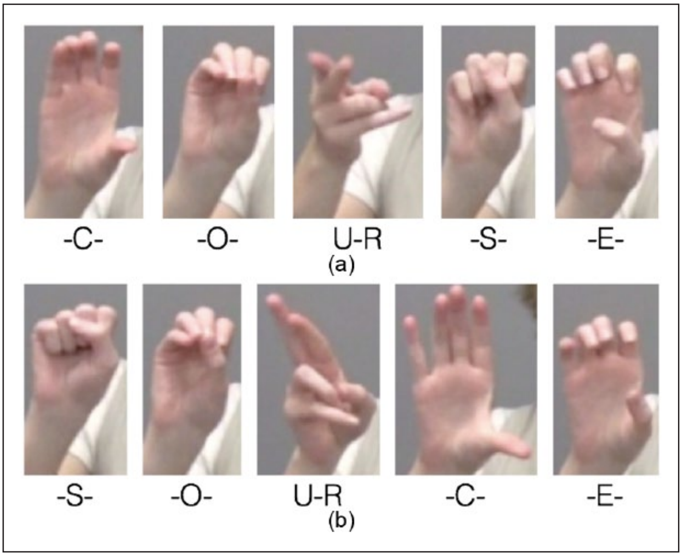

Figure 3. (a) C-O-U-R-S-E and (b) S-O-U-R-C-E naturally fingerspelled. Figure (a) exhibits both ulnar deviation and supination of the forearm, while (b) exhibits the former only.

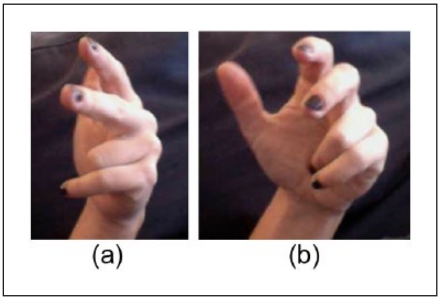

Figure 4. Two images of the transition between -G-, -H-, and -T- in the fingerspelled word N-I-G-H-T. Image (a) shows the orientation shift (supination) required by the letters -G- and -H-. Image (b) shows outward rotation (pronation) of the forearm, or returning to the default, palm-out orientation. Both images show the anticipation of the letter -T-, which requires the index and middle finger to be separated, to allow for insertion of the thumb between them. Also note that in (a), the pinky remains partially extended from the previous letter -I-, while in (b) it has returned to a more flexed position. Knowledge of anticipatory and perseveratory coarticulation would help in comprehension of words with this letter combination.

forearm, which, taken together, indicate the appearance of -U- and -R-. In both the Figure 3a and Figure 3b examples, neither letter is realized in its canonical form, but this extra movement makes it clear that both letters are intended, as it does not occur with either letter individually, nor with the combination -R- and -U-.

This movement epenthesis is consistent with Brentari's (1998) proposed phonological rules governing local lexicalization, or words that become appreciably reduced phonologically but only in a particular discourse. Long, academic terms for which there is no conventional sign are prime candidates for local lexicalization. One likely explanation for the development of epenthetic movement with -U- and -R- but not the reverse, -R- and -U-, is because of bigram frequency; -U- and -R- is the 50th most frequent English bigram, occurring in 0.54% of words, while -R- and -U- is far less common, occurring in only 0.128% of English words (Norvig, 2015). Other examples of gross movements to attend to in fingerspelling include epenthetic wrist flexion (bending downward) with the appearance of -Y- word internally or word finally, and a blending of features of the letters -G-, -H-, and -T-, pictured in Figure 4. This training lasted approximately 30–40 minutes.

b The implicit training program: Control group. Students in the control, or implicit training group, also received training in fingerspelling. Crucially, however, specific rules about fingerspelling were not explained to participants, nor could they infer one based on the training (DeKeyser, 2003).

The control group's training was meant to be a review of how fingerspelling is generally taught in ASL curricula. It included information about formation of the citation forms of each of the letters in the manual alphabet. This training included still images of each of the manual letters, except for -J- and -Z-, which were presented with short video clips since their production involves movement. In addition, participants were reminded that while most letters are produced with the palm facing away from them, there are some exceptions to this generalization. They were shown still images of two angles of letters produced with non-default palm orientation. The training concluded with reminders of how to produce double letters in fingerspelling and that fingerspelling should be produced smoothly and without jerking movements. This training, like the first, lasted approximately 30–40 minutes.

