Sign Lowering as Phonetic Reduction in American Sign Language

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Abstract

Sign phonetics is the study of the physical transmission of signed language via the movement of the arms, hands and fingers. The goal of this study is to examine phonetic reduction in American Sign Language (ASL), specifically the occurrence and physical extent of sign lowering. Just as words are hypoarticulated during fast or casual speech, signs also undergo phonetically-induced reduction in the form of raising or lowering. We are focusing on the phonetic realization of signs produced at the forehead. Adult native users of ASL produced forehead-located signs adjacent to signs with either high or low locations and at three signing rates. Signing data were collected via an opto-electronic motion capture system. Vertical displacement of the hand was measured relative to a body-centered coordinate scheme, and the hand's vertical displacement served as the measure of sign location. Preliminary data suggest that some forehead-located signs are lowered at faster signing rates. Lowering varied according to the phonetic factors we manipulated. Work in this area highlights the need for procedural and measurement standards for phonetic sign data.

1 Introduction

Signed languages are those in which linguistic information is conveyed by movements of the hands, arms, head and body. Phonetics in both speech and sign languages is the study of the movement of the articulators, the signal that results from those movements and the perception of those signals. In this paper, we focus on the realization of a particular aspect of signing, the location parameter, in a specific class of signs in American Sign Language (ASL).

A sign is composed of at least three sublexical units: handshape, movement and location [9, 4]. The location parameter refers to the physical location of the hands in space during the articulation of the sign. Locations are often described relative to a signer's body (e.g. the chin) when the hands are near that body location. Signs may also be made in neutral space, the area in front of the torso.

Locations of ASL signs may vary depending on factors such as discourse context [10, 3] and signing rate [8]. The location of forehead-located signs in particular has been shown to vary depending on the location of neighboring lexical items, sociolinguistic factors, and the grammatical category of the sign [7], though precise phonetic detail was not available in that study. Further, we have observed that while many signs may lower spontaneously, there are some signs that seem to be lowered so often that the lowering has become conventionalized.

In this study, we manipulate the rate of signing as well as phonetic environment of forehead-located signs and use a motion capture system to collect phonetic data with a high level of temporal and spatial resolution. The signs selected for study are varied in their articulation and include both "spontaneously" and "conventionally" lowered signs.

2 Methodology

The signer described here is a Deaf woman from a Deaf, signing family. She was asked to produce

the target phrases at three rates: normal, faster than normal, and as fast as possible. She produced 15 tokens of each sequence at each signing rate. For each production trial, we excluded the first utterance token and used the next 10 tokens for this analysis.

Sign movements were recorded with the Optotrak Certus system. IREDs were attached to the participant's sign articulators and tracked by three cameras at a sampling rate of 60Hz. Two IREDs were attached to the dominant hand: one on the dorsal side and the other on the ulnar side, below the metacarpophalangeal joint. They were used to indicate the hand's position during signing. Six IREDs were attached to a device on the head (Fig. 1), allowing us to track the head's movements and compare its position to the hand's position.

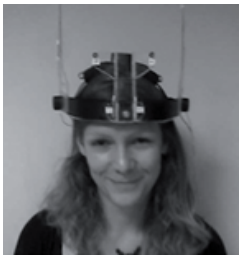

Figure 1: *Head Markers*

Previous research had suggested that a given sign's tendency to lower and the particular form of lowering that it exhibits might be related to structural aspects of the signs [5], such as whether the sign requires contact with the forehead [8]. We also hypothesize that the presence of sign-internal movement may be a factor. With these structural aspects in mind, we chose to analyze four signs from the current data set: FATHER, KNOW, SUMMER, and WHY. For the sign FATHER, all fingers of the dominant hand are extended and abducted, and the hand rises to the head, so the thumb makes contact with the side of the forehead. For KNOW, all four fingers of the dominant hand are bent and the hand rises so that the fingertips contact the right temple or side of the forehead. For SUMMER, the sign begins with the index finger of the dominant hand extended, and the hand located in front of the face at eye level, then the index finger is flexed at its medial joint, while the hand moves to the signer's right. For WHY, the dominant hand, with fully extended fingers, begins at the forehead and moves down and away from the head, while all the joints of the index, middle, and ring fingers are flexed.

