A quantitative analysis of sign lengthening in American Sign Language

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In spoken languages, disfluent speech, narrative effects, discourse information, and phrase position may influence the lengthening of segments beyond their typical duration. In sign languages, however, the primary use of the visual-gestural modality results in articulatory differences not expressed in spoken languages. This paper looks at sign lengthening in American Sign Language (ASL). Comparing two retellings of the Pear Story narrative from five signers, three primary lengthening mechanisms were identified: *elongation*, *repetition*, and *deceleration*. These mechanisms allow signers to incorporate lengthening into signs which may benefit from decelerated language production due to high information load or complex articulatory processes. Using a mixed effects model, significant differences in duration were found between (i) non-conventionalized forms vs. lexical signs, (ii) signs produced during role shift vs. non-role shift, (iii) signs in phrase-final/initial vs. phrase-medial position, (iv) new vs. given information, and (v) (non-disordered) disfluent signing vs. non-disfluent signing. These results provide insights into duration effects caused by information load and articulatory processes in ASL.

Keywords: American Sign Language, sign language, discourse, sign language phonology, lengthening, disfluency, information status

1. Introduction

This paper provides a quantitative analysis of lengthening in American Sign Language (ASL) narratives. It has been found that in spoken languages, rhetorical devices, discourse information, phrasal position, and (non-disordered) disfluent speech may influence the lengthening of sound segments beyond their typical duration. Unlike spoken languages, however, which make predominant use of the audio-vocal modality for the transmission of linguistic information, sign languages are transmitted through the visual-gestural modality resulting in

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modality-specific articulations. Are the discourse- and articulatory-based lengthening effects identified for spoken languages modality-specific or do they reflect a cross-modal cognitive process? More specifically, do role shifting, information status (new vs. given), sign-type (lexicalized signs vs. non-conventionalized forms), phrasal position, and/or (non-disordered) disfluent signing have any direct effect on the duration of signs and non-conventionalized forms? If so, what are the overall duration differences? The following subsections (1.1–1.5) provide background information on each of the discourse and articulatory mechanisms under investigation in this study.

1.1 Rhetorical lengthening and role shifting

Rhetorical lengthening is described as a device used in both conversational and narrative discourse to stress a particular word by pronouncing it with a lengthened sound (Thompson & Derr Jacobs 2007; Eijk 1997). This device can also be reproduced in written texts by repeating the grapheme which corresponds to the lengthened sound, e.g. '*The baaaad child was sent to his room*'. As for lengthening as a spoken language narrative device, McDowell (1994) showed that when storytellers assume the role of protagonist in Kasmá (a language isolate spoken in Colombia), they make extensive use of vowel lengthening during emotionally charged utterances. Watkins (1984) and Olawsky (2006) also identify vowel lengthening as a narrative effect in Kiowa (a Tanoan language spoken in United States) and Urarina (a language isolate spoken in Peru), respectively.

Like the Kasmá storytellers, spoken language users can also employ characterization techniques such as 'free indirect discourse', character voice, and/or character perspective when taking on the role of an actant (Oltean 1993). Here, spoken language users have a variety of techniques at their disposal, such as labels, pronominal shifts, and/or voice quality, to convey character perspective. In addition, if the audience is within visual range, speakers may also employ changes in body language and facial expressions to reinforce the actant.

Similarly, there is a well-documented rhetorical device attributed specifically to sign languages, known as 'role shift', 'transfer of person', 'referential shift', or 'real-space blends', which signers employ when taking on the role of an actant (Dudis 2004; Engberg-Pedersen 1995; Kegl 1986; Lentz 1986; Liddell 1990; Lillo-Martin 1995; Lillo-Martin & Klima 1990; Loew 1984; Meier 1990; Padden 1986; Poulin & Miller 1995). Role shift may be observed as a single or a combination of the following behaviours: shifts in body position and/or eye gaze (Engberg-Pedersen 1993), changes in facial expression (Loew 1984), transferals of pronominal usage, attitude, emotions (Engberg-Pedersen 1993), perspective (Janzen 2004), and the signing space (Dudis 2004) to that of the actant.

In the dataset used for this study, role shift was predominantly used as a descriptor element to describe the demeanour of an actant. For instance, in one example, a signer expresses 'nonchalantly' in the sign PICK-PEARS via non-manual behaviours, that is, the signer's relaxed and laid-back body language, facial expressions, movements, etc.

