Phonetics of sign location in ASL: Comments on papers by Russell, Wilkinson, & Janzen and by Grosvald & Corina

MARTHA E. TYRONE

Haskins Laboratories and Long Island University

1. Introduction

In sign language research, there have been far fewer studies of the physical structure of signed language – or sign phonetics – than studies of the more traditional areas of linguistics, such as syntax or morphology. Research on signed language emerged much more recently than speech research, and in particular, it emerged at a time when the field of linguistics emphasized theory over empiricism. In addition, until a few decades ago, it was widely assumed by linguists as well as non-linguists that signed languages were not on a par with spoken languages in terms of grammar or vocabulary. As a result, early sign language researchers continually had to demonstrate that signed languages were, in fact, languages, and consequently their research emphasized the similarities between signed and spoken languages over the modalities' differences. In all likelihood, these two factors both had the effect of limiting researchers' interest in phonetic analyses of signed languages.

The studies by Russell, Wilkinson and Janzen (2011) and by Grosvald and Corina (this issue) reflect a growing interest in sign phonetics, and an expansion in the availability of tools and methods for sign phonetics research. More specifically, there has been increased interest recently in the phonetics of signs produced in context, as opposed to citation forms of signs or signs produced in isolation. Several studies in the last decade or so have examined how signs are influenced by factors such as signing rate, phonetic environment, phrase position, and the distance from the signer to the interlocutor(s) (Cheek 2001, Mauk 2003, Crasborn 2001, Mauk & Tyrone 2008, Quinto-Pozos et al. 2009). Each of these areas raises questions that are relevant to the interface between phonetics and phonology in signed language.

Like spoken languages, signed languages are made up of meaningless sublexical elements that can be combined in different ways to form lexical items. Stokoe identified three phonological parameters that can differentiate signs in American Sign Language (ASL): handshape, movement and location (Stokoe 1960). Handshape describes the configuration of the hands as a sign is produced. Movement describes how the hands and arms move during a sign. Location describes where the hands are located during production of a sign. Battison (1978) later added hand

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orientation – the direction that the palm faces during a sign – to this list. Of these phonological parameters, it is location that has been investigated the most in quantitative phonetic studies. The two papers discussed here both address the question of phonetic variation in the realization of phonological location in ASL.

2. Undershoot – Russell, Wilkinson & Janzen

Mauk (2003) examined the underachievement of articulatory targets (undershoot) in ASL and found that as ASL signers sign more quickly, both handshapes and locations may be undershot and that the degree of undershoot increased as signing speed increased. More recently, Mauk & Tyrone (2008) and Tyrone & Mauk (2010) examined the lowering of ASL signs located at the forehead and described this phenomenon as phonetic reduction. These studies found that forehead-located signs were lowered as an effect of phonetic environment at fast signing rates but also found that the same signs were sometimes raised as an effect of phonetic environment and signing rate, or as an effect of signing rate alone.

In addition to these phonetic studies, there have been studies by two groups of sociolinguists on the lowering of signs located at the forehead or elsewhere in the upper region of the signing space. Sociolinguistic studies of sign lowering analyzed naturalistic data from videotape, attempting to determine how lowering is affected by social factors such as the signer's age, ethnicity, and gender, the sign's grammatical category, and the phonological locations of the signs preceding and following the target sign. In their study of ASL, Lucas et al. (2002) found that the strongest predictor of the lowering of forehead-located signs was the sign's grammatical category. The study by Schembri et al. (2009) examined the lowering of high signs in New Zealand Sign Language and in Auslan (the sign language of Australia) and found that grammatical category, lexical frequency, and the interaction between the two all affected sign lowering.

While sign phoneticians examined the lowering of forehead-located signs in tightly-controlled, kinematic data, sociolinguists examined the same phenomenon in more naturalistic contexts. Perhaps because of the difference in methodological approaches, the sociolinguists found limited effects of phonetic environment, while the phoneticians found stronger effects of phonetic environment. In addition, the phonetic studies tested whether ASL signs that had previously been reported to lower in sociolinguistic studies showed lowering more often or to a greater extent, but they found no clear difference between these signs and other signs in the scripted phonetic data. Russell, Wilkinson, & Janzen set out to investigate the seeming contradiction between findings from sociolinguistic field work and experimental phonetic research on the lowering of signs that are high in the signing space. In order to do so, they examined a set of videotaped corpus data and looked at productions of signs located at the forehead, head, or neck in order to determine whether these signs were lowered and to what extent. In addition, they investigated whether lowering occurred in a manner that was gradient or categorical.

