# The phonology of handshape distribution in Maxakalí sign

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We provide an analysis of the distribution of handshapes on the dominant and non-dominant hand in the incipient village sign language found in the Maxakalí community in Brazil. The most frequent handshapes reflect tendencies in choosing from the crosslinguistically unmarked set of handshapes, and are particularly well-suited to quantitative analyses of handshape complexity found in models such as Ann (2006) and Brentari (2003), in addition to favouring a core set chosen from the most maximally dispersed handshapes.

**Keywords:** village sign language, handshape complexity, sign language phonology, markedness, non-dominant hand

## 1. Introduction

It is a well-known fact amongst phonologists that phonological features are not dispersed equally within a language (Liljencrants & Lindblom 1972). Many phonological models have explicitly attributed a model of the basic primitive building blocks of structure in terms of those which have the most characteristic and acoustically well-isolable characteristics (e.g. Harris & Lindsey 1996, Backley 2011). Nonetheless, articulatory factors are also sometimes argued to play a role in the distribution of phonological inventories. Indeed, various competing pressures affect the phonological organisation of languages differently. Some of these pressures – especially iconicity – have modality-specific effects on the phonology of sign languages (Brentari et al. 2012: 26). More specific still is the manner in which the phonological organisation of many village sign languages is affected by their youth. Research suggests that young emerging sign languages are likely to have a higher degree of iconicity in their signs, since signs become less iconic over time (Frishberg 1975, Sandler et al. 2011). Thus, it is an open empirical question the extent to which emerging sign languages may have frequent usage of articulatorily

DOI 10.1075/lfab.14.c14

difficult handshapes, articulations on the body and outside the canonical signing space, and movement feature configurations unlike those found in established sign languages, in the construction of more iconic representations.

### 1.1 Village sign languages

Formal linguistic investigation into sign languages has a short history when compared to spoken languages; it was not until the mid-20th century that serious linguistic inquiry began (Stokoe 1960) with the recognition that sign languages are also made up of systematised, discrete, and meaningless sub-lexical units. In the years that followed, national sign languages received the majority of the attention and focus of researchers. This is not to say that other types of sign languages were not studied in the mid to late 20th century (Kakumasu 1968, Washabaugh 1979) but academic inquiry was sporadic. Village sign languages are a type of sign language which tends to arise in relatively isolated communities, often amongst a rate of deafness above the national or global average (McGregor 2015). One such village signing system has emerged in the Minas Gerais region of Brazil, among the Maxakalí people. The system has emerged in isolation, and signers have no known contact with the national sign language of Brazil (Libras), or other indigenous signers or sign systems. At the present time, only the current generation of signers is known.

### 1.2 Data and methods

The data analysed for this paper is 180 minutes of footage of 3 deaf Maxakalí signers, signing both with one another, and to hearing people.[1] It is comprised of a mixture of lexical elicitation tasks and spontaneous conversation. The analysis carried out is purely phonological, and is concerned only with configurations of hand shapes, movements, locations, and any non-manual markings, as opposed to signs and sign boundaries. Naturally there is likely to be significant congruence between configurations of shape, movement, and location, and the boundaries of lexical units. However, the discussion hereafter will use the term *configuration* as opposed to sign to avoid any commitment to the identification of lexical units. Within the footage the specification for the following variables was noted for every configuration (if it was applicable), the relevant parts of which will be discussed and defined in the subsequent sections: whether the configuration was one-handed or two-handed,

1. The data was collected during a trip to the Maxakalí indigenous territory in October, 2015 by Andrew Nevins, Julien Bismuth, Gustavo Godoy, and Mário Coelho da Silva.

handshape of the dominant hand, handshape of the non-dominant hand, hand orientation, whether configurations included path movement, internal movement, or both,[2] orientation change, handshape change, location of configuration production, setting within location, proximity and contact features of location, and which non-manual markers were co-occurring. The current analysis is concerned with type frequency as opposed to token frequency. Accordingly, all configurations which have identical values for all variables were collapsed.

## 2. Results of handshapes and discussion of models

This section is organised as follows. Section 2.1 presents the results of the most common handshapes in Maxakalí in terms of their frequency in the corpus and in terms of their distribution on dominant and non-dominant hands. Section 2.2 discusses the results in terms of maximal dispersion, including a brief comparison with the results found by Sander et al (2011). Section 2.3 compares the Maxakalí handshapes with the proposal of the most common unmarked handshapes crosslinguistically in Battison (1978) and Rozelle (2003). Section 2.4 discusses van der Hulst's (1996a) model for selected fingers as a way of deriving the markedness of handshapes, and concludes that while it contains important insights, it is not fine-grained enough for the empirical phenomena under study. Section 2.5 presents Battison's (1978) Symmetry and Dominance conditions and discusses the extent to which they are upheld in the Maxakalí data. Section 2.6 presents Ann's (2006) quantitative model of handshape difficulty and compares it with the frequency distribution of Maxakalí handshapes. Section 2.7 presents Brentari's (1998) Handshape complexity model. Finally, Section 2.8 presents perceptual data corroborating the hypothesis that the most frequent handshapes in Maxakalí are largely those that are the most perceptually robust.

### 2.1 Handshape dispersion and distinctness in Maxakalí

Handshape features are a basic sub-lexical contrastive phonological unit in sign languages, and are one of the meaningless elements that combine with others to form meaningful units. Like phoneme inventories of spoken languages, sign languages possess handshape inventories. Features of these handshapes are contrastive, forming minimal pairs analogously to features of phonemes in spoken languages.

2. Analysis of location, orientation, movement, and non-manual markers within the Maxakalí system can be found in Stoianov (2016).

The handshapes found in the inventory of the Maxakalí signing system have been sorted in descending order of frequency in Table 1,[3] and assigned a number, to be used throughout the discussion.

**Table 1.** Handshapes and frequency on the dominant and non-dominant hands

| Handshape | Occurrences on dominant hand | Frequency | Occurrences on non-dominant hand | |
|---|---|---|---|---|
| 1 | 212 | 0.237 | 149 | 118 as copy (79%) |
| 2 | 116 | 0.129 | 64 | 51 as copy (80%) |
| 3 | 88 | 0.098 | 36 | 25 as copy (69%) |
| 4 | 86 | 0.096 | 82 | 56 as copy (66%) |
| 5 | 51 | 0.057 | 23 | 20 as copy (87%) |
| 6 | 37 | 0.041 | 25 | 19 as copy (76%) |
| 7 | 32 | 0.035 | 10 | 9 as copy (90%) |
| 8 | 30 | 0.033 | 7 | 4 as copy (57%) |
| 9 | 25 | 0.027 | 4 | 3 as copy (75%) |
| 10 | 25 | 0.027 | 3 | 3 as copy (100%) |
| 11 | 20 | 0.023 | 10 | 8 as copy (80%) |
| 12 | 19 | 0.021 | 14 | 12 as copy (86%) |
| 13 | 16 | 0.017 | 1 | 1 as copy (100%) |
| 14 | 14 | 0.015 | 5 | 2 as copy (40%) |
| 15 | 13 | 0.014 | 3 | 2 as copy (67%) |
| 16 | 13 | 0.014 | 5 | 4 as copy (80%) |
| 17 | 12 | 0.013 | 13 | 7 as copy (54%) |
| 18 | 12 | 0.013 | 3 | 3 as copy (100%) |
| 19 | 11 | 0.012 | 2 | 2 as copy (100%) |
| 20 | 7 | 0.007 | 6 | 2 as copy (33%) |
| 21 | 7 | 0.007 | 6 | 4 as copy (67%) |
| 22 | 6 | 0.006 | | |
| 23 | 5 | 0.005 | 1 | 1 as copy (100%) |
| 24 | 4 | 0.004 | | |
| 25 | 4 | 0.004 | | |
| 26 | 4 | 0.004 | 2 | 0 as copy (0%) |
| 27 | 4 | 0.004 | | |
| 28 | 4 | 0.004 | | |
| 29 | 3 | 0.003 | 1 | 1 as copy (100%) |
| 30 | 3 | 0.003 | | |

3. Handshapes are demonstrated using the images of the Hamburg Notation System (Prillwitz et al. 1989). The accompanying images can be found here: http://www.sign-lang.uni-hamburg.de/dgs-korpus/index.php/hamnosys-97.html under *HamNoSys Handshapes*. The inclusion of the images in Appendix 1 should render use of the symbolic notation system unnecessary.

**Table 1.** (*continued*)

| Handshape | Occurrences on dominant hand | Frequency | Occurrences on non-dominant hand | |
|---|---|---|---|---|
| 31 | 3 | 0.003 | | |
| 32 | 3 | 0.003 | 1 | 1 as copy (100%) |
| 33 | 2 | 0.002 | | |
| 34 | 1 | 0.001 | | |
| 35 | 1 | 0.001 | | |
| 36 | 1 | 0.001 | | |

Table 1 quantifies the distribution of the handshapes found on both the dominant and non-dominant hands. For each handshape produced by the non-dominant hand, it is noted in the final column how frequently this was a mirror of the handshape on the dominant hand within the same configuration, i.e. being matched for all handshape features. The calculation of frequencies excluded any configuration duplicates, either made at a separate time by signers, or repeated within the same sign. It is of course likely that certain handshapes are allophones of a single distinctive handshape. Nonetheless, this paper will be concerned with the phonetic level of analysis rather than the phonemic.

