Some aspects of articulatory ease in American Sign Language*

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1 Overview

In this work, we present a variety of evidence that suggest the drive for ease of articulation in American Sign Language (ASL). Given that a similar drive exists in spoken language, we argue that articulatory ease plays a role in language in general, regardless of modality.

We set the stage in §2 with a brief synopsis of some instances of ease of articulation in spoken language, and then in §3, we provide the relevant background for understanding the types of joints and joint movements relevant to sign languages. In §4–5, we discuss evidence for ease of articulation in sign language, both by fluent signers and by disfluent signers. Despite important differences across the various types of evidence, we argue that each case is in fact motivated by the same underlying drive for ease of articulation.

2 Ease of articulation in spoken language

It has long been noted that many kinds of sound patterns in spoken language are significantly motivated by articulatory concerns (Passy 1891, Jespersen 1894, Martinet 1952, Kiparsky 1968, King 1969, etc.).

Diachronic example: Latin vowel length distinctions were completely lost in the development of the vowel system of modern Spanish and other Romance languages (Hall 1950, Agard 1984):

(1)

Latin		Spanish
i,ī u,ū		i u
e,ē o,ō	⟶	e o
a,ā		a

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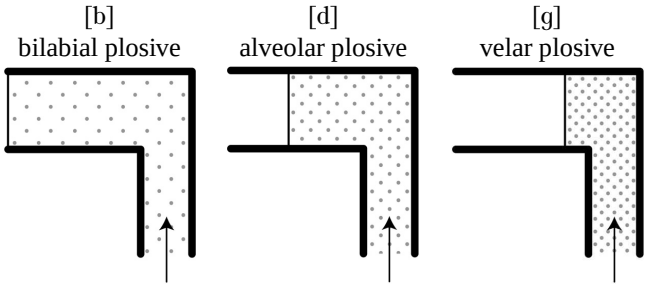
A vowel requires continuous pulmonic airflow across the vocal cords and through the oral cavity to create its signature vocalic resonance. A longer vowel is more difficult to produce than an otherwise identical shorter vowel, because of the requisite extra time (and thus, energy) spent expelling air out of the lungs. A common goal of articulatory ease is reducing articulatory effort.

Typological example: Generally, the further back in the mouth a voiced plosive is, the more difficult it is to make (Ohala 1983, Westbury and Keating 1986). Because of the continuous airflow to create vocal cord vibration, the air pressure builds faster in the smaller chambers behind the backer stop closures, and higher air pressure requires more effort to maintain a full stop closure (2):

(2)



This difference in articulatory difficulty is reflected in cross-linguistic phonological inventories: the UCLA Phonological Segment Inventory Database (Maddieson 1984, Maddieson and Precoda 1989) lists at least 48 languages with plosive inventories like (3a) (missing the more difficult [g]), but only 8 like (3b) and/or (3c) (Brao, Eyak, Kewa, Mazahua, Mixe, Pirahã, Rotokas, and Tigak).[1]

(3)

a.	p	t	k	b.	p	t	k	c.	p	t	k
	b	d	–		b	–	g		–	d	g

[1]UPSID seems to be incorrect about Rotokas, which has the full ungapped series of voiced plosives according to Robinson (2006).

Synchronic example: In the Cairene dialect of Arabic (Broselow 1976, Watson 2002), definite nouns are marked with the prefix *il-*, and the final consonant of this prefix becomes a copy of a following coronal consonant (4a), but remains unchanged before non-coronals (4b):

(4)

	bare noun	*definite*	*gloss*
a.	tˤamātˤim	i**tˤ**-tˤamātˤim	'tomatoes'
	dēl	i**d**-dēl	'tail'
	sitt	i**s**-sitt	'woman'
	ʃams	i**ʃ**-ʃams	'sun'
	rās	i**r**-rās	'head'
	nass	i**n**-nass	'text'
b.	bint	i**l**-bint	'girl'
	mudarris	i**l**-mudarris	'teacher'
	kursi	i**l**-kursi	'chair'
	ɣada	i**l**-ɣada	'lunch'
	ħāl	i**l**-ħāl	'state'
	hilāl	i**l**-hilāl	'crescent'

The lateral approximant [l] is a complex sound, so it is already inherently prone to articulatory simplification. The transition from the lateral to another coronal consonant involves precisely-timed demands of the front of the tongue. The total articulation is made simpler and easier through total regressive assimilation, completely removing the complex lateral articulation altogether.

