Variation in phrasal rhythm in sign languages

Introducing "rhythm ratio"

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In this paper. we offer a preliminary investigation of some aspects of individual and group variation in sign rate and rhythm, considering the sociolinguistic factors of Age (younger and older adults), Gender, and Sign Variety (Black and Mainstream American Sign Language). Differences in sign rate and rhythmic structure among signers were found in signers' elicited narratives. A novel approach to phrasal rhythm is introduced, called "rhythm ratio", which considers sign duration and transition duration together and is similar in spirit to the "normalized pairwise variability index" (nPVI) in spoken languages. This measure appears to be promising as a method for identifying rhythm class in sign languages; however, due to the small number of signers in each group these results can only be suggestive.

Keywords: American Sign Language, sociolinguistic variation, prosody, prominence, rhythm, Black ASL

1. Introduction

This work addresses potential differences in rhythm class among different varieties of American Sign Language (ASL) – younger vs. older signers, women vs. men, and Black ASL vs. Mainstream ASL. In the process of this work, we have discovered a measure of rhythm that includes the duration of both lexical and transitional movements, which will be described in detail and called *rhythm ratio*. In the Introduction the general state of knowledge about ASL prosody is discussed, as well as work on the sociolinguistic factors analyzed in earlier work. We then proceed with the analyses of sign rate and rhythm, followed by a general

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discussion of the implications of our findings in the broader context of within-language and across-language variation, and for sign language acquisition.

1.1 Prosody in ASL

Just as in spoken languages, sign language prosody has a hierarchy of units moving from the smallest to the largest (Nespor & Vogel 1986; Nespor & Sandler 1999; Sandler 2011): Syllable, Prosodic Word, Clitic Group, Phonological Phrase, Intonational Phrase (abbreviated I-Phrase), and Utterance. ASL prosodic cues have been studied for marking prosodic constituency and prominence, as well as for communicating specific semantic and pragmatic meanings (see Pfau & Quer (2010) and Sandler (2011, 2012) for good recent overviews). Prosodic cues include properties of a sign's movement, such as duration, acceleration, and peak velocity (Wilbur 1999; Dachkovsky, Healy & Sandler 2013) as well as non-manual behaviors, such as blinking, torso leans, and the position of brows, head, and body (Pfau & Quer 2010; Herrmann 2015); in other words, prosody appears on the hands, face, and body. Prosody is also acquired on a similar time course in signed and spoken languages (Brentari, Falk & Wolford 2015).

In spoken languages, rhythm is conveyed by timing, accent, and grouping (Patel 2008). In sign languages, rhythm is conveyed by the properties of manual movement (Sandler & Lillo Martin 2006) – not only by lexical movements but also, as we will argue here, by transitional movements. More background on rate and rhythm is given below, since the main focus of this paper is the rhythmic structure of ASL.

1.1.1 *Sign rate*

Sign rate is based on the number of signs per minute and provides a rough measure of how rapidly information is being conveyed. Linguistic information flows at roughly the same pace in ASL and English. An early study on sign rate found that there are fewer ASL signs than English words per minute (Klima & Bellugi 1979). The slower sign rate was explained, in part, by the size of articulators, and the fact that sign language articulators of the hands, arms and body are larger than those of the vocal apparatus, often make larger movements, and move more slowly than the speech articulators. As a result, more time is needed to execute a typical sign. The number of propositions per minute in ASL and English were also measured in Klima and Bellugi (1979), and proposition rates were found to be roughly equal in the two languages. The similar proposition rate was explained, in part, by the fact that signs in ASL are often polymorphemic, so fewer signs per clause are produced.

1.1.2 *Rhythm*

Rhythm class is a fundamental way of categorizing spoken languages as syllable- or stress-timed languages (Abercrombie 1965). For example, the Romance languages French, Spanish and Italian are syllable-timed languages, while the Germanic languages ~~British~~ English, Dutch and German are stress-timed languages. This distinction captures an intuition of speakers, and neonates can tell the difference between syllable and stress timed languages when they are just a few hours old (Mehler, Dupoux, Nazzi & Dehaene-Lambertz 1996). The phonetic evidence for this distinction had been based on the isochrony of syllables (i.e., the duration of any two syllables is relatively equal) vs. the isochrony of stresses (i.e., the duration of units measured from one stressed syllable to the next is relatively equal), yet time after time, the hard evidence for these different types of isochrony has been difficult to ascertain (Bertinetto 1989). Even the powerful tools of metrical theory, which capture the abstract principles by which syllable prominence propagates up through a hierarchy of prosodic constituents (Nespor & Vogel 1986), have not been able to resolve this issue (Liberman 1975; Halle & Vergnaud 1987).

Ramus, Nespor & Mehler (1999) were the first to devise a new way to approach this problem in order to capture the ability of neonates to perceive differences between languages from different rhythm classes. Rather than the duration of entire syllables or of periods between stresses they pulled apart the duration of vowels and the duration of intervocalic elements. They plotted languages in three-dimensional space: time spent on consonants, time spent on vowels and the *ratio* between them. Consider the strings in (1), which captures this shift in thinking schematically. The brackets below the units show how the syllable intervals (1a) or intervals between stresses (1b) would be calculated, which obtains an unsatisfactory result for grouping languages by rhythm classes, as Bertinetto (1989) points out; however, if we calculate a ratio of vowels to consonants we obtain a more satisfactory measure of difference between syllable- and stress-timed languages. The ratio of vowels to consonants is higher in (1a) than in (1b).

(1) Syllable timed vs. stress-timed languages

a. syllable-timed language (e.g., Spanish, Italian)

CV.CV.CVC.CV.CV.CVC.CV

Ratio: 9 consonants, 7 vowels; vowel to consonant ratio: .77

b. stress-timed language (e.g., German, English [stresses indicated in bold])

CV.CCC**V**C.CV.CV.C**V**CC.CV.C**V**C

Ratio: 10 consonants, 5 vowels; vowel to consonant ratio: .5

Ramus et al. (1999) and Ramus (2002) captured a significant difference among rhythm class by calculating not the number of vowel segments to consonant segments, but rather the ratio of the period of time used in vowels by the period of time used in consonants for 8 languages (Catalan, Dutch, English, French, Italian, Japanese, Polish, and Spanish; see Figure 1) and thus began a new line of research in this area. French, Italian, Catalan and Spanish group together as syllable-timed languages, Dutch and English group together as stress-timed languages and there are two outliers – Polish, which has defied categorization because it appears to be stress-timed but lacks an important feature of stress-timed languages (unstressed vowels do not reduce) and Japanese, which uses a different way of calculating rhythm based on the mora. Further developments of this method of calculating ratios were developed by Low, Grabe & Nolan (2001) and Grabe & Low (2002), called the *Pairwise Variability Index* (PVI) and the *normalized Pairwise Variability Index* (nPVI). These measures utilize intervocalic periods combining consonantal and pause periods. The important innovation in this work is the idea of using a ratio measure between the vocalic and intervocalic intervals instead of the measure of entire syllables.

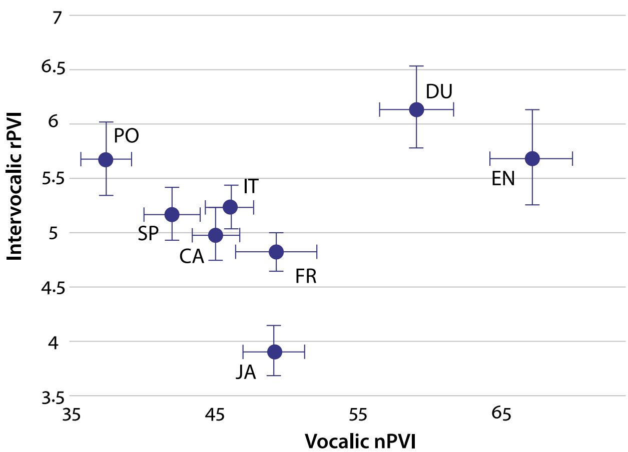


Figure 1. The Pairwise Variability Index in 8 languages (from Ramus 2002): Catalan (CA), Dutch (DU), English (EN), French (FR), Italian (IT), Japanese (JA), Polish (PO), and Spanish (SP). Error bars show +/− 1 standard error

The *rhythm ratio* measure proposed in this article takes each lexical movement (the parallel notion to vocalic periods in spoken languages) and divides by its adjacent transitions (the parallel to intervocalic periods for spoken language) to obtain a ratio between the two.

The claim we are making here is that transitional movements are important in prosodic structure, and are not empty gaps in the signal in speech or sign. This claim is based on several independent observations about words and phrases.

In English words, transitional vocal gestures in speech that occur between target articulatory gestures have been shown to result in epenthetic segments (Browman & Goldstein 1990), such as a schwa (e.g., K[ə]ruthers) instead of Kruthers), or excrescent consonants (e.g., some[p]thing instead of something). In complex word formation in ASL, transitional movements between signs can become part of the sign itself. This occurs in signs inflected for temporal aspect (Wilbur, Klima, & Bellugi 1983), and in some compounds, where the transitional movement may be the only movement retained in the compound. For example, in the signed sequence of THINK and SELF (Figure 2, left and center) the lexical movements are shown with solid black arrows: for THINK the straight movement to contact at the forehead, and for SELF the two short movements outward from the signer (the movement indicated by a dotted line is a transitional movement within the sign itself). There is a transitional movement, typically ignored for purposes of meaning, that is shown neither in Figure 2 (left) nor Figure 2 (center). The transitional movement occurs between the contact with the forehead at the end of the first sign THINK and the beginning of the first movement at the beginning of the second sign SELF. It is the transitional movement, and only that movement, that is retained in the compound THINK^SELF 'decide for oneself', as we see in Figure 2 (right).

THINK SELF THINK^SELF

Figure 2. There is a transitional movement, typically ignored for purposes of meaning, between (left) at the end of the sign THINK and before the begging of the sign SELF (center). The transitional movement is integrated into the compound THINK^SELF 'decide for oneself'. Only the transitional movement and the places of articulation in the two component signs are retained in the compound; neither of lexical movements is retained. Image reprinted with permission of MIT Press from Brentari (1998)

The spaces between syllable nuclei – i.e., the consonants and pauses – play an important role in rhythm in the speech stream and in music as well (Patel 2008). We are claiming that transitional movements in sign language phrases are likewise important for rhythm. For example, recent work has shown that one important aspect of creating natural-looking signing avatars is the manipulation of phrasal transitional movements (Duarte & Gibet 2010; Gibet, Courty, Duarte & Le Nour 2011). In addition, insights from signers with Parkinson's disease also point to the importance of transitional movements. Brentari & Poizner (1994) found that signing is perceived as monotonous when transitional movements between signs have longer durations than in typical signing, or when they look like lexical movements because of their coordination of handshape and movement. Finally, in literary form, a common device used in sign language poetry is to reduce the transitional movements between signs (Klima & Bellugi 1979; Valli 1993; Sutton-Spence 2005; Cole 2009) by choosing from among alternative expressions those that will create sequences of signs with minimal transitional movements – where a preceding sign will end close to or at the same place as the beginning of the next sign. These types of considerations indicate that transitional movements have an effect on the metrical structure of a poem. To sum up, this evidence indicates that transitional movements contribute to rhythmic structure in the phrase.