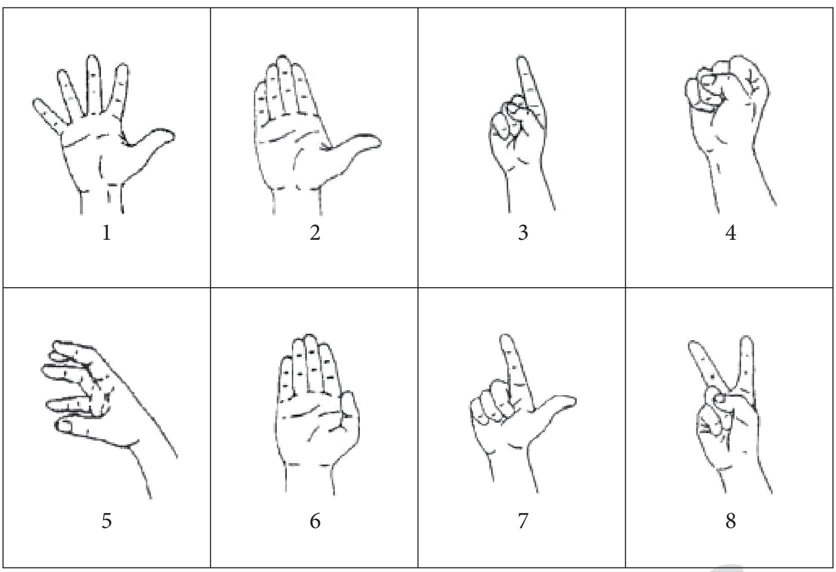



**Figure 1.** Eight most frequent handshapes in Maxakalí sign

## 2.2 Maximal dispersion of handshapes and Sandler et al 2011's model

Looking at Figure 1, it should be clear that Handshapes 1 and 3 are maximally 'dispersed', in terms of their articulatory (and perceptual) distinctness. In data from lexical elicitation tasks[4] with an Al-Sayyid Bedouin Sign Language (ABSL)[5] signer, 76.7% of configurations analysed contained either handshape 1 or 5 (Sandler et al. 2011: 526). The authors concluded that these two handshapes resulted from one more basic one, as they were unlikely to be contrastive due to their sole feature difference of tenseness and laxness,[6] and were considered to belong to one single category; "an all-five-fingers-extended handshape" (Sandler et al. 2011: 526).

The next most common handshape in the ABSL data was handshape 3. If handshapes 1 and 5 can be grouped together, these facts serve as evidence for maximal dispersion within the most common handshapes of emerging sign systems: if the most frequent handshape is among the easiest to articulate, and the second most frequent is maximally distinct from it. If handshapes 1 and 2 in Maxakalí – like handshapes 1 and 5 in ABSL – can be considered variants of the same handshape, the Maxakalí data replicates both the premise and conclusion outlined by Sandler et al. Evidence for handshape 1 being among the easiest to articulate is provided in Section 2.6 and Table 1 shows that the next most common handshape after these two is one that is maximally distinct from the first (Klima & Bellugi 1979). Like in ABSL, there is also a single feature difference between the handshapes in question. Handshapes 1 and 2 differ only in the fingers being either spread (abducted) or together (adducted). Interestingly, Sandler et al. found no minimal pairs in their ABSL data.[7] They hypothesise that this is due to the emergent status of the language, in that minimal pairs are symptomatic of a stage of phonological organisation that ABSL has not yet reached. The existence of minimal pairs in Maxakalí signing is as yet unconfirmed, but if it is the case that handshapes 1 and 2 are also not contrastive, the four most common handshapes of the inventory make up a set that has been proposed as maximally

4. Specifically, translations elicited from a second generation signer, from a word list in Hebrew.

5. ABSL is a village sign language used in the Negev region of Israel, and has emerged among a high level of deafness (Sandler et al. 2005, Kisch 2012). It is thought to be around 90 years old, with the first deaf descendants of the Al-Sayyid family being born between 1924 and 1950.

6. Tense handshapes are produced with greater articulatory effort by the relevant muscles than their lax counterparts (Sturm 1987, Matthews 2014).

7. However, the authors do acknowledge claims by van der Kooij (2002) that sign languages may generally have fewer minimal pairs than spoken languages.

distinct (Sandler & Lillo-Martin 2006: 161).[8] This is consistent with proposals put forward by Sandler (1995) and van der Hulst (1996a) concerning maximal distinction in handshape. In their work, the ALL (all fingers selected) and ONE (one finger selected) handshapes are suggested as the basic distinctive elements of handshape, analogous to the vowels /a/, /i/, and /u/. We return to a discussion of the insights of this model in Section 2.4.

### 2.3 The inventory of unmarked handshapes and how to derive them

In order to adequately interpret the Maxakalí handshape data, it must be considered in light of pre-existing phonological principles. The concept of markedness aims to capture and codify the fact that not all phonological elements are distributed equally (Rice 2007). Characteristics commonly attributed to unmarked units in the relevant literature are relative simplicity, maximal dispersion, more frequent occurrence, earlier acquisition, later loss in language deficit, and greater articulatory ease in production (Battison 1978, Sandler 1996, Johnston & Schembri 2007, Rice 2007). Although there is not universal agreement among linguists on the specific criteria for markedness, the notions of complexity and articulatory ease are central concepts which overlap in various interpretations.

Battison (1978) proposed an unmarked set of seven handshapes based on his research into American Sign Language (ASL). This set contains the handshapes that occur on the passive non-dominant hand when it does not share the handshape of the dominant hand. The characterisation of the handshapes as unmarked was further motivated by their frequency within ASL and other languages, early acquisition, articulatory and perceptual distinctness, and unrestricted combination with other elements of signs (Battison 1978). This set is shown in Figure 2. Of its seven members, six handshapes appear in the Maxakalí data, and all occur on both the dominant and non-dominant hands. These six handshapes account for 49.3% of the handshapes found on the dominant hand in all configurations in Maxakalí signing.

**Figure 2.** The handshapes in Battison's unmarked set

8. The authors' specific claim is that handshapes 1, 3, and 4 form the set of unmarked handshapes, and are maximally distinct from one another. Handshape 20 is also included, but the authors note it is unlikely to be contrastive in unmarked contexts.

Since Battison's work on ASL much more data on sign languages has become available, which is a contributing factor in subsequent disagreement on which handshapes are unmarked in different languages. A second set can be found in Rozelle's (2003) work, who suggests the unmarked set provided in Figure 3. This set is based on data from four unrelated sign languages, in which six handshapes account for 50% of all handshapes. All but handshape E occur in the Maxakalí data, and account for a similar 48.7% of handshapes on the dominant hand, and 62.5% of handshapes on the non-dominant hand.

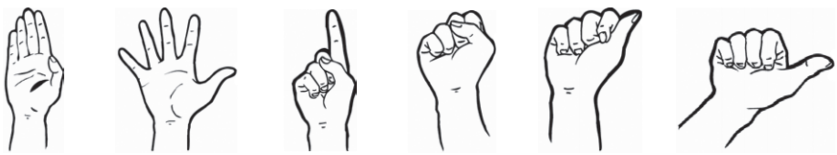


**Figure 3.** Rozelle's universal unmarked set (Rozelle 2003), henceforth labelled as A-F in the discussion below

## 2.4 Selected finger parameters in van der Hulst's (1996a) model

The handshapes in Figures 2 and 3 are interesting to consider in light of phonological approaches to generating a metric of the markedness of handshapes in terms of combinations of more primitive (e.g. based on primes) elements. Just as Dependency Phonology (Anderson & Ewen 1987) and related developments (e.g. Harris & Lindsey 1995) pursue decomposition of complex signs into combinations of simpler elements, van der Hulst (1996a) develops the following system. In parallel with |I,A,U| from Element Theory (see Backley 2011 for a canonical overview), whereby combinations such as |I>A| form /e/, |U>A| form /o/, and /I>U/ form [ü], van der Hulst (1996a) proposes the three basic Finger-Selecting Elements |All, Index, Pinky|.

In this system, |All| on its own constitutes handshapes A, B, D, E, and F in Figure 3. These are further distinguished by parameters governing whether the four selected fingers are adducted/abducted, closed/open, and on the distribution of the thumb. This theory, therefore, represents the primes as articulatory instructions: first, the appropriate fingers are selected from combinations among |All, Index, Pinky|, and are subsequently subject to further parametric specification of their configurations.

Handshape C in Rozelle's set includes |Index|. In other words, |Index| alone is just the index finger (visualisable as **…I** supposing the right hand is facing palm upward). Taking this further, |Pinky| alone is just the pinky (visualisable as **I…**), and |Index > Pinky| is the symbol found in ASL 'I love you' (visualisable as **I..I**), where the index and pinky are extended (the ring finger being too weak to extend in this position). Switching the order of scope to |Pinky > Index| yields the pinky and the index+middle fingers visualisable as **I.II**).

