Formational Units in Sign Languages
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Introduction:
Phonetics, Phonology, Iconicity and Innateness

1. Overview

This book is the result of the SignTyp conference at the University of Connecticut in 2008, which was made possible through a grant to us from the National Science Foundation. SignTyp brought together an international group of researchers primarily, though not exclusively, interested in the phonetics and phonology of sign languages. While most of the chapters are based on their presentations at SignTyp1, they have been anonymously reviewed and substantially rewritten for this volume.

The book, like the conference, shows certain interesting trends in the field. The stronger role for iconicity in signed languages as opposed to spoken languages is acknowledged, and iconicity is seen as an explanatory force as opposed to something that has to be explained away. Compared to the early days of the field, when ASL and BSL were much more prominent, many more languages are now being studied. In the book, about 17 languages are discussed, including Asian and Middle Eastern languages, and there were many more at the conference. As in other linguistic fields, there is a growing use of experimental data and databases and corpora of signs. One of the purposes of the conference was to introduce the SignTyp database (also made possible by the same NSF grant) which is now available on the web at http://www.ldc.upenn.edu/signtyp/downloads/ and is used extensively in Channon and van der Hulst’s chapter here.

The book focuses on the formational units of signs: handshapes, locations, movements, orientations, and non-manual units. At the descriptive level, the question is which units can or have been distinguished, which leads to theoretical questions as to whether and how these units, in addition to having a phonetic status, function phonologically, and how iconicity affects the phonetics and phonology of signs. The chapters included use a variety of observational, experimental and theoretical approaches to understanding these units.

In this introduction, we provide an overview of one perspective on the relationships between phonology, phonetics and iconicity and make some remarks on the possible role of innate factors. The aim here is not to give full arguments for each statement, but to provide a systematic structure for discussion and argument. In what follows, authors mentioned without dates are those included in this volume.
2. Iconicity/systematicity

Two disciplines usually claim to provide explanations of the systematic properties of the form of spoken languages: phonetics and phonology. There is a clear third contender which does not go by a traditional disciplinary name. It is abundantly clear that the form of many signs is ‘motivated’ or ‘explained’ by a mental image of the object or action that is the referent of the sign. Signs thus motivated are said to be iconic. Though iconic motivation is not absent in spoken languages, it plays a much more important role in sign languages because, compared to the acoustic material of speech, the visual medium of signing is more suitable to depict aspects of the world which are significant to a visually oriented species.

Before the linguistic study of sign languages began, they were considered to be mimic languages, composed of iconic gestures and borrowings from spoken languages, and therefore non-linguistic, primitive, borrowed, and altogether a less valuable type of language. With their high degree of iconicity, sign languages seemed to contradict the Saussurian ‘arbitrariness’ of the linguistic sign, i.e. the purely conventional relationship between form and meaning. Early linguists, in their work on sign languages, therefore avoided discussion of iconicity and downplayed its significance. Now that the true linguistic nature of sign languages is no longer in debate, it is allowable to acknowledge that signed and spoken languages, despite deep similarities and communicative equivalence, also display differences due to the fact that they draw on different modalities. Therefore, in contrast with earlier neglect, more attention is now being paid to iconicity.

Iconicity is a kind of imitation based on imagery. The signer’s hands and body are substituted for entities and actions which are animate or inanimate, abstract or concrete. The imitation is not exact: it can be altered by additions, deletions, geometric transformations (scaling, skewing or rotating), and substance transformations.

Iconicity remains in some ways the most difficult system to understand. The status of iconicity in sign languages is far more central than it is in spoken languages, so we are less able to depend on basic understandings achieved in spoken languages which could be transferred to the study of sign languages. An additional problem is that unlike phonetics and phonology which have a role in every sign, iconicity is not involved at all in a sizeable number of signs in every language.

**Arbitrary signs with historical iconicity only.** Almost all signs originate from an iconic gesture, but over time, phonetic and phonological changes make its iconic basis no longer recognizable. Cultural changes can also obscure the
iconicity. An example is the ASL sign GIRL (fist hand strokes the pad of the thumb along the jaw line down toward the chin). Some claim that this sign originated from a representation of the strings of a bonnet. Yet this iconicity has clearly worn away. Frequent use encouraged simplification and ease of articulation over faithfulness to the iconic root, and culturally, the bonnet is no longer a typical female feature. Except as etymology, it is meaningless to offer an explanation of why the sign is made as it is, because the sign now, regardless of any iconic origin, behaves as an arbitrary sign.

**Non-productive iconicity.** The iconicity of other signs is more difficult to ignore, because the iconic origin is unambiguous and still mentally available. Unlike fully arbitrary signs, an explanation in terms of iconicity is very meaningful, although they could be described without it. For example, signs connected with the written form of the culturally associated spoken language (letter, number or character signs or forms derived from these signs) are often iconic. In ASL, some letter signs resemble the written form of the same letter. Fischer and Gong describe many iconic character signs in Asian sign languages, and Kubuș and Hohenberger show similar iconicity for the letters in the TID (Turkish Sign Language) alphabet. This type of iconicity appears to be a much stronger force in languages where fingerspelling, initialization and characterization (to coin a term) are not as common in everyday signing as in ASL. The reduced usage means that in these languages, systematicity in iconic resemblance overrules the phonetic (articulatory and perceptual) and phonological ‘difficulties’ that the iconic force causes.

Iconicity may also act to constrain the types of handshapes or other characteristics that can be used in the initial creation or later modification of a sign. For example, the numbers 1 through 5 are usually iconic: the number of digits extended equals the number meaning. It would be very surprising to find a language where the number 1 is signed with two extended fingers, the number 2 with one extended finger, and the number 3 with 4 or 5 extended fingers. Note that iconicity for these signs limits, but does not absolutely predict the choice of possible handshapes: signs for the number 3 are usually limited to some set of three extended fingers, but different languages select different sets of fingers. A similar example of limitation is discussed in Brentari and Eccarius showing that signers don’t accept a flattened handshape for signs initialized using the letter O.

Some signs may or may not be iconic but displays a type of systematicity related to other signs. For example, in ASL, signs for women are frequently made on the chin/cheek area, while signs for males are often made on or near the forehead. This is a kind of ‘form’ symbolism in that aspects of the
form correlate with aspects of meaning without there being a clear semantic motivation for the form as such. In TID, as Kubuş and Hohenberger shows, systematicity within the fingerspelling alphabet produces one handed signs made on the non-dominant hand. While it might be possible to simply specify this for each sign, this misses the generalization that all one handed fingerspelling is made on the non-dominant hand, as well as missing the explanation: this occurs because some letter signs have movements on the dominant hand to show diacritics which then results in the shapes of all letters being made on the non-dominant hand. One might consider this a system internal form-symbolic effect.

Nevertheless, while iconicity or related factors like form-symbolism can explain these signs and sign systems, it is not an absolutely necessary part of the analysis, which could be stated using phonetic and phonological structure. The iconic or form-symbolic explanation is like a bonus that could be mentally real, but it might also be an after-the-fact story provided by the linguist. Furthermore, these signs are often less used, and somewhat peripheral in Brentari & Padden’s (2001) sense of core and peripheral elements of the language. We might say that the iconic and symbolic motivating factors are (somewhat) opaque and as such not necessarily acknowledged by the learner.

