
Constraints on two types of nonconcatenative morphology in signed languages

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ABSTRACT. Signed languages strongly favor nonconcatenative morphology (Aronoff, Meir and Sandler 2005, Fernald and Napoli 2000). This type of morphology includes processes that change at least one of the parameters of the stem, such as handshape, orientation, location or movement. It is argued that there are *two* types of nonconcatenative morphology in signed languages. In one type, exemplified by numeral incorporation, all the morphemes in a sign have a fixed realization. In the other type, exemplified by verb agreement, one of the morphemes in a sign does not have a fixed realization in the lexicon and requires interaction with gestural space. This type is modality-specific. Using the framework of Optimality Theory, the paper argues for the distinctiveness of these two types on the basis of phonological constraints that apply to them in data from a cross-linguistic survey of German (DGS) and American (ASL) Sign Languages.

1 Introduction

There is consensus that signed languages strongly favor nonconcatenative morphology (Aronoff, Meir and Sandler 2005, Fernald and Napoli 2000). This type of morphology includes processes that change at least one of the parameters of the stem, such as handshape, orientation, location or movement. It is argued that there are two types of nonconcatenative morphology that appear in signed languages. In one type, all the morphemes in a sign have a fixed realization. In the other type, one of the morphemes in a sign does not have a fixed realization from the lexicon and requires interaction with gestural space (also known as signing space). This type is modality-specific. The paper argues for the distinctiveness of these two types on the basis of phonological constraints that interact with them. The data are taken from a cross-linguistic survey of German (DGS) and American (ASL) Sign Languages.

The first type is exemplified by numeral incorporation. This process combines two morphemes, each of which has a fixed lexical specification: a numeral which contributes handshape, and a sign like WEEK, which contributes location, orientation and

movement. In ASL, the numerals ONE through NINE may be incorporated, but not the numerals TEN and above. The latter numerals have a particular internal movement such that if it is overlaid with the movement of, say, WEEK, it results in complex movement that is marked. The phonological constraints that interact with this process concern the *complexity* of articulation.

The second type is seen in verb agreement. Under one approach by Rathmann and Mathur (2008a), this process involves two morphemes, one of which has a fixed lexical specification: a verb like FRAGEN ‘ask’ in DGS is lexically specified for handshape, location and movement. The other morpheme marks agreement with the person and number features of the (in)direct object and alters the orientation of the verb. If the object is first person, the hand is oriented toward the signer. However, if the object is nonfirst person, there is no fixed specification for orientation. This specification is left open and may be realized through interaction with gestural space, in which an area of signing space is associated with a referent. While this space is infinite, the articulators (i.e. the hands and arms) limit the possibilities for such realization. Thus, the phonological constraints that interact with this process concern the *degree* of articulation, which holds true regardless of the particular approach assumed for verb agreement.

The next section details the analysis of numeral incorporation using the framework of Optimality Theory (Prince and Smolensky 1993, McCarthy and Prince 1993), based on Rathmann and Mathur (2008b). The successive section presents an analysis of verb agreement within the same framework, based on Mathur and Rathmann (2006). The final section brings together both analyses to reveal that constraints on complexity of articulation apply to both, while constraints on degree of articulation apply only to verb agreement, thus providing an independent way to distinguish the two types of nonconcatenative morphology. Other morphological processes in signed languages are mentioned that fall into one of the two types, further supporting the typology of nonconcatenative morphology in signed languages.

2 Numeral incorporation

Numeral incorporation exemplifies the first type of nonconcatenative morphology, in which all the morphemes are realized according to their lexical specification. Here, two cases are discussed in which numeral incorporation is not realized: DGS *VIER-MINUTE ‘four-minute’ and ASL *TEN-DAY. These cases reveal phonological constraints on the process of numeral incorporation, which are shown to concern the complexity of articulation. Being language-specific and language-internal, they have analogues in spoken languages and in that sense, are not modality-specific. The following is based on Rathmann and Mathur’s (2008) survey of numeral incorporation in DGS and ASL.