Because non-coronals do not use the front of the tongue, the transition from [l] to a non-coronal is comparatively easier to do, given that the timing does not need to be as exact. For example, the lateral coronal articulation can persist slightly into the beginning of a following labial without interfering with the labial articulation.

Likewise, velars use the tongue dorsum, pharyngeals use the tongue root, and laryngeals use the vocal cords; they do not have any specific articulatory demands on the tongue tip, so they do not have the same articulatory pressure as coronals do to trigger assimilation when preceded by the lateral.

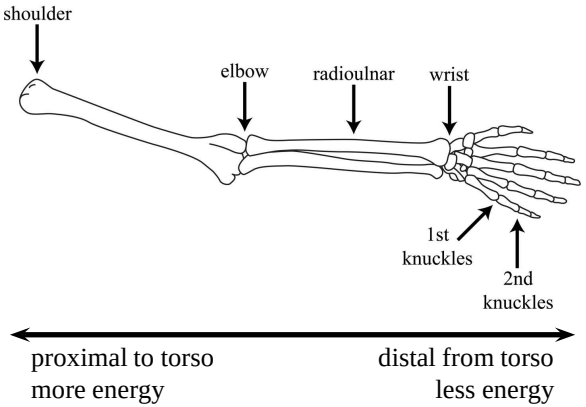
3 Joints in signing

The articulators in sign language consist of the manuals (arms, hands), as well as nonmanuals: facial parts (eyebrows, eyes, nose, cheeks, lips, tongue), the whole head, various parts of the torso, as well as the whole torso itself. All of these articulators can move in a variety of ways, many of which can be exploited in sign language.

Reducing the number of articulators in a sign would obviously reduce the effort it takes to produce the sign (Mai 2008). In fact, such change occurs historically: two-handed signs that are symmetrical across the midsagittal plane have a tendency to become one-handed (Frishberg 1975).

Our focus in this work is on the joints in the arm and hand (5). Those closer to the torso are called "proximal" and those farther away are called "distal":

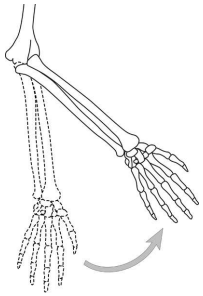
(5)



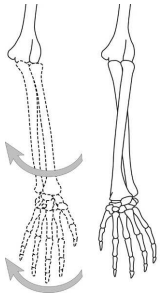
Movement of the most proximal joint, the shoulder, results in the entire upper limb moving. This movement is thus moving the greatest mass possible for a sign joint, which means in a strict comparison of one joint to another, movement of the shoulder will take the greatest amount of energy.

Likewise, as we move down the arm from the shoulder, movement of a more distal joint will move less mass than movement of a more proximal joint. So, all else being equal, movement of a more proximal joint will take more energy, and movement of a more distal join will take less energy.

Additionally, how a joint moves is relevant for a discussion of energy. Bending the elbow in order to raise the entire forearm (6a) requires a certain amount of energy, while twisting the radius and ulna around each other (6b) requires much less energy:

(6) a. 

elbow bending

b. 

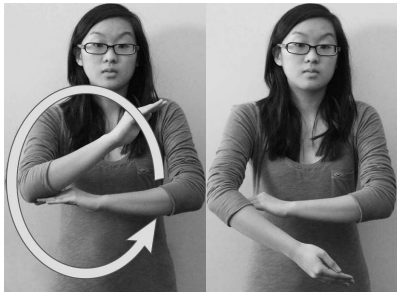
radioulnar twisting

The movement of the elbow joint acts against the resistive force of gravity, since the height of the forearm and hand changes; that is, elbow flexion has lift, while radioulnar movement does not. The muscles of the arm must expend more energy to produce the torque necessary for lifting the forearm than what is needed for twisting it.

