A constraint-based account of distributional differences in handshapes

Petra Eccarius

1. Introduction

In sign languages, as with spoken languages, phonological distributions and behaviors are rarely homogeneous, either across languages or within them. This is largely due to conflicting forces influencing language change, such as internal pressures to ease articulation and/or perception and external influences from language contact. Degree of iconicity can also play a role in these varied phonological behaviors, especially (but not exclusively) in sign language forms. But how should such a complex system of linguistic pressures be represented theoretically?

Ideally, phonological representation of such distributional variation should be able to incorporate the many kinds of conflicting forces that contribute to it, and fortunately, Optimality Theory affords us an opportunity to do just that. Optimality Theory (Prince and Smolensky 1993) considers language to be a system of conflicting forces expressed by means of violable linguistic constraints. The two main forces in this approach are Markedness, which assumes systems prefer unmarked structures, and Faithfulness, which assumes systems prefer to maintain lexical contrasts. Markedness is typically grounded in factors like articulation and perception, while Faithfulness is primarily concerned with making sure that the system has enough contrasts available to convey the necessary differences in meaning. The optimal output form is then determined according to language particular rankings of these constraints.

In this work I use a combination of established branches of Optimality Theory (OT) to explain distributional differences in handshape contrasts occurring as a result of conflicting pressures. First, I follow Flemming’s (2002) version of OT, Dispersion Theory, in which grammars balance the system-internal pressures of articulatory ease and perceptual distinctiveness, as well as the desire to maximize the number of contrasts available in word formation. Then, based on the work of Ito and Mester (1995a), I add pressures to maintain contrasts borrowed into languages from external sources.
Finally, I incorporate iconicity into the analysis, treating it as I would other pressures influencing language. Although the approach presented here is useful for multiple aspects of handshape (and potentially other sign language parameters as well), this chapter focuses on selected finger combinations (i.e., which fingers are prominent or ‘active’ in a sign).¹

2. System-internal pressures

2.1 Dispersion Theory

In his dissertation, Edward Flemming (1995, 2002) used OT in a new way to try to represent the different inventories of phonological contrasts found across spoken languages. He called this new approach Dispersion Theory.² Flemming summarizes the core of Dispersion Theory by claiming that languages have three goals in selecting their phonemic contrasts (2002:4):

- Maximize the number of contrasts
- Maximize the distinctiveness of contrasts
- Minimize articulatory effort

The first of these goals, maximize contrasts, is based on the fact that a large number of phonemic contrasts allows for a greater number of possible linguistic combinations. The second goal, maximize distinctiveness, observes that the more perceptually distinct phonemes are from each other, the easier they are to process by the recipient. In other words, languages prefer to keep perceptual confusion to a minimum. Finally, the last goal, minimize articulatory effort, speaks to the human tendency to favor motor behaviors (linguistic and non-linguistic) that require the least anatomical effort. Dispersion Theory uses these goals as a basis for OT constraints and assumes that cross-linguistic variation stems from differences in how languages choose to mediate between them, i.e., variation can be represented via different rankings of the constraints. Flemming’s theory departs from traditional OT in that his constraints address the well-formedness of contrasts rather than of segments or words in a vacuum; consequently, the candidates themselves consist of sets of contrasts and not of single words. This focus on the system-internal pressures on contrasts allowed him to place greater importance on auditory (i.e., perceptual) distinctiveness between segments in the formulation of his Markedness constraints, where other OT analyses focused primarily on articulatory factors. Faithfulness constraints in Dispersion Theory were also
affected by its focus on contrast. In traditional OT, Faithfulness constraints require aspects of the winning output to remain unchanged from an underlying input. Because Dispersion Theory deals with contrasts within a system rather than words in isolation, Flemming claims that inputs are incompatible with the theory. As a consequence, the only Faithfulness constraints he includes are MAXIMIZE CONTRASTS constraints (explained below), which only reference the state of contrasts within the grammar as a whole.\(^3\) I return to the issue of inputs in Section 3.3.

2.1.1 Example constraints

To understand the handshape constraints presented in this work, we must first look at some of the constraints introduced in Dispersion Theory. Flemming’s Minimum Distance (MINDIST) constraints, which are perceptually based, are the first type of constraint relevant to the current discussion and take the form shown in (1). These are constraints that concern the perceptual ‘distance’ \(n\) between the phonemes in an inventory relative to some (in Flemming’s case) auditory or acoustic dimension (D) (e.g., formant frequency, VOT). Basically, Dispersion Theory assumes that languages will reject inventories in which phonemes are too close together because they are too difficult to differentiate perceptually.

\[
(1) \quad \text{Minimum Distance Constraints (MINDIST = D : n): The perceptual distance between contrasts across dimension D must be } n.
\]

In his analysis, Flemming also included MAXIMIZE CONTRASTS constraints (shown in (2)) for the perceptual properties of spoken language phonemes. As a group, these constraints represent the first goal of Dispersion Theory, i.e., languages strive to maximize the number of contrasts in their inventories to allow them more ways to differentiate between words. All MAXIMIZE CONTRASTS constraints (regardless of their underlying construction) are positive scalar constraints, which means that the optimal candidate has the most observances rather than the least violations. Candidates receive check marks (‘✓’) for each instance where the conditions of the constraint are met (i.e., for every contrasting segment present) instead of the usual asterisks (‘*’) for violations. Consequently, for these constraints candidates are eliminated when they have too few check marks rather than when they have too many asterisks (as is the case with most OT constraints).
(2) **Maximize Contrasts** constraints: Count the number of contrasts in an inventory across a particular dimension.