If we analyze the actions involved in role shifting events as part of the information load transmitted from the signer to the addressee(s), it would be expected that at least the crucial elements of the event be produced if the signer is to successfully communicate her/his intended message. This additional information not only adds to the cognitive processing and production load of the signer but also requires additional gestural exertion to produce the sought after effect. At the same time, the receiver must also deal with an increase in cognitive processing as (s)he interprets the additional information. Because of these factors, I predict that in general, role shifting-information embedded in a discourse stream has a direct lengthening effect on the duration of the utterances during role shift.

1.2 Discourse information

It is well-known that information flow in discourse is 'packaged' according to how much knowledge an interlocutor presupposes to be mutually shared or known by his/her addressee(s) (Du Bois 1980; Levinson 1983; Prince 1981). These 'packages' consist of both 'new' and 'given' information. New information (frequently equated with 'focus') is often considered as the first instance an interlocutor explicitly introduces information into discourse. Given information (also referred to as 'old', 'shared', 'known', or 'presumptive') has varying definitions (cf. Prince 1981), but can be broadly summed up as explicit information previously mentioned in discourse or implicit information presupposed by the interlocutor to be shared with the addressee(s) (Du Bois 1987).

In spoken languages, the syllables in constituents bearing new information have been shown to be longer in duration compared to those bearing given information. Fowler & Housum (1987) revealed that words bearing new information were significantly longer in duration by, on average, 55 ms (11%) than their given information counterparts.

While no quantitative evidence appears in the sign language literature regarding specific duration differences between new and given signs and/or non-conventionalized forms, there is evidence to suggest a similar tendency to that of spoken languages. Crasborn & Van der Kooij's (2013: 545) analysis of prosodic cues co-occurring with focus constituents in Sign Language of the Netherlands (NGT) shows that several manual modifications are used in the expression of focus. One in particular, the 'enhancement of manual movement', includes "focused signs

articulated in a 'stressed' manner, having longer durations, larger movements and more repetitions". It has also been documented since the late 1970's that information primarily flows in topic-comment constructions in ASL (Friedman 1976; Gundel 1988; Ingram 1978). Janzen (1998) shows that new information may be introduced in the comment constituent before it becomes available as given information as a topical element. Janzen (2003, 2007) proposes a topicality hierarchy which suggests that the more topical an element becomes, that is, the more accessible the information is to the addressee(s), the less referential information is encoded within the sign. The topicality hierarchy, adapted from Janzen (2007), is presented in (1).

(1) Topicality hierarchy (adapted from Janzen 2007)
Full NP → Classifier construction → Pronoun → Spatial referencing
→ Reference shift (with body shift) → Reference shift (without body shift)
→ Zero referencing

Johnston & Schembri (2007) mention a similar trend in Australian Sign Language (Auslan), where given information is often reduced, abbreviated or even completely omitted from an utterance. Dachkovsky, Healy & Sandler (2013) show that signers of both Israeli Sign Language (ISL) and ASL make use of non-manual signals (squinting) to demarcate topics with low accessibility. These findings allude to the fact that signs produced as new information or that have low accessibility require more information to become available to the addressee(s); that is, signs with low topicality may be longer in duration due to their fuller and more information-rich forms.

Based on these findings concerning focused signs in NGT, the information load in topical elements (ASL and ISL), and 'given' information (Auslan), I predict that signs and non-conventionalized forms containing new information will have overall longer durations than those containing given information.

1.3 Phrase position

The lengthening of a final syllable rhyme at the intonational phrase (IP) boundary of a prosodic unit has been well-documented in a variety of spoken languages (for instance, Klatt (1976) and Wightman et al. (1992) for English; Rao (2010) for several Spanish dialects; Pierrehumbert & Beckman (1986) for Japanese; Jun (1993) for Korean; Nakai et al. (2009) for Finnish; to name a just few). Rao (2010) found that Spanish syllables in the phrase-final position were significantly longer by, on average, 35 ms (20%) than syllables in non-phrase final positions.