Russell et al. used a more controlled data collection procedure than past sociolinguistic studies, but unlike the phonetic studies, their data still consisted of relatively naturalistic conversation. The researchers used standard video to record the conversations but worked to maximize the consistency and precision of the measurements. For instance, they implemented a procedure for correcting the data for the position of the head and a procedure for normalizing the data to allow for comparisons across signers. In addition, unlike the sociolinguistic studies, Russell and colleagues used statistical analyses that made no assumptions about whether sign lowering was a categorical phenomenon.

Like the earlier sociolinguistic field studies, Russell et al. found that the extent of lowering differed according to the grammatical category of the sign that was lowered. In addition, they found that signs that occurred more often in the language, according to their own mini-experiment, were lowered more often and to a greater extent. However, unlike Schembri et al. (2009), they found no interaction between grammatical category and lexical frequency. Given that Russell et al. examined productions at multiple phonological locations, it would be useful to know how signs with different grammatical categories were distributed across the different locations (or for that matter, how they were distributed across the different signers).

Regarding lexical frequency, none of the ASL studies of sign lowering has been well-equipped to address its effects. There are very limited data on lexical frequency in ASL, which creates a great setback for researchers in phonetics and sociophonetics. Morford and MacFarlane (2003) carried out a preliminary study on lexical frequency in ASL, with 4,111 signs produced by 27 different signers, but much more needs to be done to allow thorough investigation of frequency effects in sign phonetics. Russell et al. recognized this issue and carried out their own small experiment to collect frequency data. While this was insightful on their part, it should not be necessary in a language as widely studied as ASL. Moreover, small datasets have only limited explanatory value in addressing questions such as lexical frequency.

Unfortunately, studies of sign lowering, including the one by Russell and colleagues, have not consistently provided comprehensive lists of the signs that were lowered or lists of the signs that were collected and analyzed. Without this information, it is impossible to know how signs in the data set were distributed across grammatical categories or across phonological locations (for studies that look at multiple locations). For example, the reader cannot interpret the implications of function words being more likely to lower without also knowing what proportion of the data consisted of function words. Perhaps more problematically, it is difficult to compare the findings of different studies or to replicate a past finding unless one knows which signs in particular exhibit lowering and which do not.

The authors conclude that sign lowering occurs as undershoot but that it also occurs as a categorical phenomenon. They point out that there is no simple relationship between lowering and reduction, when signs other than those at the

forehead are taken into consideration. In other words, phonetic reduction or undershoot might be manifested in other ways for signs with lower locations in the signing space. For example, phonetic reduction of a sign with a location at the waist could cause the sign to be raised instead of lowered. I could not agree more. The lowering of ASL signs does not uniformly equate with reduction any more than the fronting of vowels equates with vowel reduction – for back vowels, it might, but for front vowels it likely would not.

I would take this one step further and say that reduction in the sign modality needs to be considered for parameters other than location. Handshape and movement can also be reduced, and are mostly likely subject to reduction as an effect of the same factors contributing to reduction in sign location: fast signing rate, dissimilar phonetic environment, and varying phrase positions. With handshape and movement, there are also likely to be gradient differences across productions that reflect articulatory undershoot or reduction, as well as categorical differences across productions, related to distinctions in register or differences in the meaning of the sign.

Russell et al. emphasize that lowering is planned rather than accidental, and they highlight the fact that signers organize their movements such that they do not poke themselves in the eye. While this is certainly a novel and valid observation, it seems that we should be able to develop more nuanced, and more broadly applicable, criteria for differentiating planned and unplanned aspects of movement. As the authors point out, signs at phonological locations other than the forehead do not consistently resemble forehead-located signs, in terms of lowering, undershoot, or reduction. Perhaps the authors could explore additional indicators of movement planning in the sign modality.