To illustrate how these constraints work in traditional Dispersion Theory, I use an example adapted from Flemming (2002). First, let us say that D in the MINDIST constraints is the formant frequency F1 (i.e., vowel height), and that F1 can be divided into five levels as shown in (3). The tableau in (4) shows how various inventory candidates would be evaluated by the set of MINDIST = F1 constraints. One violation mark (‘*’) is assigned for each instance where a vowel contrast in the inventory is not separated by the minimum distance specified in the constraint. For example, in Candidate A, the [i - a] contrast has a distance of 4 along the F1 continuum, so it does not violate any of the constraints in the set. In Candidate B, while the [i - a] contrast continues to incur no violations, both [i - e] and [e - a] have a distance of 2, therefore violating the minimum distance requirements of MINDIST = F1:3 and MINDIST = F1:4; consequently, each constraint is violated twice (once per contrast). And so on with Candidate C. Next, when evaluating the **Maximize F1 Contrasts** constraint, each candidate receives one ‘✓’ per contrasting segment in their vowel inventory. If evaluated, the winning candidate (Candidate C in this case) would be the candidate with the most marks. (Note that in this example, there is no actual “winner”, as in the complete tableaux shown below.)

(3) F1 (vowel height) continuum.

<table>
<thead>
<tr>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>i</td>
<td>i</td>
<td>e</td>
<td>ε</td>
<td>a</td>
</tr>
</tbody>
</table>

(4) Example Dispersion Theory constraints.

<table>
<thead>
<tr>
<th></th>
<th>MINDIST = F1:1</th>
<th>MINDIST = F1:2</th>
<th>MINDIST = F1:3</th>
<th>MINDIST = F1:4</th>
<th>Maximize F1 Contrasts</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. i - a</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>✓✓</td>
</tr>
<tr>
<td>b. i - e - a</td>
<td></td>
<td></td>
<td>**</td>
<td>**</td>
<td>✓✓✓</td>
</tr>
<tr>
<td>c. i - e - ε - a</td>
<td></td>
<td>**</td>
<td>***</td>
<td>***</td>
<td>✓✓✓✓</td>
</tr>
</tbody>
</table>
2.2 Application for handshapes

Flemming’s work (as well as the work of those who followed him) focused on auditory distinctiveness and articulation of speech sounds, but (despite the numerous differences between modalities) it is reasonable to suppose that the goals of his theory could also be used to describe the type of mechanisms involved in phonemic contrasts in sign languages. Following the tenets of Dispersion Theory, I base the constraints of the current OT analysis on perceptual and articulatory pressures present in visual languages, combined with MAXIMIZE CONTRASTS constraints similar to those used by Flemming. Variation in the distributions of handshape contrasts will be represented by altering the rankings of these constraints.

2.2.1 Selected finger constraints

Just as articulation-based Markedness constraints for spoken languages are based on the anatomy of the articulators involved (e.g., those of the oral and nasal cavities), the articulation-based constraints proposed here are based on the anatomy of the hand and how it affects the range of independence for the various digits.5

I begin by proposing articulatory Markedness constraints for handshape based in the anatomical situation of the ring finger. Anatomical observations (e.g., Boyes Braem 1981, 1990; Ann 1993, 2006; Greftegreff 1993) as well as experimental evidence (Häger-Ross and Schieber 2000) suggest that the ring finger is the most dependent of all of the fingers. It is especially dependent upon the middle and pinky finger both because they are tethered in extension via ligaments (part of the juncturae tendinum), and because they share a muscle head of a flexor muscle (the flexor digitorum profundus). Based on this information, one could posit that handshapes in which the ring finger behaves independently of the middle and pinky fingers would be more difficult to articulate than those in which all three fingers share the same configuration. The Selected Ring Finger Constraint (abbreviated as *RING), provided in (5), is based on these observations.

(5) Selected Ring Finger Constraint (*RING): Do not allow the ring finger to be a selected finger unless it has the same configuration as both the middle and pinky fingers.
The second Markedness constraint is based on the dependencies that exist between all of the fingers because of their shared musculature. These dependencies have led others to propose principles or constraints concerning the adjacency of selected fingers (but not the thumb) in handshapes (Mandel 1981; Ann and Peng 2000), and I follow their lead here in the inclusion of the Adjacency constraint (ADJAC) in (6).

(6) Adjacency Constraint (ADJAC): Selected fingers must be adjacent to each other.

It is important to emphasize that, like all constraints in OT, these articulation-based constraints are violable, despite their being based on anatomical facts. We perceive a fairly wide range of joint positions to be extended or closed, so anatomical compensations making ‘impossible’ handshapes possible do occur. (For example, an ‘extended’ middle finger is used in a popular, though impolite, gesture in many Western cultures, but people rarely notice that the middle finger is not quite fully extended and/or that the other fingers are less than fully closed to compensate for it being difficult to articulate.)