Unlike the predicted lengthening effects caused by role shifting and new information, phrase-final lengthening effects in sign languages have been described

by several researchers. Liddell's (1978) measurements of monosyllabic signs show both phrase-final and phrase-initial lengthening (the former being longer) and shorter durations in phrase-medial position. Liddell (1984) and Liddell & Johnson (1989) then provided a sequential representation of ASL signs with the Hold Movement Hold model, in which final Holds are usually deleted. This model was later criticized by Sandler (1986, 1989) and Perlmutter (1992), who argued that final Holds only show up at the end of a phrase and are therefore better treated as phrase-final lengthening. Wilbur (1999) provided measurements from ASL showing that phrase-final signs were significantly longer by, on average, 30 ms compared to non-phrase-final signs. For Hong Kong Sign Language (HKSL), Tang et al. (2010) also showed phrase-final lengthening to be one of several prosodic cues. For ISL, Nespor & Sandler (1999) demonstrated that IP boundaries are often demarcated by either a pause or articulatory lengthening of the final sign in a phrase, and accompanied by changes in facial expression. They also found that phrase-final signs in ISL were often enlarged and longer in duration than non-phrase final signs. These findings were later confirmed in a comparative study by Dachkovsky et al. (2013), who observed holds, consistent changes in facial expression, and shifts in head position between topic and comment IP boundaries. In the same study, however, it was also found that ASL signers showed no indication of timing breaks between topic and comment constituents or any correlations between the constituents regarding their rate of production or their length and complexity.

Based on the evidence from the majority of these studies, I thus predict that phrase-final lengthening will occur to a greater or lesser extent in ASL under the narrative conditions used in this study.

1.4 Lexicalized signs and non-conventionalized forms

Virtually all sign languages documented to date have a division between lexicalized signs and non-conventionalized forms. Lexicalized signs are those which typically conform to the native phonological and grammatical constraints of a given sign language (Brentari & Padden 2001; Johnston & Schembri 2007). Non-conventionalized forms, also referred to as 'depicting constructions/signs' (Liddell 2003) or 'classifier constructions/forms' (Emmorey 2003; Frishberg 1975; Kegl & Wilbur 1976; Supalla 1986), on the other hand are often described as highly iconic structures (Cuxac 1985, 2000, 2001), which may depict space, movement, size, shape, location, or appearance (Johnston & Schembri 2007). Unlike the limited number of configurations attributed to lexicalized signs, non-conventionalized forms may take on any number of configurations (Liddell 2003). Another characteristic which separates the two categories is that non-conventionalized forms are actively produced by signers from combinations of both linguistic and gestural

elements (Schembri 2001; Liddell 2003). Examples of non-conventionalized forms from the dataset used in this study include: EAT-PEAR, PUZZLED, and HAT-FLY-AWAY.

Strictly regarding duration, Aronoff et al. (2003) observed in a comparative study the 'evolution' of a non-conventionalized form of LIGAMENT into a new lexicalized sign in ISL. The production of the non-conventionalized form included descriptive information pertaining to the size, shape and elasticity of the ligament. Additional elements included a long hold, eye contact with the recipient, and a head nod. Soon after the concept of 'ligament' was introduced, it was reduced to a monosyllabic lexicalized sign. The duration of the non-conventionalized form of LIGAMENT was measured at 1440 ms while the lexicalized sign only lasted 280 ms. While discourse information (new vs. given) and the lexicalized sign's place on Janzen's topicality hierarchy (see Section 1.2) may play a role in the reduction in duration, I predict that the depictive nature of non-conventionalized forms and their active production is enough to yield an overall longer duration period compared to lexicalized signs — independent of their information status or level of topicality.

1.5 Non-disordered disfluent signing

Non-disordered disfluency (henceforth disfluency) can be broadly defined as the interruption of fluent discourse. Studies have shown that two main processes are at work during disfluent events. According to the first, described in Bortfeld et al. (2001), disfluencies may occur more frequently when our cognitive processing load (conceptual, syntactic, and articulatory processes) begins to increase, for instance, through longer and more complex utterances or conversation topics. Secondly, as described in Shriberg (1996), disfluencies are more common at the beginning of an utterance which, in turn, rules out a heavy processing load. Under this process, disfluencies are used to coordinate interactions with an addressee, e.g. turn-taking and holding the floor. Because the data from this study focuses on single-signer narrations with no direct interaction with an addressee, any disfluencies should be caused by an increase in cognitive planning rather than by coordinating events.

In spoken language, one type of disfluency, known as *prolongation,* causes speech segments to be lengthened beyond their expected duration given their specific linguistic context (McAllister & Kingston 2005). In the sign language literature, however, sign prolongation is usually only mentioned in passing as one of a handful of sign language disfluencies (cf. Whitebread 2004). The working definition of disfluent sign prolongation in this study is analogous to that of spoken language prolongations: signs or sign segments which are lengthened beyond their

expected duration. The research question from this section is as follows: What is the average statistical difference in the duration of a prolonged sign when it becomes noticeable as a disfluency to an observer?