To some extent, what individual studies of sign lowering find is going to be determined by what in particular they measure. By design, past sociolinguistic studies of sign lowering would not have been able to detect effects of signing rate. Likewise, the phonetic studies of lowering were not able to detect effects related to social factors, because sociolinguistic variables were not controlled for. The study by Russell and colleagues provides an informative middle ground, bridging these two approaches. It does not address which approach's findings were more valid, but rather it mirrors the separate findings of the earlier studies: sign lowering occurs categorically, as reported by sociolinguists, and gradiently, as reported by phoneticians.

3. Coarticulation – Grosvald & Corina

A few studies have examined coarticulation in the sign modality, and all of them have reported coarticulatory effects of neighboring signs or fingerspelled letters on each other (Cheek 2001; Mauk 2003; Tyrone et al. 1999; Wilcox 1992). Cheek (2001) examined coarticulation of handshape in the production of ASL signs

with the index finger extended (1-handshapes) or with all the fingers extended (5-handshapes). Target signs with each of those handshapes were embedded in carrier phrases so that they were preceded and followed by the other handshape. She found variation in handshape that was rate-dependent and consistent with models of coarticulation. Like Cheek (2001), the studies by Wilcox and by Tyrone and colleagues looked at coarticulation in handshape, but they did so in studies of ASL fingerspelling rather than signing. Fingerspelling is a system for borrowing words from spoken languages by representing the letters of the written forms of words. Because individual fingerspelled letters are produced much more quickly than individual signs, there tends to be a high rate of coarticulation during fingerspelling, which was reported by both studies. As discussed above, the study by Mauk (2003) examined location as well as handshape in fast signing and found undershoot for both parameters.

The study by Grosvald and Corina is similar to Mauk's study, in that it examined coarticulation in sign location, and it compared phonetic location in ASL to vowel formants in English. However, Grosvald and Corina have extended the body of research on sign coarticulation in two important ways. First, they examined not only the effects of adjacent signs on the realization of location, but also the effects of signs that precede or follow the target sign at a distance of up to three intervening signs. Theirs is the first study to look at coarticulation in a signed language across multiple segments. In addition, they compared coarticulation in a signed utterance to coarticulation related to a non-linguistic limb movement preceding or following the target sign.

For this study, Grosvald and Corina collected productions of schwa vowels in English, which were embedded in carrier phrases, such that the target vowel was at varying distances from the vowel /i/ or /a/. From these data, they measured F1 and F2 for the target vowels to look for coarticulatory effects. Similarly, for the signing data, they used an ultrasonic motion capture system to collect productions of ASL signs located in the neutral space in front of the body. Those target signs were embedded in carrier phrases which contained a sign located at the forehead or at the waist. The target neutral space sign was placed at varying distances from the high or low sign, and the hand's vertical position was measured. To assess non-linguistic coarticulation, the researchers cued signing participants to flip a switch that was either above or below the middle of the signing space during a signing task.

Grosvald and Corina found coarticulation across multiple segments in speech, but weaker long-distance coarticulatory effects in sign. In addition, they found that in terms of coarticulation, linguistic coarticulation patterned more like non-linguistic coarticulation than like coarticulation in speech. Based on these findings, they concluded that there is a qualitative difference between oral and manual actions, irrespective of whether those actions are linguistic or non-linguistic. It is worth noting that, at first glance, their findings seem to be in contradiction with the findings of Mauk (2003), which emphasized the similar patterning in sign and

speech data. However, the effects in that study, and in the study by Tyrone & Mauk (2010), were present only for fast signing, not for signing at a comfortable rate. Grosvald and Corina did not manipulate signing rate but only looked for effects of phonetic environment.

Grosvald and Corina raise an important question, namely, how do limb movements for signing differ from non-linguistic limb movements? Too few studies have tried to tease apart linguistic and articulatory effects in the sign modality by looking at non-signing movements in precise detail. The authors' approach maximizes the similarity of the two types of data and the naturalness of the tasks, by placing the target sign adjacent to other signs for one task and adjacent to non-linguistic limb movements for the other task. It would be quite informative to take this approach further and look at coarticulation in a completely non-linguistic task (for example, producing a non-linguistic pointing gesture that is preceded or followed by a movement to a high or low target) and compare those results to coarticulation in signing. Comparisons of sign coarticulation and non-linguistic coarticulation in limb movements are as important as comparisons of sign and speech coarticulation for addressing language modality effects. To determine how sign and speech differ and how they are similar, it is necessary not only to compare sign to speech but to also compare it to non-linguistic limb movements.