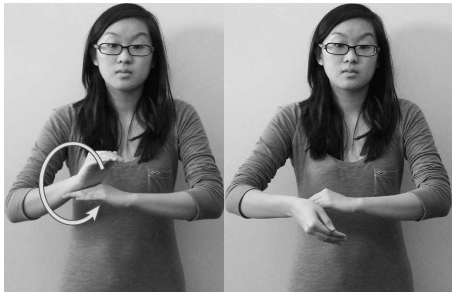
So, if sign languages have a similar drive for ease of articulation as spoken languages do (as also argued by Mauk 2003), then we expect to find a preference for **distalization** (substitution of distal joints for proximal joints) over **proximalization** (substitution of proximal joints for distal joints), since we established that there is a correlation between proximity of a joint to the torso and energy required to move that joint. We explore the use of ASL signs in casual conversation to test this expectation. (See also Crasborn and van der Kooij 2003 for evidence of distalization in Sign Language of the Netherlands.)

4 Ease of articulation in fluent signing

As with spoken language, reduction of articulatory effort in sign language is also in conflict with perceptual distinctiveness. A common theme we find is that the overall visual shape of a sign's path is usually preserved. For example, the citation form of ALL-NIGHT-LONG (7a) creates a circular path that is visually preserved in the distalized form often used in casual conversation (7b):

(7) a. 

ALL-NIGHT-LONG, citation

b. 

ALL-NIGHT-LONG, distalized casual

Data not considered: We are only concerned with joint transfer in casual conversation. We do not consider joint transfer due to morphological derivation, such as the derivation of activity nouns from verbs via trilling (Klima et al. 1979), as in CHAT (8a) > CHATTING (8b), which shifts the joints from the shoulder and elbow to the wrist and radioulnar:

(8) a. 

CHAT

b. 

CHATTING

We also do not consider whispering (Brentari 1998) or signing in a limited space (such as video chatting on small devices like iPhones; Gene Mirus, p.c.). Ease of articulation likely plays a role in the implementation of such signing (Crasborn 2001), but it is not the underlying *motivation.*

We also do not consider signs in which proximalization and distalization are not both anatomically possible. For example, particular handshapes can block joint transfer to more distal joints (Mirus et al. 2001), as in the sign YES, which has a closed fist (9a). It is possible to proximalize YES by transferring the joint movement from the wrist to the elbow and/or shoulder (9b), but because the hand is fully closed, it is anatomically impossible to transfer the joint movement to the knuckles (9c):

(9) a. 
YES, citation

b. 
YES, proximalized

c. 
YES, *distalized

In contrast, a sign like WARN (10a) can be both proximalized to the elbow (10b) or distalized to the knuckles (10c), and these are the only cases we consider:

(10) a. 
WARN, citation

b. 
WARN, proximalized

c. 
WARN, distalized

Finally, we ignore the second knuckles, because they are phonologically distinctive, so movement there is never introduced or eliminated. Throughout this talk, "knuckles" will refer only to the first knuckles.

Methods: We examined every sign listed under the letters A and R in two online dictionaries, ASL Browser and Signing Savvy, comparing the citation forms with our own knowledge of these forms as used in casual conversations and noting all instances in which the joint of movement in the citation form differed from what we were familiar with in casual conversation. Then we checked our list with native signers. Our findings of the native speaker judgments are reported in the following three sections.

For all results, we have included every example we knew of where the casual form of the sign used a different movement joint from that used in the dictionary entry (and was not otherwise excluded as discussed above). However, we make no claim that our findings are exhaustive for all signers or even most signers, nor that they are representative of the prevalence of distalization in general except in the grossest ways. We hope only to show that when distalization is possible, it sometimes happens in casual conversation among fluent signers, whereas proximalization almost never occurs.

Our data is occasionally augmented with examples mentioned in the linguistics literature, that we have noted in conversation, or that were suggested to us by native signers.