In summary, the current study investigates the aforementioned discourse and articulatory properties in ASL narrations in an attempt to isolate any direct lengthening effect on signs and non-conventionalized forms. If significant effects are found, what are the overall duration differences caused by these properties? Statistically significant results indicating the presence of lengthened signs or non-conventionalized forms could support the predictions made in Sections 1.1–1.5 that a given discourse and/or articulatory property indeed has a direct effect on the duration of a sign or non-conventionalized form. Non-significant results may suggest that discourse and articulatory properties do not affect or only marginally influence the lengthening of signs and non-conventionalized forms. The quantitative analysis in this study makes use of the *Pear Story* (Chafe 1980) narrated by five signers of ASL in order to shed light on the aforementioned predictions and investigate possible sign lengthening mechanisms in ASL narrations.

2. Method

2.1 Subjects

Five deaf signers (four males and one female) participated in this study (mean age = 45.8; range 29–61). Three were native signers (born into deaf signing families) and two were primary signers, who acquired ASL at the ages of six and 13. All the participants reported using ASL as their primary means of communication. Participants also reported that they were not familiar with the *Pear Story* narrative. All participants were from the greater Winnipeg area (a city in central Canada) and signed the Winnipeg dialect of ASL.[1] All participants were monetarily compensated for their time.

2.2 Materials and design

At the beginning of the experiment, each participant individually watched the *Pear Story* (Chafe 1980) and was allowed to re-watch it if necessary (none chose to do so). Immediately after the video ended, each participant was asked to sign the entire story from memory in front of a video camera with no direct interaction

1. There are anecdotal reports of Winnipeg having a signed dialect unique to the region compared to others.

with an addressee. After a time lapse of about 40–50 minutes, the participants were asked once more to narrate the story from memory, without having the opportunity to re-watch the video, and again with no direct interaction with an addressee. Each session lasted about an hour. The purpose of the 40–50 minute time lapse was twofold. Firstly, this provided a comparative basis for isolating identical signs from each narration from the same signer. Sign pairs were then used to identify lengthening mechanisms used during the narrations (see Section 2.3.1). Secondly, it was hoped that the intermission would induce a greater number of disfluent prolonged signs, as compared to casual discourse, by forcing the participants to recall the story from long-term memory. This increase in the number of lengthened signs would allow for a larger comparative sample for identifying lengthening mechanisms.

After annotation (see Section 2.3.2), two native signers of ASL and one advanced L2 ASL signer were asked to individually identify signs which they felt were lengthened beyond their typical duration given the context of the narration. The two native signers were then asked to individually compare the observations, and only those signs and non-conventionalized forms they agreed upon were annotated as disfluent prolongations (84 in total).

2.3 Data

2.3.1 *Lengthening mechanisms*

The dataset used in this analysis consists of a total of 686 signs from all five signers including the 84 signs marked as disfluent prolongation tokens. Using both narrations from each signer, matching signs and non-conventionalized forms were paired up per signer from similar strings of discourse from the two videos, e.g. PUT-IN-BASKET from video one and video two from the same scene. The duration difference of each sign pair was then calculated and the longer sign was marked as 'lengthened' (video one=157; video two=182; equal duration=4; i.e. a total of 343 pairs). This data was then used to identify individual sign lengthening mechanisms by comparing each sign pair and focusing on what articulatory mechanisms were responsible for the extended duration of a sign from a pair. It should be noted that additional potentially lengthened tokens were observed throughout the videos but were not included in the dataset since they had no comparable counterpart from the other video. In addition, all instances of 'reduced' signs, that is, signs produced with reduced handshape articulations and movements within a sign, were not included in this dataset.

2.3.2 *Data segmentation and annotation*

ELAN version 4.1.2 (Sloetjes & Wittenberg 2008) was used to annotate each narration. Signs were consistently marked using the following criteria: (i) transitional

movements between signs were not counted as part of the sign's duration due to the spatial differences between signs, e.g. BOY BABY (forehead to abdominal region) as compared to BOY BALD (forehead to cranial region); (ii) initial and end boundaries were demarcated at the first hint of hand tension during sign formation and at the first hint of hand tension loss during sign deformation, respectively (Wilbur & Nolen 1986). Hand tension in this sense refers to the first frame in which a noticeable change in handshape occurs as the signer begins to form a new sign or non-conventionalized form. This is often observed when the hand muscles begin to flex during the sign formation. Hand tension loss refers to the first frame in which a noticeable handshape change occurs as the signer begins to end a sign or non-conventionalized form. This is often observed when the hand muscles become lax during sign deformation. A change in facial expression could also indicate a sign's end boundary, if hand tension was not apparent (Green 1984). Changes in direction were also limited to end boundaries in elliptical signs, if hand tension was not apparent (Wilbur 1985, 1990, 1993, 2011).