In the DGS example, the sign MINUTE ‘day’ uses a hand in the handshape of ‘F’ (all fingers extended and spread, except for the index finger which contacts the thumb). The hand contacts an area between the mouth and the cheek twice. The lexical specification for this handshape is fixed and cannot be rewritten by a morphological process such as

numeral incorporation. This proposal is supported by another example from DGS which has the same handshape as MINUTE and does not incorporate numerals either: TAG ‘minute’. This sign is two-handed symmetric, in which the hands touch on the tips of the thumbs and then move away from each other. One possible reason for the absence of numeral incorporation in this example is that the language preserves the lexical specification of the sign.

One way to formalize this analysis within the framework of Optimality Theory (in a basic version) is to use a faithfulness constraint and a markedness constraint that interact with each other. The sign for MINUTE in DGS uses a marked handshape (‘F’) which contacts the cheek. The handshape must be preserved, so it does not incorporate any numeral. This comes at the cost of another strategy, which is to sign the two morphemes separately as VIER MINUTE, and is encoded by ranking the faithfulness constraint over the markedness constraint, which are defined below.

- (1) Constraints for DGS *VIER-MINUTE
 MAX-IO-M: Do not delete any marked featural specification from the input.
 (Faithfulness)
 *SEQ: No more than one specification for movement.
 (Markedness)

The first constraint (MAX-IO-M) has the effect of preserving marked lexical specifications, while the second constraint (*SEQ) has the effect of preferring candidates with one movement over candidates with a sequence of two movements or more.

The analysis for *VIER-MINUTE is presented in Table 1. In the tableau, a star indicates a violation of the constraint; two or more stars indicate multiple violations; an exclamation point denotes a fatal violation that rules it out as an optimal output; and gray shading marks those evaluations that follow a fatal violation.

Input: MINUTE + VIER MINUTE: HS _a : F (marked) Loc _a : cheek Mvt _a : double contact VIER: HS _b : 4 Loc _b : neutral space Mvt _b : outward	MAX-IO-M	*SEQ
=> a. Sign: HS _b HS _a Loc _b Loc _a Mvt _b Mvt _a		*
b. Sign: HS _b Loc _a Mvt _a	*!	

Table 1. Tableau for DGS *VIER-MINUTE

The tableau in Table 1 presents as input two morphemes along with their phonological specifications: MINUTE ‘minute’ and VIER ‘four’. *HS*, *Loc* and *Mvt* stand for the parameters of handshape, location and movement respectively, following the formalism of Fernald and Napoli (2000). The subscripts on each parameter indicate that there are different values for that parameter. Thus HS_a and HS_b refer to different handshapes. MINUTE has the ‘F’ handshape (as defined above), while VIER has the ‘4’ handshape (all four fingers extended and spread, with thumb touching palm).

Two possible candidates are considered for realizing this input. The first candidate represents the strategy of realizing each morpheme separately, as indicated by the two full sets of specifications for each parameter. In contrast, the second candidate involves numeral incorporation, as seen by the substitution of the handshape of VIER (HS_b) in the representation of MINUTE. This candidate violates MAX-IO-M because the lexical specification for the handshape of MINUTE, which is marked, is deleted. It does not otherwise violate the *SEQ constraint, because there is only value for the movement parameter. In contrast, the first candidate violates the *SEQ constraint because there are two values for the movement parameter. The first candidate emerges as the more optimal one, since it preserves all the lexical specifications of the two signs and does not violate MAX-IO-M, which is higher ranked than *SEQ.

Now let’s turn to the ASL example: the sign DAY allows incorporation of numerals up to nine, but not ten and above. The sign DAY is made by moving the dominant hand, palm facing the body, downward to contact the flat nondominant arm. The numerals ONE through NINE involve presenting a hand configuration in the neutral area (i.e. not on the face or body). Table 2 presents an Optimality-Theoretic analysis for regular cases of numeral incorporation, e.g. FOUR-DAY. The very same constraints from Table 1 apply here.

