The composition of handshapes

Harry van der Hulst
HIL, University of Leiden

Abstract In this article, I will suggest a new proposal for the representation of one aspect of the phonological structure of signs, viz. Finger Configuration. This aspect involves the *selection of finger joints* that are involved in flexion, as well as the *aperture* relation between fingers and the thumb.

1. Introduction

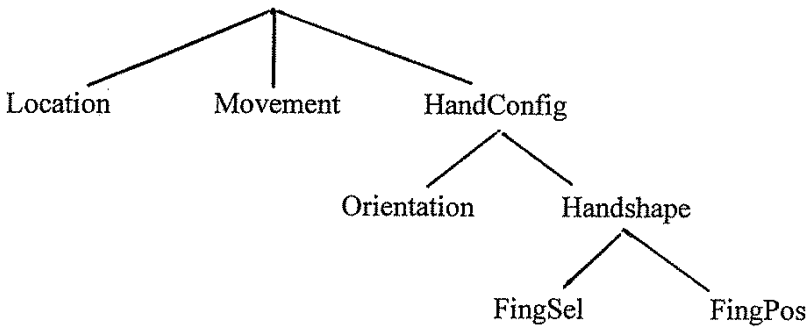
I will first sketch the kind of overall model that I will assume (section 2). Section 3 discusses a number of previous proposals for the representation of Finger Configuration. In section 4 I point out that these proposals, despite their merits and ignoring differences among them, fail for one particular reason: they characterize a large number of *handshape changes* that have not been empirically attested and that are generally judged as highly improbable by native signers. I then suggest that this problem can be solved if one formally separates joint flexion from aperture by recognizing both as separate sub-components of the component Finger Configuration. This proposal restores insights that predate the recent feature geometric trend, for example those expressed in the feature system proposed by Friedman (1977), and others discussed in Wilbur (1987).

2. The model

Stokoe (1960) proposed to decompose the phonological shape of signs into three components, Location (tab), Movement (sig) and Handshape (dez). Battison (1978) added Orientation, which Sandler (1989) proposes to regard as a subcomponent of Hand

Configuration, together with Handshape. Sandler, also proposes to incorporate Mandel's (1981) suggestion to decompose Handshape into Finger Selection and Finger Position.

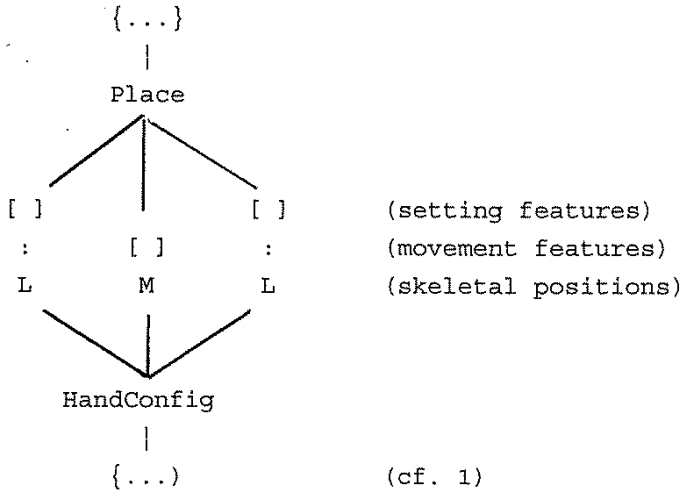
(1)



The structure in (1) summarizes the distinctions that are being made, but we cannot take it to represent the feature model that Sandler, or anyone else, proposes. Following Liddell & Johnson (1989), Sandler's model incorporates a skeletal tier consisting of L-units, for location, and M-units, for movement, to which the HandConfig node associates, as well as features expressing locational (or place) properties and movement properties. The latter specify, among others, the shape of the movement (for example: arc versus straight path).