Previous research has also suggested that phonetic environment may play a role in the lowering of forehead located signs [7, 5]. Consequently, these four signs were embedded into two carrier phrases. One phrase provided signs that were in the same spatial vicinity of the target signs: PICTURE point-to-high-position ___ SEE? meaning "Do you see the picture up there of the sign '___'?" The second phrase placed the target sign between items that were in low positions: PICTURE point-to-low-position ___ RIGHT? meaning "That's a picture of the sign '___' down there, isn't it?"

For measurement purposes, the phonetic location for a given sign is defined as the position of the relevant hand marker when it has reached the speed minimum nearest the hand's vertical peak. Phonetic locations were compared across the rate and phonetic environment conditions. The dorsal hand marker was used for measurements of KNOW and WHY, and the ulnar marker was used for FATHER and SUMMER.

A two-way ANOVA was conducted for each of the four sign types with vertical location of the IRED as the dependent variable and phonetic environment (low vs. high) and signing rate (normal vs. intermediate vs. fastest) as independent variables. In cases where the interaction term was significant, a Tukey's HSD post hoc test was conducted to determine the source of the significance.

We expected to find variation in location to some degree as signing rate increased, but especially in the low phonetic environment. We further expected that signs with an internal movement might lower more often and to a greater extent.

3 Results

Figure 2 shows the mean values and standard deviations for the vertical location of the hand marker for each signing rate and phonetic environment for the sign KNOW. For this sign, the interaction of the two independent variables was significant ($F(2, 50)=3.388$, $p=0.042$). In the low phonetic environment, there was a significant rate effect such that the sign was higher at the normal rate than the intermediate ($p<0.001$) and fastest rates ($p=0.005$) which were not found to be

different from each other. For the high environment, no significant differences were found between the rates.

Mean location values and standard deviations for the sign FATHER are shown in Figure 3. Again, the interaction of the two independent variables was significant ($F(2, 54)= 7.72$, $p=0.001$). In the high phonetic environment, FATHER was lower at the normal rate than the fastest rate ($p=0.037$). In the low environment, there was no significant difference across the signing rates.

Mean location values and standard deviations for the sign WHY are shown in Figure 4. Again, the interaction of the two independent variables was significant ($F(2, 54)= 8.76$, $p=0.001$). In the high environment, WHY was lower at the intermediate rate than the normal ($p=0.002$) or fastest rates ($p=0.031$). In the low environment, there was no significant difference across the signing rates.

For the sign SUMMER, there were no significant effects. The greatest difference between mean location values was 20.97 mm with standard deviations ranging from 8.45 to 24.53 mm.

Based on these data, lowering does not seem to occur the same way or to the same extent for all forehead signs. The signs FATHER and SUMMER showed little variation across the factors manipulated and were not found to lower to a significant degree. KNOW and WHY on the other hand both showed a fairly large degree of variation across factors and were found to lower significantly as an effect of signing rate, though not in the same phonetic environments. The data for KNOW are what we expected to find from the outset. In the low phonetic environment and with limited time to produce the sequence, the forehead sign was shifted downward, shortening the distance between itself and its neighbors. For the sign WHY, a shift happened only in the high environment and only at the intermediate rate lengthening the distance between the target sign and neighboring signs rather than shortening it.