Input: DAY + FOUR DAY: HS_a : 1 Loc_a : nondominant arm Mvt_a : downward arc to loc FOUR: HS_b : 4 Loc_b : neutral space Mvt_b : outward	MAX-IO-M	*SEQ
a. Sign: HS_b HS_a Loc_b Loc_a Mvt_b Mvt_a		*!
=> b. Sign: HS_b Loc_a Mvt_a		

Table 2. Tableau for ASL FOUR-DAY

Candidates that are parallel to those in Table 1 are considered: the first candidate realizes the two signs (FOUR and DAY) separately, while the second candidate incorporates the handshape of FOUR into the representation of DAY. The crucial difference between Table 1 and Table 2 is that there are no marked features in the input of Table 2. The signs DAY and FOUR do not have any marked lexical specification, whereas in the DGS example, the sign MINUTE has a marked handshape. Because there is no marked feature in the ASL case, neither of the candidates violate MAX-IO-M. However, the first candidate violates *SEQ, so it is eliminated in favor of the second candidate, which has just one set of values for the movement parameter.

Now let's consider what happens with the numeral TEN, which is different from the numerals one through nine: in addition to presenting a specific hand configuration in the neutral area (closed fist with extended thumb pointing up), it also involves trilled movement in the form of twisting the radio-ulnar part of the arm repeatedly. The trilled movement is a distinctive part of the numeral TEN that cannot be sacrificed when it is incorporated into another sign. However, overlaying the trilled movement with the movement required by the sign DAY leads to complex movement that, while physically possible, is not tolerated in the frozen lexicon.

Thus we need one more constraint to rule out the candidate that overlays the trilled movement of TEN with the movement of DAY, which is proposed below.

- (2) Additional constraint for ASL *TEN-DAY
 *COMPLEX: No more than one simultaneous specification for a parameter
 (Markedness)

This constraint is of the markedness type and differs from *SEQ. Whereas *SEQ concerns a sequence of two values for the movement parameter, *COMPLEX disallows two simultaneous values for the parameter, like oscillating movement overlaid with a path movement. The constraint *COMPLEX explains why signs like DAY do not incorporate numerals above TEN, since all of the numerals above TEN in ASL involve complex movement as well. In contrast, numerals ONE through NINE do not involve trilled movement or any other lexically specified movement that must be preserved with the result that the constraint does not apply to them when they are incorporated into DAY and other signs.

The constraint receives further support from DGS. Unlike ASL, this language allows incorporation of numerals up to ten. The numerals in this language are different in a way from those in ASL. Crucially, ZEHN 'ten' is made with both hands extending all fingers. They do not have any trilled movement or other special type of movement than a slight straight movement in the neutral area. Therein lies the difference: TEN in ASL has trilled movement which prevents it from being incorporated, but ZEHN 'ten' in DGS does not and thus can be incorporated. Numerals above ten in DGS, however, have complex movement and are not incorporated due to the very same phonological constraint that bars ASL TEN and above from being incorporated.

Ranking the constraint *COMPLEX before *SEQ results in the most optimal candidate. The analysis is presented in Table 3.

Input: DAY + TEN DAY: HS _a : 1 Loc _a : arm Mvt _a : arc down TEN: HS _b : A Loc _b : neutral space Mvt _b : oscillating (marked)	*COMPLEX	MAX-IO-M	*SEQ
=> a. Sign: HS _b HS _a Loc _b Loc _a Mvt _c Mvt _a			*
b. Sign: HS _b Loc _a Mvt _a		*!	
c. Sign: HS _b Loc _a Mvt _{ab}	*!		