Intuitively, we would expect that oral and manual actions would be qualitatively different in some ways, and to some extent, they certainly are. For example, manual actions can be bilateral or unilateral (i.e., two-handed or one-handed), while oral actions do not possess this quality. Ideally, it would be preferable to see more direct comparisons of movement (as opposed to acoustics) in the two modalities to be able to gauge the extent of the similarity or dissimilarity of sign and speech.

The authors explicitly state that they make no claims about the equivalency of neutral space signs and schwa vowels or about the similarity of vowels in spoken language to locations in signed language. However, they do make claims about the similarity of one type of coarticulation as opposed to the other by making direct comparisons of vowel formants and the position of a signing hand in space. So although the authors do not argue for similarity of the linguistic units they are comparing, they are implicitly treating the two types of data as analogous. While their study was carefully designed, well thought-out, and controlled for factors that often go unnoticed (such as the signer's height), we must exercise caution in drawing direct parallels between positional sign data and acoustic speech data. Given the current technical limitations of the field and the absence of normalized production measures, it is difficult enough to judge the extent of coarticulation from one signer to another. Judging the extent of coarticulation across language modalities and across physical domains is much trickier and more problematic.

Beyond the difficulties of cross-modality comparisons, it is important to consider what are signers moving relative to. The measures taken by Grosvald and Corina were not corrected for the position of the body or head. In all likelihood, for non-linguistic movement tasks with targets external to the body, participants would

move relative to allocentric coordinates, while in the signing task they would move with respect to egocentric coordinates. Examining neutral space signs, after correcting the data for the position of the head or body, in each of these contexts would allow us to better investigate how articulatory targets are defined for signs that do not have a fixed location on the body.

4. Broader issues

4.1. *Methods in sign phonetics*

Many studies of sign phonetics, including the two studies discussed here, have focused on the location parameter in signed language. This emphasis on the phonetics of location most likely results from two factors. First, location is relatively easy to define and measure in positional signing data. One need only look for the position of the hand at a movement endpoint. Second, comparing sign location to typical speech production measures is probably more straightforward than comparing other sign parameters to speech. (For example, Mauk [2003] and Grosvald and Corina [this issue] both compared sign location to vowel formant frequencies.) A few studies have also examined the phonetics of handshape (Cheek 2001; Ann 1996; Mauk 2003) and explored how it relates to phonetic aspects of speech and to the anatomy and physiology of the hands.

These studies of location and handshape have been informative, but it is important to remember that they can only tell part of the larger story of the phonetic structure of signed language. Sign phoneticians and other researchers need to examine other aspects of production, especially the movement parameter, which has received almost no attention at the level of phonetics. Unlike handshape and location, which can be operationally defined as static points in the signing stream, movement, by definition, is dynamic, and thus harder to parse and quantify. Given the well-known role of movement in agreement and indexicality (cf. Klima and Bellugi 1979), it may be the movement parameter that shows the most variability across productions.

It is not clear that vowel formants share important properties with the position of the hands during signing, but more generally, it is unclear how acoustic speech data are like or unlike sign movement data. In making comparisons between sign and speech, it is reasonable to begin with these measures, but it is worth considering their limitations in terms of comparability. Consequently, any study that identifies a modality difference should take into consideration the possibility that the difference lies in the measurement rather than in the language modality.

On a related note, sign movements are larger and slower than speech movements, so they may be less prone to coarticulation in particular, or to the effects of rate and phonetic environment more generally. One way to further probe the organization of sign movements may be to conduct a perturbation study, analogous to bite-block studies for speech. This would allow exploration of the distinction

between planning and execution in the production of signs and address some of the issues raised by Russell and colleagues.