**Productive and predictive iconicity.** However, another set of signs shows that iconicity is absolutely essential to sign languages. These are the signs using verb agreement and classifier predicates, as well as a few apparently lexical signs which allow iconic variations. In these signs, iconicity is needed to describe, to explain and to predict some characteristics (usually related to movement) of the sign. Some examples are the reversing direction signs such as IMPROVE/GET WORSE (the flat unspread hand moves on the arm either up (IMPROVE) or down (GET-WORSE), contacting two or more times), agreeing verbs such as GIVE in most sign languages, and classifier predicates showing a hand grasping an object, tracing an object, or representing a moving object. In these cases the iconic motivation is so overwhelmingly transparent and productive that we must assume that the form part of the mental representation of the sign is involved.

Thus iconic effects in signs can range from arbitrary signs with no iconicity to opaqueley iconic signs where some characteristics are explained but not fully predicted by iconicity, to transparently iconic signs many of whose characteristics can only be predicted, described and explained on the basis of iconicity. Overall therefore, iconicity must be a part of the knowledge we need to recognize and produce signs.
**Innate or learned?** The question whether our human knowledge and skills are innate or learned from experience goes back to the days of Plato and Aristotle, but Chomsky (1965) added a new dimension to this question by suggesting that there is a specific innate language acquisition device or module which the child must have in order to acquire a language. This means that when we ask the question whether something is innate or learned, if we claim that it is innate, we must then also ask whether this characteristic is specific to language.

Without some innate ability (or at minimum a bias) to imitate, language and culture could not be passed from one generation to the next. We take it that the ability to represent mental imagery through bodily action and posture is innate. It is not without significance that if people (deaf or hearing) are asked to make up a sign for some object (for which they do not have a basic sign), everyone will come up with a motivated sign. It is much easier to make up a motivated sign than to construct an arbitrary sign, and whatever comes easy to humans is most likely rooted in an innate ability.

However, the specific instances of iconic imitation obviously arise in interaction with the environment and depend on the specific usage that is made of the object or the role of actions. Iconic imitation depends on knowing the world around and in us, including cultural facts such as the shape of written letters and characters.

Iconicity therefore is primarily a learned activity of the mind. In so far as it is innate (the ability to imitate), it cannot be the case that this is specific to language, since imitation occurs in many or all human activities.

### 3. Phonetics

Our phonetic knowledge can be considered as a system of constraints which supply default information to flesh out the phonological structure. There are three possible types of phonetic constraints: articulatory, perceptual, and cognitive.

**Articulatory.** Constraints may be absolutely required or a matter of preference. An absolute constraint completely forbids some action; a preference constraint is one where something is possible, but difficult or uncomfortable (or even painful). An absolute articulatory constraint is that we cannot sign further away from our body than we can reach. A preference articulatory constraint controls the extension of the fingers. The ease with which one finger can be extended by itself has a descending order: index, pinky, middle, ring. Eccarius uses this constraint (focusing on the ring finger) in
her chapter. More generally, Ann, Myers and Tsay provide experimental evidence showing that a ranking of handshapes by their articulatory difficulty is predictive of longer response times in an experimental task.

**Perceptual.** Perceptual constraints are those constraints that benefit the viewer. A simple example is that signs must be made where they can be seen. Pizer, Meier and Points show that mothers are well aware of this constraint and expend considerable energy in making sure that their signs are moved into the child’s viewing area. Adam, Orfanidou, McQueen and Morgan show that viewers find it hardest to accurately perceive movements and easiest to perceive locations, with handshapes having intermediate difficulty. The relative difficulty in perceiving movement may be an additional explanation for why Channon and van der Hulst find a relatively small number of pathshapes being used in signs.

**Cognitive constraints.** Cognitive constraints are those imposed by our limitations on planning and executing certain actions. One such constraint could be stated as “don’t do two things at the same time”, as in rubbing the stomach and patting the head at the same time. A related constraint is a preference for symmetrical or alternating action. In sign languages, this translates to a strong preference for both hands in a two-handed sign to have the same handshape, and to perform the same action at the same time or in an alternating pattern. There is an even stronger, perhaps close to absolute, limitation against the two hands performing different movements, such as one hand moving in an upward trajectory while the other hand moves up and down. These constraints are much of what is contained in Battison’s Symmetry and Dominance Conditions (1978). Van Gijn, Kita and van der Hulst (ms.) have argued that the Symmetry Condition is a general condition found even in the gestures of hearing people, and Channon (2004) has argued that the Dominance Condition, although it appears to be a purely phonological constraint, can be understood as a set of articulatory, perceptual, cognitive and iconic constraints, which in conjunction with weak hand locations, determine the weak hand shape.

The placement of cognitive constraints under phonetics is a choice not everyone would agree with. Others might group such constraints in the phonological domain. But their phonetic character seems reasonable because these limitations are not specifically linguistic limitations. They are limitations of the human mind in all activities, and they generally have the character of overload: the mind can attend to and remember only so many things at the same time, and it can attend more easily to multiple similar activities than to multiple different activities.
An analogy may be helpful here. A desktop computer is limited in two different ways: 1) it has a limited number of abilities and 2) each of its abilities is limited. The first type of limitation means that it can store documents on a storage device but it cannot shovel snow or feel emotions. The second type of limitation means that any given storage device can only store a certain number of documents of a certain limited size. The limitations are not because we don’t know how to make a device that can store more or larger documents, but because any particular computer must have a physical instantiation with a specific amount of processing power and memory size. The cognitive limitations that are considered here to be phonetic are similar to this second type of limitation: there are finite limits to our equivalent of processors and memory. (We will not try to answer here whether there are linguistically interesting cognitive limitations of the first type.)

**Innate or learned?** Knowledge of phonetic constraints is needed to correctly produce signs. Again it would seem that the basis of much of this knowledge is ‘built in’, although there is no reason to believe that this kind of knowledge is specific to language, because constraints of the relevant sort are apparently used in all human activities to one degree or another.

However, it is likely that the specific forms of constraints arise on the basis of experience. For example, it takes time to understand how far our hands can reach. Furthermore, the knowledge of the constraints of our own body is to some extent dependent on our particular body, yet our bodies change over time. Even artificial body changes are possible. For example, driving a car entails that we become aware of the car as an extension of our body. As we turn and move, we must be aware of the size of the car to avoid impacts, and this awareness seems to be very similar to the body awareness which allows us to walk without collisions. The computer mouse provides a similar artificial extension of the body. Thus, innately we have the ability to form a mental map of our body and its actions, but the specifics of the map are formed while we experience the body and the environment and in this process, even elements of the environment can be mentally analyzed as being part of the body.

### 4. Phonology

When iconic motivations and phonetic constraints have been taken into account, one point of view is that there remains a residue of linguistic knowledge about a sign that must be phonological. Phonological structure is cognitive, but it does not relate to planning of motoric action. Rather it involves
constraints on mental representation as such. The task for a phonologist is to tease apart the various forces that determine the form of signs, to identify what is phonological, and to create a theoretical model.