The additional combinations, however, deserve further comment. For example, |All > Index| is interpreted as 'all of the fingers *except* the index' (**III.** and perhaps these can be visualised as combinations of presence/absence of a visual percept). |All > Pinky| is interpreted as 'all of the fingers *except* the pinky' (**.III**). In these combinations therefore, | X > Y| is interpreted as For $\forall$ x $\in$ X and for y, y $\in$ Y, x is a Selected Finger, where x $\neq$ y. What about |Index > All|? This is argued to result in the Selection of the index *and* the middle finger, In these combinations therefore, | X > Y| is interpreted 'the Index plus some part of All', or more generally, as For x $\in$ X, $\exists$y, y $\in$ Y $\wedge$ y $\notin$ x, then x and y are Selected Fingers.

As the comparison of |All > Index| vs |Index > All| in comparison shows, therefore, there is a distinct mode of logical composition for each ordering of these elements. This stands in contrast to the 'addition of acoustic signatures' approach in Harris & Lindsey (1995) & Backley (2011), whereby |I >A| is /e/ and |A>I| is /ɛ/ and thereby these can be consistently interpreted in terms of which one imposes a greater modulation on the acoustic signature. The upshot of this discussion is that the model in van der Hulst (1996a) is arguably exactly the *type* of model one should pursue, but in its details it needs to be revisited, perhaps with a slightly different set of elements, and certainly with a re-examination of the consistent interpretation function for each of its combinations (and indeed, potentially a re-examination whether the thumb should be part of the same Finger Selection constituent within the representation). Nonetheless, the intuition that van der Hulst develops – that the unmarked sets of Battison & Rozelle and their relative frequency in terms of order of acquisition and distribution within a corpus should be captured by a model of handshape markedness, whether in terms of articulatory complexity, perceptual robustness, or both – is not only a desideratum towards which all models of sign language phonology should strive, but also an important way of confirming that Maxakalí sign, as incipient as it may be, still upholds universal sign language phonological tendencies.

## 2.5 Battison's (1978) Symmetry and Dominance conditions

Returning to Figure 1, Battison's unmarked set also plays an important role in his Dominance Condition, one of two conditions formulated to codify constraints on handshapes and their dispersion within ASL (Battison 1978). These conditions, stated in (1) and (2) below, reflect his conclusions. Rather than placing handshapes along a continuum akin to that in Section 2.3, Battison's conditions state which handshapes are allowed or disallowed in certain phonological environments, with relation to their markedness or complexity.

(1) **The Symmetry Condition**
  a. if both hands of a sign move independently during its articulation, then
  b. both hands must be specified for the same location, the same handshape, and the same movement (whether performed simultaneously or alternatingly).

(2) **The Dominance Condition**
  a. if the hands of a two-handed sign do not share the same specification for handshape (i.e. they are different), then
  b. one hand must be passive while the active hand articulates the movement, and
  c. the specification of the passive handshape is restricted to be one of a small set (those in Figure 1). (Adapted from Morgan & Mayberry 2012)

Neither of Battison's conditions are upheld throughout the Maxakalí data. Two examples of configurations that are inconsistent with both conditions are given in Figures 4 and 5. In the first case, the signer's right hand is repeatedly moved upwards and downwards in a chopping motion. Simultaneously, his left fist repeatedly rotates. In Figure 5 the signer's right hand undergoes repeated path movement along the x-axis,[9] whilst the left hand is again repeatedly rotated at the wrist. Both configurations fit criterion 1(a) because both hands move independently in each case. However, neither configuration follows the requirement in 1(b). In both cases the dominant and non-dominant hands are specified for the same location, but neither handshape nor movement features are similarly shared. Each configuration also meets the first criterion of the Dominance Condition since the dominant and non-dominant hands do not share the same handshape. As both hands are moving in both configurations, and additionally neither hand is acting upon the other, criterion (b) is not upheld. Handshapes of both hands in both cases are members of Battison's unmarked set, but criterion (c) is inapplicable since neither hand is 'passive', unless understood as merely meaning the non-dominant hand. In either interpretation of the word, the flagrant inconsistency with criteria 1(b) and 2(b) is sufficient evidence for Figures 4 and 5 being exceptions to Battison's conditions.

In their work on ABSL, Sandler et al. (2011) note that "while constraints on the form of a sign are not absent, they are not strictly enforced" (Sandler et al. 2011: 517). They claim that this is symptomatic of less established sign languages, and that such phonotactic constraints become more strictly enforced over time as the language becomes more discretely phonologically organised. Considering the status of Maxakalí signing as similarly emerging, this seems a plausible hypothesis to explain the various inconsistencies with the phonotactic constraints discussed

9. Further explanation of planes and types of movement can be found in Stoianov 2016.

in terms of Battison's (1978) Conditions. However, as we will see below, while the emerging system of Maxakalí sign may not strictly uphold Battison's conditions, it nonetheless shows a distribution of handshapes that conforms extremely well to the quantitative predictions of Ann's (2006) and Brentari's (1998) handshape complexity models.


**Figure 4.** Configurations inconsistent with Battison's conditions

**Figure 5.** Configurations inconsistent with Battison's conditions

## 2.6 Towards a quantitatively verifiable metric of ease of articulation

Ann (2006) provides a model for quantifying ease of articulation for handshapes, which will be useful to analyse the Maxakalí data. The benefit of such a model is that it isolates one important characteristic that is relevant to markedness and allows us to test the data against a continuum, rather than against a binary marked/unmarked distinction. This continuum could prove insightful given the previously discussed disagreement among linguists on what constitutes the unmarked set of handshapes.

Ann uses five criteria to assign a given handshape a numerical ranking of articulatory ease. Such a system will allow us to chart articulatory ease in relation to type frequency of occurrence. The notion of phonological markedness predicts that we should expect to find some correlation between markedness and frequency, as handshapes that occur more frequently should be easier to produce (Battison 1978, Greenberg 1966). Of course, it is worth noting that ease of articulation is only one factor, which is subject to influence from other linguistic and non-linguistic factors. For example, the culturally recognised emblematic significance of handshape 28 in American culture is a taboo recognised by the World Federation for the Deaf, affecting its frequency and usage within ASL (Schein & Stewart 2002).

The first of Ann's criteria is muscle opposition in configurations (MOC). This criterion targets the entire hand, and refers to which muscle groups are used to achieve various states of extension and flexion within handshapes, and whether said muscle groups work in opposition. The joints and bones of the hand can be seen in Figure 6, whilst the muscles that control their extension and flexion are given in Table 2. The possible combinations of engagement of said muscles in the fingers result in four possible handshape configurations along the continuum of extension. An example of each of these is given in Figure 7, and the muscles necessary for each are listed in Table 3.

**Table 2.** The function of muscles that control the hand as a whole (Ann 2006)

| Muscle | Function |
|---|---|
| *The extensor:* Digitorum communis | Extends fingers at the metacarpophalangeal joint |
| *The flexors:* Digitorum profundus | Flexes the fingers at the distal interphalangeal joint (DIP) |
| Digitorum superficialis | Flexes the fingers at the proximal interphalangeal joint (PIP) |
| *The intrinsics:* Lumbricals and interossei | Flex the fingers at the metacarpophalangeal joint and extend the fingers at the PIP-DIP joint |

**Table 3.** Muscles necessary in hand configurations (Ann 2006)

| Configuration | Extensors | Flexors | Intrinsics |
|---|---|---|---|
| Closed | not necessary | necessary | not necessary |
| Bent | not necessary | not necessary | necessary |
| Extended | necessary | not necessary | necessary |
| Curved | necessary | necessary | not necessary |

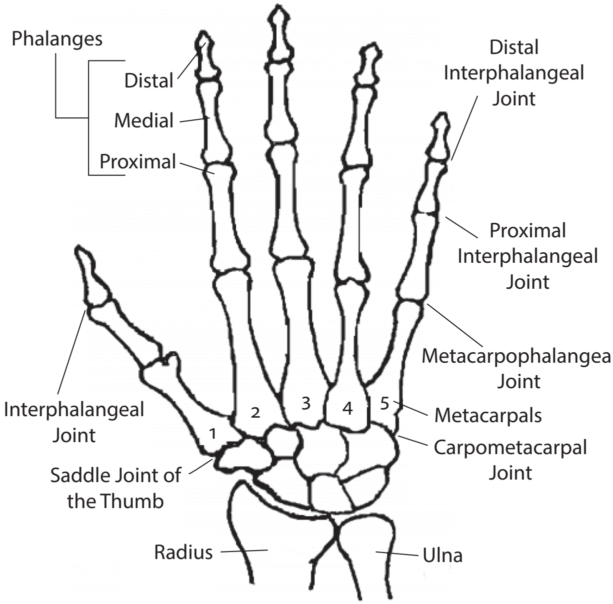



**Figure 6.** Joints of the hand (Ann 2006)

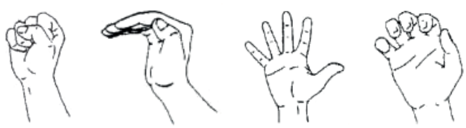


**Figure 7.** Handshapes with fingers closed, bent, extended, and curved

Table 3 demonstrates that handshapes wherein fingers are closed or bent only require one group of muscles to produce, whereas extended and curved handshapes require two. Ann argues that curved handshapes are the most difficult to produce, since they employ the extensors and the flexors, which maximally oppose each other. Since physical neutrality in the hands results in a tendency towards flexion, and infants are born with flexed muscles and only thereafter acquire full extension (Boyes-Braem 1990), departures from flexion are taken to be articulatorily more difficult than extension. For this reason, closed handshapes are considered the easiest category to produce.