Two types of place properties are distinguished: major place properties are those that remain invariant for a (monomorphemic) sign and setting properties which specify the beginning and end point of a (path) movement. A diagram that approximates the model Sandler proposes is given in (2):

(2)

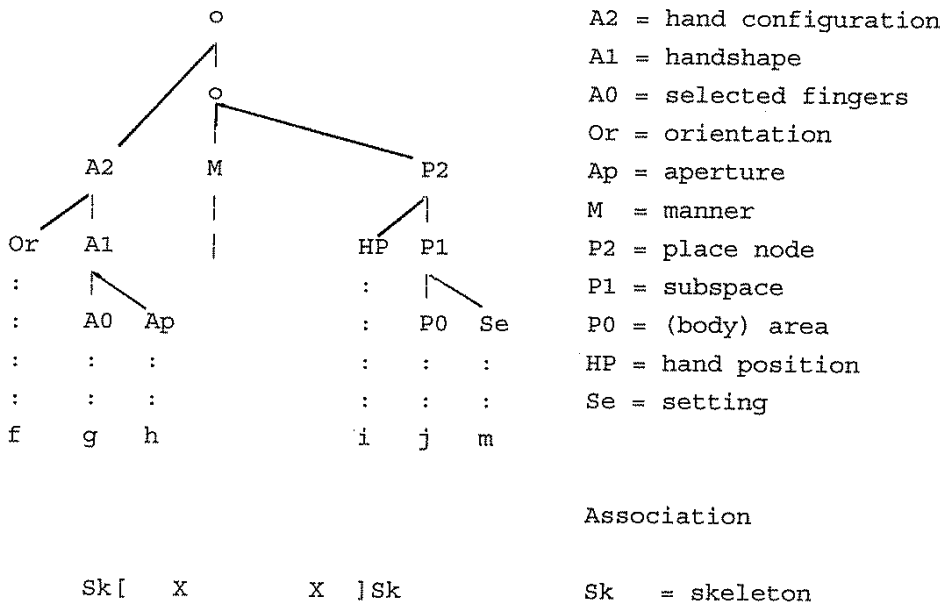


In van der Hulst (1993, in press, to appear) I propose to supplement Sandler's proposals with notions from Dependency Phonology (Anderson & Ewen 1987), in particular the basic principle that components (as well as the features they contain) enter into a head - dependent relation. Dresher & van der Hulst (1995, forthc.) can be seen as an attempt to investigate recurrent properties of heads at various levels of phonological representation. The head of a constituent is the central unit in a number of ways and graphically identified with a vertical constituent line (cf. 3).

A further difference between Sandler's model and the one I propose is that, more in line with (1), I do not express movement properties as features of a skeletal unit M, but rather in terms of a component Manner. The details of this Manner component remain to worked out, however. A consequence of this proposal is that the skeleton contains units of one type only, which can therefore be represented as unlabelled Xs.

A third difference follows partly from the fact that the components Place, Hand Configuration and Manner are represented as sisters between which a head-dependent relation is postulated. In the model proposed here, the units that are associated to the skeletal position are not the component nodes, but rather the features that they dominate.

(3) *The representation of one-handed signs*



By directly associating features rather than organizational nodes I reduce the component organization to a meta-theory of feature organization. A perspective of this kind has also

been proposed for the organization of phonology in spoken languages by Hayes (1991), van de Weijer (1994) and Padgett (1995). Alternatively, we can encode the component type of features on the features themselves (as in done in van der Hulst 1994ab, 1995). Either way, phonological representations contain only features (or feature tiers), skeletal units and association lines that go directly from the former to the latter. I will now briefly comments on the various nodes in the structure in (3). Here, I have little to say about the features themselves (with the exception of features for finger configuration; see below). I refer to Boyes-Bream (1981), Friedman (1977), Lane et al (1976), Wilbur (1987) and Sandler (1989) for proposals and overviews of the earlier literature on feature systems.

A2

In (3) the label HandConfig is replaced by the label Articulator (following Brentari, forthc.). The structure of the Articulator package is taken from Sandler (1989) and modelled in the form of a dependency structure. Combined with the node that specifies the configuration of the fingers, we get A1, i.e. the Handshape node. Orientation specifies whether the palm is up or down, toward or away from the signer and so on, and perhaps also includes finger orientation features.

Both the Orientation node and the Finger Configuration node may specify a change in value in order to characterize so called local (or hand-internal) movements. The only node that does not allow a change of value (during the monomorphemic sign) is A0. This is one of the reasons for taking this node to be the head; cf. van der Hulst (1993) for further discussion of this point. In this article, I will not be concerned with the features under A0, and I refer to a proposal in Brentari et al. (in prep.) that is compatible with the model outlined here.