The need to postulate a phonological representation, indeed the need to acknowledge phonology as distinct from phonetics is because the phonetic substance (even of a single sign) occurs in infinite variety. This variety of physical signals must be mentally filtered to produce categories or groups of items that count as ‘the same’. For example, in English the numerous speech sounds that fall under the umbrella ‘/t/’ are grouped into one category (the phonological concept ‘/t/’), just like the semantic concept DOG categorizes the infinite variety of hairy and barking animals that we consider to be of ‘the same kind’. It is this categorization which gives rise to what we call phonology. We could of course categorize the form of each word holistically rather than in terms of a collection of smaller building blocks (phonemes and features). Here it could be argued that a decomposition into phonemes serves the purpose of allowing a systematic (‘alphabetic’) arrangement of words according to their form which makes easy and fast retrieval possible. The ability that native speakers have to judge whether a given form belongs to their language (or could belong to it) testifies to the idea that word forms are not stored holistically, or at least not exclusively holistically. As Cruz and Lamprecht show in their chapter, children are aware of the parts of a sign, an awareness that increases with increasing exposure to the language.

4.1 Types of phonological knowledge

**Features.** Features are the smallest element of form. They are mental concepts or categorizations of phonetic attributes related to the handshape, location, movement, orientation, and nonmanual properties of signs. In this volume, Mak and Tang propose a new feature [return] as a new subcategory of repetition, and Hansen proposes movement phonemes. Just how far nonmanual characteristics are a part of the sign is one of the least well-developed aspects of the feature system. Weast’s chapter suggests that while eyebrow raising is involved in phrase level prosody, emotional states, and syntax, it is not involved directly in the phonology: there is no phonological feature [eyebrow raise].

*Feature relationships – hierarchical structure and dependencies.* Features also have hierarchal relationships and dependencies among themselves. For example, if a sign repeats, this repetition can be connected with the handshape opening and closing, a change of orientation, or a path change (the
hand moves between different locations). Mak and Tang show that hand-
shape change and orientation change must be grouped together under a local
movement node, and that repeat features may be dependently related to either
path or to local movements.

Segments and Syllables. At least in spoken languages, features form units
called segments (or phonemes) which in turn group into larger units like
syllables. One of the celebrated issues in comparing signed to spoken
languages is the question whether units like segments and syllables occur in
sign language structure as well. This issue has led to an exploration into the
very nature of these types of units (see for example Channon 2002a and van
der Hulst 1995).

Temporal relationships between features and segments. Features and
segments may also be related to each other in a temporal sequence. The
simplest example of this is that in English (disregarding effects of coartic-
ulation) cat and tack are minimally different in terms of sequential order.
In ASL, IMPROVE and GET-WORSE and similar sign pairs can also be
perceived as minimal pairs for temporal order. This temporal order can be
expressed in a model as either a series of sequential segments (or syllables,
or other elements) which change order, as in [a][b][c] vs. [c][b][a], or as the
effect of a change of features from [up] to [down] as argued in Channon
(1996, 2002a and 2002b). In this volume Channon and van der Hulst argue
that a pathshape feature can also help determine the temporal order of other
features.

Phonological constraints. A phonological constraint would be a constraint
that encodes a regularity across morphemes, signs or words that cannot be
attributed to phonetic or iconic facts. It could be true of all languages, or a
type of language such as sign languages, or a particular language or language
group.

Phonological constraints in spoken languages arise in two ways. First,
they arise when the phonetic substance is categorized as described earlier.
An important principle of categorization seems to be to categorize phonetic
spaces into binary opposed subcategories (such as voiceless versus voiced).
Another phonological constraint might be that these opposing categories
are treated asymmetrically, with one being special in one way or another
(i.e. having a wider distribution). Whether constraints that result from these
principles are specific to phonology or even to language is in question, but
it is nonetheless the case that they lead to a systematicity in the phonology
that appears to be distinct from phonetics or iconicity. Second, phonolog-
cal constraints also deal with universal or language-specific ways in which
elements of the phonological structure can be combined. Constraints of this
sort encode that whereas *cat*, *act* and *tack* are grammatical combinations, *kta*
and *atk* are not.

Consider the hypothetical phonological constraint for sign languages:
“Only the pinky finger may be extended when signing”. If this were an
actual constraint, it would have to be phonological. It could not be a phonetic
constraint or based on iconicity because humans commonly extend different
fingers in nonlinguistic situations, and there is no iconic reason for such a
constraint. However, a hypothetical example was chosen because it appears
that actual phonological constraints in sign languages are few to non-existent,
and many apparent constraints appear phonological because of the wording,
but when correctly stated they often can be seen to have a phonetic and/
or iconic basis. Two examples of apparent phonological constraints are the
Symmetry and Dominance Conditions, which as mentioned above are more
likely to be based on phonetic and iconic knowledge interacting with phono-
logical features.

**Innate or learned?** Are features/feature sets innate or learned? The logical
possibilities are that 1) only one type of language (sign or speech) has innate
features, 2) that there are two innate sets, 3) that there is only one set which
applies to both speech and sign, or 4) that features are learned (perhaps using
the principles of categorization mentioned above).

Option 1 can be easily dismissed because children learn both types of
languages on roughly the same time scale. If the two sets of features differed
in innateness, the presence of an already established feature set would make
the learning task much quicker in the innate feature language than in the
language with features which must be learned.

Option 2 is logically possible but absurd. It would mean that every child
is born knowing the feature set for both types of languages, yet the only chil-
dren which ever use both sets would be the tiny group of bilingual/bimodal
children of deaf parents.

Option 3 is not completely impossible. For example, both sign and speech
are assumed to use place or location features. One might group other features
as manner, articulator shape, and choice of articulator, for both sign and
speech. If this were the case, then it must be assumed that children then
elaborate these basic innate categories into the specific features for their
language type. So in a sense this could be called a hybrid system, where
the basic elements are innate, and the details are learned. Note that if this
option were correct, the innate knowledge required is unlikely to be specific to the language faculty, because the categories of place, shape, articulator, and manner are so general that they can be used for many non-linguistic activities as well.

Since options 1 and 2 can be dismissed, this leaves only options 3 and 4. In both cases, features are learned, although option 3 allows for some basic innate, but not language-specific, knowledge.

Essentially the same arguments and reasoning applies to hierarchical structures, temporal relationships, and phonological constraints.

4.2 The tools of a phonologist

There are two important tools that the phonologist can use to determine what must be included in the phonological model: minimal pairs and systematic gaps.

**Minimal pairs.** Minimal or near-minimal pairs are important in determining the phonological features of a language. Sometimes models will not recognize the same sets of minimal pairs. For example, IMPROVE and GET-WORSE are a minimal pair in the Channon (2002a) model but not in the Liddell and Johnson (1989) model. In this volume, Israel and Sandler discuss an emerging language with very few minimal pairs and suggest that this is because in this language the phonological system is in development, allowing individualized phonetic properties that would not be tolerated in a more conventionalized sign language. Hansen uses minimal pairs to find features for her model, which has a primary division between movement and non-movement segments, with allophones of the same feature in the different segmental environments.