5 Summary of training programs

The validity of this experiment rests on the fact that these training programs are as similar as possible, except for the obvious ways in which they have to differ with respect to explicit versus implicit instruction. Both training programs had the same number of slides and took roughly the same length of time. Most of the media (all videos and most of the still images) included in the explicit training was also included in the implicit training, but participants' attention was not drawn to specific aspects of still images or videos.

Here are two examples of the ways in which the same media were incorporated into both trainings. The explicit training details exactly what the difference is between hold and transition segments using Figure 2. In the implicit training, Figure 2a appears after seeing an example of fingerspelling (the word S-O-R-T) and the text reads 'Here is a series of still images of the word you just saw' (Geer, 2016, p. 144). The explicit training directed the learners' attention to the production of the U-R bigram discussed above and pictured in Figure 3. The way in which this bigram's production differs from the citation form of each of the letters is explained as is the phonetic environment in which this particular production is found. Students then see videos of words with U-R sequences. Students in the implicit training group see the same video but are not directed to attend to any specific aspect of the phonetic realization of the words.

III Results

Responses in this experiment were counted as *correct or incorrect*. To be counted as correct, the typed response participants provided had to match the target word exactly. For example, if the fingerspelled target word were E-F-F-E-C-T, the typed response would have to be *effect*. Responses which were close – diverging from the target by only one or two letters– were counted as incorrect. This type of data is known as categorical because there are no in-between values, and binary because there are two potential outcomes (correct or incorrect). Table 2 presents the mean proportion of correct responses in each condition, for each test, and for each group of participants.

Several trends can be noted in these data:

- Performance overall was poor. On the pre-test, scores averaged approximately 37% across all conditions.
- Performance is better in the holds-only condition versus transitions-only condition for both groups of participants. Average performance for holds-only was in the 40%-accuracy range, while average performance for transitions only was below 20%.

Table 2. Mean proportion of correct responses and standard deviations by test type, condition (block), and training.

Block	Test type	Training	
		Implicit mean (SD)	Explicit mean (SD)
All Clear A	Pre-test	0.30 (0.46)	0.39 (0.49)
	Post-test	0.30 (0.46)	0.66 (0.45)
Holds-only	Pre-test	0.42 (0.49)	0.42 (0.494)
	Post-test	0.45 (0.50)	0.61 (0.49)
Transitions-only	Pre-test	0.19 (0.39)	0.19 (0.39)
	Post-test	0.24 (0.426)	0.29 (0.45)
All Clear B	Pre-test	0.56 (0.50)	0.56 (0.50)
	Post-test	0.48 (0.50)	0.67 (0.47)

Table 3. Significant output of the mixed effects logistic regression model.

	Coefficient β (standard error)
(Intercept)	−1.26 (0.53)*
PostTest Explicit Training	1.68 (0.68)*

Note. *$p < 0.05$.

- Performance is better in the allClearB condition (second control condition) than the other conditions (for both groups of participants). In allClearA (first control block), average performance on the pre-test was 35% while performance in allClearB was 56%.
- Participants in the implicit group performed equally on the pre- and post-tests across conditions.
- Participants in the explicit group improved from pre- to post-test.

A commonly used statistical measure in the social sciences is the Analysis of Variance or ANOVA. However, problems with ANOVA for categorical data, such as these, is well documented (for summaries of these issues, see Agresti, 2002; Hogg & Craig, 1995). To combat these issues, data collected here were submitted to a mixed effects logistic regression model computed in `R` (R Core Team, 2013) with the package `lme4` (*v.1.1-7*; Bates, Mächler, Molker, & Walker, 2015), which Jaeger (2008) advocates for in place of the ANOVA.

The findings address the two research questions posed earlier in this section. The significant portions of the output of the mixed effects model can be found in Table 3. The text that follows will help the reader interpret this table. For readers interested in the complete output of the statistical model, it can be found in Appendix 1.