P2

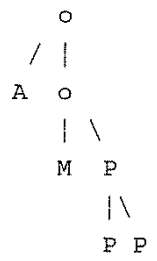
P2 is the place unit. Following Sandler (1989) I make a distinction between major location and setting. The latter subcategorize the distinction made by the former, much like features such as [posterior] and [laminal] subdivide the class of coronal consonants. Among the class of major place features we find [head], [trunk], [neck], [arm] and [weak hand]. The lower dependent node here labelled Se dominates setting features. The highest dependent within Place, Hand Position, (similar to the what Liddell & Johnson 1989 call 'facing') specifies how the hand is placed vis-a-vis the direction of movement or point of contact

(i.e. side of the hand, fingertips or flat side of the hand facing the direction of movement). The node, P0, is taken to be the head. Again, one reason for this is that within monomorphemic signs no change of major location occurs in by far the majority of cases.

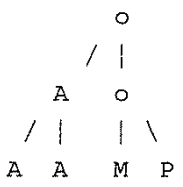
The content of the Manner unit (which specifies properties of movement) I propose has not been worked out. Both the Place and the Articulator unit are represented as dependents on Manner. The head status of Manner expresses the perceptual centrality of movements properties. The reason for making the Articulator the higher dependent is that this unit appears to be the more mobile package in assimilatory processes. In van der Hulst (1993) I argue that relative closeness to the head entails relative immobility, the head itself being completely immune to spreading tendencies.

The basic organization in (3) allows for two types of further complexity. Van der Hulst (in press) suggests that certain types of complex movements (i.e. 7-shape and perhaps all non-straight path movements) appear to involve a combination of two P-units, (4a), whereas two-handed signs can be seen as a combination of two A-units, (4b):

(4) a.



b.



The structure in (4b) is more fully explored in van der Hulst (to appear).

3. Finger configuration: previous proposals

3.1 Static shapes

In order to make a proposal for the featural representation of Finger Configuration one must first decide on the set of (potentially) distinctive configurations. This, of course, is not a trivial matter. Nonetheless, there is a certain consensus that at least the configurations in (5) must be representable. Handshapes that are made with all fingers selected show the biggest array of finger configurations, so I use these to exemplify the attested variety (I use

the symbol " ┌" for the the flat handshape. Instead of 'flat' others have used the terms 'bent' or 'hooked'):

(5) a. Closed S-hand : fingers folded in a fist
Curved C-hand : finger base and non-base joint slightly flexed
Flat ┌-hand : finger base joint sharply flexed
Open B-hand : fingers fully extended (i.e. no flexion at base of non-base joints

b. Closed Curved Flat Open

In fact, most current feature system take this to be all the finger configurations that must be represented. Corina (1990) uses the feature system in (6):

(6)

	+bent	-bent
+curved	CLOSED	CURVED
-curved	FLAT	OPEN

Brentari (1990) proposes the following system:

(7)

	-open	+open
+peripheral	CLOSED	OPEN
-peripheral	FLAT	CURVED

Sandler (1995) adopts a dependency-based system with two unary features, open and closed:

(8)

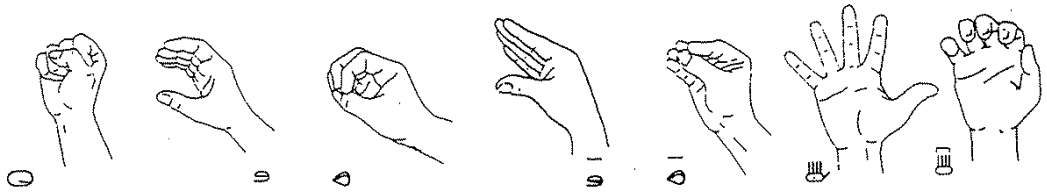
closed	closed	open	open
	open	closed	
CLOSED	CURVED	FLAT	OPEN

At first sight, it would seem that the a four-way distinction in handshapes (however featurally characterized) does not do justice to the array of handshapes that occurs (in e.g. Sign Language of the Netherlands, SLN) (note the ad hoc symbols for the flat handshape and claw):

(9) a.