**Systematic gaps and counterexamples.** Systematic gaps and the related concepts of overgeneration and undergeneration are important in determining the correctness of a proposed phonological model. A model that overgenerates would accept sets of signs as being well-formed which are systematically missing from the language (a systematic gap). An example of a systematic gap in sign languages is that there are no non-compound signs with a sequence of more than three body contacts. For example, contacting the ear then the jaw then the forehead and then the palm of hand does not occur in a sign, even though this is a legal sequence for a series of signs (see Channon 2002a, 2002b for further discussion). A complete and correct phonological model of signs must explain this systematic gap, as well as others.
Channon uses systematic gaps in her work to argue that some features must have a dynamic interpretation (like *pathshape* features) because complex pathshapes are systematically missing (in non-classifier signs). Mak and Tang use the absence of signs where only orientation repeats or only aperture change repeats to motivate a node for local movement at which repetition features can be inserted.

Of course, a model can also undergenerate – it can fail to accept well-formed signs. The test for undergeneration is via counterexamples, particularly systematic groups of counterexample signs, and especially those with documented frequent use in the language over multiple generations. A model is unlikely to be overturned on the basis of one or two signs. It is reasonable to assume that special constraints or more complex representations might be needed for a few signs, particularly if the signs are rare. Especially in sign languages, due to cultural factors, it may also be that there has been “outside interference”: inappropriate material imposed on the language which has not (yet) been integrated and modified as required by the phonology, phonetics and iconicity of the language. (This may be the case for some fingerspelling alphabets, for example.) It is also crucial in this respect to remember that iconicity must be considered when testing a model since many apparent counterexamples or systematic gaps are fully explained when iconicity is taken into account (see van der Hulst and van der Kooij 2006 for further discussion of this last point).

5. Conclusion

The attempt here has been to suggest that the study of the form of signs must make reference to and rely on three forces: iconicity, phonetics and phonology, each of which involves an interplay between innate capacity and learning. There do appear to be innate characteristics or abilities of human beings which assist us in recognizing and producing the signs of the language. These are characteristics such as the ability to imitate, the ability to produce and understand partial and distorted imitations, the preference for efficient and easy articulations, the need to see signs clearly, limitations on what we can understand or do at the same time, the ability to perceive characteristics of an object, the ability to organize information hierarchically and temporally and the ability (indeed the need) to categorize. These are all limitations and abilities with innate roots, but none of them seem to be specific to language. Many aspects of language arise from the combined forces of these innate abilities and from learning.
It may be that the role of iconicity in sign languages, which is clearly much greater, and far more systematic, than in spoken languages, has altered the development of sign languages away from the historic model of speech. That is, speakers inherit a language full of arbitrary relationships between form and meaning. What is arbitrary is easily changed, with the result that the many histories of different cultures have produced many different spoken languages. In sign languages, iconicity (given that it comes so easily and naturally to humans) perhaps curtails the rate, degree or kind of change. It may be that there is a substrata of a deeply rooted system of iconic material which, when compared to spoken languages, causes sign languages to more closely resemble each other phonetically, phonologically, morphologically and syntactically.

The study of sign languages is essential to linguistics no longer just because of its parallels to spoken languages, but also and perhaps more importantly because of the differences. A full understanding of the human capacity for language requires detailed study of both modalities.

It is not to be expected that this book will resolve the large questions we have pondered in this introduction. We look forward to our databases, including SignTyp, growing larger and adding more languages, to more studies of the interaction of iconicity with the other elements of language, and how best to integrate it into a phonological model, to a better understanding of the role of non-manual information and temporal sequencing. In the meantime, we hope you will enjoy and find useful our small steps forward in this book.

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Rachel Channon
Harry van der Hulst
Introduction

Notes

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2. An interesting counterexample is shown in Fischer and Gong’s photo of JSL numerals where the numbers 1 through 4 follow this pattern but the number 5 is a fist with the thumb extended.

3. This formulation presupposes that the forms of linguistic signs do indeed have a phonological structure which is independent of the phonetic substance. For those who no longer believe in phonological structure, phonetic constraints directly specify this substance in terms of its articulatory and auditory properties. We will return to this issue in the next section and put it aside for now.

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Van Gijn I., Kita, S. and Harry van der Hulst
(ms) The non-linguistic status of the Symmetry Condition in signed language: Evidence from a comparison of signs and spontaneous co-speech gesture.
Part I. Observation
Marked Hand Configurations in Asian Sign Languages

Susan Fischer and Qunhu Gong

Abstract

In East Asian sign languages, as in Western sign languages, some marked handshapes appear only in restricted contexts or vocabulary, most of which are in signs borrowed or adapted from nonnative sources; fingerspelling (if it exists) and numbers are recent overlays onto the native vocabulary. East Asian sign languages also have character signs, which are functionally equivalent to fingerspelled loan signs. Character signs can be traced or depicted; while tracing does not violate any posited constraints for sign language phonology, depicting can. Many depicted character signs have not only marked handshapes but also marked phonotactics. Character signs display a type of iconicity related to the written form rather than, or in addition to, the shape of the referent. Another source of marked handshapes is the conflation or combination of two morphemes into one handshape, a process that seems to be rare in Western sign languages. The study of East Asian sign languages thus provides insights into the integration of non-native phonology into a sign language, as well as information about the interface between signed and written languages.

1. Introduction

1.1 History and geography

In this paper we will be discussing the Chinese (CSL) and Japanese (JSL) families of sign languages in East Asia. The CSL family comprises northern and southern dialects of CSL proper as well as Hong Kong Sign Language (HKSL: see works of Tang and her colleagues). CSL appears to have had some influence from British Sign Language (BSL; Bencie Woll, p.c.), and one apparently finds some similarities in grammatical constructions
in Southeast Asia, i.e., Thai, Singapore, and perhaps Malaysia (Marianne Collins-Ahlgren research notes). The first school for the deaf in China was founded in 1887.

The Japanese Sign Language (JSL) family comprises Japanese, Taiwanese, and Korean Sign Languages (JSL, TSL, KSL). The first schools for the deaf in Japan were established during the Meiji era (1868-1912), after Japan had opened its doors to Western influences. In the late 19th and early 20th centuries Japan colonized Taiwan and Korea, and sent teachers to those regions to set up schools for the deaf; JSL was exported along with the teachers. Since the Japanese occupation ended in 1945, KSL and TSL have had 65+ years of near-isolation from JSL and have diverged in interesting ways. Sasaki (2003) estimates that about 60–70% of the vocabulary of TSL and KSL are cognate with JSL, but this is probably an underestimate, due to the existence of productive classifier predicates, which are largely identical in the three languages. Since 1949, with large influxes of mainland Chinese into Taiwan, CSL has had some influence on TSL.

1.2 Goals of this paper

In this paper, we have two major aims:

– To describe the marked handshapes in Asian sign languages
– To elucidate the sources of those handshapes.

The sources we have been able to identify include iconicity of the shape of the referent, iconicity related to Chinese characters or syllabary, iconicity related to other symbols, visual puns, and compositionality, i.e., handshapes resulting from a combination of two morphemes.

We are using an intuitive notion of “marked,” based on frequency in the language, frequency in the world’s sign languages, timeline of acquisition, and ease of articulation (see Jakobson 1968). We are concerned not only with the handshapes themselves but also their phonotactics; a handshape might by itself be unremarkable, but its orientation or relative position with respect to other handshapes could still be marked.