Since transition periods (TP) were not counted as part of the sign's duration, this method also proved effective for capturing undershoots. It was noted that undershoots appear to shorten the overall duration of transitions between signs but not necessarily the duration of the sign itself. Based on this observation, there was no need to remove undershot signs as long as no reduction was observed in the handshape or movement within the sign.

Each sign's phrasal position (initial, medial, final, or entire phrase), information status (new vs. given), and whether or not it took place during role shift was also registered. Each sign was also marked as belonging to one of two categories: (i) lexicalized signs, e.g. MAN, WRONG, and EMPTY (378 signs in total, including 36 disfluent prolongations), and (ii) non-conventionalized signs, e.g. EAT-PEAR and HAT-FLY-OFF-HEAD (308 signs in total, including 48 disfluent prolongations).

3. Results

3.1 Lengthening mechanisms

By comparing the lengthened sign with its non-lengthened counterpart, three major sign lengthening mechanisms were identified: *elongation, deceleration*, and *repetition*. Elongation takes place when the size of a sign or non-conventionalized form or a movement within a sign appears to be overstated or enlarged compared to its non-lengthened counterpart. In Figure 1, the sign PUT-BASKET-ON-BIKE takes up more space compared to the same sign in Figure 2, thus causing an overall longer duration.

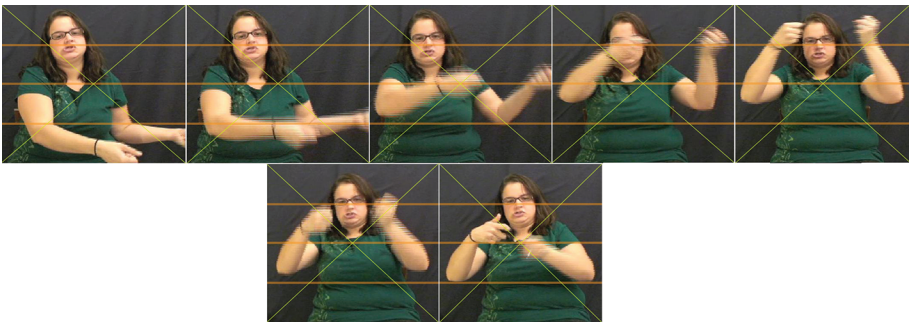

Figure 1. Lengthening through sign elongation: PUT-BASKET-ON-BIKE (792 ms); every fourth frame.

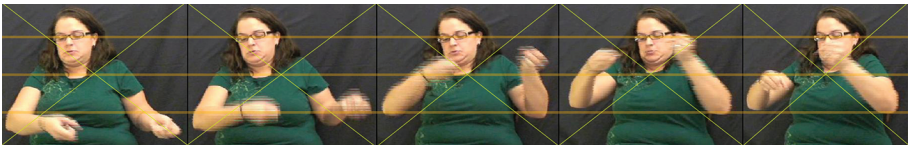

Figure 2. Non-lengthened version of PUT-BASKET-ON-BIKE (528 ms); every fourth frame.

Deceleration takes place when a sign or non-conventionalized form is articulated more slowly compared to its non-lengthened counterpart. Unlike the sign in Figure 1, the sign SPILL-PEARS in Figure 3 is not characterized by a larger movement, but rather it is produced more slowly compared to the same sign in Figure 4.