In Table 3, a positive value for a predictor indicates that that it is correlated with relatively more correct answers; a negative value for a predictor correspondingly correlates with relatively fewer correct answers. The magnitude and direction correspond to the

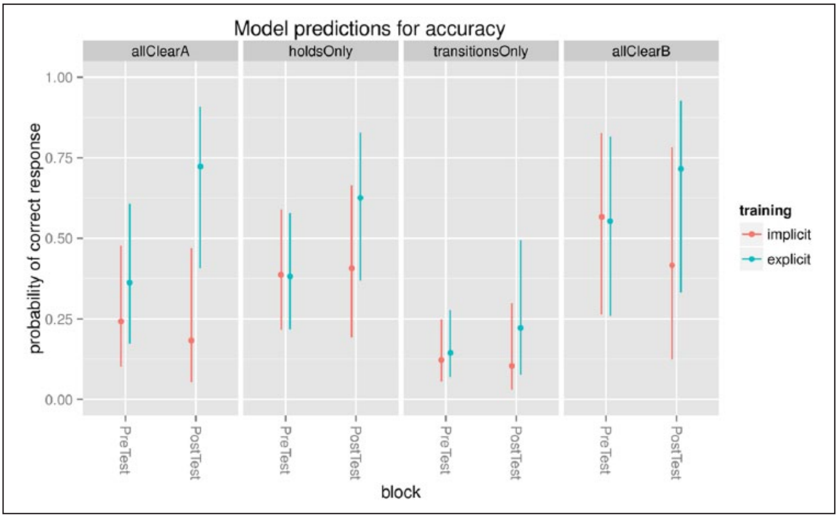

Figure 5. Model predictions plot. Dots represent model predictions and lines represent 95% confidence intervals. The x-axis shows the two types of test. Within each condition, the pre-test is always on the left and the post-test is always on the right. Conditions are labeled at the top: allClearA has video of the full word with no masking (control condition); holdsOnly and transitionsOnly have masking such that the holds or transitions are the only visible portions of the signal (experimental conditions); and allClearB has the full video – like allClearA – and serves as a second control condition. The y-axis represents the probability of a correct response in each condition, on both tests, and for each group of participants. Values for the implicit group in red, appear on the left, and values for the explicit group in blue appear on the right.

relative likelihood of a correct answer. Thus, a bigger positive number means the answers are more likely to match the target while a bigger negative number means the answers are less likely to match. The intercept represents the prediction for all reference levels, so in this model the value is the prediction for the implicit training group in the pre-test in the clear A condition. This value is listed as significant in the table. The significance indicates that overall performance in this group was poor and correct answers were provided less than 50% of the time. This has no bearing on either research question so the intercept will not be discussed further except to note that it demonstrates the extent to which students struggle with fingerspelling comprehension.

The first research question asks whether the explicit training will help students improve more on a fingerspelling comprehension measure than those students who received the implicit training. The model reveals that students with explicit training improved significantly from their pre- to post-test by a statistically significant margin ($p < 0.05$). The second question asks whether the training, which focuses on drawing students' attention to information contained in the transition segments through descriptions of phonetic variation, impacts performance in all experimental conditions equally. No such interaction was found, which will be discussed in Section IV. These results can be seen visually in Figure 5. Two important features of this figure to note are: (1) Student performance on the pre-test is roughly equal across groups, and (2) students in the explicit training group improve across conditions on the post-test. This is supported by the statistical analysis detailed above.

IV Discussion

The goal of this study was to determine whether explicit phonetic instruction would benefit adult students acquiring ASL as a second language, with a particular focus on fingerspelling comprehension. Specifically, this study assesses whether knowledge about the structure of fingerspelling – and the ways in which ASL phonology (abstract units including handshape, location, movement, and palm orientation) can vary when it is realized phonetically (how these units are physically produced) – will have a positive impact on comprehension performance. Previous work has explored fingerspelling comprehension but this is the first to apply it to teaching practices. Geer and Keane (2014) and Keane and Geer (2016) suggest that perhaps one reason adults acquiring ASL as a second language struggle with understanding fingerspelling is related to incorrect cue-weighting. This problem has been noted for learners of spoken languages as well, and explicit instruction has been found to be successful in helping students to improve. That technique is therefore assessed here with ASL learners. This study examined two research questions, which will be summarized and discussed in Section IV.1. Section IV.2 addresses ways in which the present study can be extended in the future through additional studies.

1 Summary of results

While explicit training has been shown to be effective for users of spoken languages acquiring a second spoken language, the same has yet to be shown for learners of a second language in a new modality. The first research question asks whether the explicit training will result in a more significant improvement in fingerspelling comprehension scores than students who were trained implicitly. This was in fact the case. Students in the explicit training group improved significantly from the pre- to post-test. The second question asked whether the explicit training would impact student performance on all experimental conditions equally. Because the training focuses students' attention on information contained in the transition segments, information that previous work has shown students are not skilled at making use of, it was hypothesized that the training would result in a more significant improvement in the transitions-only condition. This was not found to be the case, but that could be due to a lack of sufficient power to test that specific question. In a larger follow-up study with 80 participants, Geer (2016) found a significant improvement in the transitions-only condition – for items containing letters with non-default palm orientation – from pre- to the first post-test and again from the first post-test to the second, suggesting that the reason for the null result in the present study is in fact due to the small number of participants.