Closed	S-hand	: fingers folded in a fist
Curved	C-hand	: finger base and non-base joint slightly flexed
Curved-closed	O-hand	: like C-hand with thumb in contact with fingers
Flat	┌-hand	: finger base joint sharply flexed
Flat-closed	▷-hand	: like ┌-hand with thumb in contact with fingers
Open	B-hand	: fingers fully extended (i.e. no flexion at base of non-base joints
Claw	#-hand	: base joints extended and other joints flexed

b. Closed Curved Curved-closed Flat Flat-closed Open Claw



Uyechi (1995) proposes a somewhat more elaborate system which separates flexion at the base joints (the joint closest to the hand body) and non-base joints (the other two joints). For each joint type she allows three values various:

(10)
a. Extended: [-flexed, +extended]
b. Neutral : [-flexed, -extended]
c. Flexed : [+flexed, -extended]

Allowing these three values for the base and non-base joints generates a set of 9 possible handshapes:

(11)

Non-base / base	flexed	neutral	extended
flex	CLOSED	CURVED-CLOSED	FLAT-CLOSED
neut	*1	CURVED	FLAT
ext	*2	FLAT-CURVED	OPEN

(Flat-curved = claw)

This system gives a place to the extra handshapes in (9), compared to (5), but in doing so, it generates two possibilities that are either unnecessary or difficult to distinguish from the handshapes to their immediate right (in table 11). Uyechi suggests that *1 could be identified with the shape of the index finger in ASL APPLE and *2 with the shape of the index finger in the letter X.

It would seem then that the systems that we have seen so far are unable to neatly characterize the set of finger configurations in (9). Before we consider alternatives, either proposed in the literature that I am aware of or ones that I can think of (and that are probably available in literature that I am not aware of), let us discuss a second kind of testing ground for an appropriate feature system, namely handshape changes.

2.2 Handshape changes

The central argument in favor of a division between Selected Fingers and Finger Configuration is that monomorphemic signs (as established for ASL and confirmed for other sign languages as well) typically do not have a change of finger selection, whereas configurational changes (often called hand internal changes) are common place. Sandler (1989) refers to Mandel (1981) for this generalization. Thus, handshape changes cannot

simply be characterized as changes from one handshape to the other since this would not allow us to distinguish between the changes in (12a) and (12b):

(12) a. 1 → 5
b. ⌐ → ▷

A holistic view on handshape fails to reveal that handshape change in monomorphemic signs cannot involve finger selection, as in (12a). (12b) is properly restricted to a finger configuration change. Liddell and Johnson (1985, 1989) and Liddell (1990) nonetheless argue in favor of completely specifying both handshapes in a handshape change independently. This seems to imply that they cannot straightforwardly discriminate between the impossible (e.g. 12a) and the possible (e.g. 12b) hand shape changes. A discussion and refutation of their position can be found in Sandler (1989) and Brentari (1990).

By claiming that handshape changes can only involve a change in Finger Configuration, we significantly narrow down the set of possible changes, but, and this is the central point I wish to make here, the set is still too big. The handshape changes in (13), for example, although involving a change in finger configurations only, are also unattested, but they are predicted to be possible by all systems discussed above:

(13) a. ▷ → C
b. S → O

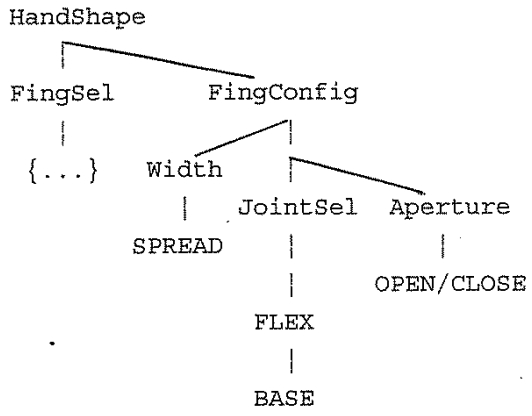
The researchers that have proposed these systems have of course been aware of the fact that not all changes in finger configuration lead to a grammatical handshape change. To narrow down the possibilities they therefore propose restrictions of various kinds. Ther consensus of these constraints is that in all handshape changes one handshape must be open or closed. This excludes changes from curved to flat and vice versa. Uyechi (1994) suggest that the relevant restrictions must make reference to the fact that the flexion of the finger joints cannot change. This idea is taken up in the proposal I make in the following section, where I wish to show that we can do without constraints of this sort. If I succeed in that, the need for evaluating or comparing constraints that trim down an overgenerating feature system evaporates.