To calculate ease of articulation, handshapes are given a value for this MOC criterion relating to such departures from flexion.[10] Closed handshapes are given a 0, as they are maximally flexed. Bent handshapes are given a 1 as they are somewhat flexed. Extended handshapes are given a 2 because they employ two groups of muscles which somewhat oppose one another. Finally, curved handshapes are given a 3 as the groups of muscles necessary to produce them are in maximum opposition.

The second criterion is the support for extension (SE), which targets groups of fingers as opposed to the entire hand. It is concerned with whether extended fingers are able to extend independently, or whether they have adequate support to extend if not. SE only applies to those handshapes in which there is more than one group of fingers, i.e. in which the fingers are not all doing the same thing. The thumb, index finger, and pinky finger are able to extend independently, as they possess independent extensors (Ann 2006), whilst the middle and ring fingers do not. The middle and ring fingers can extend "(a) with an immediately adjacent [extended] independent extensor finger or (b) with a group of extended fingers in which each member is adjacent to at least one other member of the group and one of the members has an independent extensor" (Ann 2006: 94). The SE criterion applies to the most extended group of fingers in a handshape. If this group has an independent extensor or falls under the two aforementioned contexts of supported extension, it is given a 0 value for the SE criterion. If the fingers have no independent extensor or supported extension, the handshape is given a 1 value.

The next criterion (support for flexion, or SF) determines whether the middle, ring, and pinky fingers are all involved in the same act of flexion or extension. The effects of having a singular muscle head affecting this group of fingers, alongside other confines of the skeletal composition of the fingers means that it is more difficult for these fingers to behave independently than collectively.[11] If the middle, ring, and pinky fingers are all simultaneously flexed or extended, the handshape is given a 0 value for SF. The handshape is given a 1 if this is not the case. Like the SE criterion, it is easily observable that SF is only applicable to handshapes with more than one group of fingers, since it is logically necessary that all the fingers are behaving identically in a one-group handshape.

10. If all the fingers in a handshape are configured identically, the MOC applies to the entire hand. If only some of the fingers are extended, it applies to the most flexed finger(s). If some fingers are closed, the MOC applies to the least flexed finger(s) (Ann 2006).

11. Further evidence for targeting this group of fingers is given in Chapter 3 of Ann (2006).

The tendency to oppose the thumb (TOT) criterion targets the smaller subset of opposed handshapes.[12] Handshape 21 in the Maxakalí inventory is an example of one such handshape. The value assigned to each handshape for this criterion is determined by the opposed finger's muscular disposition to oppose the thumb. For the pinky finger to oppose the thumb, a specific muscle must be used to place it in opposition. Research also suggests the ring finger opposes the thumb with some articulatory difficulty and effort (Ann 2006). This is not the case for the index or middle fingers. Their joint structure and position on the hand means that the thumb can oppose the index and middle fingers with greater ease (Mandel 1981). With this in mind, Ann assigns a 0 value to opposed handshapes in which only the index or middle fingers oppose the thumb. Other opposed handshapes are given a value of 1 for TOT.

The final criterion is the tendency to spread (TS), and is applicable to curved and extended handshapes. Ann's reasoning for this is that fingers will naturally be adducted in bent and closed handshapes. Conversely, she notes, abduction transpires naturally in curved and extended handshapes,[13] and extra muscle engagement is needed to adduce the fingers in such handshapes. Again it is assumed that any departure from physical neutrality will result in a more difficult to produce handshape. If the handshape in question is both extended or curved, and adducted, its TS value is 1. If a curved or extended handshape has abducted fingers, its TS value is 0.

To calculate the overall ease of articulation score, the equation is as follows. Firstly, the SE and SF values are added together; according to Ann they "contribute equally and in the same way to the difficulty of a handshape" (Ann 2006: 104). This is then multiplied by the handshape's MOC value, as muscle opposition is a more significant contributory factor in ease of articulation. The TOT and TS values are then added to this figure, and the resulting number is the overall score. Table 4 shows the values and scores for each handshape found in Maxakalí data, and Figure 8 displays these scores plotted against their type frequency of occurrence, with the legend of handshape scores given in the top right corner.

12. Ann's definition of opposed is "when either the pad [of a finger/fingers] is touching the pad of the thumb or the tip is touching the thumb tip." (Ann 2006: 78).

13. Or when the digits are extended at the metacarpophalangeal joint, more specifically. As Table 3 demonstrates, this only occurs within curved and extended handshapes.

**Table 4.** Articulatory ease calculations and scores

| Handshape | MOC | SE | SF | TOT | TS | Score |
|---|---|---|---|---|---|---|
| 1 | 2 | – | – | – | 0 | 0 |
| 2 | 2 | – | – | – | 1 | 1 |
| 3 | 2 | 0 | 0 | – | – | 0 |
| 4 | 0 | – | – | – | – | 0 |
| 5 | 1 or 3[14] | – | – | – | – | 0 |
| 6 | 2 | – | – | – | 1 | 1 |
| 7 | 2 | 0 | 0 | – | – | 0 |
| 8 | 2 | 0 | 1 | – | 0 | 2 |
| 9 | 1 | – | – | 0 | – | 0 |
| 10 | 2 | 0 | 1 | – | 0 | 2 |
| 11 | 3 | 0 | 0 | – | – | 0 |
| 12 | 3 | 0 | 0 | – | – | 0 |
| 13 | 1 | 0 | 0 | 0 | – | 0 |
| 14 | 2 | – | – | – | – | 0 |
| 15 | 3 | 0 | 0 | 0 | – | 0 |
| 16 | 1 | – | – | – | – | 0 |
| 17 | 1 or 3 | – | – | – | – | 0 |
| 18 | 2 | 0 | 1 | – | 1 | 3 |
| 19 | 3 | 0 | 1 | – | 0 | 3 |
| 20 | 3 | – | – | 1 | 1 | 2 |
| 21 | 3[15] | 0 | 0 | 0 | 0 | 0 |
| 22 | 3 | 0 | 1 | 0 | 0 | 3 |
| 23 | 2 | – | – | – | 1 | 1 |
| 24 | 1 | 0 | 0 | – | – | 0 |
| 25 | 2 | 0 | 1 | – | 1 | 3 |
| 26 | 2 | – | – | – | 0 | 0 |
| 27 | 2 | 0 | 1 | – | 0 | 2 |
| 28 | 2 | 1 | 1 | – | – | 4 |
| 29 | 1 | 1 | 1 | – | 1 | 3 |
| 30 | 1 | 0 | 1 | 0 | 1 | 2 |

14. Both handshape 5 and handshape 17 could arguably be considered as bent or curved, since both the extensor and flexor muscles are somewhat flexed in production of both handshapes. However, this is not of concern as either assignment would not change the overall ease of articulation score for either handshape.

15. For handshapes 21 and 22, the MOC has been applied to the opposed (curved) fingers. Usually Ann's conditions for applying the MOC to these fingers would require the other fingers to be fully extended, but since Ann specifically notes that she does not consider opposed handshapes to be closed (Ann 2006: 103), this rules out the possibility of applying the MOC to the other non-opposed fingers.

Table 4. (*continued*)

| Handshape | MOC | SE | SF | TOT | TS | Score |
|---|---|---|---|---|---|---|
| 31 | 3 | – | – | – | 0 | 0 |
| 32 | 3 | – | – | – | 0 | 0 |
| 33 | 2 | 0 | 1 | – | – | 2 |
| 34 | 2 | 0 | 1 | – | 0 | 2 |
| 35 | 3 | 0 | 0 | 0 | 1 | 1 |
| 36 | 2 | 0 | 1 | – | – | 2 |

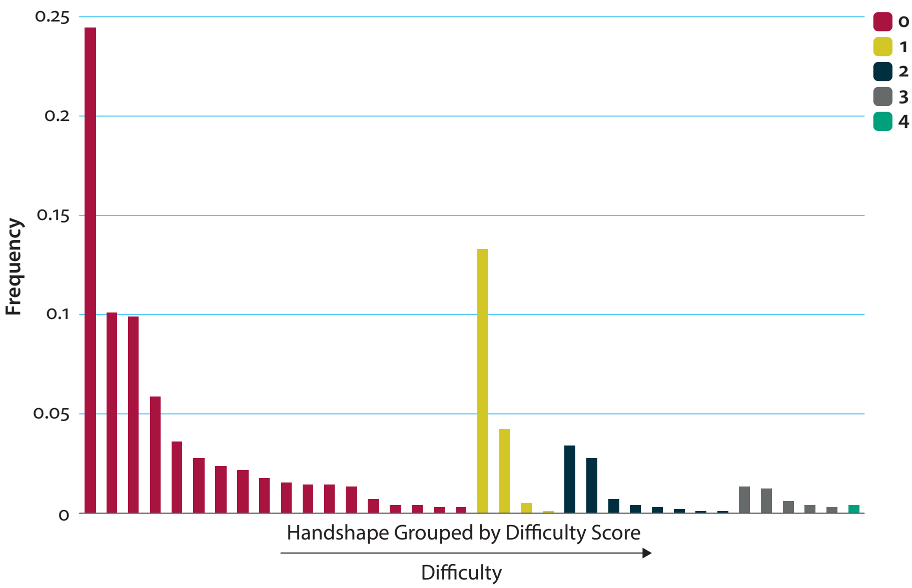



**Figure 8.** Handshape frequency grouped by handshape difficulty score

It is immediately obvious that 0 was the most common score, meaning that handshapes that are easier to articulate are more populous in the Maxakalí inventory. 50% of handshapes in the inventory had a score of 0. This is consistent with ideas about unmarked structures and complexity outlined in previous subsections, insofar as ease of articulation and ubiquity go hand in hand. If we compare these scores with the dispersion of handshapes on the non-dominant hand in Table 1, we can observe that most handshapes which only occurred on the non-dominant hand as a copy did not generally receive low difficulty scores. Only two had a score of 0 out of the seven handshapes which form this group.