4.1 Results: One-joint distalization

Our first set of results are those in which the citation form and the casual form both involve exactly one joint. The table in (11) summarizes the results.

The diagonal is marked with dashes since we are only interested in changes in the joints used in signs.

Numbers indicate the number of total signs we found in which at least one native signer could use a different join in casual conversation from the joint used for the citation form of a sign in at least of the two dictionaries. Numbers in parentheses are supplemental examples.

A superscript falsum (contradiction) symbol $^{\perp}$ is used to mark cases where no distalization occurs, but for reasons that we have an explanation for (see below).

(11)

	casual				
citation	shoulder	elbow	radioulnar	wrist	1st knuckles
shoulder	–	?	1	3	?
elbow	0	–	8	24	1
radioulnar	0	0	–	$0^{\perp}$	$0^{\perp}$
wrist	0	0	0	–	?
1st knuckles	0	0	0	0	–

The data for the table in (11) are given in (12):

(12) a. *shoulder > radioulnar*
REMEMBER$_{SS}$

b. *shoulder > wrist*
ABSENT$_{AB}$ (GONE)
ACCUMULATE$_{AB}$ (ADD-ON)
ANNOUNCE$_{SS}$

c. *elbow > radioulnar*
ARGUE
ASSOCIATION (CLASS)
RABBI
REDEEM (SAFE)
RELAX
RELIGION
REMEMBER$_{AB}$
RISK$_{AB}$

d. *elbow > wrist*
ABOUT (WHEN)
ABSENT$_{SS}$ (GONE)
ABSORB
ACCOMPLISH (SUCCEED)
ACCURATE (EXACT)

d. *elbow > wrist (cont'd)*
AGAIN
ALERT (WARN)
ALLERGIC
ANNOUNCE$_{AB}$
ANSWER
ANYWAY
APPLY
RAGE (MAD)
RAIN
RAKE
RAT$_{AB}$ (MOUSE)
READY
REBUKE$_{SS}$
RECOVER (HEALTHY)
REGISTER (SIGN-UP)
RELINQUISH (GIVE-UP)
RIGID$_{SS}$ (FROZEN)
ROOM
ROUTINE (PROGRAM)

e. *elbow > first knuckles*
AFTERNOON

key: $_{AB}$ = this sign has this citation joint in ASL Browser only
$_{SS}$ = this sign has this citation joint in Signing Saavy only
SIGN = all informants have this casual joint for this sign
SIGN = at least one informant (but not all) has this casual joint for this sign

The most obvious fact about these results is that there are no examples of proximalization at all in our data (the entire bottom left half of the table in (11) is filled with zeroes). That is, for every sign in which proximalization of the citation form would be anatomically possible, a proximalized variant is never used by any of our native signers in casual conversation.

Secondly, while most of the possible cases of distalization have examples, there are some notable gaps. Most notably, we never find distalization from the radioulnar joint (marked as $0^{\perp}$ in (11)). This is not surprising: as discussed above with the example ALL-NIGHT-LONG (7), distalization should result in a recognizable sign, so that even though the sign will be smaller, it will maintain its characteristic shape.

But with the exception of the index finger, the knuckles cannot easily move in a circle, so they cannot adequately mimic radioulnar movement. And though the wrist has more freedom than the knuckles, it also cannot adequately mimic radioulnar movement without involving the radioulnar joint. Thus, we do not expect distalization from the radioulnar to either the knuckles (unless the handshape selects only the index finger) or the wrist.

The other gaps in our data (marked with question marks) are not as easy to explain. The wrist and the knuckles both share the ability to flex, so we might expect to see examples of distalization from the wrist to the knuckles. This turns out to be an accidental gap in our search: the sign WARN (10) does occur in distalized form in casual conversation (Mirus et al. 2001).

Similarly, the shoulder and knuckles have some overlap in possible movements, but we found no examples of distalization in our dictionary search. However, for some speakers, the sign COME-HERE normally uses the shoulder, but uses the knuckles in casual conversation, so such joint transfer exists, just not in the signs we looked at.