It would be premature to assign a single role to transitional movements in sign languages. We will argue only that they are important for phrasal rhythm. Since schwas (and other epenthetic segments) have many different functions in spoken languages at the syllable, word, and phrasal levels (Hall 2011) it may also be the case that transitional movements have more than one metrical function in sign languages.

Previously, phrasal rhythm in sign languages has not been extensively analyzed. Boyes Braem (1999) has suggested that side-to-side leans in Swiss German Sign Language (DSGS) are a marker of a rhythmic unit, but this finding has not been replicated in other sign languages, and it seems to appear only when signers are standing (rather than sitting). Miller (1996) discussed foot structure in Langue des Signes Québécoises (LSQ), which is related to word-internal rhythm, but he did not consider transitional movements in his analysis.

1.2 Sociolinguistic factors

Several sign languages have been studied from a sociolinguistic perspective (for ASL, see Bayley, Lucas & Rose (2000,;2002); Lucas, Bayley & Valli (2001, 2003); Lucas, Bayley, Rose & Wulf (2002); and Lucas & Bayley (2010); for Australian Sign Language and New Zealand Sign Language, see Schembri et al. (2009); for British Sign Language, see Fenlon et al. 2013; and for British, Australian, and New Zealand Sign Language as a related group, see Schembri et al. (2010)). In the work on ASL, Age, Gender, and Sign Variety are the typical sociolinguistic factors under investigation, and these factors have been shown to have an effect on sign production along several dimensions. Lucas, Bayley & Valli (2001) have found Age, Gender, and Sign Variety to be significant in lexical variation; for example, in shifts of sign production to lower places of articulation on the face, and in the presence vs. absence of pronouns using pro-drop. In general, this research has found that female signers, older signers, and Black ASL signers tend to produce more conservative forms (less shift of place of articulation and less pro-drop). Here we address prosodic structure along these dimensions, although it is less clear what more conservative rhythmic structure would look like, since there is so little work on the topic.

The work on Black ASL is relatively sparse, but Woodward (1976), Woodward, Erting, & Oliver (1976), Woodward & De Santis (1977), Hairston & Smith (1983), and Aramburo (1989) have all described aspects of ASL signing among the African American Deaf community that differ from that of Mainstream ASL.[1] The most extensive work to date, which quantitatively analyzes the signing of African American signers from several Southern states along a number of lexical and phonological dimensions, is the sociolinguistic variation study by McCaskill, Lucas, Bayley & Hill (2011). Their study of Black ASL included multi-signer conversations as well as cartoon narratives. McCaskill and her team found that Black ASL signers: produced more 2-handed forms of signs, produced more signs outside of typical signing space, used a greater number of constructed dialogue forms in conversation, and spent more time using constructed action in the cartoon narratives than did Mainstream ASL signers. Overall, they concluded that Black ASL was a more conservative variety than Mainstream ASL; specifically, Black ASL signers retained canonical citation forms of signs more frequently than did Mainstream ASL signers. In addition, McCaskill et al. (2011) observed that African American signers incorporated specific expressions from African American English (AAE) into their signing, such as an ASL expression for the AAE *you're trippin!*, which demonstrates the multi-dimensional language landscape in which Deaf African Americans live. These scholars and Hairston & Smith (1983:55) caution us, however, that the features of Black ASL may interact with other aspects of a signer's identity. They write, "We maintain that there is no Black sign language. There is, however, a Black way of signing used by Black Deaf people in their own

1. Throughout the text "Deaf" refers to the cultural identity of individuals old enough to have experienced Deaf enculturation, while "deaf" refers, in general, to the biological condition of being deaf, or to children not yet enculturated. Labeling the sign language varieties in our study required careful thought. We have chosen "Black ASL" because this term was popularized by McCaskill, Lucas, Bayley & Hill (2011). The data from that work are also used here, so we maintained their label for consistency. We have chosen "Mainstream ASL" in order to capture the fact that there is no standard variety of ASL, but that that the variety under investigation here is used by a majority of ASL signers in both live and virtual interactions on social media.

cultural milieu – among families and friends, in social gatherings, and in Deaf clubs."

1.3 The effect of social and educational policies on ASL varieties

The sign varieties investigated here require consideration within the larger social context in which they occur, particularly with respect to Black ASL. The social realities that took place during the Jim Crow period of segregation (1870s to 1960s) affected many aspects of life of the African American community for hearing and Deaf people. Spoken white and black varieties of English have developed along different trajectories, and accordingly, different social ideologies, which are beyond the scope of this paper (see, for example, Carpenter 2009; Lanehart 2015). With regard to education in particular, prior to *Brown v. Board of Education* (1954) and even for quite a long time afterwards, African American hearing and deaf children experienced segregated education, and this has had an effect on the development and continued use of AAE and Black ASL varieties, as well as on the language attitudes of those who use them (Lanehart 2015; McCaskill et al. 2011; Hill 2012). An even more complex set of language ideologies is at work in the Black ASL community than in the AAE community. The practice of segregation in deaf education has been argued to be an important factor that has maintained Black ASL as a separate variety in older, but not younger Black ASL signers (McCaskill et al. 2011).

The more recent deaf educational policy known as *mainstreaming* that continues to the present time is also an aspect of educational policy that may have sociolinguistic consequences. This policy strives to place all deaf children in the "least restrictive environment" with respect to their hearing peers, so deaf children are often placed in classrooms with hearing children to the greatest extent possible with varying levels of support as mandated by the federal legislation known as PL94–142, which was passed in 1975. This current practice of mainstreaming, which should not be confused with the term Mainstream ASL that we are using throughout this paper, results in many deaf children from hearing families having late or little exposure to ASL, when compared to earlier periods in deaf education when deaf children were educated at residential schools and had more opportunities for peer and multi-generational interactions in the classroom and dormitories (Nunes, Pretzlik & Olsson 2001). In a mainstreamed educational setting there may be only one or at most a few deaf children in an entire public school. Teachers and support staff are typically not fluent signers of ASL in such environments. They may use varieties, known as "Signed English" or "contact signing" (Lucas & Valli 1989), which incorporate morphological and syntactic structure that is more closely aligned with English than ASL. Hearing parents often adopt these varieties as well. These two educational policies (the end of segregation and the increase of mainstreaming) both have a potential on Black ASL in different ways. Desegregation puts pressure on Black ASL to change towards a more Mainstream ASL variety, and mainstreaming may put pressure on all varieties of ASL towards the inclusion of some Signed English-like features.

The goals of the present study are therefore two-fold: to add to the work on variation (individual and group) by examining rhythm, and to investigate a new kind of measure of sign language rhythm that incorporates transitional and lexical movements.

2. Methods

2.1 Participants

The data in this study are a subset of the narrative data that were collected and analyzed in McCaskill et al. (2011). These data consist of single-signer controlled narratives and include 12 Black ASL and 12 Mainstream ASL signers. As this is a small group, our results are preliminary, and we hope that future studies will take up these questions with larger samples. Even though McCaskill et al. also collected multi-signer conversations in which 96 signers took part, for the current study, only the narratives were analyzed because longer stretches of signing with sequences of multiple I-Phrases were needed. One signer was excluded because she learned ASL at age 16, and we expected that such a late age of acquisition would affect the signer's prosodic pattern. Therefore, data from 23 of the 24 narratives were analyzed. The 23 signers learned ASL either from their Deaf signing parents or relatives, or when they entered school; however, not all participants could remember the exact age when they entered school. All signers use ASL as their primary mode of communication; their profiles are schematized in the Appendix: Table A1.

The older group consisted of thirteen signers who were 55 years of age or older (age range 55–72; mean age 63.4). The six older Black ASL signers (4 males, 2 females) were from the Southern states of Alabama, Arkansas, Louisiana, and North Carolina. The seven older Mainstream ASL signers (3 males, 4 females) were from Maryland (4 females, 3 males). Besides being native signers or early learners of ASL, the signers from both older groups were chosen because of their school experience, which occurred during the period of segregation in residential schools for the Deaf (none of them were mainstreamed with hearing children).

The younger group consisted of ten signers who were 35 years of age or younger (age range 18–34; mean age 25.6). The five younger Black ASL signers

(3 males, 2 females) were from Alabama and North Carolina. The five younger Mainstream ASL signers (2 males, 3 females) were Gallaudet students at the time of the study, and grew up in Vermont, Kentucky, Washington, DC, Arkansas, and Maryland. All had mixed educational experiences – i.e., they did not experience segregated education. Of the younger signers, four of them – one female Black ASL and all three of the Mainstream ASL female participants – were also mainstreamed for some part of their educational experience; the other younger signers received their education at residential schools for the Deaf.

This distribution of participants gives us two-four signers in each group: Black Older Females (2), Black Older Males (4), Mainstream Older Females (4), Mainstream Older Males (3), Black Younger Females (2), Black Younger Males (3), Mainstream Younger Females (3), and Mainstream Younger Males (2). No other socio-cultural details of the participants were gathered from the participants, such as socio-economic status, patterns of socialization, or whether they grew up in an urban or rural environment. Moreover, only two of the Mainstream ASL signers grew up in Southern states that overlapped with those of the larger group of Black ASL participants. We therefore cannot rule out that other factors, such as regional, attitudinal, or socioeconomic factors may be important, but they cannot be addressed with these data.

2.2 Procedure

Conversation partners tend to adjust their speaking or signing to bring it closer to what they perceive to be the preference of their interlocutor, a phenomenon known as *accommodation* or *convergence* (Pardo 2006; Babel 2009; Sonderegger 2012). Along these lines, it has been shown that ASL signers sometimes accommodate to the audiological and ethnic status of the interviewer (i.e., hearing vs. deaf, Caucasian vs. African American; Lucas & Valli 1992; Lucas 2013). The narratives analyzed in this study were retold to other Deaf participants of the same race and age group accordingly. The signers were asked to retell one of two Disney cartoons after watching it ("Taxi Turvy", a Popeye cartoon, or "Dog Gone Tired", a Pluto cartoon). The data were collected in private homes, community centers, or schools for the Deaf. All signers were seated while signing.