Next, I present a handshape constraint based on perceptual factors. Because of a lack of detailed perceptual research on sign languages, judging the perceptual distance between handshapes is not as straightforward as taking acoustical readings (and even those, Flemming admits, can be somewhat arbitrary measures). One very basic perceptual constraint (provided in (7)) is used in this analysis, namely MINDIST = SF: $n$. (Given the complexity of handshape perception and all that is still to be learned, I consider this constraint to be temporary until more perceptual research can be done.)

(7) Minimum Distance Constraint for Selected Fingers (MINDIST = SF: $n$): The perceptual distance between contrasts must be at least $n$ with respect to number of selected fingers not shared in common.

MINDIST = SF constraints are based on a basic quantification of selected finger difference (e.g., $\begin{array}{c} \text{a} \\ \text{b} \end{array}$ and $\begin{array}{c} \text{c} \\ \text{d} \end{array}$ have one finger different, $\begin{array}{c} \text{a} \\ \text{b} \end{array}$ and $\begin{array}{c} \text{e} \\ \text{f} \end{array}$ have two, etc.), assuming (at least for the time being) that the more selected fingers handshapes have in common, the closer they will be perceptually.

Finally, I introduce one system-internal Faithfulness constraint in this work, Maximize SF Contrasts (MAXSF), described in (8).

(8) Maximize Selected Finger Contrasts (MAXSF): Maximize the number of handshape contrasts with respect to selected finger combinations.
Like Flemming’s Maximize Contrasts constraints, MaxSF is a positive scalar constraint based on the pressure of maximizing the possible number of combinable segments in a language. As with the example in (4), when evaluating this constraint, it receives one ‘✓’ for every contrasting segment in their handshape inventory (this time with respect to contrasting selected finger combinations), and the winner is the candidate with the most marks.

2.2.2 Cross-linguistic example

To illustrate how these kinds of constraints can be used to represent distributional differences in handshape, I begin with a simple cross-linguistic comparison of selected finger contrasts using three of the constraints described above, namely *RIng, AdjAC, and MaxSF.

Before presenting the example, however, a few notes are in order about the OT tableaux themselves. First, the tableaux presented in this work use many of the standard OT indicators. For example, ‘∗’ indicates that a candidate has violated a particular constraint; ‘!’ indicates that a given violation (or, here, lack of ‘✓’s) was sufficient to eliminate the candidate in question; shaded cells indicate constraints occurring after an elimination; solid lines between constraints indicate a fixed ranking; and dotted lines between constraints indicate an undeterminable ranking order.

However, these tableaux do differ from those standardly used by OT in a few key ways. One slight difference is that an arrow replaces the traditional pointing hand as an indicator of the winning candidate; this is to differentiate the pointer from the handshape font used for the candidates. Two more important differences about these tableaux are as follows. First, (as explained in 2.1), the candidates consist of contrasts/inventories rather than individual word forms. Second, the handshape symbols pictured in these candidate inventories are not meant to represent whole handshape segments. Instead, the extended fingers in each picture represent the selected finger combinations used in the handshapes of the languages in question. For example, the left in the candidate set could represent the selected finger combinations in the handshapes $\text{index}$, $\text{middle}$, $\text{ring}$, and/or any other handshape with the index, middle and ring fingers selected. (I do not include thumbs in these combinations because their status as selected fingers is often uncertain.)

We now return to our crosslinguistic example. Candidates in the following tableaux consist of the inventories of selected finger contrasts used for core lexical items in three languages—American Sign Language (ASL), Swiss-German Sign Language (DSGS), and Hong Kong Sign Language (HKSL).
First, we examine constraint rankings for HKSL, as shown in Tableau (9). Based on the entries in Tang’s (2007) disctionary, HKSL’s core lexical signs utilize nine selected finger combinations—a much larger inventory of selected fingers than ASL or DSGS—as seen in Candidate A. From the large number of selected finger contrasts in HKSL’s inventory, we can surmise that this language values the maximization of contrasts over pressures towards easing articulation. This preference can be represented by ranking MaxSF very high for HKSL, above constraints like *Ring and AdjAC. Given this constraint ranking, Candidate A earns the largest number of check marks (nine—one for each contrasting selected finger combination), and Candidates B and C (which have fewer check marks) are eliminated immediately.

<table>
<thead>
<tr>
<th></th>
<th>MaxSF</th>
<th>*Ring</th>
<th>AdjAC</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. HKSL</td>
<td>✓ 9</td>
<td>**</td>
<td>*</td>
</tr>
<tr>
<td>b. ASL</td>
<td>✓ 6</td>
<td></td>
<td>*</td>
</tr>
<tr>
<td>c. DSGS</td>
<td>✓ 5</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

In contrast, according to the entries in Boyes Braem (in progress), DSGS’s core lexicon (excluding foreign borrowings) utilizes only the five selected fingers combinations in Candidate C. Given that the same selected finger combinations are available to both languages, there must be a reason why DSGS does not use the same combinations as HKSL. One possible explanation is that DSGS ranks Markedness constraints such as *Ring and AdjAC above the maximization of contrasts, as shown in Tableau (10). In this ranking, Candidate A is eliminated because it contains two combinations that use selected ring fingers without selected pinkies, as well as a combination utilizing non-adjacent fingers. Candidate B is also eliminated because it contains a non-adjacent combination, leaving Candidate C as the optimal candidate.
(10) Example constraint ranking for DSGS.