The lack of examples of distalization from the shoulder to the elbow is unexplained, since both joints share a range of movements. This could simply be another accidental gap in our data, but we have not yet been able to think of any examples. Suggestions are welcome!

In summary, for one-joint signs, distalization to a single joint is overwhelmingly more preferable to proximalization, which seems never to occur. Further, distalization from the elbow appears to be most common, especially to the wrist. This is an interesting fact that warrants further research.

4.2 Results: Multi-joint distalization

We next consider joint transfer in which either or both the citation and casual forms have more than one joint. The distalization data are given in (13) and the one marginal example of proximalization is given in (14):[2]

(13) a. *shoulder > radioulnar and wrist*
AFRICA

b. *shoulder and elbow > wrist*
ACCUMULATE$_{SS}$ (ADD-ON)
AGO$_{SS}$ (BEFORE)
READ
REQUIRE$_{SS}$
RIGID$_{AB}$ (FROZEN)
ROAR

c. *shoulder and elbow > radioulnar and wrist*
ACCOUNT (COUNT)
ACROSS
AGAIN$_{SS}$
AMBULANCE (HOSPITAL)
ANNUL (CANCEL)

d. *elbow > radioulnar and wrist*
ACTUAL (TRUE)
ADDRESS (noun, cf. LIVE)
ADOLESCENT (YOUNG)
ALARM
ATTENTION (PAY-ATTENTION)
RACE (COMPETE)
REMINISCE
REPLACE
REQUIRE$_{AB}$

e. *elbow and radioulnar > radioulnar and wrist*
ADAPT (CHANGE)
REFER$_{SS}$ (SEND)

(14) *wrist > shoulder and elbow*
RENT$_{SS}$

First, we note once again the general preference for distalization over proximalization. There are many more gaps here since there there are many more ways to transfer joints in such a way to start or end with two joints, and we do not try to explain these gaps.

Second, every example of distalization uses the wrist in the casual form, and almost every example (13a,c,d,e) uses the radioulnar and the wrist. The special status and synergy of these two joints warrants further examination.

Finally, we turn to the sole case of proximalization we found in our data. In ASL Broswer, the sign RENT only involves wrist movement. The citation form in our other dictionary, Signing Savvy, does not sign it this way, nor do any of the other online dictionaries that we checked (ASL Pro, Handspeak, and Start-American-Sign-Langauge).

Further, none of our native speaker consultants use that particular version of RENT, whether signing slowly or quickly. All of those dictionaries and our consultants use the shoulder and elbow joints. In fact, our consultants criticize the way RENT is presented in ASL Browser, claiming that this rendition of the sign is not even recognizable, since it traces no visible circle.

We do not know whether the signer for RENT in ASL Browser is a native signer, but natives of any language can and do make mistakes in production; dictionary signers are presumably trying to be careful in their demonstrations, although sometimes this can lead to hyperarticulation.

Regardless, the citation form in ASL Browser exists, and in comparison to this particular citation form, our consultants proximalize this sign, which means RENT, at least as given in this one dictionary, goes against the tendency we are arguing for.

In summary, for citation forms and/or casual variants involving multiple joints, we again see a strong preference for casual variants to exhibit distalization rather than proximalization, with one marginal counterexample.

[2] Note that the citation forms of many of the signs discussed above as one-joint signs are rather stiff, so the citation forms many signers are familiar with might involve multiple joints and belong in the current section. We are faithful to our dictionaries, but our fundamental arguments do not hinge on which joint or joints distalization occurs from, only that it occurs.

4.3 Results: Espaliation

Another strategy similar to distalization used to decrease articulatory effort in casual conversation is **espaliation**: freezing of the most proximal joint in a multi-joint sign so that movement only occurs at the distal joints.[3]

Espaliation differs from distalization in that there is no joint transfer: all of the joints used in an espaliated casual form are used in the citation form. The data we found showing espaliation are given in (15):

(15) a. ~~*shoulder and*~~ *radioulnar and wrist*
REFER$_{\text{AB}}$ (SEND)

b. ~~*elbow and*~~ *radioulnar*
ANOTHER (OTHER)
ANY
ATTEMPT (TRY)
ALREADY$_{\text{SS}}$ (FINISH)

c. ~~*elbow and*~~ *wrist*
AGO$_{\text{AB}}$ (BEFORE)
REJECT$_{\text{SS}}$

Again, we note the special status of the radioulnar and wrist joints: they never seem to be espaliated.