2. Iconicity and Phonological Marginality

One of the things that we have often swept under the rug with regard to sign language phonology is the interaction of phonology with iconicity. As we shall discuss below, some unusual handshapes relate to the shape of referents
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Brentari (1998), following Itô & Mester (1986), makes a distinction between native and foreign vocabularies, which can have different phonologies. This idea is elaborated further by Brentari & Padden (2001). Even though initialized signs may count as foreign, they have a long and established history in ASL, as evidenced by the older signs for “thousand” and “doctor” which utilize M handshapes, based on French mille and médecin. The 19th century LSF (French Sign Language) sign for “king” (Lambert, 1865) is the same as the ASL sign KING except that instead of a constant K handshape, the signer spells R-O-I while moving diagonally across and down the torso. A few fingerspelled loan signs such as #NO also participate in grammatical processes such as agreement.

Many “foreign” handshapes come directly or indirectly from written language. Note, for example, that the ASL letters C, D, F, I, J, K, L, M, N, O, P, R, T, V, W, Y, and Z bear some resemblance to the corresponding Roman letters (F to upper-case and R to lower-case). Van der Kooij (2002) suggests that sign language phonology can be simplified and made more restricted by having an iconic component alongside more traditional phonological structure. Her proposal can account for the vast majority of foreign handshapes in ASL. The same approach appears to work for Asian sign languages. Figures 1-2 show two examples of signs with unusual handshapes that mimic the shapes of their referents; first is the CSL (and TSL) sign for ‘ginger’, and the second is the TSL (and CSL) sign for ‘goose.’ In both cases, the handshape is unique to the sign; no other sign in the language uses it.

![Figure 1. CSL sign for ‘ginger’](image1)

![Figure 2. TSL sign for ‘goose’](image2)
3. Symbols and character signs

3.1 Symbols

In Japan, there are two symbols that are common enough to have their own Unicode symbols; each has been internalized to JSL, but in somewhat different ways. Figure 3 shows the JSL sign for ‘post office’ accompanied by its Unicode symbol. In Figure 4, we see the JSL sign for the agreement verb ‘mail.’ When used as an agreement verb, it is signed horizontally instead of vertically and moves from source to goal. The symbol (seen outside every post office) has thus been grammaticized, similar to the ASL fingerspelled loan sign #NO.

Figure 3. JSL sign for ‘post office’

Figure 4. JSL sign for ‘mail’

A second symbol with its own Unicode character represents hot springs. Figure 5 shows the JSL sign for hot spring accompanied by its Unicode symbol; the fingers wiggle in the sign. Figure 6 shows the JSL fingerspelling symbol YU. Yu is the Yamato Japanese word for ‘hot water,’ which of course one finds in hot springs.

Figure 5. JSL sign for ‘hot spring’

Figure 6. JSL YU (ű)
Roman letters too can become symbols, even in a language that does not use them alphabetically. This is what has happened to the abbreviation WC. Figure 7 shows the East Asian (it may be more ubiquitous) symbol for WC, which, when moved from side to side, becomes the sign for ‘toilet’ in all the languages being considered here.

![Figure 7. Representation of WC](image)

### 3.2 Character Signs

Ann (1998) has described the interface between Chinese characters and TSL in her discussion of so-called *character signs*. These are signs based on the shape of a Chinese character, usually by either tracing the character or depicting it; see also Fischer & Gong (2010) for further discussion. Just as any word in English can be fingerspelled, any Chinese character can be drawn in the air or on the palm of the hand. Character *signs* are analogous to fingerspelled loan signs (Battison, 1978) in that they may not show the entire character and can be grammatically active. Depicted character signs are in a sense more iconic in that they reflect, again often in a simplified way, how the character looks on the page as opposed to being drawn.

The order of magnitude of character signs is roughly that of fingerspelled loan signs; CSL has about 30, JSL slightly fewer, and TSL quite a few more, (see Ann 1998). One could conjecture that TSL may have more character signs than JSL or CSL because it lacks fingerspelling as a way of borrowing words into the sign language. Note that KSL has vestigial character signs for place names, though written Korean no longer uses Chinese characters (Byun Kang-Suk, p.c.).
3.2.1 Depicted character signs

Signs that are depicted rather than traced are usually fairly simple, but even these simple signs may have marked configurations. Consider for example the depiction of the character 田 meaning rice paddy. JSL and TSL depict 田 as in Figure 8, while CSL depicts it as in Figure 9; the differences in handshape are due to frequency, perhaps related to differences in the representation of the numeral 3 in the two cultures.

![Figure 8. TSL, JSL representation of 田](image)

![Figure 9. CSL representation of 田](image)

The markedness of the configurations in Figures 8-9 lies not necessarily in the individual handshapes but in their relation to each other. Another example of a depicted character sign that is exceptional in its phonotactics is one JSL sign for (Unitel 'day') shown in Figure 10. It occurs only in compound signs such as ‘birthday;’ otherwise the sign for ‘day’ is unrelated to the Chinese character.

![Figure 10. JSL sign for .Sqrt 'day'](image)

Ann (1998) points out that in TSL, not only the fingers but the mouth can be recruited to depict Chinese characters. She shows one TSL sign for “middle” with the forefinger on the mouth. The Chinese character for “middle” is 中,
which is composed of a line and the classifier □, which means ‘mouth’. It is therefore perhaps natural to sign middle’ using the mouth in place, say, of a finger configuration representing the box in 中. CSL can do the same thing: see Figure 11. By contrast, the JSL sign for ‘middle’ is a two-handed depicted sign, as in Figure 12; that is also an acceptable option for CSL and TSL.

TSL uses the mouth in other ways as well: for example, the sign for “product”, whose character is 品, is shown as in Figure 13.

Depicted characters can participate in grammatical processes. Two examples from the northern dialect of CSL are based on the sign for ‘person’ (Yang, 2004): The CSL language family depicts the character 人 as in Figure 14 In the northern dialect, twisting the finger on the dominant hand changes the meaning from “person” to “who”, while changing the dominant index finger to a wiggling “5” handshape changes the meaning to ‘how many people’; both the twisting and wiggling are semi-productive and can be superimposed onto other signs to change the meaning appropriately.
Two other examples of depicted character signs participating in grammatical processes is the CSL and TSL sign for “introduce” (Figure 15) and the JSL sign for “enter” (Figure 16). Both participate in agreement: “introduce” moves between the direct and indirect objects, while “enter” shows spatial agreement with goal.3

Figure 15. ‘enter’ CSL sign for հ

Figure 16. JSL sign for ೖ ‘enter’

There are a few depicted character signs in CSL that appear to violate Battison’s (1978) phonotactic conditions on monomorphemic signs. Battison stipulates that if both hands move and one hand does not impinge on the other, then both hands must have the same handshape. One Chinese sign for ‘prosperity’ violates this condition. The source of this violation is transparent: the character has one instance of @Column 3 of 4: ೔ above another. The sign reflects this relationship and uses a combination of two handshapes to depict ೔. The two hands do not touch; hence one hand does not affect the other. See Figure 17.4

Figure 17. CSL sign for Կ ‘prosperity’

3.2.2 Traced character signs

We have already mentioned that many very complex Chinese characters can be drawn in the air or on the palm of the non-dominant hand. The difference between drawing a Chinese character and executing a traced character sign lies in how the latter interacts with the grammar of the sign language. One way in which this grammatical activity is shown is with the possibility of numeral incorporation. We saw above, Figure 14, that the sign for ‘person’ in
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CSL depicts the character 人. In the JSL family, that same character is traced with an index finger. Members of the JSL family can add numeral marking by tracing the 人 character using the appropriate numeral handshape in place of the forefinger. Similarly, in both the CSL and JSL families, one can do a simplified, cursive trace of the character for thousand (仟) while incorporating numeral handshapes. See Ann (1998), Fischer and Gong (2010) for other examples.