<table>
<thead>
<tr>
<th></th>
<th>*RING</th>
<th>ADJAC</th>
<th>MaxSF</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. (HKSL)</td>
<td><img src="image1" alt="Handshapes" /></td>
<td><em>!</em></td>
<td>*!</td>
</tr>
<tr>
<td>b. (ASL)</td>
<td><img src="image2" alt="Handshapes" /></td>
<td></td>
<td>*!</td>
</tr>
<tr>
<td>c. (DSGS)</td>
<td><img src="image3" alt="Handshapes" /></td>
<td></td>
<td>✓ 5</td>
</tr>
</tbody>
</table>

Finally, in Tableau (11) we see that to represent the optimality of ASL’s six selected finger combinations in Candidate B (based on the non-initialized signs listed in Stokoe et al. 1965), MaxSF must be ranked below *RING (since its inventory does not include any combinations with an unsupported ring finger), but above ADJAC (since the inventory does include a non-adjacent combination).

(11) Example constraint ranking for ASL.

<table>
<thead>
<tr>
<th></th>
<th>*RING</th>
<th>MaxSF</th>
<th>ADJAC</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. (HKSL)</td>
<td><img src="image4" alt="Handshapes" /></td>
<td><em>!</em></td>
<td>✓ 9</td>
</tr>
<tr>
<td>b. (ASL)</td>
<td><img src="image5" alt="Handshapes" /></td>
<td>✓ 6</td>
<td>*</td>
</tr>
<tr>
<td>c. (DSGS)</td>
<td><img src="image6" alt="Handshapes" /></td>
<td>✓ 5</td>
<td>!</td>
</tr>
</tbody>
</table>

3. System-external pressures

3.1 Lexical stratification and linguistic pressures

Not only has OT been used to represent cross-linguistic differences in contrasts, but it has also been used to represent differences within the lexicons of individual languages. One problematic assumption often made about
the nature of contrast is that once a particular contrast has been determined, it remains constant across the whole lexicon of a language. Ito and Mester (1995a, 1995b, 2001, 2003), among others, have shown that this kind of assumption is rarely true for spoken languages. In their work they point out that a variety of social and historical factors influence language change, and that those changes are often not uniform with respect to phonological constraints. To account for such differences, they propose the Core-Periphery model, arguing that the lexicon is comprised of a native core and increasingly peripheral substrata, usually formed as a result of historical contact with other languages. In this model, the further you move from the core, the weaker the adherence to the core constraints becomes, while Faithfulness to external sources (in their case, foreign borrowings) becomes stronger. This is represented in OT by reranking only external Faithfulness constraints and leaving the ranking of all other constraints (i.e., the core constraints) untouched. In this way Ito and Mester have successfully analyzed examples of lexical stratification from multiple languages, including Japanese (1995a, 1995b), Russian (1995a), German and Jamaican Creole (2001).

Brentari and Padden (2001) show that a similar stratification exists in the lexicon of American Sign Language (ASL). They argue that the ASL lexicon consists of a core lexicon, native to the language; a spatial component (peripheral to the core but also native) containing the forms commonly referred to as ‘classifiers’; and a foreign (i.e., non-native) component with a series of peripheral substrata including signs using fingerspelled letters and borrowings from other sign languages. This stratification is illustrated in Figure 1. As in Ito and Mester’s work, the further a form is from the core (in this case, either in the direction of classifier forms or of foreign vocabu-

![Figure 1. Stratification of the ASL lexicon (Brentari and Padden 2001).](image-url)
lary), the fewer of the core’s phonological constraints are obeyed, i.e., core constraints become lower ranked. Brentari and Padden focused on representation of the foreign component in their analysis; here, I expand upon their work, both by expanding the use of OT to classifiers, and by including non-linguistic as well as linguistic forms as borrowed sources.

3.2 Iconic pressures

The literature on the topic of iconicity is vast, even if limited only to its role in sign languages (for reviews, see Taub 2001; Brennan 2005; or Brentari to appear). However, in general, iconicity can be defined as a perceived similarity between the form of a sign and its meaning. Researchers have long debated the role (or lack thereof) that iconicity plays in the phonology of sign languages. Most of these arguments treat the issue as an ‘all or nothing’ situation—either iconicity is an external force that nullifies attempts at phonological formalization for the forms it affects (e.g., Sandler 1996), or it is largely irrelevant and alterations can be explained without making direct reference to it (e.g., Supalla 1982). The few who have tried to incorporate iconicity into some sort of formal representation (e.g., Boyes Braem 1981; van der Hulst and van der Kooij 2006) have typically done so by relegating iconic features and more purely phonological features to separate levels of the representation. OT affords us an opportunity to reach a middle ground in this debate, acknowledging that iconicity must play a part as a motivating force in these forms, but treating it as only one of the conflicting forces at play in an already established architecture. I argue here that the desire to be faithful to certain aspects of the real-world adds an additional pressure on the phonological system, but that this pressure—like that of articulatory and perceptual Markedness—is not inviolate.