5 Ease of articulation in disfluent signing

Since there is a general trend towards distalization and espaliation motivated by concern for articulatory ease, we should not expect to see any consistent tendency for proximalization. However, contrary to apparent logic, we do find circumstances in which signers routinely proximalize their articulations.

As before, we must set aside some possible confounding cases. When signers are angry, excited, or separated by large distances, they will often shout, making their signs larger, using more proximal joints. As with whispering, shouting must be set aside, since the fundamental motivation is not articulation, but rather the circumstances of the signing interaction.

[3]We coin "espaliation" on analogy to the botanical practice of training a plant to grow along a flat surface by tethering the proximal parts of its branches in order to fix the direction of their growth, leaving the distal parts of the branches free.

5.1 Signing in first-language acquisition

Deaf children acquiring ASL tend to proximalize movement in their signs, gaining distal movement over time (Meier et al. 1998, Meier et al. 2008).

For example, the sign HORSE is made by adults with movement of the first knuckle on the first and second fingers, but a signer who was 11 months and 3 weeks old signed it with wrist nodding instead of finger bending.

In the sign BOOK, which is made by adults with rotation of the forearm involving the radioulnar joint, this same signer at the age of 14 months signed it with shoulder movement instead.

In both cases, proximalization occurs, resulting in increased energy requirements, exactly the opposite of what we might expect if energy reduction were the main consideration for ease of articulation.

Meier et al. 1998 and Meier et al. 2008 attribute this to matters of motor control: infants generally gain motor control of proximal articulators before distal articulators (see also Gesell 1929, Gesell and Thompson 1934, Kuypers 1981).

This can be seen in children's motor skills beyond signing. Children first learning to write typically use large movements of the shoulder and elbow, only gradually learning to write with smaller movements of the wrist and fingers (Saida and Miyashita 1979), and babies kick with more proximal activity than adults do (Jensen et al. 1995).

In summary, children acquiring sign language produce language that differs from adult language not in random ways, but in systematic ways (Emmorey 2002), and proximalization is one of those systematic ways. Adults who have good motor skills will distalize because it is more efficient for them.

But children who have developing motor skills will proximalize because their gross motor skills are in place before their fine motor skills are, so they cannot access the more efficient distalized articulations.

That is, children who proximalize movement in acquiring sign are doing what is easiest *for them*, and thus, they are exhibiting the drive for articulatory ease, although physical ability (rather than simple efficiency) is the driving force.

5.2 Signing by adult learners

Adults have mature fine motor skills, so unlike children, adults have the physical ability to use distalization as a strategy for reducing articulatory effort. However, a study by Mirus et al. (2001) revealed that adult second-language learners of sign languages also proximalize their signs as child first-language learners do.

Their subjects were a mixture of hearing and Deaf. The hearing subjects were all Americans or Germans, and the Deaf subjects were native signers of either ASL or German Sign Language (Deutsche Gebärdensprache, DGS), with little to no knowledge of the other sign language. Both sets of subjects were asked to imitate videotaped renditions of signs taken from ASL and DGS.

Both German and American hearing subjects proximalized approximately 20% of the stimuli, but the Deaf subjects proximalized significantly less: ASL signers proximalized 3% of the stimuli, while DGS signers proximalized 8.75%.

Prevalent errors across subjects were to omit some distal movements entirely, to replace wrist movement with elbow or shoulder movement, and to add a movement in a proximal joint (such as adding shoulder movement to a sign that had only elbow movement). Proximalization was frequent, whereas distalization was extremely rare.