2 Future work

While the current work offers encouraging results, it raises additional questions, which will have to be addressed in future experiments. These can be divided into two main categories: (1) work that modifies the training program, and (2) work that assesses the comprehension abilities of signers from various backgrounds including already skilled signers who are Deaf and hearing and have acquired ASL at various ages, and also students at different levels of the learning process. Both of these is discussed briefly.

a Training modification. Various researchers (including Holt & Lotto, 2006; Giannakopoulou et al., 2013; Ylinen et al., 2010) have noted that a crucial aspect of teaching foreign language segment identification and discrimination is exposure to variation. Through exposure to a wide range of talkers, students are better able to learn about the range of possible phonetic realizations of phonological segments, and how those segments come together to form words. This is also likely the case for ASL. Students in an experiment assessing the efficacy of fingerspelling curriculum lamented the fact that there was only one signer in the training (Thoryk, 2010). This suggests that one way to vary the explicit training in the future is to include fingerspelling examples from more than two signers, which it has currently. As has been shown for learners of a second spoken language, it is likely the addition of more variation in signers presenting fingerspelled tokens would further help students improve their comprehension.

Another way to modify the training program is to expose students more to transition-only stimuli. Geer and Keane (2014), Keane and Geer (2016), Geer (2016) and the work detailed here all show that students perform better in the holds-only condition as compared to the transitions-only condition. Were they to be trained specifically on these stimuli, it may force them to be attentive to cues they otherwise ignore or have difficulty using, and will help them learn to attend to cues they should weight more heavily. This has been shown to be the case in L2 learners (Giannakopoulou et al., 2013).

b Perceiver skill level. A synthesis of work on Deaf signers, adults, and children suggests that understanding fingerspelling is not simply understanding ‘the sum of its letters’ (Akamatsu, 1985). Skilled signers can provide ASL translation equivalents for words fingerspelled to them but cannot always spell them back (Hanson, 1981), suggesting comprehension without reading letter-by-letter, and they can use information contained in the transition segments to identify the shape of masked letters (Schwarz, 2000). Geer and Keane (2014), Keane and Geer (2016), and the present study show that students seem to use a different approach, which relies heavily on attention to only the hold portions of the signal. It would be useful, however, to better understand the ways in which skilled versus L2 learners diverge in fingerspelling comprehension, to test a wider range of signers with the paradigm employed here.

Native signers, as well as those who acquired ASL at various points in their life but are now all highly skilled, should be tested in this paradigm to confirm that the divergence is in fact due to differences in ability to use cues provided in the hold versus transition segments. Impressionistically, when these stimuli have been shown to skilled signers, both Deaf and hearing, native and late learners, they have not been able to appreciate a difference in the two conditions and appear to understand them equally. This suggests that their performance is unlikely to differ significantly across conditions, as was the case for the ASL students.

It may also be prudent to test ASL students at various stages of their learning process and also to vary the time at which the explicit training is introduced. It could be the case that reliance on hold segments is a characteristic of learners in their first and second years of ASL acquisition, but not of students in their third and fourth years, for example. The optimal time to introduce the explicit training can also be assessed in future work.

V Concluding remarks

The overarching goal of this project has been to use information about how students understand fingerspelling, a challenging aspect of ASL acquisition, to assess the efficacy of a pedagogical tool designed to address this challenge. At the conclusion of the experiment, the first author met with study participants to discuss their experience. They were told a follow-up study would be conducted in the near future and that their feedback could be useful for preparing it. All students indicated they felt their training was beneficial to them. Students in the explicit training group said they appreciated being made aware of the ‘inner workings’ of fingerspelling. They felt it made them better prepared to appreciate fingerspelling as a whole, rather than letter-by-letter, which is what skilled signers are doing already. This is an interesting remark because many ASL teachers instruct students to ‘sound words out’ rather than stating the name of each letter in their heads, because it is possible to correctly identify a long string of letters, but not understand the whole word. The goal of this instruction is to encourage students to see the whole word and not each of the letters, but it seems phrasing it in this way is ineffective. So, while teachers tell students to ‘sound out’ fingerspelled words, they are not giving them the tools to learn how to do this. Worse still, as Li and Juffs (2015) suggested, how students are taught (static posture by static posture) could be hindering their ability to see the forest (whole words) instead of the trees (individual letters). Students who received the explicit training said it helped to shed light on that. In addition, students expressed frustration with phonetic variation they encountered in fingerspelling prior to the study. ‘It’s hard when one signer produces [some fingerspelled letter] like this [showing some variant of the letter], while other signers do it like that [showing some other variant of the letter].’ Arming them with knowledge of the types of variation they might encounter helped them feel more secure in tackling fingerspelling comprehension tasks.