But how is this to be done? Perlmutter (2006) disagrees with other researchers’ relegation of iconic forms to the semantic level, and says instead that such features are phonological. Among the alternatives he suggests is an idea he calls the Loan Hypothesis:

(12) The Loan Hypothesis: Iconicity is a form of borrowing. Iconic signs in sign languages are loan words. (320)

This hypothesis predicts that, phonologically, iconic signs are like loan words in spoken languages in two ways: 1) they can violate the patterns/constraints of the native vocabulary, and 2) they are expected to conform to
more of those native patterns the longer they are in the language. As support of this hypothesis, he cites Frishberg’s (1975) observation that iconic signs become less iconic and conform more to ASL’s phonological constraints over time, much as loan words tend to do the longer they are in a language. As a continuation of Perlmutter’s idea, I argue here that the phonology is not directly accessing the semantics, per se (as others have claimed), but instead that it is actually borrowing from physical aspects of the visual form itself, articulating comparable visual structures with the hands, and then filtering the resulting forms through the linguistic constraints of the system.

3.3 The problem of inputs

Before I describe how external influences can be represented using OT, however, we must first return to the issue of linguistic inputs. Recall that Flemming’s approach required no input to the system because his constraints focused on system-internal pressures. However, Ito and Mester’s analysis of behavior across lexical components depends upon a reranking of Faithfulness to borrowed inputs. How can the two approaches be reconciled? An answer can be found by looking at Padgett’s (2003) use of Dispersion Theory for historical changes in contrast. Although he acknowledges that it is a departure from Flemming’s original concept, he assumes inputs from earlier stages in a language’s history when modeling sound changes over time. I take a similar approach here. Because lexical components (although they are synchronic divisions) are largely based on diachronic relationships to historically borrowed forms, like Padgett, I need to have some sort of input to the system if I want to explain their behavior. Since I will be including borrowings from visual sources as well as linguistic forms in my analysis, and since the former are not ‘inputs’ in the traditional sense for OT, I refer to all of these borrowed forms as ‘external referents’.

Furthermore, in the tableaux used to present my analyses, I place these ‘external referents’ in a side-bar beside the candidate set rather than above them in the traditional ‘input’ slot. It should be noted that when these external referents are used, they, like the candidates, are still in the form of contrasts; they are simply contrasts from sources external to the current phonological structure, such as historically contrasting segments (often from foreign sources) or visual relationships (e.g., a thinner vs. a thicker object).
3.4 Application for handshapes

We now return to an application of these ideas using selected finger constraints and example tableaux. I begin with an historical example of linguistic borrowing from an external source, and conclude with synchronic examples of selected finger combinations used in classifier forms to represent various thicknesses.

3.4.1 Linguistic constraints and example

The historical example of linguistic borrowing first requires the introduction of an additional Faithfulness constraint, \textsc{IdentSF}, shown in (13). Unlike the \textsc{MaxSF} Faithfulness constraint previously discussed, this constraint does not reference system-internal contrasts, but instead concerns Faithfulness to external referents—in this case, Faithfulness to the selected finger combination of the external referent.

(13) Selected Finger Identity (\textsc{IdentSF}): Corresponding segments between external referent contrasts and output contrasts should have identical Selected Finger combinations.

The example analysis itself refers to an on-going handshape change in ASL signs such as \textsc{doctor} and \textsc{thousand}. These signs were originally borrowed from the initialized Old French Sign Language (OFSL) signs \textsc{médecin} and \textsc{mille} using ‘M’ handshapes (\textbullet{}), but there seems to be a diachronic move toward the use of four selected fingers (\textbullet{}\textbullet{}) as these signs lose their foreign status and their connection (i.e., Faithfulness) to the foreign, initialized forms.\footnote{\textsuperscript{10}} Tableaux (14) and (15) illustrate this lowering of rank for external Faithfulness to the fingerspelled letter ‘M’ (\textbullet{}) as contrasted with its two-fingered neighbor ‘N’ (\textbullet{}) (e.g., as in ASL’s minimal pair, \textsc{doctor} vs. \textsc{nurse}). In Tableau (14) (the original initialized ranking), the Faithfulness constraint \textsc{IdentSF} is ranked higher than the Markedness constraints *\textsc{ring} and \textsc{mindist = SF:2}, eliminating the handshape contrast in Candidate B because it does not share the same selected finger combination as the external referent (i.e., the fingerspelled ‘M’). In Tableau (15) (the newer core ranking), however, the rank of external Faithfulness has been lowered below the Markedness constraints of ASL’s core. Because the ‘M’ handshape has an unsupported ring finger and/or because it is too similar perceptually to
the ‘N’ handshape (it is unclear which), the older contrast in Candidate A is eliminated, making the contrast in Candidate B optimal.

(14) Ranking representing the older handshape for ASL’s DOCTOR (vs. NURSE), borrowed from OFSL’s initialized sign MÉDICIN.