3. Finger configuration: a new proposal

I wish to propose a split in the Finger Configuration node in order to restrict the class of handshapes changes accurately and in a straightforward manner. The basic idea is to split Finger Configuration into Joint Selection and Aperture.

In older feature systems (such as proposed in Friedman 1977, and others discussed in Wilbur 1987) we find features specifying bending and curving of the fingers as well as features such as [±open] to specify the relation between fingers and thumb. The proposal I wish to make returns to separating bending/curving from closure. The difference between traditional systems and the proposal here lies in using the concept of feature grouping and in the precise way in which bending/curving is specified. The structure in (14) expressed the proposal in its essential form:

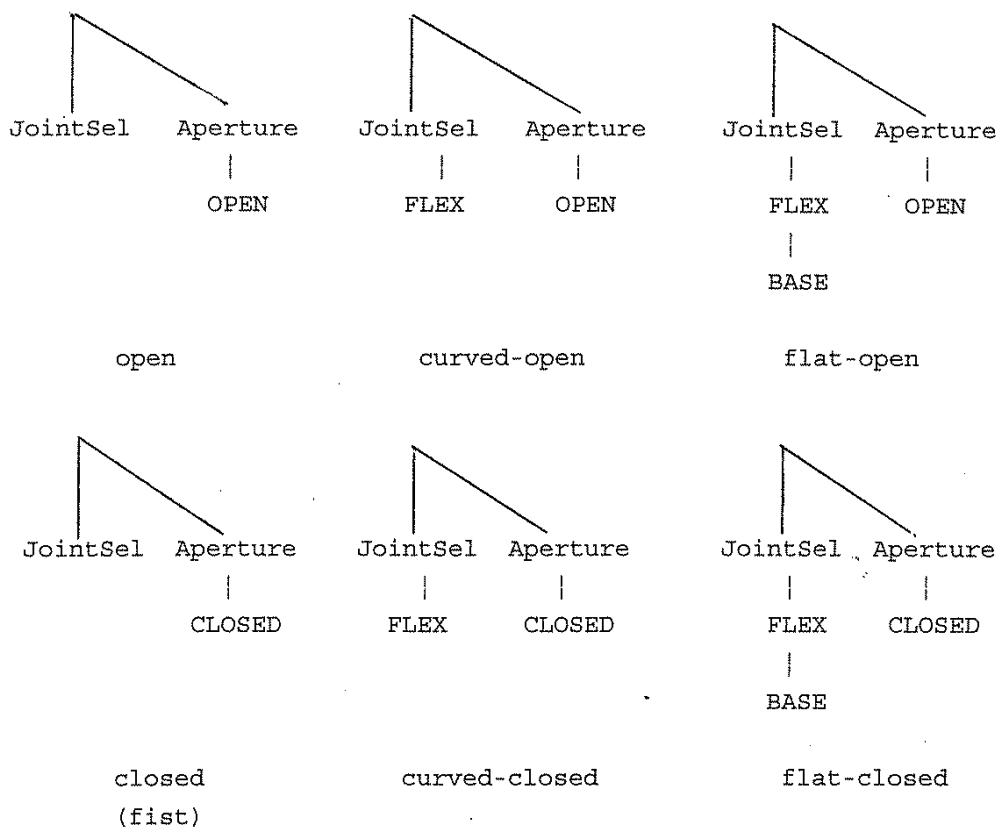
(14)



In the structure in (14), I also assume that a feature SPREAD is part of the Finger Configuration node, but I do not wish to press that point here. An alternative affiliation for this feature is suggested in Brentari et al. (in prep).

Under joint selection I allow the three following possibilities, which, combined with the two aperture values, allows six possible configurations:

(15)



With these structures we allow ourselves to formally express a limitation on handshape changes and say that these can only involve a branching Aperture node. This node is represented as the dependent node, while Joint Selection is the head. To say, then, that the Aperture value may change, but not the value for Joint selection is in line with our reasoning for making the Selected Finger node the head of Hand Configuration (cf. section 1.2). We now expect to find exactly three types of handshape changes, namely those relating each vertical pair in (15).