The principles of markedness and ease of articulation predict that articulatorily difficult handshapes (as labelled by Ann's model) that are also infrequent in other sign language inventories should not occur in the Maxakalí data – yet they occasionally do. Sandler et al. (2011) discuss this issue with regards to ABSL, and conclude that such handshapes "occur randomly as signers seek to create visual images of items for which they have no conventionalized sign" (Sandler 2011: 526). The authors discuss specific handshapes as examples of this phenomenon; crosslinguistically uncommon handshapes appearing in emerging sign systems. Handshape 22 is one such example that occurs in both ABSL and Maxakalí inventory, though they share many more marked handshapes. Data from established sign languages also corroborates this theory. A comparative study of ASL signs from 1913 onwards demonstrates a shift away from iconicity toward arbitrariness in signs (Frishberg 1975). This has had an impact on the complexity of handshapes, involving a tendency away from body-articulated signs, and towards an increased symmetry in two-handed signs. More generally, increasing arbitrariness of signs correlated with a decline in unconstrained form and behaviour of phonological elements. It is clear how a high degree of iconicity may lead to more complex signs. Maxakalí system appears to be no exception.

### 2.7 Brentari's (1998) handshape complexity model

An alternative measure of handshape complexity can be adapted from Brentari (1998). Under her account of the Prosodic Model, the features of the articulators with regards to handshape are hierarchically structured. A representation of this structure is provided below in Figure 9.[16]

In further work Brentari has used such structuring as a measure of handshape complexity (Brentari et al. 2016), by analysing the number of branches and features within the representation of each handshape. For the Maxakalí data, the complexity score of each handshape was calculated by adding the number of branches to the number of additional (assuming each branch has a terminal node) features within each handshape's representation. Examples of two handshapes and their representations are given in Figures 10 & 11. The handshape in Figure 10 has a score of 7 as it contains 6 branches and the one additional feature of [flexed] under the joints node. The handshape in Figure 11 is identical apart from the additional feature of [unopposed] under the thumb node, resulting in a higher score of 8.

16. Motivation for such structuring is given in Chapter 3 of Brentari (1998).

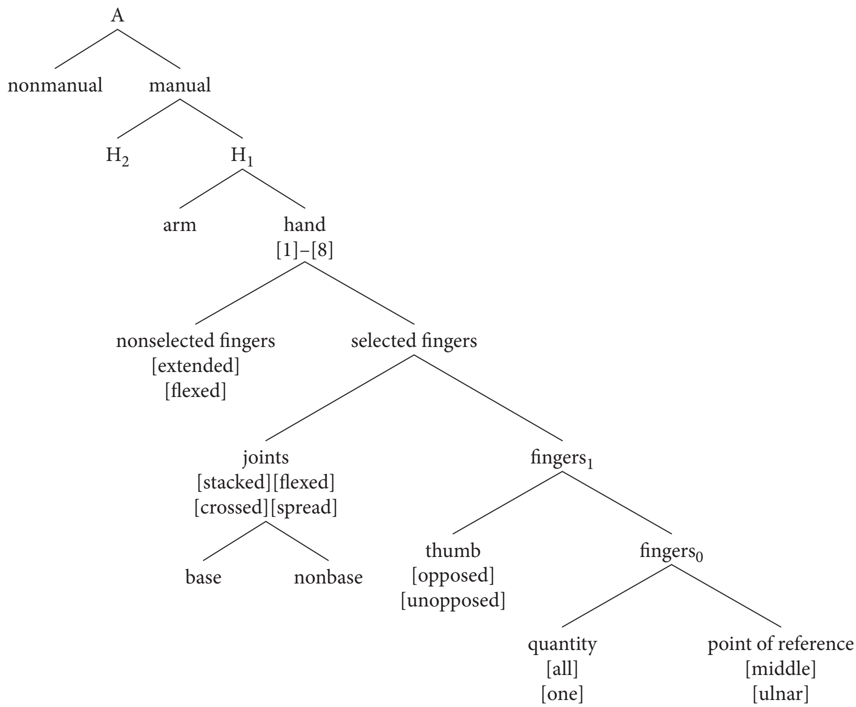
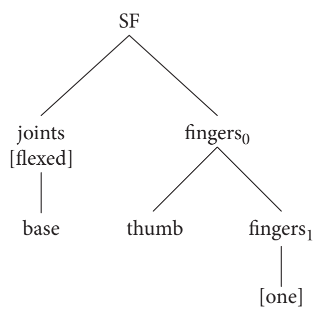
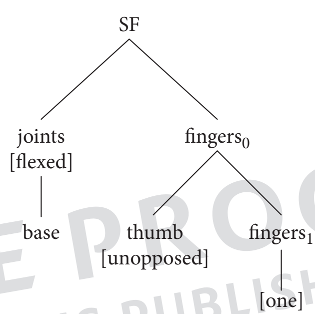



**Figure 9.** Articulator feature hierarchy in the Prosodic Model (Brentari 1998)




**Figures 10.** Representations of handshapes 13 and 24




**Figures 11.** Representations of handshapes 13 and 24

In the subsequent analysis, handshapes with more than one group of selected fingers[17] were calculated by adding the number of branches and additional features for each group of fingers, minus the features that the groups shared. The results are displayed in Table 5 and Figure 12.

**Table 5.** Handshape complexity scores using the Prosodic Model structure

| Handshape number | Number of branches | Extra features | Total |
|---|---|---|---|
| 1 | 5 | 1 | **6** |
| 2 | 3 | 0 | **3** |
| 3 | 3 | 0 | **3** |
| 4 | 1 | 1 | **2** |
| 5 | 7 | 2 | **9** |
| 6 | 4 | 0 | **4** |
| 7 | 4 | 0 | **4** |
| 8 | 4 | 2 | **6** |
| 9 | 6 | 0 | **6** |
| 10 | 5 | 2 | **7** |
| 11 | 6 | 1 | **7** |
| 12 | 7 | 2 | **9** |
| 13 | 6 | 1 | **7** |
| 14 | 3 | 0 | **3** |
| 15 | 7 | 1 | **8** |
| 16 | 5 | 1 | **6** |
| 17 | 7 | 2 | **9** |
| 18 | 3 | 1 | **4** |
| 19 | 6 | 3 | **9** |
| 20 | 7 | 1 | **8** |
| 21 | 7 | 3 | **10** |
| 22 | 9 | 3 | **12** |
| 23 | 7 | 2 | **9** |
| 24 | 6 | 2 | **8** |
| 25 | 4 | 1 | **5** |
| 26 | 4 | 1 | **5** |
| 27 | 4 | 2 | **6** |
| 28 | 4 | 0 | **4** |
| 29 | 8 | 2 | **10** |
| 30 | 6 | 2 | **7** |
| 31 | 6 | 1 | **7** |
| 32 | 7 | 2 | **9** |

17. This analysis follows the distinction between *primary selected fingers*, *secondary selected fingers*, and *unselected fingers* as outlined by Brentari (2011).

Table 5. (*continued*)

| Handshape number | Number of branches | Extra features | Total |
|---|---|---|---|
| 33 | 5 | 0 | **5** |
| 34 | 5 | 2 | **7** |
| 35 | 9 | 2 | **11** |
| **36** | **4** | **0** | **4** |

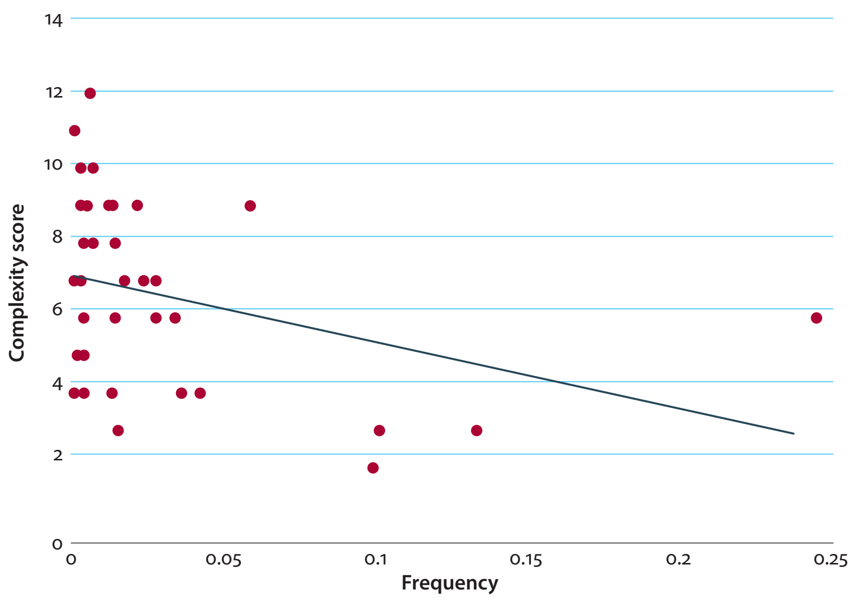



**Figure 12.** Complexity scores and type frequencies of Maxakalí handshapes

The Maxakalí data is also consistent with more specific implicational proposals concerning ease of articulation and dispersion. Woodward (1987) compiled data from ten sign languages and compared the dispersion of opposed handshapes. He proposed a hierarchy of markedness among single-finger opposed handshapes (i.e. excluding those such as handshape 9), based on the idea that "if a handshape can occur in a more marked location, it tends to occur also in a less marked location" (Woodward 1987: 379). The proposed hierarchy with relation to features is displayed in Table 6.