2.3 Coding and transcription

For these analyses video clips of the 23 narratives were annotated in ELAN (Crasborn & Sloetjes 2008) for gloss, sign duration, transition duration, phrasal position of each sign, as well as the use of size of signing space, blinks, holds, torso leans and type of sign (manual, constructed action, constructed dialogue). Only three cues are used in this analysis – sign duration, transition duration, and phrasal position.[2] Their definitions are given in the following paragraphs.

2.3.1 *Phrasal position*

Prosodic constituent boundaries (I-Phrases and Utterances) were annotated in order to determine a sign's position within them. They were annotated independently by two fluent, hearing ASL signers who did not annotate the cues mentioned below so that these judgments would be independent from annotation of individual cues. The judges were instructed to break the narratives into the largest units first, which were labeled Utterances, and next into the second largest units, which were labeled I-Phrases. The judges were linguistically trained, and therefore familiar with the non-manual cues used for ASL prosodic constituency (i.e., pre-boundary lengthening, blinks, head and body recalibration, and changes in non-manual markers of the face, particularly of the upper face, such as brow and eye position), but they were instructed *not* to depend on any single cue for their judgments. The judges watched each narrative five times: twice at 50% speed using the full screen view, twice at normal speed using the full screen view, and a fifth time with the clips reduced to a 2″ by 2″ square. Each judge contributed one set of judgments after the whole procedure. By altering the speed and size of the image across the five viewings, we were confident that judgments were made on the basis of the whole constellation of cues involved. Signs were then annotated according to mutually exclusive categories as follows: Utterance-initial and Utterance-final, I-Phrase-initial, medial, and I-Phrase-final.

2.3.2 *Sign duration*

Sign duration was measured from the frame where the first handshape of the sign is fully formed until the frame when the last handshape of the sign begins to degrade. For counting purposes, the manual prosodic word determines the boundaries of each sign; in other words, if a constructed action form spans three

2. Sign glosses, signing space, and the type of sign (constructed action vs. manual signs) were annotated for the initial study of Black ASL (McCaskill et al. 2011) and were not the subject of this study. The other prosodic cues will not be discussed here for several reasons. Holds were not correlated with I-Phrase boundaries here, confirming other recent analyses of holds (Tyrone, Nam, Salzmann, Mathur & Goldstein 2010; Tang et al. 2010; Brentari et al. 2011; Brentari, Nadolske & Wolford 2012), nor were they correlated with any of the other measures of interest in this study, so an analysis of holds is not included here. The analysis of blinks was ultimately not included because the filming of some of the Black ASL signers occurred in bright sunlight outdoors, and this may have influenced the rate and placement of blinks. Torso leans will not be discussed further, because unlike previous studies where participants were standing (Boyes Braem 1999), the participants in our study were seated.

manual signs the manual signs determine the count. In polymorphemic forms, each sequential movement was counted as a separate manual form (vehicle-move-forward, vehicle-back-up, vehicle-move forward is 3 signs). Holds, which are static periods of handshape in a single location, were considered part of the associated sign.

2.3.3 *Transition duration*

Transition duration was calculated as the time from the end of one sign until the beginning of the next sign. Transitional movements within signs were not measured (e.g., between the two movements of a sign with repetition, such as SELF in Figure 2). The phrasal position of transitions was also noted (between signs, between I-Phrases, between Utterances).

2.3.4 *Reliability*

For the constituent boundaries, the independent annotators had 92% and 90% agreement for Utterances and I-Phrases labels before discussion among judges, and all cases on which there was disagreement were resolved after discussion. For the tiers of duration (sign and transition) 10% of the annotations were re-coded by a second, fluent signer; 90% reliability was obtained for the beginning and end of each annotation, and all disagreements were resolved after discussion.

3. Results

Analyses will first be presented for sign rate, then for rhythm. Rhythm consists of the individual cues of sign duration, transition duration, and rhythm ratio. In the analyses of rhythm, first the raw data will be presented by individual to show the range of inter-subject variation, and then by group using mixed linear regression models in R including the predictors of Age (older, younger), Sign Variety (Black, Mainstream), and Gender (female, male). Additional predictors will be added in specific studies. We included all possible interactions of these predictors in our models because we expected variation to be due not only to these factors alone (old vs. young; females vs. males, etc.), but also to the smallest subgroups within them (younger Black ASL males vs. younger Black ASL males), where this difference is not explained solely by a single factor. The number of data points by sign type contributed by each participant is given in the Appendix: Table A1.

3.1 Sign rate

The analysis of sign rate was based on number of signs per minute; individual raw values are shown in Figure 3 (top), and results of statistical modeling with predictors for Age, Sign Variety, Gender, and interactions are shown in Figure 3 (bottom). All sign types were included, including Constructed Action and Constructed Dialogue, a total of 2611 signs. Because average sign rate has only one observation for each subject, a mixed-effects linear regression model reduces to a simple linear regression model (Gelman & Hill 2007); therefore, there is no random variable for subject. The only significant effect is a three-way interaction among Age, Sign Variety, and Gender; younger Black ASL males have a faster rate than otherwise predicted (coefficient 73.83; standard error 26.38; $p < .05$). The abbreviations for all of the predictors and their values are given in the Appendix: Table A2, and the full output of statistical model is shown in the Appendix: Table A3.

These results show that most of the groups have sign rates that overlap, and in addition, we can observe that there is a tendency for Black ASL signers to have fewer signs per minute, but the result is not significant. Notice that the younger Black ASL males have rates similar to the Mainstream ASL groups – i.e., the three-way interaction mentioned above –, while the younger Black ASL females have rates similar to the older Black ASL males. In addition, the older male signers of Black ASL and Mainstream ASL have non-overlapping distributions, while the older female signers of Black ASL and Mainstream ASL overlap considerably.

3.2 Rhythm

Analyses of sign duration, transition duration, and rhythm ratio will be presented in this section. Because the number of subjects in our sample is quite small, we wanted to choose our statistical models carefully, and include all factors that could be producing significant effects, but only where there was enough data to support using these factors. There were 269 Utterances and 415 I-Phrases in the data set (684 combined). I-Phrase-Final and Utterance-Final signs were therefore grouped as “final” signs because there were so few data points contributed by each subject in U-final position (an average of 11 per subject). Utterance-initial, I-Phrase-initial, and medial signs were grouped together in the category “non-final” because we do not have a theoretically motivated reason to think that they differed, and on visual inspection, the distributions of durations were similar.

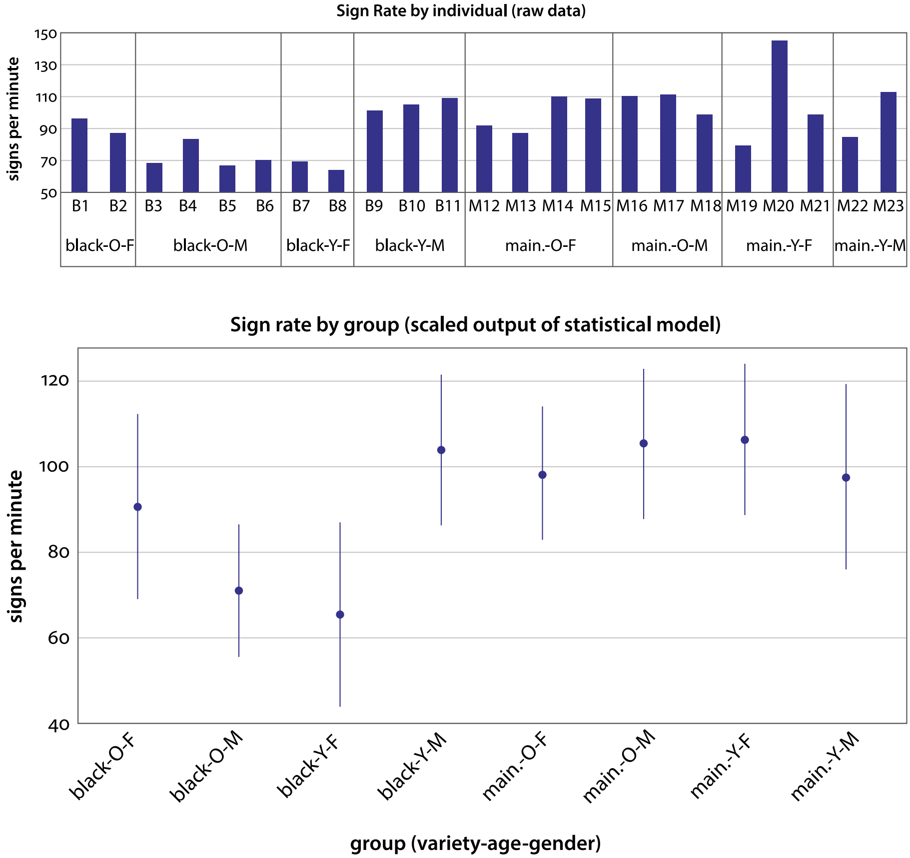


Figure 3. (top) Raw values of signs per minute by individual. (bottom) Model predictions for sign rate, expressed as signs per minute. The dots are the model predictions, and the lines are the 95% confidence intervals around those predictions. The ASL groups are indicated along the x-axis by Sign Variety (Black, Main.), Age ((O)lder, (Y)ounger), and Gender ((M)ale, (F)emale)

3.2.1 *Sign duration*

Four different linear mixed-effects models were used to analyze sign duration, and the predictors were Age, Sign Variety, Gender, and Phrasal Position (non-final, final), as well as their interactions. The characteristics of the models are shown in Table 1. In addition to these predictors we had wanted to include Sign Type (constructed action, constructed dialogue, manual), but ultimately did not do so because the number of constructed action and constructed dialogue forms contributed by each signer varied considerably. Some signers produced only four constructed action structures, and some signers produced no constructed dialogue structures at all. We therefore included only the manual signs in the duration analysis (2005 observations). For this analysis the data were log-transformed (taking the natural log) and then scaled by subtracting the mean and dividing by the standard deviation because the durations for all groups have a heavy positive skew; that is, there are numerous examples of extremely long durations, but very few examples of extremely short durations, and durations had an absolute lower bound of 0 (the duration of a sign cannot be less than 0). This skewness is a common occurrence in durational data in signed and spoken languages, and analyzing log-transformed, scaled data is common practice for such skewed data (Gellman & Hill 2007). The outcome of the models is the log-transformed, scaled duration of signs. Log-likelihood ratio model comparison was performed on these four models, starting with the full model, removing each predictor one at a time, and evaluating the model's fit using information theoretic measures (AIC and BIC) to determine the predictive power of the addition or removal of a predictor. Neither the fully saturated Model (Model 1) nor the simplest model with no interactions (Model 4) was chosen.