<table>
<thead>
<tr>
<th></th>
<th>IDENTSF</th>
<th>*RING</th>
<th>MINDIST = SF:2</th>
</tr>
</thead>
<tbody>
<tr>
<td>‘M’  vs. ‘N’</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>a. (OFSL)</td>
<td></td>
<td></td>
<td>*</td>
</tr>
<tr>
<td>b. (ASL)</td>
<td></td>
<td>* !</td>
<td></td>
</tr>
</tbody>
</table>

(15) Re-ranking representing the more recent handshape for ASL’s DOCTOR (vs. NURSE) as a core sign.

<table>
<thead>
<tr>
<th></th>
<th>*RING</th>
<th>MINDIST = SF:2</th>
<th>IDENTSF</th>
</tr>
</thead>
<tbody>
<tr>
<td>‘M’  vs. ‘N’</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>a. (OFSL)</td>
<td>* !</td>
<td>* !</td>
<td></td>
</tr>
<tr>
<td>b. (ASL)</td>
<td></td>
<td></td>
<td>*</td>
</tr>
</tbody>
</table>

3.4.2 Iconic constraints and examples

Like the example just presented, iconic borrowings are also represented via a conflict between core constraints and external Faithfulness. The iconic Faithfulness constraints here behave like the linguistic Faithfulness constraints (e.g., IDENTSF), except that instead of being faithful to aspects of a linguistic referent, they are faithful to visual aspects of the real world objects they represent. Determining what Faithfulness means between an object and a handshape can be difficult. The Faithfulness I propose with respect to iconic relationships in the classifier component is not arbitrary, nor does it make reference to the semantic relationships involved. Keeping in mind the Loan Hypothesis and the idea that iconic forms borrow from visual aspects of their referents, the iconic Faithfulness constraints proposed here are based on visually perceptible characteristics shared by both the physical form of the referent and the form created by the relevant articulators of the hand. For the purposes of this chapter, I introduce one such dimension, namely ‘surface
size’ (i.e., thickness or width), to illustrate iconic pressures. I define surface size as the distance between outside edges of a continuous surface—be it of an object or of an (unspread) hand—as shown in Figure 2.

One potential difficulty in the formulation of Faithfulness constraints referencing a quality like size is that it is a characteristic typically thought of in relative terms (‘small’, ‘big’, ‘bigger’, etc.). This turns out not to be a problem in an analysis where both output candidates and external referents are expressed as contrasts. For example, given a contrast between two real world objects along a given dimension, if Object A’s size is greater than Object B’s size, then the same should be true of their representations, i.e., Classifier A’s handshape size should be greater than Classifier B’s for that same dimension. Consequently, the constraints proposed here relating to surface size (provided in (16) and (17)) can be structured in similar ways to the linguistic constraints previously mentioned.

(16) Maximize Surface Size Contrasts (MAXSS): Maximize the number of contrasts with respect to the distance between outside edges of a continuous surface.

(17) Surface Size Identity (IDENTSS): Corresponding elements between external referent contrasts and output contrasts should have comparable amounts of space between outside edges of their continuous surfaces.

The first example analysis used to illustrate how these iconic Faithfulness constraints work is based on linguistic representations of the simple thin-to-thick contrast of a drink coaster versus a soda can. ASL (as well as other
languages) uses the selected finger contrast in Candidate A to represent the
difference in thickness or ‘surface size’ between the coaster and the soda
can (as in $\overset{\circ}{\mathcal{O}}$ vs. $\overset{\circ}{\mathcal{O}}$) but this is not the only possibility. Candidates B and C are also plausible options because they represent hand-thicknesses that
correspond to a ‘thinner-to-thicker’ relationship much like A does. Furthermore, if the choice were completely arbitrary (and it could be), the contrast
in Candidate D (i.e., the thicker handshape representing the thinner object
and vice versa) would also be possible. How do we represent the fact that
Candidate A is chosen over the others? It can be done by evaluating each
handshape contrast using an iconic Faithfulness constraint (IDENTSS), an
articulatory Markedness constraint (*RING), and a perceptual Markedness
constraint (MINDIST=SF:3). In this case, ranking is irrelevant for the correct
output–IDENTSS eliminates Candidate D because its surface-size relation-
ship is not faithful to that of the objects being represented; Candidate B is
eliminated because its contrast is perceptually too close together; and *RING
(in addition to the MINDIST constraint) eliminates Candidate C because it
contains a combination with an unsupported ring finger.

(18) Selected finger combinations representing the surface-size contrast of
a coaster vs. a soda can.