At the top of this hierarchy is index finger opposed handshapes. These, Woodward claims, do not sit in an implicational relationship with any other opposed handshapes as they are the least complex. In short, these appeared in all the sign languages from which he collected data, but they do not imply the existence of any other single-finger opposed handshapes, as they are the least articulatorily complex of the four and they lack both the central and ulnar features. Middle finger opposed handshapes are the next most complex because they possess a feature (central) where the index opposed handshapes lack any, and because of the middle finger's location relative to the thumb (Mandel 1981). Woodward claims the presence of middle finger opposed handshapes implies the existence of index finger opposed handshapes – a prediction that is upheld by the Maxakalí handshape inventory as it has both. The status of middle finger opposed handshapes as less marked than pinky opposed handshapes is explained by Woodward's classification of the ulnar feature as more marked than the central feature. This is substantiated by Ann's observations on the extra muscles needed to produce pinky opposed handshapes. Again, he notes that pinky opposed handshapes imply the existence of middle, and therefore index opposed handshapes within the same inventory. Lastly he classes ring finger opposed handshapes as the most marked, and predicts that they imply the presence of the rest. The Maxakalí data lacks any ring or pinky opposed handshapes, and since it has only middle and index finger opposed handshapes, is consistent with all the implicational relationships proposed by Woodward.

**Table 6.** Features on 1-finger contact handshapes (Woodward 1987)

| Index | Middle | Pinky | Ring |
|---|---|---|---|
| -ulnar | -ulnar | +ulnar | +ulnar |
| -central | +central | -central | +central |

## 2.8 Perceptual distinctness

A subset of handshapes found in the Maxakalí data can also be considered in light of research into perceptual distinctness. Of the handshapes that occur in the Maxakalí data, Lane et al. (1980) found that the handshapes in Figure 13 were the least frequently confused when native signers observed signing in a visually noisy environment. In the Maxakalí data they occurred with frequencies of 0.237, 0.041, and 0.007 respectively. They were also all found to occur on the non-dominant hand, aligning with expectations from theories of markedness which would predict less marked and therefore perceptually more distinct handshapes to be produced with the non-dominant hand. The full results of the 20 handshapes tested and their confusion frequencies can be seen in Figure 14. The researchers found finger extension to be the most critical cue for perceptual distinction in the trial that more closely resembled natural signing (i.e. with varying orientation and movement). In the trial where the orientation of the palm was always towards the participant, handshapes having more salient palm visibility was the critical feature. The results of the former trial are of course more relevant to natural sign languages.

**Figure 13.** Handshapes from the Maxakalí data found to be the least confused in Lane et al. (1980)

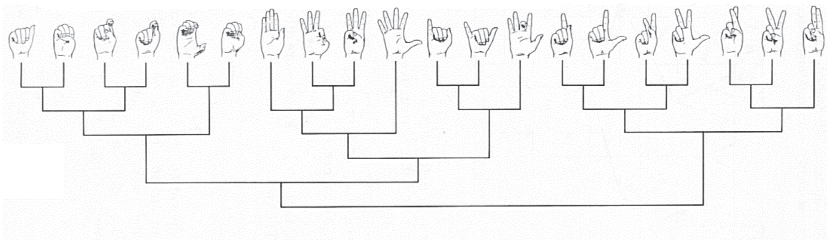


**Figure 14.** Clusters of 20 Hand Configurations in ASL, based on their confusion frequencies when identified in visual noise (adapted from Lane et al. 1980)

A separate study into perceptual distinctness (Stungis 1981) found the handshapes in Figure 15 to be the most commonly confused out of the set of those that occur in the Maxakalí data. These are all found on both the dominant and non-dominant hands in the Maxakalí system. Stungis proposed a model of handshape similarity, suggesting that the two most important features in perceptual distinction are that of finger extension and uniform breadth.[18] The handshapes that were the most commonly confused can be seen to be [+extended] but [−uniform breadth].

**Figure 15.** Handshapes from NGT (among those that were also present in the Maxakalí data) found to be the most frequently confused in Stungis 1981

18. A feature used by Stungis (1981) specifying the equal distance between all fingers. If a handshape is [+uniform breadth], all fingers are an equal distance apart, e.g. handshapes 1 and 6 from the Maxakalí data

## 3. The non-dominant hand

The hands form the main two articulators in sign languages, and are in a dominant/non-dominant relationship. The non-dominant hand is apparatus that is specific to the modality of sign languages. Sandler refers to it as "a dual articulator with no spoken language equivalent" (Sandler 2012: 162). Handshape features of the non-dominant hand occasionally spread onto neighbouring signs, an example from NGT (Sign Language of the Netherlands) is given in Figure 16. This has been compared to feature spreading within segmental phonology, however it is all the features of the non-dominant hand that are prolonged, as opposed to individual segmental features (Crasborn 2011). Crasborn claims that it is not clear which node the features of the non-dominant hand spread onto, and that whilst this spreading is evidence for varying levels of prosodic organisation[19] much like in spoken languages, the non-dominant hand has no analogous counterpart in spoken languages. Similarly, Brentari notes that the non-dominant hand has been compared to coda or word-level appendices in terms of prosodic structure (Brentari 1998: 22), but proposes that this is not comparable since these constituents are expressed simultaneously with the core syllable in signing, and sequentially in spoken languages.

**Figure 16.** The non-dominant hand holds the two-handed item TO-SIGN, while the dominant hand continues to sign FEEL AT-HOME MOTHER^TONGUE PALM-UP. 'Signing feels like you're using your mother tongue' (adapted from Crasborn 2011)

19. The Prosodic Word, the Phonological Phrase, the Intonational Phrase etc. (Nespor and Vogel 1986)

All attested sign languages have both one-handed and two-handed signs (Crasborn 2011), and occasionally this distinction can form (near-)minimal pairs (van der Hulst 1996b).[20] Signers will have different dominant hands depending on handedness, and other potentially situational factors. Whilst hand preference is a characteristic of the signer, dominance is a property of the signing itself (Crasborn 2011). Features are specified for the dominant and non-dominant hands, as opposed to the left or right hands; in no sign languages studied to date are one-handed signs contrastive at the level of left-right handedness (van der Hulst 1996b, Meurant et al. 2013). The arbitrary nature of handedness is corroborated by reports from native signers, stating that they often cannot recall whether a new signer they have met was right-handed or left-handed (Frishberg 1985). The fact that phonological processes such as Weak Drop, Weak Freeze, regressive assimilation, perseveration, and deletion all affect the non-dominant hand serves as evidence for the dominant/non-dominant relationship of the hands, and that they operate on separate tiers (Corina & Sandler 1993).

However, the functions of the non-dominant hand are not as varied as theoretically and anatomically possible. One could imagine signers conveying distinct but simultaneous information with each hand. The limits of human motor skills render this highly demanding to produce. In addition, our visual and cognitive abilities are not fit for the processing of two simultaneous yet entirely independent movements (Crasborn 2011: 224). There is consensus among sign linguists that the non-dominant hand generally functions either as a copy of the dominant hand, or as a place of articulation (Blevins 1993, Sandler 1993, Crasborn 2011). Nonetheless, there are some interesting exceptions to this. Classifier constructions are one cross-linguistic example, wherein each hand can represent a different morpheme. Additionally, in Quebec Sign Language it has been observed that the dominant and non-dominant hands can sometimes co-articulate separate signs simultaneously (Miller 1994). Exceptions can also arise through stylistic conventions, and have been found in some ASL conversation (Battison 1974) and poetry (Brentari 1998). Otherwise, the functions of the non-dominant hand are very restricted.

Table 7 provides information on handshapes which occurred on the non-dominant hand in Maxakalí signing. Frequency is calculated from the set of two-handed handshapes only. 53% of the configurations in the data were two-handed, which is a rate similar to ASL in which 60% of signs are two-handed (Sandler et al. 2011) Handshape difficulty is calculated using Ann's (2006) ease of articulation model. The fourth column displays the number of occurrences of each handshape

20. See van der Hulst (1996b) for examples from NGT.

on the non-dominant hand, excluding instances in which the non-dominant hand was a copy of the dominant hand. Figure 17 provides a visual representation of the frequency of handshapes with reference to their difficulty score.