4. Numerals

4.1 A few CSL numerals

We shall not discuss CSL number signs in general. There is, however, one curious type of formation in CSL that we would like to mention. Similar to what we saw in the depiction of characters like 中 in CSL and TSL where the mouth replaces 口, the Xi’an variety of CSL depicts some numerals using another part of the face to show part of the numeral. Numerals for hundreds (100, 500, 700, etc.), are signed with the handshape for the first numeral placed at the side of the head, and the eyes representing the two zeroes. This is somewhat reminiscent of jokey signs in ASL for wow, where the mouth represents the o and w is signed on either side of the face. See Figures 18-20 for the CSL examples.

Some numbers in the CSL family also have marked handshapes. The number 10 is represented in two ways: one with the handshape (thumb bisecting the forefinger [Shanghai variety]) and the other with the index and middle fingers crossed (Beijing variety).

One interesting type of phonologically (and spoken-language) conditioned borrowing has occurred in TSL. In JSL, all but one of the signs for days of the week are based on the meaning of the Chinese characters for the Japanese names, so Monday = moon day, Tuesday = fire day, etc. The one
exception is “rest day” instead of “sun day”. However, in spoken Chinese, the days are numbered, so in CSL Monday = the numeral 1 signed at the armpit, Tuesday = the numeral 2, and so forth. Since TSL has contact with written Chinese, the CSL signs have replaced the original JSL signs, but with JSL phonotactics; while the CSL sign for Wednesday uses an $f$ hand (cultural sign for 3 in Chinese-speaking regions), TSL nativizes the CSL 3 by substituting the $w$ handshape for the CSL 3, which is an ASL $f$. The use of the $f$ handshape for the numeral 3 is part of Chinese culture, but the phonotactics of TSL trump the hearing cultural gesture for 3.

4.2 Numerals in the JSL family

JSL, KSL, and TSL have essentially the same number system. The JSL numerals 1-10 are shown in Figure 21. One exception is that JSL and KSL do not have the handshape for the numeral 7 that TSL appears to have borrowed from CSL (see Figure 21,) though TSL also uses the JSL 7 handshape in Figure 21, and uses it morphologically in signs like WEEK, which has a JSL: 7 handshape as its nondominant hand. The TSL numerals for 100 and 1000 are shown in Figure 22.

The handshapes shown in Figure 22 are now used in JSL only in the Osaka dialect and only for talking about money; the hands move in an ipsilateral direction to show ¥100 or ¥1000.

Not all of the handshapes in Figure 21 are marked. We have included them here to show the number system and also to show how the Japanese names and katakana for the numbers (shown in a corner of each figure) are exploited in the fingerspelling system, to be discussed in the next section.

The sign for 10, as well as teens and multiples of 10 in the JSL family involve bending the relevant extended fingers; however, the bent extended fingers themselves without movement are sufficient for the recognition of the numeral. This is what happens in signs like 30-YEARS, where a $\beth$ handshape (3 middle fingers extended and bent) substitutes for the 1 handshape in the sign YEAR (Hung, 2010; Fischer, Hung, and Liu, 2011). See below, section 7, for more discussion of numbers in the JSL family.
Figure 21. JSL numerals 1–10

Figure 22. TSL 100, 1000; JSL Osaka dialect ¥100, ¥1000
5. Fingerspelling

HKSL and TSL do not have fingerspelling. The current JSL syllabary was borrowed and adapted from ASL, but is new enough that older Japanese do not know it; and CSL fingerspelling, also adapted from ASL, was introduced in the early 1960s to represent Pinyin. Although JSL, CSL, and KSL all have fingerspelling, it is used much less than in ASL, and at least in JSL, is done much more slowly even by native signers (Leslie Greer, p.c.).9 KSL has fingerspelling (Byun Kang-Suk, p.c.), which is based on Hangul; each Hangul character compositionally represents a syllable in spoken Korean but is structured like a Chinese character; and this is reflected in the fingerspelling system, which is also spatially compositional.

JSL has relatively few initialized signs, which are seen as quite recent additions; JSL also does not use initialization for name signs; nor does KSL, though CSL does. The role of fingerspelling in JSL and CSL appears to be more marginal than it is in ASL, and until recently was used chiefly in schools where signed Japanese or Chinese were employed.10 Not only the handshapes, but some of the orientations appear to be quite unusual. Figures 5 and 6 show the JSL representation for the syllables HE, KI, TI and TU.

According to Bradshaw (2007), JSL fingerspelling is based largely on the two kana syllabaries, though more on the katakana than on the hiragana. The syllabaries are in turn based on kanji, and in the case of simple kanji, the syllable and the kanji are the same, but the syllable has been bled of the meaning of the kanji. For example, the kanji for the name of the number 2, ‘ni,’ is ２; the katakana for the syllable ‘ni’ is が. Similarly with ‘mi’ meaning 3 (３ vs. ミ). In developing fingerspelling, JSL has made use of this kind of overlap, and even where there is no overlap between the kana and the kanji, has also made massive use of homonymy. Thus, the syllable KU can be based on the representation of the number 9 because one pronunciation of 9 in Japanese is ‘く’. Other examples are hi (1), ni (2), mu (6), si (7) (see figure 23). Other fingerspelled syllables in JSL appear rather transparently to be either depicted (コ, ス, ツ, ソ, フ, へ, よ, リ, レ, ロ) or traced (ノ, リ, syllabic ン)versions of katakana. Note also that the orientations for the fingerspelled syllables ニ, ヨ and ミ shown in figure 24 follow the orientation of the written symbol for the syllable and are distinct from the JSL numerals seen in Figure 21, which suggests strongly that these syllable representations are based on the written syllable rather than the number concept. The overlap between pronunciation, kanji, and meaning can be rather complex. Thus, we saw a representation for the number 1000 in figure 22. On one level, this could be iconic with
Figure 23. JSL fingerspelling based on number names

Figure 24. JSL fingerspelling resembling kana: KO, SU, TU, NO, HU, HE, YO, RI, RU, RE, RO, syllabic N
the extended pinky representing the numeral 1 and the other closed fingers representing three zeroes. Now, one pronunciation for 1000 in Japanese is ‘ti’ (phonetically ‘chi’). The handshape in Figure 22 is thus used to represent the Japanese syllable ‘ti’. At the same time, however, it bears some resemblance to the hiragana representation of that syllable, namely と. There is thus a kind of convergence in which there are several possible sources for one handshape.

The handshape for HE へ in Figure 24 is not particularly marked, but because it is mimicking the Japanese kana へ, its orientation with the palm facing in and the fingers pointing downward is highly unusual. The only other JSL sign we know of that uses the Y handshape in the HE orientation is one dialectal sign for tea.