Table 3. Tableau for ASL *TEN-DAY

In this tableau, there are three candidates. The first candidate realizes the two signs separately, while the second candidate incorporates the handshape of TEN into the representation of DAY but deletes the marked lexical specification for the movement of TEN and the third candidate incorporates both the handshape and movement of TEN into the representation of DAY. The third candidate is ruled out due to a violation of *COMPLEX because there are two simultaneous values for the movement and the second candidate is eliminated due to a violation of MAX-IO-M because it deletes the marked lexical specification for the movement of TEN. While the first candidate violates *SEQ, it emerges as the most optimal candidate because it does not violate the higher-ranked constraints, unlike the other candidates.

Thus far, two kinds of phonological constraints on numeral incorporation have been illustrated, predicting whether it occurs or not. First, a constraint that preserves marked lexical specifications (MAX-IO-M) prevents some signs from incorporating numerals. Second, a constraint against the complexity of movement (*COMPLEX) prevents some numerals with special movement from being incorporated. While the particular content of these constraints differs from those in spoken languages due to the different articulatory systems, the general nature of these constraints is remarkably similar to those seen in spoken languages, suggesting that numeral incorporation is a familiar type of nonconcatenative morphology that is subject to the usual language-internal constraints.

3 Verb agreement

Verb agreement illustrates the second type of nonconcatenative morphology, in which at least one of the morphemes is realized through interaction with gestural space. This section, based on Mathur and Rathmann's (2006) survey of verb agreement in DGS and ASL, focuses on two cases: *you-ANALYZE-us and I-TEST-you-all. While these examples are taken from ASL, there are parallel examples in DGS. These cases suggest a number of phonological constraints on the morphological process of verb agreement, some of which are shown to relate to the degree of articulation. Such constraints do not seem to have analogues in spoken languages, since the constraints are triggered only when there is potential to exceed the limits of the articulatory system due to interaction with gestural space, and it is this interaction that is unique to the signed modality.

Let's start with the first example, you-ANALYZE-us. This sign is two-handed and symmetric: the two arms are raised, the index and middle fingers are spread and crooked while the other fingers are closed, and the hands move down in sync as the fingers wiggle. To realize the *you-to-us* form, the palms of the hands would have to face the signer and move in an arc toward the signer. This places strain on the nondominant arm, which has to twist at an awkward angle at the beginning of the arc. Instead, some signers choose to realize the form in a simpler way by dropping the arc and just having the palms face the signer, and using context (e.g. pronouns) to clarify the plural feature of the direct object. This scenario also occurs in DGS, e.g. with the verb VERSPOTTEN 'tease'.

This case suggests a markedness constraint against pronation that exceeds the physiological limits of the articulator. Pronation means twisting the arm so that the palm goes from facing up to facing down; this description assumes the fingertips point away from the signer, but the term applies to the same movement even if the fingertips point up, as in this case. The limit on pronation seems to be no more than 90 degrees in the if 0 degrees is taken to be the state in which the right palm faces to the left or vice versa. In addition, the analysis requires a faithfulness constraint that preserves the morphological marking of the direct object as well as a more general faithfulness constraint that preserves the lexical specifications of the morphemes. These constraints are formulated as follows.

- (3) Constraints for ASL *you-ANALYZE-us
*R-U-PRON: Do not pronate the radio-ulnar part of the arm more than 90 degrees.
(Markedness)
MAX-IO-OBJ: The target form for the direct object in the input has a correspondent in the output. (Faithfulness)
MAX-IO: Every target in the input has a correspondent in the output.
(Faithfulness)

To derive the correct analysis for *you-ANALYZE-us, the markedness constraint *R-U-PRON must be ranked between MAX-IO-OBJ and MAX-IO. The analysis is presented in Table 4.