**Table 7.** Handshapes on the non-dominant hand

| Handshape | Occurrences on non-dominant hand | Frequency | Occurrences excluding copies | Handshape difficulty |
|---|---|---|---|---|
| 1 | 149 | 0.313 | 31 | 0 |
| 2 | 64 | 0.134 | 13 | 1 |
| 3 | 36 | 0.075 | 11 | 0 |
| 4 | 82 | 0.172 | 26 | 0 |
| 5 | 23 | 0.048 | 3 | 0 |
| 6 | 25 | 0.052 | 6 | 1 |
| 7 | 10 | 0.021 | 1 | 0 |
| 8 | 7 | 0.014 | 3 | 2 |
| 9 | 4 | 0.008 | 1 | 0 |
| 10 | 3 | 0.006 | 0 | 2 |
| 11 | 10 | 0.021 | 2 | 0 |
| 12 | 14 | 0.029 | 2 | 0 |
| 13 | 1 | 0.002 | 0 | 0 |
| 14 | 5 | 0.010 | 3 | 0 |
| 15 | 3 | 0.006 | 1 | 0 |
| 16 | 5 | 0.010 | 1 | 0 |
| 17 | 13 | 0.027 | 6 | 0 |
| 18 | 3 | 0.006 | 0 | 3 |
| 19 | 2 | 0.004 | 0 | 3 |
| 20 | 6 | 0.012 | 4 | 2 |
| 21 | 6 | 0.012 | 2 | 0 |
| 23 | 1 | 0.002 | 0 | 1 |
| 26 | 2 | 0.004 | 2 | 0 |
| 29 | 1 | 0.002 | 0 | 3 |
| 32 | 1 | 0.002 | 0 | 0 |

As Table 7 shows, handshapes with an articulatory difficulty value of 3 are only found on the non-dominant hand when they are a copy of the dominant hand. Battison's unmarked handshape set accounts for 74.2% of handshapes found on the non-dominant hand. Excluding instances wherein the non-dominant hand is a copy of the dominant hand, Battison's unmarked set accounts for 71.1% of the non-dominant handshapes. Iconicity functioning as a placeholder for arbitrariness in emerging sign systems is again likely to be a factor in the high number of marked handshapes appearing on the non-dominant hand when it is not a copy of the other.

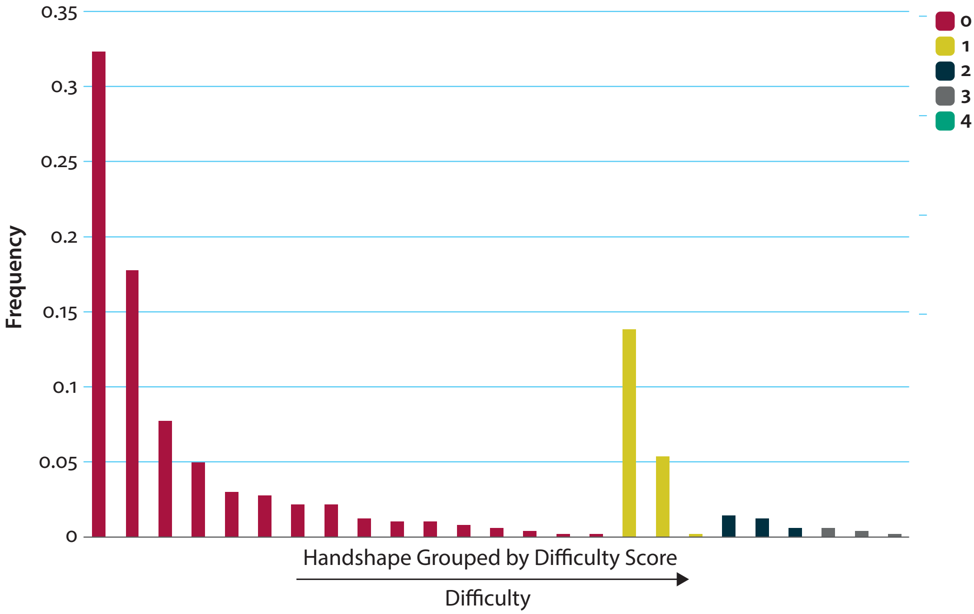


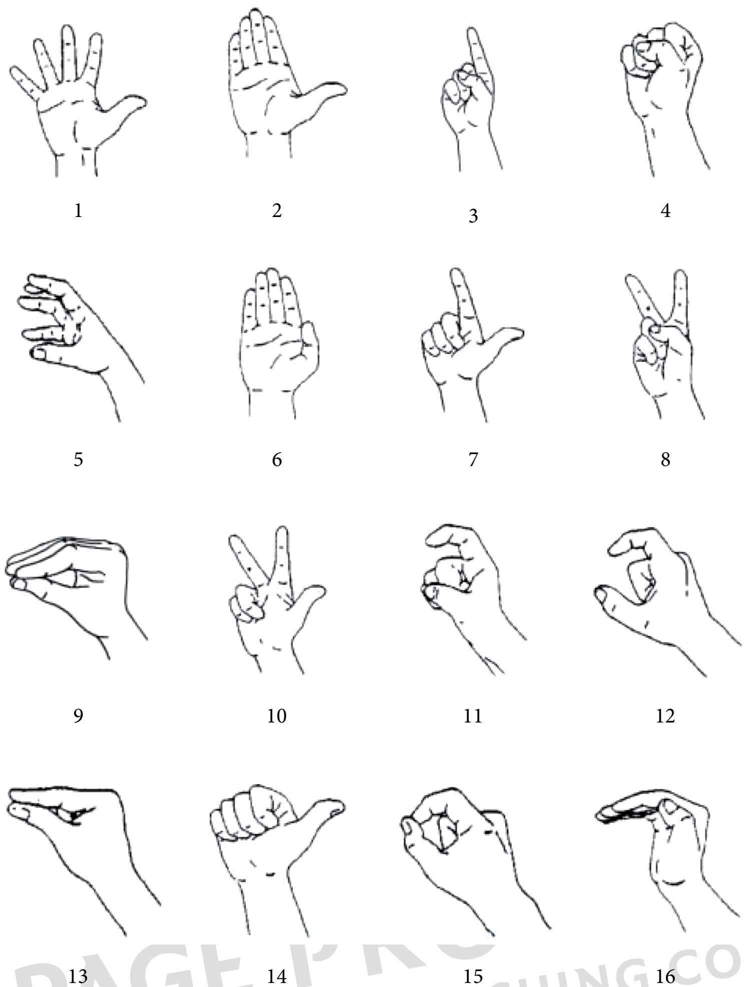

**Figure 17.** Handshapes of the non-dominant hand grouped by difficulty score

## 4. Conclusion

The descriptive aim of this paper is to detail the complexity and dispersion of phonological features in the Maxakalí signing system. We have seen that the system favours unmarked handshapes to a similar degree found in other sign languages in terms of type frequency, but that complex or marked handshapes are also present in the inventory. Like many other aspects of its phonological system, it is likely that this can be explained by its emergent status to an extent. The tendency of less established sign languages to be more iconic affects their inventory of handshapes, location, movement, and non-manual feature dispersion, as well as their adherence to (or lack of) certain phonotactic constraints. This hypothesis is compatible with the data analysed in this paper. At the same time, the overall adherence of the distribution of Maxakalí handshapes to crosslinguistic phonological tendencies of unmarkedness based on articulatory complexity and perceptual distinctness vindicate its status as a signing system, however incipient it may be.

Any conclusions drawn from a preliminary analysis naturally have their limitations. Larger scale lexical elicitation research could investigate the existence of minimal pairs and more accurately establish variation among signers for the same lexemes. Both of these would be beneficial in determining the extent to which the phonology of Maxakalí signing is discretely organised. The observable features available to us from our preliminary analysis suggest that Maxakalí signing exhibits many of the characteristics we may have expected in a young, emerging sign system. We hope to see further investigation into Maxakalí signing and its users. In the meantime, this paper provides a description of the sub-lexical building blocks of handshape within an emerging system and their distribution within it, and is therefore a useful step towards the documentation of often overlooked and under-described signing systems and their relevance for models of phonological complexity.

**Appendix 1.** Maxakalí Handshape Inventory

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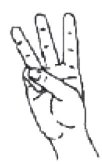
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## Acknowledgements

The authors would like to thank Julien Bismuth, Gustavo Godoy, Mário Coelho da Silva, Wendy Sandler, and Bencie Woll, and to situate the importance of John Harris' inspiration in thinking about handshape phonology in terms of distinctive visual signatures.

## References

Anderson, John M. & Colin J. Ewen. 1987. *Principles of Dependency Phonology* (Cambridge Studies in Linguistics 47). Cambridge: Cambridge University Press. doi:10.1017/CBO9780511753442

Ann, J. 2006. *Frequency of Occurrence and Ease of Articulation of Sign Language Handshapes: The Taiwanese Example*. Washington, DC: Gallaudet University Press.

Backley, P. 2011. *An Introduction to Element Theory*. Edinburgh: Edinburgh University Press.