Table 1. Model comparisons for the analysis of sign duration. Model 2 (underlined) was used in the analysis

	Predictors	Outcome	Interactions	Random intercepts	Random slopes
M 1			all	subject	position
M 2			demographic predictors	subject	position
M 3	Age, Sign Variety, Gender, Position	scaled, standardized duration of signs	demographic predictors	subject	none
M 4			none	subject	none

The model that was chosen by the model comparison procedure was Model 3; however, the effect directions, sizes, and significances for Models 2 and 3 are nearly identical, which means that the interpretation of the results does not change when looking at either Model 2 or 3. The only difference between Models 2 and 3 is that Model 2 includes a (random) slope adjustment for the position variable by subject (in other words: the effect of position was allowed to vary for each subject.) This additional random effects structure has been shown to be critically important for detecting situations where only a subset of subjects are responsible for a particular effect (Barr, Levy, Scheepers & Tily 2013). Because these two models are extremely similar, and because there is evidence that (random) slope adjustments are important to be kept in mixed models, we will report Model 2 here, even though Model 3 was the one that was chosen by model comparison. See Figure 4 (top) for the raw data by subject, Figure 4 (bottom) for the output of Model 2 analyzed by group; and Appendix: Table A4 for the full output of each model.

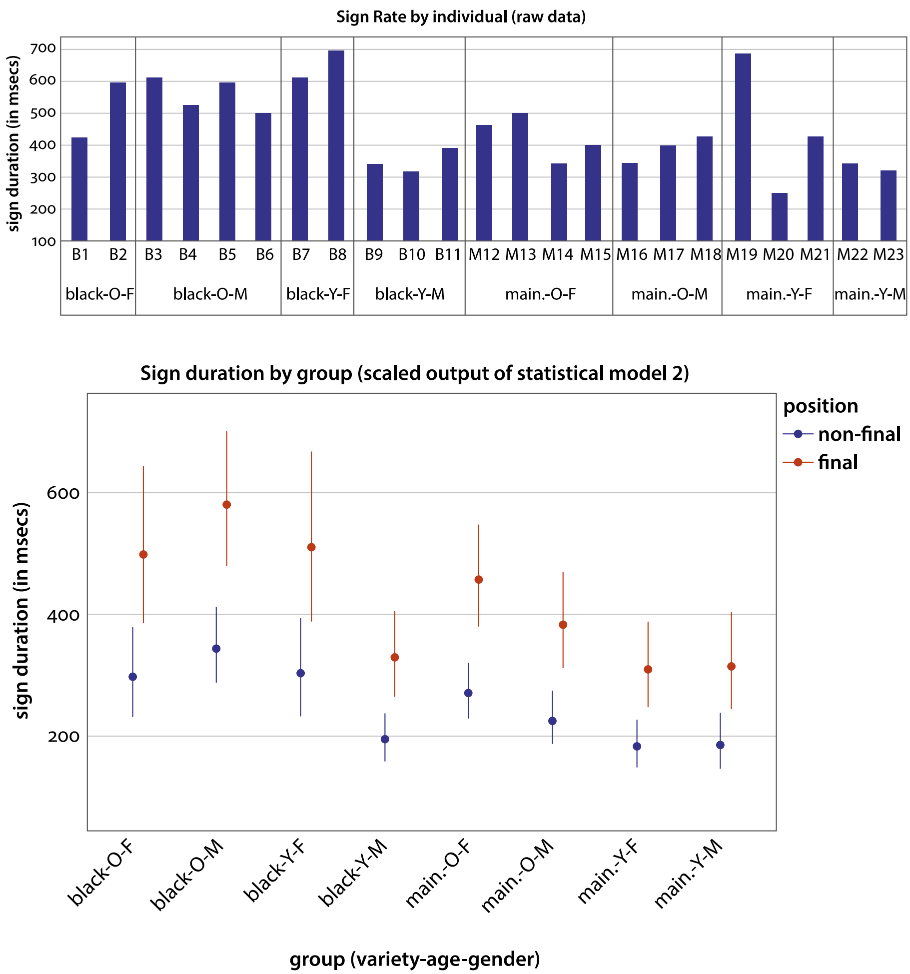


Figure 4. (top) Raw values for average sign duration by individual. (bottom) Model predictions for sign duration for medial (black) and final signs (red). The dots are the means, and the lines are the 95% confidence intervals around those predictions. The ASL groups are indicated along the x-axis by Sign Variety (Black, Main.), Age ((O)lder, (Y)ounger), and Gender ((M)ale, (F)emale)

Among the simple predictors, Age and Phrasal Position had a significant effect. Younger signers have shorter sign durations than older signers (coefficient

−0.49; standard error 0.17, $p < .05$), and final signs are longer than medial signs (coefficient 0.66; standard error 0.05, $p < .001$). There is also a significant three-way interaction between Age, Sign Variety, and Gender (0.99, standard error 0.38, $p < .05$), where younger male Black-ASL signers have shorter manual signs that would be otherwise predicted.

These results confirm that final signs are longer, but that this effect does not vary according to any of the sociolinguistic predictors under investigation. Age is the only main sociolinguistic predictor, and the sign duration results tell a similar story to the previous analysis of sign rate: as we have seen with sign rate, the older Black ASL male signers have longer signs than their Mainstream ASL counterparts, while the older Black ASL and Mainstream ASL females have similar sign durations. Also, the younger Black ASL females pattern like the older Black ASL males (longer signs), while the younger Black ASL males pattern like the Mainstream ASL groups (shorter signs).

3.2.2 *Transition duration*

As above for sign duration, linear mixed-effects regressions were used to analyze transition duration (2621 observations), in which the outcome is the scaled, log-transformed transition duration. The predictors are Age, Sign Variety, Gender, Phrasal Position, as well as two additional predictors – Sign Before (the duration of the sign before the transition) and Sign After (the duration of the sign after the transition), and, depending on the model, their interactions. Three models were fit as shown in Table 2.

Table 2. Model comparisons for the analysis of transition duration. Model 2 (underlined) was used in the analysis

	Predictors	**Outcome**	**Interactions**	**Random intercepts**	**Random slopes**
M 1	Age, Sign Variety, Gender, Position, Sign Before, Sign After	scaled, standardized duration of transitions	all	subject	position, sign before (SB), sign after (SA), interaction of SB and SA
<u>M 2</u>			demographic predictors	subject	position
M 3			demographic predictors	subject	none

Model comparison was performed on the three models using the same method as for the analysis of sign duration; however, choosing which model is preferred through model criticism was not clear-cut. All of the models come to very similar conclusions for our variables of interest, and we report on Model 2 here. Model 1 or Model 3 is chosen by model comparison, depending on if we are doing stepwise simplification (as is advocated by Harrell 2001), or if we are choosing the simplest model. Model 3 has an extremely reduced grouping structure (no slope adjustments at all), and we know from Barr et al. (2013), that models without slope adjustments can lead to incorrect results, so to make sure we are not falling into that trap we have also included Model 2, which is identical to Model 3 except that it has (random) slope adjustments for position~~, previous sign duration, and following sign duration~~. See Figure 5 (top) for the raw values for each individual, Figure 5 (bottom) for the results from the statistical analysis by group for Model 2, and Appendix: Table A5 for the full outputs of all three models.[3]

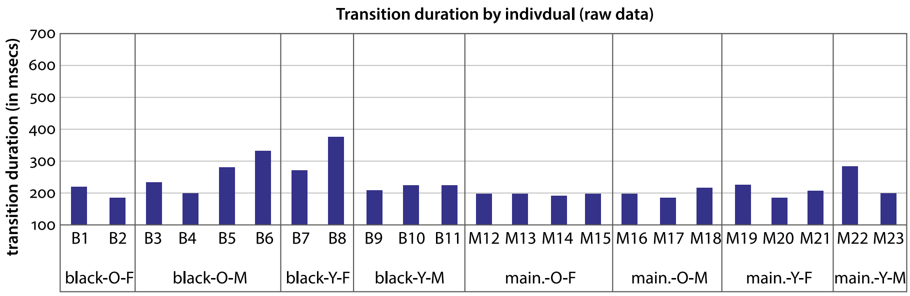
The simple predictors that have a significant effect are Phrasal Position (coefficient 0.75, standard error 0.06, $p<.001$), where I-phrase final transitions are longer, Sign Before (coefficient 0.06, standard error 0.02, $p<.01$), Sign After (coefficient 0.11, standard error 0.02, $p<.001$), where the transition is longer if the duration of either sign flanking the transition is longer, with Sign After having a stronger effect. The interaction of Age and Sign Variety is also significant (coefficient 0.53, standard error 0.16, $p<.001$), where younger Black ASL signers (males and females) have longer transitions than would be predicted by the main effects alone.

The analysis of transition duration shows that transitions are generally shorter than their adjacent signs and vary less than sign duration. Like sign duration, there is a main effect for Phrasal Position; therefore, transitions are not uniform in duration. In addition, transition duration also varies by individual and by group independently of sign duration: the two younger Black ASL groups have longer transitions than the other groups, which is a different pattern from that of sign duration. This analysis sets up the next section on rhythm ratio, where sign duration and transition duration are analyzed as a unit. This will allow us to see how sign duration and transition duration interact, and also to factor out the positional effects of sign and transition duration in order to better see how the sociolinguistic factors play a role.

3.2.3 *Rhythm ratio*

The predictors of Sign Before and Sign After emerged as significant in the transition analysis above, so we also subsequently analyzed the ratio between the sign and its adjacent transitions on either side as a rhythmic unit that could display

3. Just as we did with the sign duration models above, we also fit a reduced model that did not include any interactions. This model was not selected under any model selection procedure. Because this model was not selected by model comparison, we have left this model out of the discussion in order to save space.