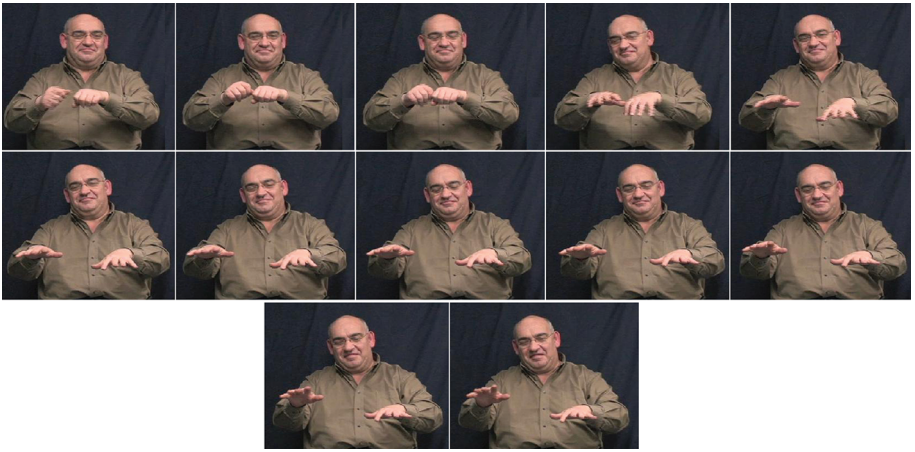

Figure 3. Lengthening through sign deceleration: SPILL-PEARS (1350 ms); every fourth frame.

Figure 4. Non-lengthened version of SPILL-PEARS (660 ms); every fourth frame.

Finally, repetition is attested when a sign or non-conventionalized form contains more full or partial repetitions of movement than its non-lengthened counterpart. Repetitions typically involve the reduplication of one or more syllables.[2] This phenomenon is illustrated in Figure 5, where the signer repeats the sign BOY three times causing an overall longer duration compared to the same sign in Figure 6, which is not repeated.

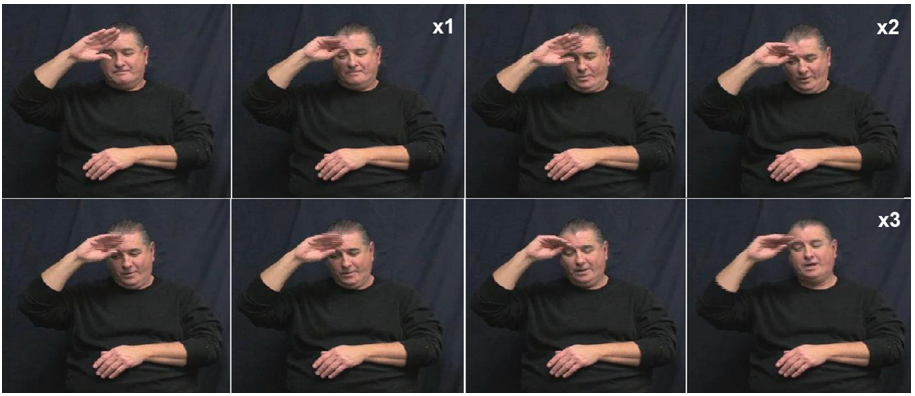

Figure 5. Lengthening through sign repetition: BOY (924 ms); every fourth frame.

Figure 6. Non-lengthened version of BOY (264 ms); every fourth frame.

Two further minor lengthening mechanisms, which make up 5% of all sign pairs, were also identified. The first includes the use of more letters in a fingerspelled word after a reduced spelling was previously established (e.g. P-E-A-R vs. P-E-A; this is referred to as "complete form" in Table 1), and the second involves initial and final holds, that is, the signer holds a sign for a longer duration than its

2. For an overview of sign language syllables, see Wilbur (2011).

non-lengthened counterpart at the beginning or end of a sign. Sixteen sign pairs (5% of the total dataset) contained a lengthened sign that was so close in duration to its non-lengthened counterpart (mean difference +/- 15 ms; listed as "N/A") that assigning them to a specific lengthening mechanism seemed not to make any sense. Four sign pairs (1% of the total dataset) were of equal duration. Table 1 provides an overview of the distribution of the various lengthening mechanisms.

Table 1. Lengthening mechanisms

Lengthening mechanism	Instances	Percentage
Elongation	123	36%
Deceleration	100	29%
Repetition	82	24%
N/A	16	5%
Complete form	6	2%
Final holds	8	2%
Equal duration	4	1%
Initial holds	4	1%
TOTAL	**343**	**100%**

3.2 Interactions with sign types and sign conditions

A mixed effects model was built containing *disfluency*, *sign type* (lexical signs vs. non-conventionalized forms), *information status*, *role shift*, and *phrasal position*[3] (phrase-initial and phrase-final) as fixed effects and *sign* and *signer* as random effects. When a result is significant, the coefficient estimate (β), a conservative estimate of the average duration difference of the values under analysis, provides the lengthening differences in milliseconds (ms). A significant result can stand alone or be added to one or more predictors if it contains more than one condition (for example, a sign produced for the first time in a narrative (new information) during a role shift in the phrase-final position).