Input: ANALYZE (crooked index & middle fingers) +target for first person object +target for plural number	MAX-IO-OBJ	*R-U-PRON	MAX-IO
a. ANALYZE (crooked index & middle fingers) +target for first person object (hands face body) +target for plural number (hands move in an arc)		*!	
=> b. ANALYZE (crooked index & middle fingers) +target for first person object (hands face body)			*
c. ANALYZE (crooked index & middle fingers) +target for plural number (hands move in an arc)	*!		*

Figure 4. Tableau for ASL *you-ANALYZE-us

In the tableau in Figure 4, there are three possible candidates for realizing the form you-ANALYZE-us. The first candidate preserves the target form for the first person feature of the direct object in the form of having the palms of the hands face the signer's body. In addition, it preserves the target form for the plural feature by inserting an arc into the movement of the hands. The second candidate is similar except that it drops the marking for the plural feature, and the third candidate preserves the marking of the plural feature but drops the marking for the first person direct object.

The first candidate preserves all target forms in the input, so it does not violate either faithfulness constraint. However, it violates the *R-U-PRON constraint since the realization of the first person and plural features together places an awkward strain on the nondominant hand. The next candidate preserves the marking for the direct object, so it does not violate MAX-IO-OBJ. It also does not violate *R-U-PRON because, now that the marking for the plural feature has been dropped, and the palms of the hands just face the signer, there is no strain on the nondominant hand. However, it violates MAX-IO because it deletes the marking for the plural feature. The last candidate violates both faithfulness constraints because it drops the marking of the person feature of the direct object, but otherwise satisfies the *R-U-PRON constraint. The middle candidate which marks the person feature and not the number feature emerges as the most optimal form, on account of the fact that the other constraints violate higher-ranked constraints.

Now let's turn to the other example, I-TEST-you-all. The sign TEST is two-handed and symmetric, with the palms of both hands facing the addressee. The index finger is extended, with the other fingers closed, and the index finger crooks repeatedly as it moves downward. The repetition of downward movement is preserved in the realization

of I-TEST-you-all: the hands move down repeatedly as they proceed along an arc toward the addressee. Another similar example that comes from DGS is VERSPOTTEN ‘tease’.

As a point of contrast, let’s compare I-TEST-you-all with I-ASK-you-all. ASK is similar to TEST except that it is one-handed and while there is repeated crooking of the index finger, there is no repeated downward movement. Rather, in the uninflected form, the hand moves outward. There are two possible ways to realize I-ASK-you-all. In one way, with the palm facing the addressee, the extended index finger is crooked once as it is moved in an arc toward the addressee. In the other way, the index finger is crooked repeatedly while moving along the arc, like in TEST. The latter way is not attested in practice. There is a preference for crooking the finger just once over the arc, than repeatedly crooking it, even when the latter option is seen in other verbs like TEST. A corresponding example in DGS that realize the form without repeated movement is GEBEN ‘give’.

To account for the absence of repeated movement in I-ASK-you-all, two constraints are needed: a general faithfulness constraint that preserves the lexical specification of the input and a markedness constraint that disfavors the repeated movement. It turns out that some of the constraints seen in earlier tableaux meet these needs, namely, MAX-IO and *COMPLEX. Ranking the faithfulness constraint above the markedness constraint would lead to the most optimal form for I-ASK-you-all. The analysis is presented in Table 5.

Input: ASK (crooked index finger) +target for nonfirst person object +target for plural number Mov: handshape change, arc	MAX-IO	*COMPLEX
=> a. ASK (crooked index finger) +target for nonfirst person object +target for plural number Mov: handshape change, arc		
b. ASK (crooked index finger) +target for nonfirst person object +target for plural number Mov: handshape change, arc, repeated movement		*!

Table 5. Tableau for I-ASK-you-all (without repeated movement)

In Table 5, two candidates are considered for the realization of I-ASK-you-all. The first candidate crooks the index finger just once over the arc movement, while the second candidate crooks the finger repeatedly over the arc. The first candidate violates neither of the constraints: it preserves all of the lexical specifications in the input, and there is no complex movement in the sense that there is no repeated crooking overlaid with the arc movement. While the second candidate preserves the lexical specifications of the input, it

violates *COMPLEX by repeating the crooking movement and overlaying it with the arc movement. Thus the first candidate emerges as the more optimal form.