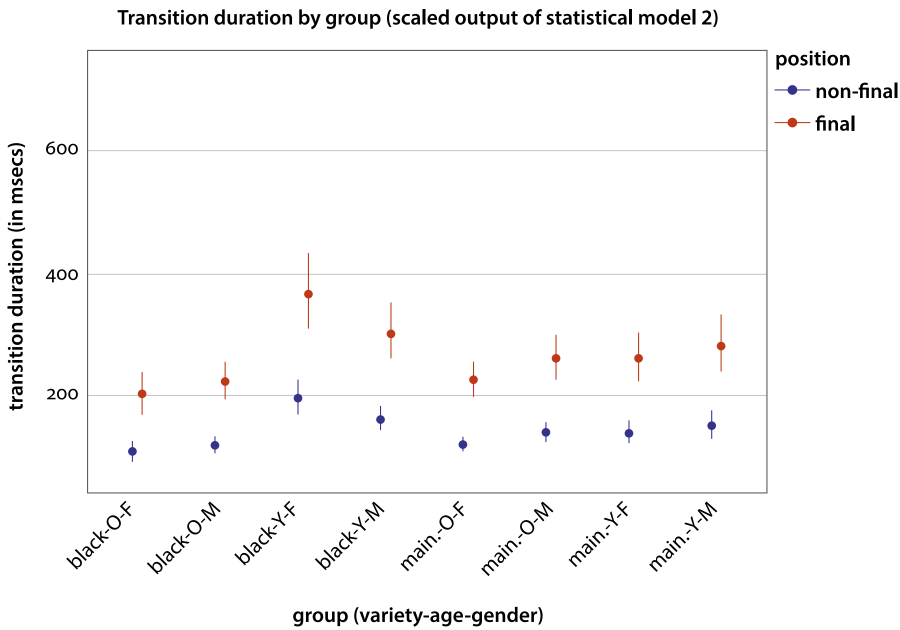


Figure 5. (top) Raw values for average transition duration by individual. (bottom) Model predictions for transition duration for non-final (black) and final transitions (red). The dots are the means, and the lines are the 95% confidence intervals around those predictions. The ASL groups are indicated along the x-axis by Sign Variety (Black, Main.), Age ((O)lder, (Y)ounger), and Gender ((M)ale, (F)emale)

sociolinguistic variation. We define this as *rhythm ratio* (2); note that the sign durations and transition durations are already log-transformed and scaled.

(2)
$$\text{rhythm ratio} = \frac{\text{sign duration}}{\text{previous transition} + \text{sign duration} + \text{following transition}}$$

A ratio of .33 means that the transition durations and sign durations are equal. Ratios greater than .33 indicate longer sign durations and shorter transitions. Ratios lower than .33 indicate longer transitions and shorter sign durations. The important similarity of the rhythm ratio with the nPVI (Grabe & Low 2002) is that both are indices of variability between "vocalic" and "intervocalic" units; the ~~similarity~~ of vocalic intervals ~~and~~ sign durations, and intervocalic intervals ~~and~~ transitional periods should be clear. There are also some differences between the measures of nPVI and rhythm ratio. First, we considered each sign duration and adjacent pair of transitions individually as tri-grams and then by group, while the nPVI as described in Grabe & Low (2002) calculated the vocalic and intervocalic intervals as bigrams and then by group. The second difference concerns what is included in intervocalic intervals. Intervocalic intervals of the nPVI in speech include both pause time and consonant intervals (i.e., anything between vocalic intervals). The model we report on here uses the measure of sign duration as vocalic intervals, and this includes holds. We included holds as part of sign duration in the single cue analyses, and we thought it would be best to be consistent about that throughout our analyses. Hypothetically lexical movements in sign could be the movements alone, excluding the holds, and the holds would then be considered part of the intervocalic intervals. To ensure that our findings were robust, we ran the models including holds as part of the sign and as part of the transition. The results did not change, perhaps because only 22% of the signs in our study had any hold at all. It would be interesting to try these two alternative methods of calculating rhythm ratio on other data sets.

For the analysis of rhythm ratio, we again fit multiple models, as shown in Table 3.[4] In each, the outcome is the ratio of sign to previous transition + sign +

4. Just as we did with the sign duration and transition models above, we also fit a reduced model that did not include any interactions to this data, as well as a beta regression model. Beta regressions are ideal for data that involve ratios (Kieschnick & McCullough 2003; Smithson & Verkuilen 2006; Bonat, Ribeiro & Zeviani 2015). Beta regression allows for, and is restricted to, outcomes between 0 and 1; exactly the space where ratios are, such as those of the sign duration and transition duration. The results from the beta regression models are strikingly similar to those for the linear mixed effects models. The predictors all have the same sign and all of the predictors that are significant in the linear model are significant in the beta model (the beta model also has two additional significant effects, one of which is marginally significant in our linear model). The overall magnitude of effect sizes differs between the two models because they assume a different relationship between the predictors and the outcome: the linear regression assumes a linear relationship, whereas the beta regression uses a link function between the predictors and responses to conform to a beta-distribution. Because the variables we report here are significant in both models, they are not dependent on which model we chose, and our conclusions about them are valid with either modeling approach. The predictors that are only significant in the beta model show similar tendencies in the linear model, however they do not

following transition described above (2035 observations). The raw values for each individual are given in Figure 6 (top), the results from the statistical analysis by group in Figure 6 (bottom), and the full outputs from each model in Appendix: Table A6.

Table 3. Model comparisons for the analysis of rhythm ratio. Model 2 (underlined) was used in the analysis

	Predictors	Outcome	Interactions	Random intercepts	Random slopes
M 1			all	subject	position
<u>M 2</u>	Age,Sign Variety, Gender,	ratio of sign duration to the adjacent transitions as described	demographic predictors	subject	position
M 3	Position	in (2)	demographic predictors	subject	none

Using the same model selection procedure as above, the model that is selected is Model 2.[5] Two of the simple predictors have significant effects: Age (coefficient: −0.09, standard error: 0.02, $p < .001$) where younger signers have lower ratios, and Gender (coefficient: −0.05, standard error: 0.02, $p < .05$) where males have lower ratios. The interaction of Sign Variety and Gender has a marginal effect[6] (coefficient: 0.06, standard error: 0.03, $p < 0.1$) where Black ASL males have larger ratios than otherwise predicted by the simple effects. Phrasal Position is not a significant predictor in rhythm ratio.

All signers have a rhythm ratio greater than .33, which indicates that, on average, their signs are longer than their transitions, as also seen earlier in comparing Figures 4 and 5. Signers' rhythm ratio varies from .4 to .6. There are also notable differences when one compares the results of the rhythm ratio analysis with that of sign duration or transition duration. So far, Age was the only main sociolinguistic factor that was a significant predictor (for sign duration); now Age and Gender are both significant. Older signers have higher ratios than younger signers in both varieties. Female signers have higher ratios than their male counterparts in older and younger groups; however, Black ASL signers show less difference between the genders within their respective age groups than the Mainstream signers.

reach the level of statistical significance, further data and analysis is necessary to confirm if these trends are present in the broader populations that we are studying.

5. As with the previous sections, we also fit a radically reduced model that had no interactions at all. Like all of the sections above, this model was not selected by model comparison.

6. This effect is significant in the beta regression models we fit, and are given in Appendix: Table A6.

These results suggest that the ratio of a sign plus its adjacent transitions can help clarify patterns that the individual cues of sign duration or transition duration alone cannot. Moreover, since the rhythm ratio measure allows us to include both sign and transition information, this measure also has the effect of backgrounding the strong positional effects we see in the sign and transition duration cues alone; i.e., there is no statistical difference in rhythm ratio between final and non-final forms, which may allow the sociolinguistic factors to be observed more directly.

4. General discussion

The results will be discussed around the new construct of rhythm ratio, and the sociolinguistic differences with respect to rhythm. It is crucial to acknowledge that the generalizations presented here are only a first step because, due to the heterogeneity of the signers' backgrounds, we cannot rule out that the variation seen is due to individual variation or to other factors, such as region, language attitudes, or socioeconomic status.[7]

4.1 Implication of rhythm ratio within and across languages

We suggest that rhythm ratio is a novel, and potentially insightful, way to analyze rhythm in sign languages. This measure reveals patterns that differ from the individual measures of sign duration and transition duration alone, and it allows us to add Gender to Age as a sociolinguistic predictor of our data. Patel (2008) observed that vocalic intervals vary more markedly than the transitions between them in spoken language, and this creates the subjective impression that the transitions do not vary at all. This may be why transitions have been largely overlooked in sign language research as well. In future work we will explore the measure of rhythm ratio as a factor for explaining in cross-linguistic prosodic variation in sign languages, similar to the way in which nPVI has been used to divide spoken languages into syllable timed or stress-timed languages. The distinction in sign languages may take many forms, perhaps not a binary distinction as in spoken languages, but rather a typological grouping. For example, Tang, González & Sze (2010) found that signers of Japanese Sign Language (JSL) tend to use head nods rather to mark I-Phrases along with blinks, whereas signers of Hong Kong Sign language, DSGS and ASL tended to use pre-boundary lengthening along

7. The results for sign rate and sign duration concur with those of Wilbur (2009) for "normal" ASL production.

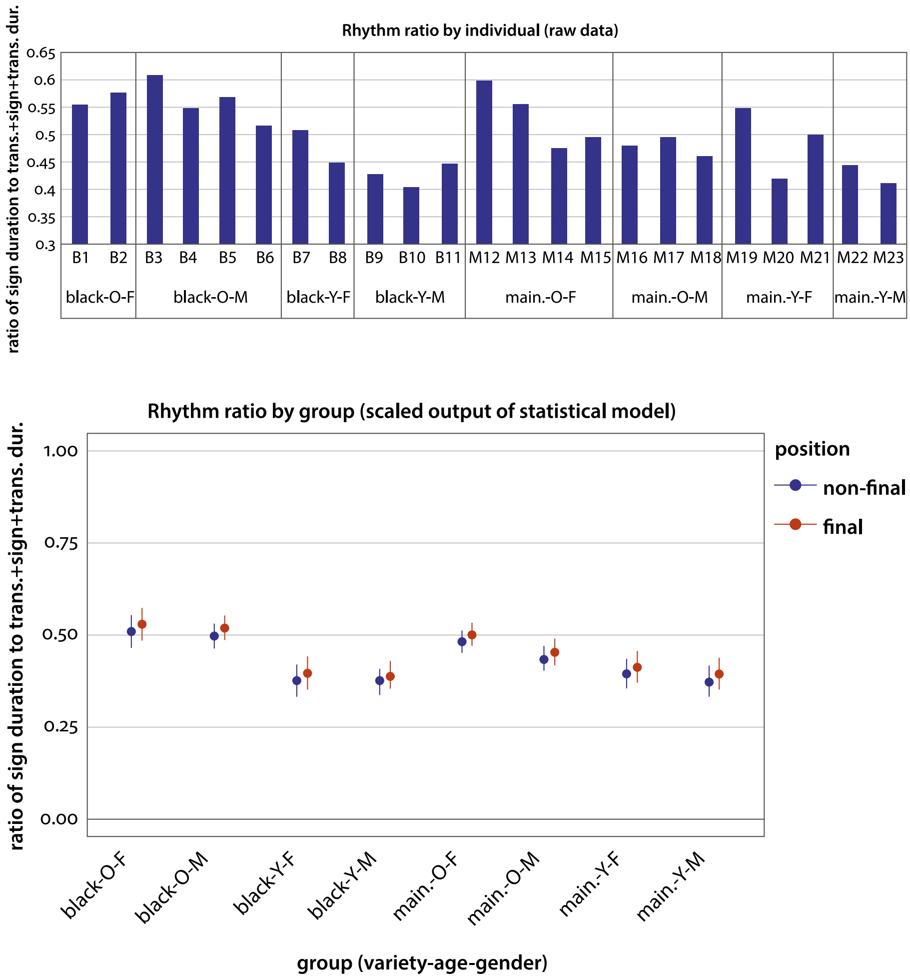


Figure 6. (top) Raw values for average rhythm ratio by individual. (bottom) Model predictions for the ratio of sign duration to previous transition+sign duration+following transition. The dots are the model predictions, and the lines are the 95% confidence intervals around those predictions. The ASL groups are indicated along the x-axis by Sign Variety (Black, Main.), Age ((O)lder, (Y)ounger), and Gender ((M)ale, (F)emale)