Before we investigate the problematic aspects to this claim, I wish to make a few remarks about the the thumb. The values for the nodes JointSel and Aperture imply a certain position for the thumb. If aperture is OPEN, the thumb is "opposed" in case FLEX is specified under JointSel. If the JointSel is unspecified (which represents that the fingers are extended) the thumb is in a "neutral" position (as in a 5 hand). If aperture is CLOSED, the thumb makes contact with the selected finger in case FLEX is specified and is folded over the fingers (to form a fist) in case JointSel is unspecified. In all these cases the thumb position is not the result of a specific thumb-feature specification, but rather implied by the values for Finger Configuration. When the thumb restrains unselected fingers (as in the

3-handshape), its position is also implied (i.e. by the finger selection specifications). This leaves us with only one situation in which the thumb position must be the result of a specific thumb-feature, viz. the case in which the thumb is extended "outward". Cf. Brentari et al. (in prep) for a more detailed discussion.

Let us now turn to the claim that handshape changes can only involve a change between the members of the vertical pairs in (15). Problematic to this proposal is not the set of handshape changes that it predicts, which all seem to occur, at least in SLN, as demonstrated in Blees (1994). Rather it would appear that the set of handshape changes that we allow is too restricted.

Firstly, one might argue that an opening movement which has either O or ▷ as the beginning handshape (when unrepeated) can easily result in an ending handshape that has no flexed finger joints. The end handshape in such cases resembles a spread 5 handshape rather than C and ┌, respectively. If this is the correct analysis, such cases involve a change in joint selection, or in any event a loss of joint selection specification.

Consider the following examples:

(16)	a.	SLN STORM	O	→	5	(and not: O → C)
	b.	SLN WAKE UP	▷	→	5	(and not: ▷ → ┌)

The ending handshape differs from a 'real' 5 handshape in that the thumb will usually be somewhat forward (i.e. slightly opposed); In KOMVA the ending handshape is called the 'shower' hand.

Following Brentari et al. (in prep), I assume that we deal here with a dissimilation effect functionally motivated by the pressure to enhance the difference between the beginning and end handshape. The fact that the end finger configurations show no phonetic flexion does not imply that their phonological specification has changed (Els van der Kooij, pc.). The claim is thus that the feature FLEX is not necessarily phonetically interpreted as actual flexion of the finger joints. FLEX, rather, means that the joints are activated. The default phonetic interpretation of joint activation is flexed, but in the context of the aperture feature OPEN, FLEX is interpreted as extended to enhance the property OPEN.

The reverse situation also occurs, i.e. a handshape change that ends in a closed-curved O-shape does not necessarily start out with a phonetic C shape. In the SLN sign for SON, the initial handshape looks more like a 5 hand (with a somewhat forward pointing

thumb). Again, I would claim that this is simply a phonetic realization of FLEX (without dependent) in the context of the feature OPEN.

Dissimilation effects of this type seem to disappear when handshape changes are repeated. This is understandable, because the changes are made as small as possible due to the pressure of repetition. In some sense then, repeated handshape changes bear out the phonological structure more clearly then unrepeated aperture changes.

The second problem for this approach are so called partial handshape changes, like clawing and winging, which appear to have an aperture change without the thumb being opposed:

(17)	a.	Clawing	b.	Winging
		SLN DREAM		SLN AUGUST

Since there is no thumb opposition, these changes cannot be analyzed as aperture changes. These changes are usually repeated (as in the examples in (17), but not necessarily:

(18)	a.	Clawing	b.	Winging
		SLN DEPENDENT		SLN WARM

I would like to suggest that, even though these movements are hand-internal, they can perhaps be seen as hand-internal versions of path movements (i.e. movement that we specify under place), thus as small versions of movements that can in principle be carried out through higher joints. If this is the correct analysis, we are not dealing with aperture changes, which explains why the thumb is not opposed. For clawing this is perhaps most clear in the index hand movement for 'COME HERE'. Greftegreff (1993) also argues that winging can be analyzed as a 'path' movement.