3. This study divides phrasal position into two binary variables, (i) phrase-initial and (ii) phrase-final, to cross-cut the four categories of phrasal position where the 'phrase-initial' value identifies the additional duration of signs in phrase-initial position, while the 'phrase-final' value identifies the additional duration of signs in the phrase-final position, and both phrase-initial and phrase-final values added together identify the additional duration of signs making up an entire phrase. Finally, not taking into account both phrase-initial and phrase-final values identifies the average duration of signs in phrase-medial position, i.e., the value identified in the intercept. I would like to thank Kevin Russell for identifying the binary nature of these variables.

Table 2. Statistical results of the lengthening parameters taken into account in the mixed effects model.[4]

Model results			In milliseconds	
Fixed effect	**p-value (P_{MCMC})**	**t-value**	**CI_{95}**	**Co. Est. β**
Intercept[4]	0.0042	6.4	179 : 500	410
Disfluency	0.0001	14.6	751 : 971	776
Non-conventionalized	0.0001	4.4	161 : 322	219
New information	0.0062	2.6	54 : 317	175
Role shift	0.0004	2.5	64 : 224	105
Phrase initial	0.028	2.3	5 : 146	80
Phrase final	0.0004	2.4	47 : 194	85

The results from this model (Table 2) show that within this dataset, disfluent signs were, on average, 776 ms longer than non-disfluent signs. Non-conventionalized forms were significantly longer than lexicalized signs by, on average, 219 ms. Signs referring to new information were significantly longer than those referring to given information by, on average, 175 ms. Signs produced during role shift were significantly longer by, on average, 105 ms than their non-role shift counterparts. Signs found in phrase-initial position were lengthened by, on average, 80 ms while signs found in phrase-final position were lengthened by, on average, 85 ms. Finally, signs which made up an entire phrase were lengthened by, on average, 165 ms (phrase-initial + phrase-final). The baseline for adding these values and the average duration of all signs, when the aforementioned parameters are not part of the sign, is 410 ms, as shown in the intercept.

4. Discussion

Since sign lengthening is a continuous variable, it was imperative to have consistent sign segmentation criteria which allow for a precise definition of the beginning and end of a sign. The segmentation criteria used in this study provided both a simplistic and effective means for isolating the lengthened pairs within the dataset. By removing transitional periods (TP) between signs and focusing primarily on hand tension, this method also allowed for the inclusion of signs produced with undershoot — a common occurrence during the narratives. At the same time, this method also avoided the inclusion of common disfluencies such as fillers and pauses which are often manifested during TPs. By focusing solely on

4. The intercept can be defined as our 'starting point' or the estimated value of the duration if all the predictors were not present in a sign.

the signs themselves, the lengthening effects from each sign were then identifiable and analyzable.

During the ASL narratives, five types of lengthening mechanisms were observed: elongations, decelerations, repetitions, initial/final holds, and complete fingerspelled forms for previously established reduced fingerspellings. These lengthening mechanisms take advantage of the gestural modality of sign languages permitting signers to diversify narrative effects, parse discourse information, and identify phrasal positions. These gestural modality-specific lengthening mechanisms often appear to perform the same function as segment lengthening in the vocal modality. While these articulatory processes for sign lengthening have been identified, it is unclear how they interact and whether their interaction further lengthens a sign, for instance, when a sign is characterized by both deceleration and repetition. While a preliminary investigation suggests that no particular lengthening mechanism is responsible for lengthening a sign more than another, signs which involve more than one lengthening mechanism have yet to be tested. Future studies should also address the question whether there is a categorical tendency for specific types of signs to favour a specific lengthening mechanism. For instance, a preliminary investigation suggests an overwhelming tendency for signs with more than one syllable to undergo 'repetition' as a preferred lengthening mechanism. Regarding 'elongation' and 'deceleration', however, the answer to this question remains elusive.