Now let us return to I-TEST-you-all. Note that the realization of the form preserves the repeated crooking while it is overlaid with the arc movement. One way to analyze this form using the same constraints and the same ranking as above is to encode the repeated crooking in the input. See the tableau for I-TEST-you-all, which is given in Table 6.

Input: TEST (both index fingers crooked) +target for nonfirst person object +target for plural number Mov: handshape change, arc, repeated movement	MAX-IO	*COMPLEX
a. TEST (both index fingers crooked) +target for nonfirst person object +target for plural number Mov: handshape change, arc	*!	
=> b. TEST (both index fingers crooked) +target for nonfirst person object +target for plural number Mov: handshape change, arc, repeated movement		*

Figure 6. Tableau for I-TEST-you-all (with repeated movement)

The crucial difference between the tableaux for ASK and TEST lies in the specification of repeated movement of the handshape change in the input for TEST, but not for ASK. The result is that the first candidate, which lacks repeated crooking of the index finger, violates the faithfulness constraint MAX-IO, and loses out to the second candidate, which emerges as the more optimal candidate, even though it violates the markedness constraint *COMPLEX.

Thus far, the analyses of verb agreement reveal that this morphological process is subject to two kinds of constraints. First, it is subject to the same kind of constraint that applies to numeral incorporation, i.e. *COMPLEX. This constraint concerns complexity of articulation and is not rooted in the limits of the articulatory system but rather ensures the simplest production of language-specific properties encoded in the lexicon. Second, verb agreement is subject to a constraint that is rooted in the limits of the articulatory system, e.g., *R-U-PRON. This kind of constraint relates to the degree of articulation and does not seem to apply to the first type of nonconcatenative morphology as exemplified by numeral incorporation.

Constraints on degree of articulation receive cross-linguistic support. They appear in both DGS and ASL. The appearance of the constraints in both signed languages can follow from their roots in the limits of the articulatory system, which is common to both signed languages. Moreover, the interaction of such constraints with morphological processes

seems unique to the signed languages. It is difficult to construct analogous examples in spoken languages where the application of a morphological process is directly constrained by the physiological limits of the articulatory system. On the other hand, in signed languages, some morphological processes like verb agreement often require interaction with gestural space for their realization. This interaction, which is modality-specific, allows such a wide range of possibilities, such that the morphological realization can be constrained by the limits of the articulatory system.

4 Conclusion

The Optimality-Theoretic analyses of constraints on numeral incorporation and verb agreement demonstrate that there are two types of nonconcatenative morphology according to their interaction with phonological and phonetic constraints. First is the type exemplified by numeral incorporation, where all of the morphemes receive their realization from the lexicon. This type of morphological process is subject to the usual constraints on complexity of articulation that are seen in spoken languages and is not modality-specific. The other type has been illustrated with verb agreement. In this type, one of the morphemes often requires interaction with gestural space for its realization. While this type of morphological process is subject to constraints on complexity of articulations seen with the first type, it is also subject to constraints on degree of articulation. These constraints do not appear with numeral incorporation, which does not require interaction with gestural space for its realization. The emergence of degree-based constraints appears unique to signed languages and arises from the modality-specific property of using gestural space – a potential infinite space - to realize some morphological forms.

Other morphological processes in signed languages fall into one of these two types, supporting our proposed typology of nonconcatenative morphology in signed languages. In particular, aspectual modulations belong to the same type as numeral incorporation, since they do not require interaction with gestural space for realization, while some classifier constructions pattern with verb agreement, owing to the fact that they can be realized in a potentially infinite number of ways due to their interaction with gestural space. One prediction which seems to be borne out is that constraints on degree of articulation apply to some of the classifier constructions but not to the aspectual modulations, while constraints on complexity of articulation apply to both.

In sum, morphological processes in signed languages are governed by language-internal constraints just as in spoken languages; at the same time, a restricted set are also governed by constraints on the degree of articulation that have emerged to balance the wide range of possibilities offered by gestural space, the use of which is prominent in signed languages.

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