A problem with this suggestion is that the claw shape must also be specifiable as a static shape (i.e. ASL APPLE, X). This problem does not arise for the hooked handshape, which can be specified as FLEX-BASE and no aperture node, but we have not provided a way of specifying the claw handshape. A possible change of the system is to add a feature NONBASE under FLEX (as suggested in Brentari et al. in prep), but this would give us one extra aperture change which does not seem to occur. We would have to find a reason for this which might lie in the reasonable claim that the claw configuration is the most marked one. Another solution is to regard the static claw hand as a 'tense' version of the

C-hand, and to assume that tensing blocks an aperture distinction. Lacking arguments for choosing between these two options, I submit both as possible solutions to the problem that the claw shape confronts us with.

4. Conclusion

In this article, I have made a new proposal for the representation of Finger Configuration. The central idea is that we formally separate Joint Selection from aperture. This separation allows me to pinpoint the class of handshape changes rather accurately as those involving a change in Aperture. Though this observation as such is not new (as is evident from the literature on handshape changes), none of the models that have been put forward in the recent literature succeeds in providing a formal explanation for it without constraints that must trim down an overgenerating feature system. The present proposal overcomes this problem by restoring an aspect of certain feature systems that have been proposed in the earlier days of sign language research.

References

Anderson, J.M. and C.J. Ewen (1987). Principles of Dependency Phonology. Cambridge University Press, Cambridge.

Ann, J. (1992). Physiological Constraints in Taiwan Sign Language Handshape-Change. In Nordic Journal of Linguistics 15.2.

Battison, R. (1978). Lexical Borrowing in American Sign Language. Linstok Press, Silver Spring, Maryland.

Blees, M. (1994). Een Fonologische Analyse van de Handvormen van de Nederlandse Gebarentaal [A Phonological Analysis of the Hand Forms in Sign Language of the Netherlands]. MA Thesis, University of Leiden.

Boyes-Braem, P. (1981). Distinctive Features of the Handshape in American Sign Language. Doctoral dissertation, University of California, Berkeley.

Brentari, D. (1990). Licensing in ASL Handshape Change. In C. Lucas (ed.) Theoretical Issues in Sign Language Research 2, 27-49. Gallaudet University Press, Washington DC. Doctoral dissertation, University of Chicago.

Brentari, D. (forthc.). Two-Handed Signs [Chapter of Forthcoming Book]. Ms.

Brentari, D. H. van der Hulst, E. van der Kooij & W. Sandler (in prep). ONE over ALL and ALL over One: a dependency view on finger selection. Ms.

Corina, D.P. (1990). Handshape Assimilations in Hierarchical Phonological Representations. In C. Lucas (ed.) Theoretical Issues in Sign Language Research 2, 27-49. Gallaudet University Press, Washington DC.

Corina, D.P. (1993). To Branch or Not to Branch: Underspecification in ASL Handshape Contours. In G. Coulter (ed.) Current Issues in ASL Phonology, 63-95. Academic Press, New York.

Corina, D.P. & E. Sagey (1989). Predictability in ASL Handshape Sequences, with Implications for Features and Feature Geometry. Ms, University of California, San Diego.

Corina, D.P. & W. Sandler. (1993). On the Nature of Phonological Structure in Sign Language. Phonology 10, 165-207.

Dresher, B.E. & H.G. van der Hulst (1995). Head-Dependent Asymmetries in Phonology. In H.G. van der Hulst and J.M. van de Weijer (eds.). Leiden in Last HIL. Phonology Papers 1, 401-31. (distributed by Holland Academic Graphics, The Hague).

Dresher, B.E & H.G. van der Hulst (forthc.). Head-Dependent Asymmetries in prosodic phonology, Unpublished ms, University of Toronto and HIL/University of Leiden [Toronto Working Papers in Linguistics 12.1, 1-18].

Ewen, C. (1995). Dependency Relations in Phonology. In J.A. Goldsmith (ed.). The Handbook of Phonological Theory, 570-85. Basil Blackwell, Cambridge/Oxford.

Friedman, L. (1977). Formational Properties of American Sign Language. In L. Friedman (ed.) On the Other Hand: New Perspectives on American Sign Language, 13-57. Academic Press, New York.