Bradshaw (2007) also shows that several of the syllables in the JSL inventory are semantically and/or iconically based:

KI ~ kitune ‘fox’ (with outside fingers raised like ears and middle two touching the thumb like a snout); SE ~ se ‘spine’ (a raised middle finger, but with the palm facing the viewer); SO ~ sore ‘that’ (pointing); TE ~ te ‘hand’ (an open hand); TO ~ to ‘and’ (first two fingers side-by-side); NE ~ ne ‘root’ (all fingers pointing down); HO = ho ‘sail’ (back of hand like billowing sail); ME ~ me ‘eye’ (between thumb and forefinger); MO ~ mo ‘too, also’ (JSL sign for onaji ‘same’); YU ~ yu ‘hot water’ (three fingers like symbol for public bath house).

We have in fact already seen the syllable YU in our discussion earlier of representations of symbols, cf. Figure 4. The syllabary sign for KI comes from a hearing gesture for “fox”, which in Japanese is Kitune. This handshape is also used by some signers as a classifier for foxes, dogs, and occasionally cats (Fischer 2004). See Figure 25. Some of these iconic handshapes are quite common, while others are marked, but the important thing to note here is that there is iconicity with respect to the written form.
6. Cultural and linguistic determinants of handshape frequency

In ASL, the extended pinky (I) handshape is rather infrequent outside of initialized signs like I and INSURANCE. However, because it has morphological significance in both the JSL and CSL families, it is more frequent. In the JSL family, this handshape is a female gender marker (the male gender marker in JSL is the ‘thumbs-up’ (fist with thumb extended upward). In CSL, the extended pinky handshape is used as a negative morpheme (the thumbs-up handshape is its positive equivalent). This results in greater frequency of an otherwise marked handshape in East Asian sign languages. For example, the CSL signs for “deaf” and “hearing” are shown in Figure 26.

![Figure 26. CSL DEAF, CSL HEARING (from Fischer & Gong 2010)](image)

The pinky extended, the ‘thumbs-up’ and the ください (kitune) (Figure 25) handshapes are all part of Japanese culture; hearing people with no knowledge of JSL use them, but in JSL they have become grammaticized. The same appears to be true for the positive and negative thumb-extended and pinky-extended handshapes in the CSL family. Kinship signs provide another source for marked handshapes in the JSL family. The signs for male siblings in JSL, KSL, and TSL use the extended middle finger, which is not taboo as it is in American culture. The extended ring finger is used for female siblings in TSL and KSL; in older JSL sign language lexicons, this finger is shown, but in contemporary JSL it has been regularized to the I (I) handshape. Note that the ‘sister’ handshape violates Eccarius’s *RING condition (Eccarius, 2008). The extended middle finger and ring finger handshapes are fairly frequent because of the fact that they are used frequently, though only in kinship signs.
7. Marked handshapes through compositionality

ASL has a couple of handshapes that result from compositionality: one is the now well known I-LOVE-YOU, combining I, L, and Y, which in turn can be made even more compositional by adding an R for I-REALLY-LOVE-YOU, shown in Figure 27a. This handshape is also used for SPACE-SHUTTLE, a combination of ROCKET and AIRPLANE. Analogously, I-HATE-YOU or HOLIER-THEO (see Figure 27b) combines I, H, and Y. In both cases, the result is a marked handshape.

![Figure 27. ASL I-REALLY-LOVE-YOU(a), I-HATE-YOU (b)](image)

At least one fingerspelled letter in CSL is also compositional. CSL has adapted some of its fingerspelled letters from ASL, but invented others. Figure 30 shows the CSL letter Z; Figure 31 shows the letter ZH, which is effectively Z+H. (CSL H was borrowed from ASL). The result of this composition is again a highly marked handshape.

![Figure 28. CSL Z (a) CSL ZH (b)](image)

Another source of compositionality that results in marked handshapes occurs in Korean Sign Language KSL, for names signs in particular. In KSL, as in many sign languages, name signs are based on temporary (e.g., black eye) or permanent (e.g., dimples) individual characteristics. Like JSL and TSL,
KSL also has gender marking, which is added simultaneously in name signs, resulting in a marked handshape. For example Figure 29a shows the KSL sign for ‘dimple.’ Figure 29b shows the KSL name sign for a female who is known by her dimple (DIMPLE + FEMALE).

A really striking form of compositionality occurs in the signs for 12-19 in the JSL family. These have been reported for TSL by Hung (2010) and Liu (2010), but have been confirmed to exist also in both JSL (Osugi Yutaka, Tomita Nozomi, p.c.) and KSL (Byun Kang-Suk, p.c.). The JSL number system is basically agglutinative; for example, 23 resembles a compound of 20 and 3. Recall that the signs for 10, multiples of 10, and teens involve bending the requisite number of fingers. Normally, then, a sign for ‘12’ would involve a sequence of 10^2, i.e., the sign would have internal movement. However, there is a shorthand for 12 that involves no internal movement, but the result of combining 10 and 2 into one handshape results in a shape that is so marked that it does not appear in existing handshape inventories. The TSL handshapes for 12-19 are presented in Figure 34. Note that the sign for the numeral 16 is exceptionally not compositional, nor is the sign for 11, which is simply 10^1.17

There are consequences of the availability of these reduced compositional forms elsewhere in the grammar. Generally movement within a sign reduces the likelihood that it will be able to combine easily with other signs. For example, in ASL one can sign 2-YEAR, 4-YEAR substituting 2 and 4 for the fist with which one usually signs YEAR, but not *12-YEAR because 12 has internal movement; rather, two separate signs are required. Similarly, one can sign 2-APPROACH-CAR but not *12-APPROACH-CAR. However, in the case of the JSL family, such signs are possible precisely because of the lack of movement, bizarre though the handshapes might be. (Hung, 2010; Liu, 2010; Fischer, Hung, and Liu, 2011). In TSL, 80-YEARS or 18-YEARS or 12-APPROACH-CAR are all in fact grammatical.
Figure 31. TSL numerals 12–19
8. Conclusions

We have seen that there is a multitude of sources for marked handshapes in Asian sign languages: fingerspelling, Chinese characters (both katakana and kanji), written symbols, spoken language/visual language “puns”, cultural influences, and combinatorial processes. We have also seen that, even though different sign languages may have different selected fingers, accounting for the different phonotactics, some differences remain that are related to the iconicity of Chinese characters and syllabary symbols.

We have shown that there is an intimate connection between the use of Chinese characters and syllabaries in written Asian languages and their representation in their respective sign languages. It is our general impression that the use of Chinese characters in signing is more extensive in those sign languages that lack fingerspelling (e.g., HKSL and TSL) than in those that have it (CSL, JSL, KSL), since sign languages that have fingerspelling would have two options for borrowing from the written language rather than just one. In a way, Chinese fingerspelling is more “foreign” than Japanese, in that it is based on a romanization of Chinese that serves as a notation system for the pronunciation of standard Chinese and which is used only minimally in Chinese writing; in contrast, Japanese uses syllabaries in everyday writing. We have also seen that Chinese characters function analogously to fingerspelling and fingerspelled loan signs in Western languages like ASL. However, the use of character signs, as opposed to the more widespread use of drawing complex Chinese characters in the air or on the palm, appears to be more extensive in TSL than in JSL or CSL.