<table>
<thead>
<tr>
<th></th>
<th>IDENTSS</th>
<th>*RING</th>
<th>MINDIST = SF:3</th>
</tr>
</thead>
<tbody>
<tr>
<td>a.</td>
<td><img src="image1.png" alt="Image" /></td>
<td><img src="image2.png" alt="Image" /></td>
<td><img src="image3.png" alt="Image" /></td>
</tr>
<tr>
<td>b.</td>
<td><img src="image4.png" alt="Image" /></td>
<td><img src="image5.png" alt="Image" /></td>
<td><img src="image6.png" alt="Image" /></td>
</tr>
<tr>
<td>c.</td>
<td><img src="image7.png" alt="Image" /></td>
<td><img src="image8.png" alt="Image" /></td>
<td><img src="image9.png" alt="Image" /></td>
</tr>
<tr>
<td>d.</td>
<td><img src="image10.png" alt="Image" /></td>
<td><img src="image11.png" alt="Image" /></td>
<td><img src="image12.png" alt="Image" /></td>
</tr>
</tbody>
</table>

This same method can be used to represent the inventories of selected fingers
used by languages to symbolize (theoretically) all of the possible surface-
size contrasts in real-world objects.11 Tableaux (19) and (20) show the cross-
linguistic variation in such inventories for ASL, DSGS and HKSL.12 Interest-
ingly, none of the three languages ranks Faithfulness to iconicity above all
else (in this case, faithfulness to the infinite number of real-world surface-
size via a maximization of hand surface-sizes using MAXSS)–if they had,
the full range of hand surface-sizes in Candidate A would have been optimal.
Instead, ASL ranks MaxSS below articulatory Markedness, while the other
two languages rank it below both articulatory and perceptual Markedness.

(19) Selected finger inventory for ASL representing possible real-world
surface-size contrasts.

<table>
<thead>
<tr>
<th>*RING</th>
<th>MaxSS Contrasts</th>
<th>Mindist = SF:2</th>
</tr>
</thead>
<tbody>
<tr>
<td>infinite number of object thicknesses</td>
<td></td>
<td></td>
</tr>
<tr>
<td>a. (not attested)</td>
<td>![ASL fingers]</td>
<td>*!</td>
</tr>
<tr>
<td>b. → (ASL)</td>
<td>![ASL fingers]</td>
<td>✓ 3</td>
</tr>
<tr>
<td>c. (DSGS/HKSL)</td>
<td>![DSGS/HKSL fingers]</td>
<td>✓ 2 !</td>
</tr>
</tbody>
</table>

(20) Selected finger inventory for DSGS and HKSL representing possible
real-world surface-size contrasts.

<table>
<thead>
<tr>
<th>*RING</th>
<th>Mindist = SF:2</th>
<th>MaxSS Contrasts</th>
</tr>
</thead>
<tbody>
<tr>
<td>infinite number of object thicknesses</td>
<td></td>
<td></td>
</tr>
<tr>
<td>a. (not attested)</td>
<td>![DSGS/HKSL fingers]</td>
<td>*!</td>
</tr>
<tr>
<td>b. (ASL)</td>
<td>![ASL fingers]</td>
<td>*!</td>
</tr>
<tr>
<td>c. → (DSGS/HKSL)</td>
<td>![DSGS/HKSL fingers]</td>
<td>✓ 2</td>
</tr>
</tbody>
</table>

In addition to the synchronic examples offered above, iconic constraints can
also be used in diachronic analyses. As previously mentioned, over time,
signs have a tendency to become less iconic (Frishberg 1975). This again can
be represented by a re-ranking of constraints—Faithfulness to the original
external referent (i.e., some physical characteristic(s) of the object being
represented) becomes increasingly lower ranked over time, giving language
particular Markedness constraints and system-internal Faithfulness more
priority in the determination of the final form.
4. Conclusion

In this chapter, I have introduced an analytic approach toward explaining the cross-linguistic and cross-componential variation in handshape contrasts using various instantiations of OT. First, following Flemming’s (2002) Dispersion Theory, I argue that forms in the core component strike a language particular balance between universally ranked articulatory Markedness constraints, Markedness constraints maximizing perceptual salience, and Faithfulness constraints maximizing the number of contrasts in the system. In non-core components, however, I believe that there is an additional group of Faithfulness constraints at play—ones that depend on Faithfulness to sources outside of the language in question, either in the form of foreign linguistic borrowings or visual aspects of real world objects. In either case, following Ito and Mester’s work, I believe that these Faithfulness constraints come into conflict with native constraint rankings to varying degrees depending on the lexical component. Both diachronically and synchronically, the closer forms are to the core, the lower these Faithfulness constraints are ranked, leaving the phonological contrasts to be shaped by both articulatory and perceptual Markedness constraints and system-internal Faithfulness to contrasts. Additionally, in forms that do eventually become nativized (from the foreign components) or lexicalized (from classifiers), Faithfulness to these outside forms becomes increasingly lower ranked over time.

Admittedly, there are potential difficulties in using these versions of OT with sign languages as opposed to spoken languages. First, while Flemming bases much of his analysis on the relative acoustic dimensions of auditory contrasts (e.g., formant frequency values), the visual equivalents for sign languages are not yet well understood; little is known about the visual mechanisms involved with perception with regard to sign articulation. For instance, most of the non-linguistic literature on shape perception deals with the perception of geometrical shapes or novel objects, and not the shape of the hand. Further, the small amount of research that has been done on the perception of sign language handshapes (e.g., Lane et al. 1976; Stungsis 1981) has been limited to forms found in fingerspelling and/or the core of ASL, leaving out many of the additional contrasts found in the ASL classifier component and in other sign languages. On the articulation side, too, we have very little information on handshape. Only a relatively small amount of work has been done comparing the anatomical structure of the hand with linguistic handshape distribution in sign languages (e.g., Mandel 1979, 1981; Boyes Braem 1990; Ann 1993, 2006; Greftegreff 1993), and all of the work I have found thus far is based on observational and dictionary data rather than
on physiological measurements during sign production. Finally, we also lack information about the nature of the contrasts themselves. While a great deal of information is available to many spoken language linguists regarding the inventories and contrasting segments of the languages they study via experimentation, historical texts, and extensive fieldwork, sign language linguists have only just begun to explore the potential phonological features and the acceptable phonetic variation of segments in their languages with any detail.