Greftegreff, I. (1992). Orientation in Indexical Signs in Norwegian Sign Language. Nordic Journal of Linguistics 15, 159-82.

Greftegreff, I. (forthc.). Doctoral dissertation, University of Trondheim.

Hayes, B.P. (1990). Diphthongisation and Coindexing. Phonology 7, 31-71.

Hulst, H.G. van der (1993). Units in the analysis of signs. Phonology 10/2, 209-241.

Hulst, H.G. van der (1994a). Radical CV Phonology: The locational gesture. In: UCL Working Papers in Linguistics #6, 439-477.

Hulst, H.G. van der (1994b). An introduction to Radical CV Phonology. In: S. Shore & M. Vilkuna (eds.). SKY 1994: Yearbook of the linguistic association of Finland. Helsinki, 23-56.

Hulst, H.G. van der (1995). Radical CV Phonology: The categorial gesture. In: J. Durand and F. Katamba (eds.). Frontiers of Phonology. Essex: Longman.

Hulst, H.G. van der (in press). Head-dependency relations in the representation of signs. To appear in H. Bos & T. Schermer (eds.) Sign Language Research 1994. Proceedings of the 4th European congres on Sign Language Research in Munich. Munich 1-3 September 1994. Hamburg: Signum Press.

Hulst, H.G. van der (to appear). On the other hand. In H.G. van der Hulst and A.Mills (eds). Issues in the phonology of sign language. To appear as a theme issue of Lingua.

KOMVA (1988). Notatie-Systeem voor Nederlandse Gebaren. De Nederlandse Stichting voor het Dove en Slechthorende Kind, Amsterdam.

Klima, Edward & U. Bellugi (1979). The Signs of Language. Harvard University Press, Cambridge, Mass.

Lane, H., P. Boyes-Braem & U. Bellugi (1976). Preliminaries to a Distinctive Feature Analysis of Handshape in American Sign Language. Cognitive Psychology 8, 263-89.

Liddell, S.K. (1990). Structures for Representing Handshape and Local Movement at the Phonemic Level. In S.D. Fischer & P. Siple (eds.) Theoretical Issues in Sign Language Research. Volume 1: Linguistics, 37-65. The University of Chicago Press, Chicago and London.

Liddell, S.K. & R. Johnson (1989). American Sign Language: The Phonological Base. Sign Language Studies 64, 197-277.

Mandel, M. (1981). Phonotactics and Morphophonology in American Sign language. Doctoral dissertation, University of California, Berkeley.

Padgett, J. (1995). Feature Classes. Paper presented at the second HIL Phonology Conference, University of Amsterdam.

Prillwitz, S., R. Leven, H. Zienert, T. Hanke & J. Henning (1989). HamNoSys Hamburg Notation System for Sign Languages: An Introductory Guide. Version 2.0. Signum, Hamburg.

Sandler, W. (1989). Phonological Representation of the Sign: Linearity and Nonlinearity in ASL Phonology. Foris Publications, Dordrecht.

Sandler, W. (1995). Markedness in American Sign Language Handshapes: A Componential Analysis. In H.G. van der Hulst & J.M. van de Weijer (eds.). Leiden in Last. HIL Phonology Papers 1. Leiden University Press, Leiden.

Sandler, W. (in press). Representing Handshapes. International Review of Sign Language.

Stokoe, W.C. (1960). Sign Language Structure. 2nd edn (1978). Linstok Press, Silver Spring, Maryland.

Uyechi, L. (1994). The geometry of visual phonology. Doctoral dissertation, Stanford University.

Weijer, J.M. van de (1994). Segmental Structure and Complex Segments. Doctoral dissertation, University of Leiden.

Wilbur, R.B. (1987). American Sign Language: Linguistic and Applied Dimensions. 2nd edn. Boston: Little/Brown.

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FOREWORD

Three of the sign phonologists who presented papers at the Workshop on Sign Language Phonology in Trondheim in November 1994 - **Harry van der Hulst**, University of Leiden, **Wendy Sandler**, Haifa University, and **Catharina Kylander Unger**, Stockholm University - consented to prepare full-length versions of their papers for publication in the University of Trondheim Working Papers series, and here is the result.

Enjoy!

Thorstein Fretheim