with blinks. Such differences in temporal properties across sign languages may extend to rhythm as well. Analyses of rhythm ratio can also help us understand which mechanisms of sign languages are true across sign languages, and which vary by language or typological group. Some prosodic cues differ cross-linguistically. For example, Dachkovsky et al. (2013) found differences in the use of squints between ASL and Israeli Sign Language, and Herrmann (2015) found prosodic differences in marking focus in German Sign Language, Irish Sign Language, and Sign Language of the Netherlands. But even if rhythm class does not vary across sign languages, but rather by sociolinguistic factors within language, such as Age and Gender as was found here, this finding would be useful as well. For example, it would be important to find out whether the tendency of younger signers and female signers to have higher rhythm ratios than older signers and male signers is robust across sign languages.

With regard to acquisition, Peperkamp & Mehler (1999) have argued that rhythm class is one of the first properties of language that neonates can discern, so it may be that once we have a way of measuring rhythm class, we can determine whether neonates of native-signing mothers may also be sensitive to the rhythm class of their sign language.

4.2 Sociolinguistic effects

Our results indicate that all three factors of Age, Sign Variety, and Gender are important in sociolinguistic variation: Age is the most predictive factor, then Gender, and then Sign Variety. Sign Variety interacts with other factors in all of the aspects studied, but is not predictive on its own, at least along the dimensions analyzed here, and we can therefore make only tentative observations in this regard. As noted in the Introduction there are two policy changes that have taken place in deaf education that are relevant to our data regarding Sign Variety. The first was desegregation, bringing black and white deaf children together in school, and the second was mainstreaming, bringing hearing and deaf children together in school. We offer a few possible interpretations of our prosodic data with respect to potential changes in Black ASL regarding these two policy changes. We suggest that the female Black ASL signers are leading prosodic changes with regard to both of these policy changes.

In both older and younger signers, there are greater differences between male and female signers in Black ASL than in Mainstream ASL, particularly in sign rate and sign duration. It has been argued that in some respects females are at the vanguard with respect to language change (Labov 1990, 2001). In spoken languages, "women conform more closely than men to sociolinguistic norms that are *overtly prescribed*, but they conform less than men when sociolinguistic norms are *not prescribed*" (Labov 2001: 293; italics ours). An example from spoken languages is the spread in Early Modern English of the *my*, *thy*, and the third-person singular *-s* forms (Nevalainen & Raumolin-Brunberg 2003). These authors argue that these forms were not prescribed in Early Modern English, started in the lower literate end of the social hierarchy, and that women were among the first to adopt these forms and spread these changes within their own class, whatever that class happened to be.[8] In ASL, the effect of the desegregation, as McCaskill et al. (2011) have argued, has been instrumental in seeing a decline in Black ASL use. In the data we have just presented, the difference between older male and female Black signers may be evidence that the older male Black ASL signers are retaining Black ASL prosodic patterns, while female Black ASL signers are losing these patterns more rapidly than males.

The effect of mainstreaming as an educational policy is that deaf children are exposed to more Signed English or contact sign varieties of ASL (Lucas & Valli, 1989) and may be moving towards varieties of ASL that include some of the features arising due to mainstreaming. There is a greater difference between young Black ASL females and males than in the corresponding groups of young Mainstream signers on sign rate, sign duration and transition duration. One explanation for this may be that the young Black ASL females in this study may be on the vanguard of a change in progress involving prosodic style in which mixed and Signed English varieties of ASL are becoming more prevalent and more widely accepted. Early work on pauses showed that Simultaneous Communication or SimCom (a mixed variety of signing and speaking at the same time) has a higher proportion of pause time than ASL (Klima & Bellugi 1979), and specifically, subject B8 has one of the lowest sign rates, the longest transition durations, as well as a low rhythm ratio. Language attitudes may also play a role. Hill (2012) found that some Black ASL signers were more likely to judge mixed samples of ASL and contact signing to be ASL than Mainstream ASL groups. The younger Black ASL females may show stronger evidence of these language attitudes than the males. Since the young female Black ASL group consisted of only two signers, this possible interpretation would need confirmation from a larger data set of young Black female signers. Moreover, more work is needed in order to understand the prosody of mixed varieties of ASL, and whether other lexical and morphosyntactic characteristics of mixed varieties of ASL co-occur with the prosodic characteristics we see here

It is also worth noting that much of the previous work on Black ASL has concluded that it is a more conservative variety than Mainstream ASL (McCaskill et al. 2011). These conclusions have been based on historical changes of phonological operations that have been observed in ASL at the lexical level (Battison 1974; Frishberg 1975). With respect to prosody there is no historical work thus far, so we cannot draw any conclusions that one variety is more conservative than any other. The availability of video data from some older varieties of ASL may provide a means of remedying this situation in the future; see Supalla & Clarke (2015).[9]

8. We thank an anonymous reviewer for pointing this out.

9. See also http://hsldb.georgetown.edu/index.php

5. Conclusion

In this work we have proposed the new measure "rhythm ratio" as a way of capturing rhythmic patterns in sign varieties of ASL. This new linguistic measure will allow us to understand sign language rhythm from a new perspective, and can be pursued in future work to understand its implications for sign language variation more generally – both within languages, and in cross-linguistic variation.

Our findings also suggest that the sociolinguistic factors of Age, Gender, and Sign Variety (in decreasing strength) may be salient with respect to rhythm. The results of this study concur with the conclusions of Hairston & Smith (1983), Aramburo (1989), and McCaskill et al. (2011), insofar as rhythm features of Black ASL are secondary to factors of Age and Gender, and potentially other factors not explored here, such as region (North/South, or even Urban/Rural) and potentially socioeconomic status. This work attests to the fact that signers express themselves as members of a number of different communities via their prosodic patterns, and more work is needed to investigate how these factors interact.

Acknowledgements

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References

Abercrombie, David. 1965. *Studies in phonetics and linguistics*. London: Oxford University Press.

Aramburo, Anthony. 1989. Sociolinguistic aspects of the Black Deaf community. In Ceil Lucas (ed.), *The sociolinguistics of the Deaf community*, 103–119. San Diego: Academic Press.

Babel, Molly. 2009. *Phonetic and social selectivity in speech accommodation*. Berkeley, CA: University of California PhD dissertation.

Barr, Dale, Roger Levy, Christoph Scheepers & Harry Tily. 2013. Random effects structure for confirmatory hypothesis testing: Keep it maximal. *Journal of Memory and Language* 68. 255–278. https://doi.org/10.1016/j.jml.2012.11.001

Battison, Robbin. 1978. *Lexical borrowing in American Sign Language*. Silver Spring: MD: Linstok Press. [reprinted 2002, Sign Media, Burtonsville, MD]

Bayley, Robert, Ceil Lucas & Mary Rose. 2000. Variation in American Sign Language: The case of DEAF. *Journal of Sociolinguistics* 4(1). 81–107. https://doi.org/10.1111/1467-9481.00104

Bertinetto, Pier Marco. 1989. Reflections on the dichotomy of "stress" vs. "syllable-timing". *Revue de Phonétique Appliquée* 91–93. 99–130.

Bonat, Wagner, Paulo Ribeiro Jr. & Walmes Zeviani. 2015. Likelihood analysis for a class of beta mixed models. *Journal of Applied Statistics* 42(2). 252–266. https://doi.org/10.1080/02664763.2014.947248

Boyes Braem, Penny. 1999. Rhythmic temporal patterns in the signing of early and late learners of German Swiss Sign Language. *Language and Speech* 42(2/3). 177–208. https://doi.org/10.1177/00238309990420020301

Brentari, Diane. 1998. *A prosodic model of sign language phonology*. Cambridge, MA: MIT Press.

Brentari, Diane & Howard Poizner. 1994. A phonological analysis of a deaf Parkinsonian signer. *Language and Cognitive Processes* 9(1). 69–100. https://doi.org/10.1080/01690969408402110

Brentari, Diane, Carolina González, Amanda Seidl & Ronnie Wilbur. 2011. Sensitivity to visual prosodic cues in signers and nonsigners. *Language and Speech* 54(1). 49–72. https://doi.org/10.1177/0023830910388011

Brentari, Diane, Marie Nadolske & George Wolford. 2012. Can experience with gesture influence the prosody of a sign language?: ASL prosodic cues in bimodal bilinguals. *Bilingualism: Language and Cognition* 15(2). 402–412. https://doi.org/10.1017/S1366728911000587

Brentari, Diane, Joshua Falk & George Wolford. 2015. The acquisition of American Sign Language prosody. *Language*, 91(3). e144–e168. https://doi.org/10.1353/lan.2015.0042

Browman, Catherine & Louis Goldstein. 1990. Tiers in articulatory phonology, with some implications for casual speech. In John Kingston (ed.), *Papers in laboratory phonology, vol. 1: Between the grammar and physics of speech*, 341–376. Cambridge University Press. https://doi.org/10.1017/CBO9780511627736.019

Carpenter, Jennifer. 2009. *Voices of Jim Crow: Early urban African American English in the segregated south*. Durham, NC: Duke University PhD dissertation.

Cole, Jessica. 2009. *American Sign Language poetry: Literature in motion*. San Diego, CA: University of California MA thesis.

Crasborn, Onno & Han Sloetjes. 2008. Enhanced ELAN functionality for sign language corpora. In *Proceedings of LREC 2008, Sixth International Conference on Language Resources and Evaluation*, 39–43.