This seems to be an unexpected result, given that adults have access to distal articulations. However, adults learning a new motor skill tend to reduce the number of biomechanical degrees of freedom they have to manage by freezing some articulators (usual distal) (Bernstein 1967). Some documented examples include racquetball (Southard and Higgins 1987), skiing (Vereijken et al. 1992), and writing with the non-dominant hand (Newell and McDonald 1994).

Mirus et al. suggest that desire to reduce the degrees of freedom is the proper account of the tendency for adult learners of a sign language to proximalize: "Skilled use of the distal articulators depends on skilled use of proximal articulators whereas the converse is not true" (2001:105).

As with children, the choice of articulator here is based on what is easiest for the signer and is within the signer's skill set. Cognitive and motor issues conspire to make movement of the proximal joints easier than movement of the distal joints, despite the distal joints requiring less energy to move. Thus, the drive toward ease of articulation depends on skill level: fluency leads to distalization, disfluency leads to proximalization.

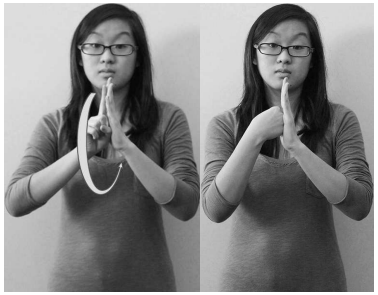
6 Awkwardness

As we have already seen, the radioulnar joint seems to have a special status.[4] This is not surprising, given that the radioulnar joint only rotates and does involve lift, as the other joints usually do.

However, there is a notable counterexample in which radioulnar movement is dropped in casual conversation (as is the wrist), and furthermore, a proximal articulation (the elbow) is added. This sign, HOUR, warrants discussion, because rather than presenting a problem for our argument, it in fact offers a new type of evidence for a kind of ease of articulation — avoidance of awkwardness.

In the ASL Pro, Handspeak, and Start-American-Sign-Language dictionaries, the citation form of HOUR involves shoulder, radioulnar, and wrist movement, and has iconic movement of the dominant fingertip tracing the edge of the non-dominant hand as if it were a clock face (16).

(16)



HOUR, iconic citation

However, in casual conversation, signers instead use the shoulder and elbow to make a circular motion, keeping the dominant hand's orientation non-iconically fixed (17a); a similar sign is used as the citation form in ASL Browser and Signing Savvy, but with the dominant hand facing contralateral rather than outward (17b):

[4]This special status surfaces elsewhere in sign language. For example, Mathur (2000) found that cross-linguistically, verbs with radioulnar movement more easily allow for agreement for first person object and for arguments associated with loci on either side of the signer, while verbs with other types of movement are less likely to show such agreement

(17) a. 
HOUR, casual

b. 
HOUR, non-iconic citation

The proximal variants in (17) appear to require a greater amount of energy than the citation form in (16), so why are they used, especially in casual conversation?

As always, what is at issue here is generic ease of articulation, not necessarily simply energy efficiency. The iconic citation form in (16) requires maximal radioulnar movement, as well as maximal wrist flexion, in order to keep the index finger of the dominant hand in contact with the palm of the non-dominant as much as possible during the circle. Producing this citation form of HOUR is awkward and difficult, even uncomfortable for some.

Fluent signers often give up on iconicity (though preserving the overall circular shape of the movement), eliminating the awkwardness in favor of the more comfortable movement in (17). Though this non-iconic variant requires more energy, by using more proximal joints and larger motions, it is much more comfortable, since it does not require extreme movement of any particular joint.

Thus, even for fluent signers, the drive for ease of articulation does not always dictate distalization. Considerations of physical awkwardness may make a proximal articulation easier under certain circumstances.

7 Conclusion

Ease of articulation is a factor in all languages, regardless of modality. In sign language, what counts as an easier articulation is not necessarily based on energy efficiency, but is instead tied to skill and comfort. Fluent signers tend to reduce energy through distalization and espaliation, disfluent signers tend to proximalize due to motor control issues, and awkward articulations may be proximalized to avoid extreme or uncomfortable articulation.

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