In addition, I acknowledge that the inclusion of non-linguistic referents in a linguistic theory challenges the current understanding of what kinds of constraints can (and should) be in a grammar. The decision to include iconic motivations in phonological representations has always been a precarious one, and although more and more researchers are recognizing that iconicity is a force that cannot be ignored in sign language analyses, the decision to base linguistic constraints on non-linguistic visual characteristics has even more potential for controversy. However, because aberrant phonological behavior based in iconic relationships is not peculiar to sign languages, I feel that this approach is not simply a ‘bandaid’ for a modality specific problem—it may, in fact, prove useful for a subset of problematic spoken language data as well. It is not uncommon for spoken language users to try and reproduce (i.e., borrow from) acoustic signals when trying to convey onomatopoetic information to others (e.g., when communicating the sounds of an ailing car to a mechanic). While these spontaneously created reproductions do not necessarily conform to the linguistic constraints of the user’s language, they have the potential to become more conventional and linguistically ‘well-behaved’ over time with continued use. However, these conventialized forms still often remain phonological outliers to a certain extent. For example, Ito and Mester mention that accounting for the behavior of the spoken Japanese lexical substrata based in sound symbolism and onomatopoeia (called ‘Mimetics’) may require additional and more specific intervening phonological constraints than other strata (1995a:190). The current analysis might have implications for these rare occasions where iconicity plays a part in spoken language structure; perhaps faithfulness to aspects of the original sound structures could be used to help explain their phonological inconsistencies.

Until more experiments and large-scale data analyses have been undertaken on sign languages, we will continue to have an incomplete picture of the kinds of articulatory, perceptual, and language-external factors in conflict within the phonology. In this work, I do not claim to present final answers explaining why handshape contrasts differ within and across sign languages, but rather, I present an approach that I hope will be useful in the ongoing pursuit of those answers.
Acknowledgments

This work was funded in part by a dissertation grant from the Purdue Research Foundation and by NSF grant 0112391-BCS, P.I. Diane Brentari. I would also like to thank Gladys Tang for use of her handshape font (available at: http://www.cuhk.edu.hk/lin/Faculty_gladystang/handshape2002-dec.TTF).

Notes

1. See Eccarius (2008) for an expanded version of this analysis.
2. Flemming’s work was based largely on the work of Lindblom (e.g., 1986; see Flemming for further references.)
3. Flemming does not explicitly refer to MAXIMIZE CONTRASTS constraints as Faithfulness constraints, but because they deal with the maintenance of contrasts in the system, I label them as such here.
4. I single out F1 for illustrative purposes only and do not mean to imply that this dimension alone is adequate to fully represent the vowels in question.
5. I use ‘fingers’ when only talking about the index, middle, ring, and pinky, and ‘digit’ to mean fingers or thumb.
6. As with other OT analyses, here I assume an infinite number of candidates, both attested and unattested. However, in the interest of space and clarity, I have reduced the candidate set in these examples to include only attested inventories. See Eccarius (2008) for additional analyses including unattested inventories.
7. Because this is only an introduction to a larger analysis, I do not include selected finger combinations only used in numbers (e.g., a lone ring finger in ASL’s ‘7’). Researchers often note that number signs behave differently than other core signs with regard to handshape features, phonological context, and handshape change (e.g., Sandler 1996). Consequently, numbers may constitute their own native subcomponent of the lexicon (see Section 3.1).
8. Perlmutter further maintains that signs that maintain their iconicity (i.e., do not eventually conform) either: 1) should be analyzed as a separate stratum of the lexicon following the work of Ito and Mester (e.g., 1995a and Brentari and Padden 2001) or 2) they can be considered outside the phonological system entirely. I adopt the former of these two alternatives.
9. In traditional OT, the input (to which an output form is faithful) is usually thought of as a linguistic construct. See Eccarius (2008) for an argument in favor of including non-linguistic inputs in OT analyses.
Interestingly, the newer four-finger handshape has further differentiated itself from M perceptually via an extended thumb, but because so little is known about thumb positions in general, I do not include it in my analysis here.

Here I only address size representations using handshapes alone; I leave representations of size combining both handshape and movement for future work.

See Eccarius (2008) for a description of how these inventories were determined.

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Ito, Junko, and Armin Mester
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<table>
<thead>
<tr>
<th>Year</th>
<th>Author(s)</th>
<th>Title and Details</th>
</tr>
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Tang, Gladys (ed.)

Taub, Sarah F.

van der Hulst, Harry, and Els van der Kooij