Battison, R. 1974. Phonological deletion in American Sign Language. *Sign Language Studies* 5: 5–19.

Battison, R. 1978. *Lexical Borrowing in American Sign Language*. Silver Spring, MD: Linstok Press.

Blevins, J. 1993. The nature of constraints on the nondominant hand in ASL. *Phonetics and Phonology* 3: 43–62.

Boyes-Braem, P. 1990. Acquisition of the handshape in American Sign Language: A preliminary analysis. In V. Volterra & C.J. Erting (eds.), (1994) *From Gesture to Language in Hearing and Deaf Children*, 107–127. Washington, DC: Gallaudet University Press. doi:10.1007/978-3-642-74859-2_10

Brentari, D. 1998. *A Prosodic Model of Sign Language Phonology*. Cambridge, MA: MIT Press.

Brentari, D. 2011. Sign language phonology. In J. Goldsmith, J. Riggle, & A. Yu (eds.), *The Handbook of Phonological Theory*, 2nd edn, 691–721. UK: Wiley-Blackwell. doi:10.1002/9781444343069.ch21

Brentari, D., M. Coppola, P.W. Cho & A. Senghas. 2016. Handshape complexity as a precursor to phonology: Variation, emergence, and acquisition. *Language Acquisition*, accepted for publication. doi:10.1080/10489223.2016.1187614

Brentari, D, M. Coppola, L. Mazzoni & S. Goldin-Meadow. 2012. When does a system become phonological? Handshape production in gesturers, signers, and homesigners. *Natural Language & Linguistic Theory* 30(1): 1–31. doi:10.1007/s11049-011-9145-1

Corina, D., & W. Sandler. 1993. On the nature of phonological structure in sign language. *Phonology* 10(2), 165–207. doi:10.1017/S0952675700000038

Crasborn, O. 2011. The other hand in Sign Language Phonology. In M. van Oostendorp, C. Ewen, E. Hume & K. Rice (eds.), (2011) *The Blackwell Companion to Phonology*, 223–240. UK: Blackwell Publishing.

de Vos, C. 2007, August. Kata Kolok: A village-based Sign Language of Northern Bali. In *International Symposium On the Languages of Java*. Semarang, Java, Indonesia.

Frishberg, N. 1975. Arbitrariness and iconicity: Historical change in American Sign Language. *Language* 51: 696–719. doi:10.2307/412894

Frishberg, N. 1985. Dominance relations and discourse structures. In W. Stokoe & V. Volterra (eds.), *SLR '83: Proceedings of the 3rd International Symposium on Sign Language Research*, 79–90. Rome: Consiglo Nazionale delle Ricerche.

Greenberg, J. 1966. *Language Universals: With Special Reference to Feature Hierarchies*. Berlin: Mouton de Gruyter

Harris, John & Geoff Lindsey. 1995. The elements of phonological representation. In Jacques Durand & Francis Katamba (eds.), *Frontiers of Phonology*, 34–79. Harlow, Essex: Longman.

Hulst, H.G. van der. 1996a. Acquisitional evidence for the phonological composition of handshape. In C. Koster & F. Wijnen (eds.), (1985) *Proceedings of Gala*, 39–56.

Hulst, H.G. van der. 1996b. On the other hand. *Lingua: International Review of General Linguistics* 98(1–3): 121–143. doi:10.1016/0024-3841(95)00035-6

Johnston, T. & A. Schembri. 2007. *Australian Sign Language: An Introduction to Sign Language Linguistics*. UK: Cambridge University Press. doi:10.1017/CBO9780511607479

Kakumasu, J. 1968. Urubu Sign Language. *International Journal of American Linguistics* 34: 275–281. doi:10.1086/465027

Kisch, S. 2012. Demarcating generations of signers in the dynamic sociolinguistic landscape of a shared sign-language: The case of the Al-Sayyid Bedouin. In U. Zeshan & C. de Vos (eds.), (2012) *Sign Languages in Village Communities*, 87–125. Boston, MA: Mouton de Gruyter. doi:10.1515/9781614511496.87

Klima, E. & U. Bellugi. 1979. *The Signs of Language*. Cambridge: Harvard University Press.

Lane, H., P. Boyes-Braem & U. Bellugi. 1980. A featural analysis of handshapes. In E. Klima & U. Bellugi (eds.), (1980) *The Signs of Language*, 164–180. Cambridge, MA: Harvard University Press.

Liljencrants, J. & B. Lindblom. 1972. Numerical simulation of vowel quality systems: The role of perceptual contrast. *Language* 48(4): 839–862. doi:10.2307/411991

Mandel, M.A. 1981. *Phonotactics and Morphophonology in ASL*. Ph.D. dissertation, Department of Linguistics, University of California, Berkeley.

Matthews, P.H. 2014. *The Oxford Concise Dictionary of Linguistics*. Oxford, UK: Oxford University Press.

McGregor, W. 2015. *Linguistics: An Introduction*. London, UK: Bloomsbury Publishing Plc.

Meurant, L., A. Sinte, M. van Herreweghe & M. Vermeerbergen (eds.). 2013. *Sign Language Research, Uses and Practices: Crossing Views on Theoretical and Applied Sign Language Linguistics*. Nijmegen, The Netherlands: Mouton de Gruyter. doi:10.1515/9781614511472

Morgan, H. & R. Mayberry. 2012. Complexity in two-handed signs in Kenyan Sign Language. *Sign Language Linguistics* 15(1): 147–174. doi:10.1075/sll.15.1.07mor

Miller, C. 1994. Simultaneous constructions in Quebec Sign Language. In M. Brennan & G. Turner (eds.), (1994) *Word-Order Issues in Sign Language*, 89–112. Durham, NC: ISLA.

Nespor, M. & I. Vogel. 1986. *Prosodic Phonology*. Dordrecht: Foris.

Prillwitz, S., R. Leven, H. Zienert, T. Hanke & J. Henning. 1989. HamNoSys, version 2.0; Hamburg Notation System for Sign Languages: An introductory guide. *International Studies on Sign Language and Communication of the Deaf 5*. Hamburg: Signum.

Rice, K. 2007. Markedness in phonology. In P. De Lacy (eds.), (2007) *The Cambridge Handbook of Phonology*, 79–97. Cambridge, UK: Cambridge University Press. doi:10.1017/CBO9780511486371.005

Rozelle, L. 2003. *The Structure of Sign Language Lexicons: Inventory and Distribution of Handshape and Location*. PhD dissertation, University of Washington.

Sandler, W. 1993. Hand in hand: The roles of the nondominant hand in Sign Language Phonology. *The Linguistic Review* 10(4): 337–390. doi:10.1515/tlir.1993.10.4.337

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 I*. The Hague: Distributed by Holland Academic Graphics.

Sandler, W. 1996. Representing handshapes. In W. Edmondson & R. Wilbur (eds.), (1996) *International Review of Sign Linguistics*, Vol. 1, 115–159. Mahwah, NJ: Lawrence Erlbaum Associates.
Sandler, W. 2011. The phonology of movement in Sign Language. In M. van oostendorp, C. Ewen, E. Hume & K. Rice (eds.), (2011) *The Blackwell Companion to Phonology*, 577–603. UK: Blackwell Publishing.
Sandler, W. 2012. The phonological organization of Sign Languages. *Language and Linguistics Compass* 6(3): 162–182. doi:10.1002/lnc3.326
Sandler, W., I. Meir, C. Padden & M. Aronoff. 2005. The emergence of grammar in a new sign language. *Proceedings of the National Academy of Sciences of the United States of America* 102(7): 2661–2665. doi:10.1073/pnas.0405448102
Sandler, W. & D. Lillo-Martin. 2006. *Sign Language and Linguistic Universals*. New York, NY: Cambridge University Press. doi:10.1017/CBO9781139163910
Sandler, W., M. Aronoff, I. Meir & C. Padden. 2011. The gradual emergence of phonological form in a new language. *Natural Language and Linguistic Theory* 29: 503–543. doi:10.1007/s11049-011-9128-2
Schein, J. & D. Stewart. 2002. *Language in Motion*. Washington, DC: Gallaudet University Press.
Stoianov, D. 2016. *Phonological Dispersion in Maxakalí Sign*. Unpublished M.A. thesis, Department of Psychology and Language Sciences, University College London.
Stokoe, W. 1960. Sign language structure: An outline of the visual communications systems. *Journal of Deaf Studies and Deaf Education* 10(1): 3–37. doi:10.1093/deafed/eni001
Stungis, J. 1981. Identification and discrimination of handshape in American Sign Language. *Perception and Psychophysics* 29: 261–276. doi:10.3758/BF03207293
Sturm, V. 1987, July. The Phonemic Nature of Sign Language. In *Deseret Language and Linguistic Society Symposium*. Utah, U.S.A.
van der Kooij, E. 2002. *Phonological categories in Sign Language of the Netherlands. The Role of Phonetic Implementation and Iconicity*. Utrecht: LOT.
Washabaugh, W. 1979. Hearing and deaf signers on Providence Island. *Sign Language Studies* 24: 191–214. doi:10.1353/sls.1979.0003
Woodward, J. 1987. Universal constraints across Sign Languages: Single finger contact handshapes. *Sign Language Studies* 0(57): 375–385. doi:10.1353/sls.1987.0023