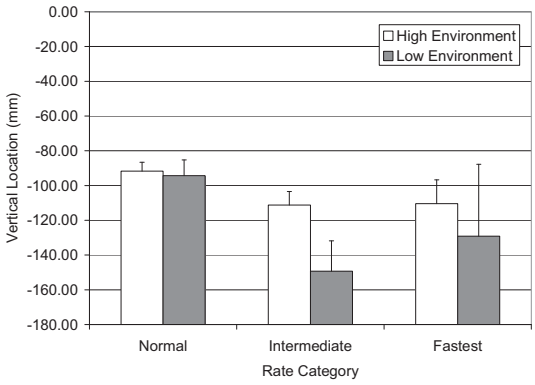

Figure 2: *Mean and standard deviation values for the sign KNOW for each rate and phonetic environment*

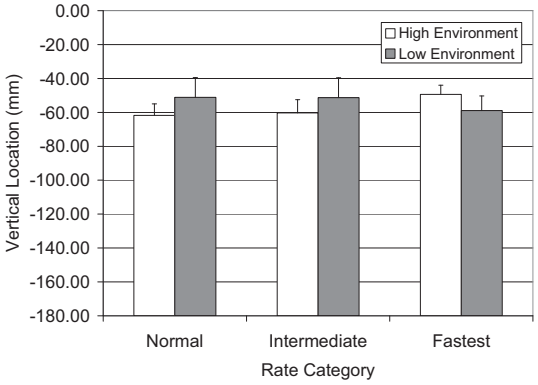

Figure 3: *Mean and standard deviation values for the sign FATHER for each rate and phonetic environment*

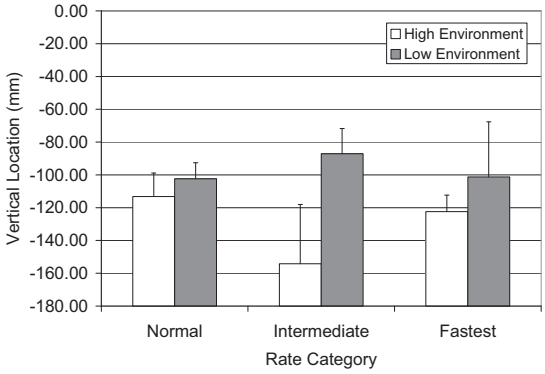

Figure 4: *Mean and standard deviation values for the sign WHY for each rate and phonetic environment*

4 Discussion

In this paper, we have examined the lowering of forehead-located signs as a form of phonetic reduction. Our preliminary results suggest that phonetic reduction in sign is subject to some of the same factors as phonetic reduction in speech, such as production rate and phonetic environment.

Two of the signs examined (FATHER and SUMMER) did not lower significantly as an effect of either rate or environment. By contrast, two other signs (KNOW and WHY) were lowered as an effect of factors that we manipulated. This is of interest because WHY and KNOW are signs that have been reported to lower in conversation. As we predicted, lowering occurs more frequently and to a greater extent for this set of signs. The current study provides a separate line of evidence for which signs can be lowered and which cannot: Lucas et al. [7] investigated sign lowering in conversational contexts, but we do not have a comprehensive sense of this category.

Preliminary analyses suggest that some signers tend to raise both high and low signs at faster production rates. It may be that signs are subjected to a different type of phonetic effect when the production rate is sufficiently high. While phonetic reduction occurs in both the speech and sign modalities as an effect of increased production rate [e.g., 6, 8], research on non-linguistic limb movement suggests that increased movement speed can cause individuals to overshoot a movement target [1]. At the fastest production rate, these two effects may be combined, such that the signer's tendency to overshoot partially cancels out the tendency to lower.

5 Conclusion

Our preliminary findings suggest that the lowering of high signs is not solely a consequence of grammatical category or sociolinguistic effects—the factors that had been emphasized previously. Phonetic factors such as production rate and phonetic environment can affect sign lowering as well. More research is needed to understand the interaction among phonetic factors and between phonetic and non-phonetic factors.

Phonetic phenomena in signed language have gone largely undocumented, which constitutes a serious gap in the field. Sign lowering has been analyzed in terms of phonology [5], sociolinguistics [7], and neurogenic deficits [2]. This study has observed sign lowering as a type of phonetic reduction, which is conditioned by the same factors as in speech.

Work in this area highlights the need for procedural and measurement standards for analyzing phonetic sign data. Only with more empirical research on phonetic detail can linguists have a foundation upon which to build principled comparisons of variation across individuals, across sociolinguistic groups, and across signed languages.

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