Dachkovsky, Svetlana, Christina Healy & Wendy Sandler. 2013. Visual intonation in two sign languages. *Phonology* 30. 211–252. https://doi.org/10.1017/S0952675713000122

Duarte, Kyle & Sylvie Gibet. 2010. Reading between the signs: How are transitions built in signed languages. Presentation at the 10th International Conference on Theoretical Issues in Sign Language Research, West Lafayette, Indiana, USA, Sept. 30-Oct. 2.

Fenlon, Jordan, Adam Schembri, Ramas Rentelis & Kearsy Cormier. 2013. Variation in handshape and orientation in British Sign Language: The case of the '1' handshape configuration. *Language & Communication* 33. 69–91. https://doi.org/10.1016/j.langcom.2012.09.001

Frishberg, Nancy. 1975. Arbitrariness and iconicity. *Language* 51. 696–719. https://doi.org/10.2307/412894

Gelman, Andrew, & Jennifer Hill. 2007. *Data analysis using regression and multilevel/hierarchical models*. New York: Cambridge University Press.

Gibet, Sylvie, Nicolas Courty, Kyle Duarte & Thibaut Le Naour. 2011. The Signcom system for data-driven animation of interactive virtual signers: Methodology and evaluation. In *ACM transactions on interactive intelligent systems (TiiS)*. https://doi.org/10.1145/2030365.2030371

Grabe, Esther & Ee Ling Low. 2002. Durational variability in speech and the rhythm class hypothesis. In Carlos Gussenhoven & Natasha Warner (eds.), *Papers in laboratory phonology 7*, 515–546. Berlin: Mouton. https://doi.org/10.1515/9783110197105.515

Hairston, Ernest & Linwood Smith. 1983. Black Deaf students. In Lois Bragg (ed.), *Deaf World: historical reader and primary sourcebook*. New York: NYU Press.

Hall, Nancy. 2011. Vowel epenthesis. In Marc van Oostendorp, Colin Ewen, Elizabeth Hume & Karen Rice (eds.), *The Blackwell companion to phonology*, 1576–1596. Oxford: Blackwell.

Halle, Morris & Jean-Roger Vergnaud. 1987. *An essay on stress*. Cambridge, MA: MIT Press.

Harrell, Frank E. 2001. *Regression modeling strategies: With applications to linear models, logistic regression, and survival analysis*. New York: Springer. https://doi.org/10.1007/978-1-4757-3462-1

Herrmann, Annika. 2015. The marking of information structure in German Sign Language. *Lingua* 165. 277–297. https://doi.org/10.1016/j.lingua.2015.06.001

Hill, Joseph. 2012. *Language attitudes in the American Deaf community*. Washington, DC: Gallaudet University Press.

~~Keane, Jonathan. 2014. *Towards an articulatory model of handshape: What fingerspelling tells us about the phonetics and phonology of handshape in American Sign Language*. Chicago, IL: University of Chicago PhD dissertation.~~

Kieschnick, Robert & Bruce McCullough. 2003. Regression analysis of variates observed on (1,0): percentages, proportions and fractions. *Statistical Modeling* 3(3). 193–213. https://doi.org/10.1191/1471082X03st053oa

Klima, Edward & Ursula Bellugi. 1979. *The signs of language*. Cambridge, MA: Harvard University Press.

Labov, William. 1990. The intersection of sex and social class in the course of linguistic change, *Language Variation and Change* 19. 205–254. https://doi.org/10.1017/S0954394500000338

Labov, William. 2001 *Principles of linguistic change, volume 2: Social factors*. Oxford, UK & Cambridge, MA: Blackwell.

Lanehart, Sonja. 2015. *The Oxford handbook of African American language* Oxford, UK: Oxford University Press.

Liberman, Mark. 1975. *The intonation system of English*. Cambridge, MA: MIT PhD dissertation.

Low, Ee Ling, Esther Grabe & Francis Nolan. 2001. Quantitative characterisations of speech rhythm: Syllable-timing in Singapore English. *Language and Speech* 43 (4). 377–401.

Lucas, Ceil. 2013. Conducting sociolinguistic interviews in Deaf communities. In Christine Mallison, Becky Childs & Gerard Van Herk (eds.), *Data collection in sociolinguistics: Methods and applications*, 105–109. Oxon, UK: Routledge.

Lucas, Ceil & Clayton Valli. 1989. Language contact in the American Deaf Community. In Ceil Lucas (ed.), *The sociolinguistics of the Deaf Community*, 11–40. San Diego: Academic Press.

Lucas, Ceil & Clayton Valli. 1992. *Linguistics of American Sign Language: A resource text for ASL users*. Washington, DC: Gallaudet University Press.

Lucas, Ceil, Robert Bayley & Clayton Valli. 2001. *Sociolinguistic variation in American Sign Language*. Washington, DC: Gallaudet University Press. https://doi.org/10.1017/CBO9780511612824

Lucas, Ceil, Robert Bayley, Mary Rose & Alyssa Wulf. 2002. Location variation in American Sign Language. *Sign Language Studies* 2(4). 407–440. https://doi.org/10.1353/sls.2002.0020

Lucas, Ceil, Robert Bayley & Clayton Valli. 2003. *What's your sign for PIZZA? An introduction to variation in American Sign Language*. Washington, DC: Gallaudet University Press.

Lucas, Ceil & Robert Bayley. 2010. Variation in American Sign Language. In Diane Brentari (ed.), *Sign languages: A Cambridge language survey*, 451–475. Cambridge, UK: Cambridge University Press.. https://doi.org/10.1017/CBO9780511712203.021

McCaskill, Carolyn, Ceil Lucas, Robert Bayley & Joseph Hill. 2011. *The hidden treasure of Black ASL: Its history and structure*. (book and DVD). Washington, DC: Gallaudet University Press.

Mehler, Jacques, Emmanuel Dupoux, Thierry Nazzi & Ghislaine Dehaene-Lambertz. 1996. Coping with linguistic diversity: The infant's viewpoint. In James L. Morgan & Katherine Demuth (eds.), *Signal to syntax: Bootstrapping from speech to grammar in early acquisition*, 101–116. Mahwah, NJ: Lawrence Erlbaum.

Miller, Christopher. 1996. *Phonologie de la langue des signes québecoise: Structure simultanée et axe temporel*. Montreal: Université de Québec a Montréal PhD dissertation.

Nespor, Marina & Wendy Sandler. 1999. Prosody in Israeli Sign Language. *Language and Speech* 42. 143–176. https://doi.org/10.1177/00238309990420020201

Nespor, Marina & Irene Vogel. 1986. *Prosodic phonology*. Dordrecht: Kluwer.

Nevalainen, Terttu & Helena Raumolin-Brunberg. 2003. *Historical sociolinguistics: Language change in Tudor and Stuart England*. London: Pearson Education Ltd.

Nunes, Terzinha, Ursula Pretzlik & Jenny Olsson. 2001. Deaf children's social relationships in mainstream schools. *Journal of Deaf Education International* 3. 123–136.

Patel, Anirruddh. 2008. *Music, language, and the brain*. Oxford: Oxford University Press.

Pardo, Jennifer S. 2006. On phonetic convergence during conversational interaction. *Journal of the Acoustical Society of America* 119. 2382–2393. https://doi.org/10.1121/1.2178720

Peperkamp, Sharon & Jacques Mehler. 1999. Signed and spoken language: A unique underlying system? *Language and Speech* 42 (2/3). 333–346. https://doi.org/10.1177/00238309990420020901

Pfau, Roland & Josep Quer. 2010. Nonmanuals: Their grammatical and prosodic roles. In Diane Brentari (ed.), *Sign languages: A Cambridge language survey*, 381–402. Cambridge, UK: Cambridge University Press. https://doi.org/10.1017/CBO9780511712203.018

Ramus, Franck. 2002. Acoustic correlates of linguistic rhythm: Perspectives. In Bernard Bell & Isabelle Marlien (eds.), *Proceedings of speech prosody*, 115–120. Aix-en-Provence, France: Laboratoire Parole et Langage.

Ramus, Franck, Marina Nespor & Jacques Mehler. 1999. Correlates of linguistic rhythm in the speech signal. *Cognition* 73. 265–292. https://doi.org/10.1016/S0010-0277(99)00058-X

Sandler, Wendy. 2011. Prosody and syntax in sign languages. *Transactions of the Philological Society* 108. 298–328. https://doi.org/10.1111/j.1467-968X.2010.01242.x

Sandler, Wendy. 2012. Visual prosody. In Roland Pfau, Markus Steinbach & Bencie Woll (eds.), *Sign language. An international handbook*, 55–73. Berlin: De Gruyter Mouton. https://doi.org/10.1515/9783110261325.55

Sandler, Wendy & Diane Lillo-Martin. 2006. *Sign language and linguistic universals*. Cambridge/New York: Cambridge University Press. https://doi.org/10.1017/CBO9781139163910

Schembri, Adam, David McKee, Rachel McKee, Sarah Pivac, Trevor Johnston & Della Goswell. 2009. Phonological variation and change in Australian and New Zealand Sign Languages: The location variable. *Language Variation and Change* 21. 193–231. https://doi.org/10.1017/S0954394509990081

Schembri, Adam, Kearsy Cormier, Trevor Johnston, David McKee, Rachel McKee & Bencie Woll. 2010. Sociolinguistic variation in British, Australian, New Zealand Sign Languages. In Diane Brentari (ed.), *Sign languages: A Cambridge language survey*, 476–496. Cambridge, UK: Cambridge University Press. https://doi.org/10.1017/CBO9780511712203.022

Smithson, Michael & Jay Verkuilen. 2006. A better lemon squeezer? Maximum-likelihood regression with beta-distributed dependent variables. *Psychological Methods* 11(1). 54–71. https://doi.org/10.1037/1082-989X.11.1.54

Sonderegger, Morgan. 2012. *Phonetic and phonological dynamics on reality television*. Chicago, IL: University of Chicago PhD dissertation.

Supalla, Ted & Patricia Clarke. 2015. *Sign language archaeology*. Washington, DC: Gallaudet University Press.

Sutton Spence, Rachel. 2005. *Analysing sign language poetry*. London: Palgrave Macmillan.

Tang, Gladys, Diane Brentari, Carolina González & Felix Sze. 2010. Crosslinguistic variation in the use of prosodic cues: the case of blinks. In Diane Brentari (ed.), *Sign languages: A Cambridge language survey*, 519–542. Cambridge, UK: Cambridge University Press. https://doi.org/10.1017/CBO9780511712203.024

Tyrone, Martha, Hosung Nam, Elliot Saltzman, Gaurav Mathur & Louis Goldstein. 2010. Prosody and movement in American Sign Language: A task-dynamics approach. *Proceedings from Speech Prosody 2010*, Chicago, IL.