The results of this experiment indicate that ASL teachers should begin to incorporate some type of phonetic instruction in their curricula. Students not only perform better but also feel more confident and empowered in their fingerspelling comprehension. Phonetic instruction for lexical signs may also be useful, although this has yet to be tested. The results of this experiment are encouraging that this may be the case and should be the topic of future study.

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Notes

1. We draw the comparisons to spoken language studies not because they are the closest parallels, but because there simply are no other studies (or only very few) that do this in the sign modality. We fundamentally believe that fingerspelling and spoken languages have phonetics (and phonetic variation), and that this phonetic variation can be one source of struggle for non-native speakers, and the purpose of this investigation is to test / help with that.
2. Testing skilled signers with this paradigm is underway. The implications of the expected results for the present work are addressed in the discussion.

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Appendix 1

Full output of the statistical model

The full output of the statistical model is given in this appendix. This mixed effects model requires that one level be set as the reference level for each of the predictor variables. This means that the interpretation of Table 5 depends on understanding which level is set as the reference level. It may also be useful to understand why each of these reference levels was selected; see Table 4.

Table 4. Table of predictor variables and their reference levels.

Predictor	Number of levels	Reference level
Test-type	2	Pre-test
Group	2	Group B (implicit training)
Condition	4	Clear A

For the test-type predictor, the pre-test is the reference level because the experiment is assessing how much change there is from pre-test to post-test. This means that if participants improve from pre-test to post-test, the number should be positive, or a positive number of greater magnitude than the pre-test. For the group predictor, the implicit training group (group B), is the reference level because the study is testing whether the explicit training group (group A), will diverge from the assumed baseline that group B represents. The condition has four levels. Clear A is the reference level, which means that all comparisons are related to the first block of the experiment. Positive values represent performance better than the reference level and negative values represent performance worse than on the reference level. The hypothesis then (based on Geer & Keane, 2014; Keane & Geer, 2016) is that the values would be equal or positive in the holds-only condition and negative in the transitions-only condition.

Table 5. Mixed effects logistic regression coefficient estimates and standard errors.

	Coefficient β (std error)
(Intercept)	−1.26 (0.53)*
conditionClearB	1.42 (0.76)
conditionholdsOnly	0.68 (0.56)
conditiontransOnly	−0.91 (0.56)
testTypePostTest	−0.26 (0.51)
groupA	0.68 (0.50)
conditionclearB:testTypePostTest	−0.24 (0.56)
conditionholdsOnly:testTypePostTest	0.44 (0.47)
conditiontransOnly:testTypePostTest	0.18 (0.50)
conditionclearB:groupA	−0.62 (0.57)
conditionholdsOnly:groupA	−0.59 (0.43)
conditiontransOnly:groupA	−0.38 (0.47)
testTypePostTest:groupA	1.68 (0.68)*
conditionclearB:testTypePostTest:groupA	−0.58 (0.75)
conditionholdsOnly:testTypePostTest:groupA	−0.98 (0.62)
conditiontransOnly:testTypePostTest:groupA	−1.18 (0.65)
AIC	2,636.29
BIC	2,912.04
Log Likelihood	−1,271.14
Num. obs.	2,610
Num. groups: qNumber	90
Num. groups: word	90
Num. groups: group:subjCode	16
Variance: qNumber.(Intercept)	0.00
Variance: word.(Intercept)	2.01
Variance: word.conditionclearB	0.30
Variance: word.conditionholdsOnly	0.01
Variance: word.conditiontransOnly	0.10
Variance: word.testTypePostTest	0.05
Variance: group:subjCode.(Intercept)	0.52
Variance: group:subjCode.conditionclearB	0.31
Variance: group:subjCode.conditionholdsOnly	0.06
Variance: group:subjCode.conditiontransOnly	0.08
Variance: group:subjCode.testTypePostTest	0.66
Variance: Residual	1.00

Note. $^{*}p < 0.05$.