Another methodological issue in sign phonetics is that there are no established normalization procedures for comparing data across signers. Because different signers have articulators of different sizes, we cannot interpret a larger (or smaller) movement trajectory in one signer than in another as representing anything behavioral. Such a finding could simply reflect a difference in articulator size. Both of the studies discussed here recognized this problem and implemented some type of normalization procedure. However, as long as different research groups are using different normalization procedures, it will be extremely difficult to compare findings across studies. Sign phonetics would benefit from a measurement study designed to investigate this and develop normalization routines that are reliable, valid and broadly applicable for signing data, based on behaviorally and anatomically relevant factors.

4.2. *Sign phonetics and phonology*

The studies by Grosvald and Corina and by Russell and colleagues both indirectly address the question of articulatory targets in the sign modality and how these are defined. This is an important issue that remains almost entirely unexamined. Locations on the body are described in terms of anatomical landmarks (such as the chin, the forehead, or the chest), but we do not know that these landmarks are what signers are targeting during sign production. Indeed, the study by Russell and colleagues would suggest otherwise. There are potentially straightforward cases, in which the hand consistently seems to make contact with a specific point on the body (e.g., the ASL sign ME, in which the index finger moves to contact the chest), although there are limited data about articulatory targets even on productions like these. The more puzzling cases are signs located in the neutral space, which do not seem to be referenced to a particular point on the body (e.g., the ASL sign BICYCLE: in which the two closed fists cyclically move in forward alternating circles in front of the body). Such signs are not produced in arbitrary locations or with an arbitrary movement direction, but it is unclear how the signer is defining the articulatory targets for them. Studies such as the one carried out by Grosvald and Corina could help address this question.

Along similar lines, some models of sign phonology have treated the neutral space in front of the body as an unspecified location (cf. Crasborn 2001). Grosvald and Corina's research suggests that the neutral location does not vary much as an effect of phonetic environment, which is not what we would predict if the neutral space location were simply the lack of a phonological specification. However, the authors do note that the placement of the neutral space signs varies as an effect of signer. Given the current limitations of sign phonetics procedures and analyses, we cannot tell if this type of variability across signers is anatomical or behavioral, and we cannot tell if it is real or simply a measurement artefact. Nevertheless, this find-

ing supports the idea that phonetic measures need to be explicitly tested for validity and reliability. Both of the studies discussed here suggest that sign phoneticians should avoid framing measures of sign phonetics too simplistically (for example, assuming that the phonological forehead is equivalent to the anatomical forehead).

In addition to addressing the phonetics and phonology of location, both studies also have implications for the articulatory space used for signing – what is referred to as the signing space. Klima and Bellugi (1979) offered an approximation of the size of the signing space, which is considerably smaller than the volume of space reachable by the sign articulators. However, the concept of the signing space remains nebulous, because it has not been explored experimentally. Uyechi (1996) proposed that there are multiple signing spaces embedded within one another. The local signing space is the space in which an individual sign is articulated – her model specifies a local signing space rather than a location for individual signs. The global signing space is the area in which a string of signs is articulated, and the discourse signing space is the space used across an entire discourse. It is clear that undershoot and coarticulation of sign location cause the local signing space to be re-configured. What is less clear is whether they cause the global signing space to be reconfigured as well. Preliminary data from Tyrone and Mauk (in press) suggest that for some signers, it is the entire signing space that is raised in fast signing, rather than just individual signs. This should be explored in more detail, as it has implications for how to consider the distribution of phonological locations in ASL and other signed languages.

5. Concluding thoughts

While speech researchers have debated the question of whether it is the articulatory gestures or the acoustic correlates of speech that are the units of speech perception and production, no such debate has arisen in the realm of sign language research. No one has suggested that the objects of sign perception are inherently hidden or difficult to access. It has been taken as a given that signers directly perceive the articulatory gestures of signed language. Therein lies the challenge for sign phonetics and phonology: what are the underlying units in the sign modality and how do they differ (if at all) from what a human coder can observe and annotate? The visual nature of the sign modality can make it difficult for us to appreciate the importance of non-contrastive variation in sign production, because it seems that sign gestures should be transparent to any observer. As a result, there has been limited quantitative research in sign phonetics, and not much consideration given to the interface (or distinction) between sign phonetics and sign phonology. The broader field of sign language research would benefit greatly if sign phonetics and phonology were more clearly delineated and could inform each other explicitly.

Correspondence e-mail address: tyrone@haskins.yale.edu

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