Valli, Clayton. 1993. *Poetics of American Sign Language poetry*. The Union Institute Graduate School PhD dissertation.

Wilbur, Ronnie. 1999. Stress in ASL: Empirical evidence and linguistic issues. *Language and Speech* 42(2/3). 229–250. https://doi.org/10.1177/00238309990420020501

Wilbur, Ronnie. 2009. Effects of varying rate of signing on ASL manual signs and nonmanual marker. *Language and Speech* 52. 245–285. https://doi.org/10.1177/0023830909103174

Wilbur, Ronnie, Edward Klima & Ursula Bellugi. 1983. Roots: On the search for the origins of signs in ASL. *Proceedings from the Chicago Linguistics Society*, 314–336. Chicago, IL: Chicago Linguistics Society.

Woodward, James. 1976. Black Southern signing. *Language in Society* 5. 211–218. https://doi.org/10.1017/S004740450000703X

Woodward, James, Carol Erting & Susan Oliver. 1976. Facing and hand(l)ing variation in American Sign Language. *Sign Language Studies* 10. 43–52. https://doi.org/10.1353/sls.1976.0012

Woodward, James & Susan DeSantis. 1977. Two to one it happens: Dynamic phonology in two sign languages. *Sign Language Studies* 17. 329–346. https://doi.org/10.1353/sls.1977.0013

Appendix

Table A1. Subject information and data frequency

Subject: Black ASL, Mainstream ASL	Age: (O)lder (Y)ounger	AoA	Gender	Education: (S)egregated, (M)ixed	Education: (R)esidential, (M)ainstreamed	state of residence	data points: sign rate/duration non-final	final	data points: transitions
B-ASL 1	O	birth	F	S	R	AL	98	21	118
B-ASL 2	O	4	F	S	R	AR	56	22	85
B-ASL 3	O	school entry	M	S	R	AL	46	21	80
B-ASL 4	O	7	M	S	R	AR	67	21	95
B-ASL 5	O	school entry	M	S	R	LA	59	25	95
B-ASL 6	O	school entry	M	S	R	NC	56	19	86
B-ASL 7	Y	3	F	S	R	AL	39	18	41
B-ASL 8	Y	7	F	S	R/M	NC	147	49	192
B-ASL 9	Y	birth	M	S	R	AL	82	17	103
B-ASL 10	Y	school entry	M	S	R	NC	69	20	107
B-ASL 11	Y	school entry	M	S	R	NC	88	17	117
M-ASL 12	O	birth	F	Mixed	R	MD	167	40	192
M-ASL 13	O	school entry	F	Mixed	R	MD	80	21	111
M-ASL 14	O	school entry	F	Mixed	R	MD	110	21	131
M-ASL 15	O	school entry	F	Mixed	R	MD	112	17	119
M-ASL 16	O	school entry	M	Mixed	R	MD	103	35	140
M-ASL 17	O	native	M	Mixed	R	MD	101	14	123
M-ASL 18	O	school entry	M	Mixed	R	MD	225	42	216
M-ASL 19	Y	school entry	F	Mixed	R/M	VT/DC	39	10	55
M- ASL 20	Y	school entry	F	Mixed	R/M	KY/DC	81	24	112
M-ASL 21	Y	school entry	F	Mixed	R/M	DC/DC	77	13	99
M-ASL 22	Y	birth	M	Mixed	R	AR/DC	59	26	108
M-ASL 23	Y	birth	M	Mixed	R	MD/DC	117	29	86
							2078	533	
TOTAL 23							**2611**		**2611**

Table A2. Abbreviations for the predictors and their values

variable (abbreviation)	level (abbreviation)
age (a)	older (O); younger (Y);
sign variety (v)	Black ASL (B); Mainstream ASL (Ms)
gender (g)	male (M); female (F)
phrasal position (pos)	final (FI); medial (ME)
previous duration	prevDur
following duration	follDur

Table A3. Sign Rate Statistical Model

	coefficient (standard error)
(Intercept)	98.22 (7.61)***
aY	7.98 (11.63)
vB	−7.68 (13.19)
gM	7.11 (11.63)
aY:vB	−33.08 (19.16)
aY:gM	−15.91 (18.13)
vB:gM	−26.58 (17.59)
aY:vB:gM	73.83 (26.38)*
R2	0.59
Adj. R2	0.39
Num. obs.	23
RMSE	15.23

* $p < 0.5$ ** $p < 0.01$ ** $p < .001$

Table A4. Sign duration

	Model 1	Model 2	Model 3	Model 4
(Intercept)	0.00 (0.11)	0.00 (0.11)	0.00 (0.11)	−0.03 (0.09)
aY	−0.47 (0.18)*	−0.49 (0.17)*	−0.49 (0.17)*	−0.41 (0.10)***
vB	0.12 (0.19)	0.11 (0.19)	0.11 (0.19)	0.34 (0.10)**
gM	−0.23 (0.16)	−0.22 (0.16)	−0.22 (0.16)	−0.14 (0.10)
posFI	0.62 (0.12)***	0.65 (0.05)***	0.66 (0.05)***	0.66 (0.05)**
aY:vB	0.42 (0.29)	0.52 (0.28)	0.52 (0.28)	
aY:gM	0.28 (0.27)	0.24 (0.26)	0.24 (0.26)	
vB:gM	0.39 (0.26)	0.41 (0.25)	0.41 (0.25)	
aY:posFI	−0.11 (0.22)			
vB:posFI	−0.02 (0.22)			
gM:posFI	0.08 (0.17)			
aY:vB:gM	−0.91 (0.39)*	−0.99 (0.38)*	−0.99 (0.38)*	
aY:vB:posFI	0.47 (0.34)			
aY:gM:posFI	−0.17 (0.31)			
vB:gM:posFI	0.08 (0.29)			
aY:vB:gM:posFI	−0.36 (0.45)			
AIC	5428.31	5409.86	5405.89	5401.04
BIC	5540.38	5482.7	5467.53	5440.26
Log Likelihood	−2694.16	−2691.93	−2691.95	−2693.52
Num. obs.	2005	2005	2005	2005
Num. groups: subject	23	23	23	23
Variance: subject.posFI	0	0		.05
Variance: Residual	0.84			.84

* $p < 0.5$ ** $p < 0.01$; *** $p < .001$

Table A5. Transition duration

	Model 1	**Model 2**	**Model 3**
(Intercept)	−0.33 (0.06)***	−0.33 (0.06)***	−0.33 (0.06)***
aY	0.16 (0.09) *	0.14 (0.10)	0.13 (0.10)
vB	−0.03 (0.11)	−0.11 (0.11)	−0.11 (0.11)
gM	0.16 (0.08) *	0.15 (0.09)	0.16 (0.09) *
prevDur	0.05 (0.02)*	0.06 (0.02)**	0.06 (0.02)**
follDur	0.10 (0.02)***	0.11 (0.02)***	0.11 (0.02)***
posFI	0.75 (0.06)***	0.75 (0.06)***	0.76 (0.04)***
aY:vB	0.42 (0.15)**	0.53 (0.16)***	0.54 (0.16)***
aY:gM	−0.06 (0.13)	−0.02 (0.15)	−0.02 (0.15)
vB:gM	−0.08 (0.14)	−0.05 (0.14)	−0.05 (0.15)
prevDur:follDur	−0.03 (0.03)		
aY:vB:gM	−0.23 (0.20)	−0.31 (0.22)	−0.31 (0.22)
AIC	6954.58	6955.14	6960.22
BIC	7118.97	7043.21	7036.55
Log Likelihood	−3449.29	−3462.57	−3467.11
Num. obs.	2621	2621	2621
Num. groups: subject	23	23	23
Variance: subject.(Intercept)	0.01	0.01	0.01
Variance: subject.posFI	0.04	0.05	
Variance: subject.prevDur	0		
Variance: subject.follDur	0		
Variance: subject.prevDur:follDur	0.01		
Variance: Residual	0.8	0.81	0.82

* $p<.1$ * $p<0.5$ ** $p<0.01$ *** $p<.001$

Table A6. Rhythm ratio

	Model 1	**Model 2**	**Model 3**	**Model 4**	**Beta Model**
(Intercept)	0.48 (0.02)***	0.48 (0.02)***	0.48 (0.02)***	0.48 (0.01)***	−0.04 (0.04)
aY	−0.09 (0.03)**	−0.09 (0.02)***	−0.09 (0.03)**	−0.10 (0.02)***	0.40 (0.07)***
vB	0.04 (0.03)	0.01 (0.03)	0.02 (0.03)	0.02 (0.02)	0.06 (0.07)
gM	−0.05 (0.03)	−0.05 (0.02)*	−0.05 (0.02)*	−0.02 (0.02)	−0.25 (0.05)***
posFI	0.01 (0.02)	0.02 (0.01)	0.02 (0.01)	0.02 (0.01)	0.08 (0.04)
aY:vB	−0.07 (0.05)	−0.01 (0.04)	−0.04 (0.04)		−0.09 (0.11)
aY:gM	0.03 (0.04)	0.02 (0.04)	0.03 (0.04)		0.21 (0.10)*
vB:gM	0.02 (0.04)	0.06 (0.03)	0.04 (0.04)		0.23 (0.09)*
aY:posFI	0.02 (0.04)				
vB:posFI	−0.06 (0.05)				
gM:posFI	0.02 (0.04)				
aY:vB:gM	0.00 (0.07)	−0.06 (0.05)	−0.03 (0.06)		−0.21 (0.14)
aY:vB:posFI	0.13 (0.07)				
aY:gM:posFI	−0.03 (0.06)				
vB:gM:posFI	0.09 (0.06)				
aY:vB:gM:posFI	−0.14 (0.09)				
Precision: (phi)					6.12 (0.18)***
AIC	−1045.19	−1051.9	−1049.83	−1052.64	
BIC	−932.82	−978.86	−988.03	−1013.31	
Log Likelihood	542.59	538.95	535.92	533.32	598.99
Num. obs.	2035	2035	2035	2035	2035
Num. groups: subject	23	23	23	23	
Variance: subject.(Intercept)	0	0	0	0	
Variance: subject.posFI	0	0			
Variance: Residual	0.03	0.03	0.03	0.03	
Pseudo R2					0.07

* $p < .1$ * $p < 0.5$ ** $p < 0.01$ *** $p < .001$

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