This study has also provided statistical support for the discourse and articulatory lengthening processes predicted in Sections 1.1–1.5. The presence of lengthening in all the participants' narrations and the statistical results support the assumption that lengthening is used in ASL narratives as a mechanism for marking role shift events and the information status of a sign. It was also predicted in Section 1.4 that the iconic nature and information load encoded within non-conventionalized forms may play a role in lengthening their overall duration compared to lexicalized signs. The findings from this study support this prediction quantitatively as non-conventionalized forms lasted 53% longer, on average, than lexicalized signs (219 ms non-conventionalized forms / 410 ms intercept * 100). These results suggest that information load is indeed a factor in lengthening. Not only does the lengthening of signs with higher information content give the signer additional time to process and produce the articulations required for effectively communicating the message, it also gives the addressee additional time to interpret and process the extra information. From Janzen's (2003, 2007) work on topicality, it is evident, however, that the information status of a sign (new vs. given) is gradient instead of binary. Now that duration differences between new and given information have been established, future investigations may want to look at the duration of signs under each condition along Janzen's hierarchy (see (1))

to determine more precisely the effects of lengthening for each category. Other questions to be addressed in future research may ask: Can 'sign-type' be broken down into further categories, such as, for instance, body-anchored signs vs. signs produced in neutral space? How does the place of articulation of each sign-type affect its duration? Preliminary investigations suggest that there is little difference between these two categories, but these findings are by no means conclusive.

Statistical evidence from the mixed effects model also provides moderate evidence for the usage of lengthening as a cue for demarcating phrase boundaries. According to the model, the overall duration of phrase medial signs (average 410 ms based on the intercept) was shorter than those of signs in both phrase-initial and -final positions (490 ms and 495 ms, respectively), while signs which made up an entire phrase were longer than signs in all three positions (575 ms). While these results support the findings of Liddell (1978) and Tang et al. (2010) concerning phrase-final lengthening, there was practically no difference between the lengthened duration of phrase-initial and phrase-final signs (5 ms difference). This result runs counter to most sign and spoken language findings which indicate that phrase-final signs are longest (Klatt 1975; Liddell 1978; Perlmutter 1992; Turk & Shattuck-Hufnagel 2007; Sandler 1986, 1989; Wightman et al. 1992). This finding, however, may explain why Dachkovsky et al. (2013) did not observe any timing or lengthening discrepancies between topic and comment constituents in ASL. It could be argued that since both constituents make up independent phrases, and since phrase-initial and phrase-final signs are shown here to have nearly identical lengthening statistically, the effect on the topic-final sign would be no different from that on the following comment-initial sign. Further examination is required to draw safe conclusions regarding phrasal lengthening.

Another factor that can be held responsible for the statistically nearly identical durations of phrase-initial and -final lengthening is the 'entire-phrase' variable which has been overlooked in past studies. The use of information-rich non-conventionalized forms and the topic-comment structure of ASL make it possible for a single sign to occupy an entire phrase, as is shown in (2).

(2) topic ——— role shift
BASKET LIFT-BASKET-ONTO-BIKE
'The basket was lifted onto the bike.'

Instances likes these have been analyzed as 'entire-phrase' signs occupying both initial and final positions of a single phrase. Since entire-phrase signs also make up part of the single phrase-initial and -final categories, their longer duration may have marginally counterbalanced an otherwise greater lengthening effect between phrase-initial and -final positions. Alternatively, it is possible that similar importance is given to both initial and final positions regarding duration. At first glance,

the latter explanation seems counter-intuitive since the purpose of final lengthening is to indicate the end of an utterance. However, the topic-comment structure of ASL may also use lengthening as a cue for topics (mostly utterance-initial) which may be similar in duration when compared to final lengthening. Further work is needed to pinpoint the nature of this effect.

Lengthening is an articulatory phenomenon found in both spoken and sign languages that may reflect similar cognitive processes resulting in decelerated language production in both modalities. This being the case, we would also expect lengthening to be a common mechanism for dealing with moments of high cognitive load planning. The significant effect of 'disfluency' demonstrates that ASL signers indeed make use of sign lengthening during such moments. Based on the coefficient estimates from Table 2, signs were identified as disfluent when their duration was, on average, 1.9 times longer than a non-disfluent sign (776 ms disfluency / 410 ms intercept). Interestingly, the 95% confident intervals in Table 2 also show a zone of approximately 250 ms between the longest non-disfluent signs and the shortest disfluent signs (500 ms intercept & 751 ms disfluency). On a subconscious level, this zone may allow signers additional processing time before a disfluency becomes obvious to an addressee and the signer risks losing the floor. Further analysis is required in order to confirm or disconfirm that this extra duration indeed serves as an area of leeway designated for additional processing time.

In sum, the results of this study suggest that lengthening is a discourse-based cross-modal phenomenon, whereby comparable articulatory signals reflect similar cognitive processes in both modalities.

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