Many of the handshapes we have discussed are fairly recent overlays and have thus not yet fully assimilated into the existing phonological systems of these languages. Some, especially in CSL, require a familiarity not only with the written language but also with the spoken language (e.g., “pun” signs in CSL).

Although there is handshape iconicity in Western sign languages as well as in Asian sign languages, we would argue that the type of iconicity found in borrowings from Chinese characters is of a different character, one that permits restricted violations of phonological constraints. Phonological theories that take language history as well as language acquisition into account in order to deal with markedness may provide helpful insights into explaining how these foreign handshapes and combinations of handshapes finally integrate into the Asian sign languages.
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Notes

1. See, however, Kuroda’s 2002 critique of Itô and Mester with regard to certain phonological processes in Japanese.

2. 品 is in fact depicted in TSL, CSL, and JSL, but differently in all three; in JSL, one hand sequentially shows three circles, while in CSL, one hand holds the top circle while the other hand places two circles sequentially underneath.

3. The CSL and TSL (probably borrowed) sign for 䊭 is the only instance of which we are aware in which agreement is between two objects rather than between subject and objects. However, it still follows Meir’s theory in that it is in some sense moving from source to goal.

4. One reviewer suggests that even though the hands do not touch, there is still a close relationship between them. It is interesting that in other pronunciations of this sign, the fingers of one hand actually grasp the extended finger of the other, thus indeed regularizing the phonotactics.

5. Note that this is not a character sign, as 500 and 700 would be written in Chinese characters as 五百 and 七百, respectively.

6. The Mandarin pronunciation of “10” is identical with the word for “yes” aside from the tone, and the CSL sign for “yes” uses the ASL r (index and middle finger crossed) handshape, constituting a cross-linguistic pun.
7. TSL signers also make these signs near the armpit but not in it.
8. ‘ti’ is one possible reading of the character for 1000 in Japanese. If one stretches the imagination, one could think of the syllable/number in Figures 22 and 24 as a 1 followed by 3 zeros.
9. There are two possible reasons for this difference in velocity: first, JSL requires 50 handshapes as well as some diacritics to convey the Japanese syllabary. This requires finer distinctions than those found in ASL, hence more attention. . . . A second possible explanation is that since one is dealing with syllables rather than segments, each fingerspelled syllable is carrying more information.
10. Fingerspelled loan signs are extremely rare in Asian sign languages, as their function is subsumed by character signs; rather, full fingerspelling is used, which again shows that fingerspelling is not as fully integrated into even those Asian sign languages that have it as in ASL. One which we have observed is the name Mayumi, the spelling of which involves a sequence of syllables all of which have three extended fingers in the same plane but with three different fingertip orientations: down, up, side.
11. The ksi handshape (index and pinky extended, middle and ring fingers contacting thumb) is used in Makaton, an invented sign system previously prevalent in special education in the UK as a classifier for animals.
12. CSL uses the same handshape to represent the Pinyin letter ‘t.’
13. Bencie Woll (p.c.) suggests that the thumb extended and pinky extended handshapes for positive and negative may have entered CSL from contact with either BSL or British culture via Shanghai.
14. It is interesting to note that CSL also distinguishes among older and younger brothers and sisters. In CSL, kinship signs are made in the area of the chin and mouth. Handshapes distinguish FATHER (extended thumb), MOTHER (extended index finger), OLDER-SIBLING (extended middle finger) or YOUNGER-SIBLING (extended pinky); to distinguish sisters from brothers, a sequential gender marker is added.
15. Thanks to Byun Kang-Suk for pointing this out and for demonstrating the handshapes.
16. Harry van der Hulst (p.c.) has an interesting take on the composite shapes discussed in this section. He suggests that what we have in the cases of Figures 27, 28b, 30, and 31, are the simultaneous production of two unmarked handshapes, similar to mechanisms of fast speech, where, for example, unacceptable clusters show up due to vowel elision. This approach is appealing; the one response we would have that goes against that view is that a lot of fast speech results both in and from ease of articulation. In this case, the composite handshapes are much more difficult to produce than either element alone. This idea is worth further exploration.
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The phonetics and phonology of the TİD (Turkish Sign Language) bimanual alphabet

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1. Introduction

This paper focuses on the TİD bimanual2 alphabet in terms of the tension between sign phonetics and phonology. The letters in the TİD bimanual alphabet are based on the visual appearance of the printed letters in the Turkish alphabet. They differ from one-handed fingerspelling systems (e.g., ASL) and even from other two-handed fingerspelling systems (e.g., BSL). TİD letter signs may differ phonologically from TİD handshapes. We will show that they do not necessarily conform to the phonological constraints of TİD. In addition, we investigate how these strongly iconic letters are borrowed into the TİD vocabulary (as in ASL, cf. Brentari and Padden, 2001), and whether these newly formed signs, i.e. initialized and fingerspelled signs, conform to the phonological constraints of TİD.3

There are three main findings: (i) one-handed TİD letters are signed with the dominant hand when they are involved in signs as part of the TİD lexicon while otherwise one-handed TİD letters are fingerspelled with the nondominant hand, (ii) the handshape of a TİD sign can slightly differ from the handshape of the respective TİD letter (as in the case of the letter P) in order to conform to phonological well-formedness constraints on TİD lexical signs, (iii) a movement can be added to both uni- and bimanual letters to form an initialized sign.

The paper is organized into four parts: after briefly introducing the classification of two-handed signs in the remaining part of section 1, we will present the reader with the TİD alphabet and discuss to what extent it meets phonological constraints on the use of one and two hands (section 2). In section 3, we will discuss processes by which TİD letters enter the TİD lexicon, what linguistic challenges arise through this integration and how they are resolved (see Kubus, 2008). In section 4, we summarize our main findings and draw some general conclusions about the relation between sign language phonetics and phonology.
1.1 Two-handed signs

In order to answer our first research question whether the TİD bimanual alphabet is to be described phonetically or phonologically, we will test whether it conforms to phonological well-formedness conditions for two-handed signs. Therefore, we first introduce Battison’s (1978) well-known classification of two-handed signs and secondly the phonological constraints that govern them. There are three types of signs in terms of handedness: one-handed signs, two-handed signs, and compounds consisting of one one-handed and one two-handed sign (Johnston and Schembri, 2007). Two-handed signs vary in terms of hand dominance and the handshapes of the two hands (Battison, 1978) :

(i) Type 1: Both hands have the same handshape, the same movement and generally either the same location or a symmetric location (FESTİVAL ‘festival’, see Figure 1a).

(ii) Type 2: While both hands have the same handshape one hand is dominant and the other is non-dominant (DÜĞÜN ‘wedding’, see Figure 1b).

(iii) Type 3: the hands have different handshapes, one is dominant and one is non-dominant (TAVUK ‘chicken’, see Figure 1c). In these signs, the non-dominant hand acts as articulator and its handshape must be taken from the set of unmarked handshapes.

Figure 1. (a) Type 1: FESTİVAL ‘festival’ (b) Type 2: DÜĞÜN ‘wedding’, (c) Type 3: TAVUK ‘chicken’
1.2 Phonological constraints on two-handed signs

Sandler (2006) summarizes the phonological constraints on the dominant and especially on the non-dominant hand in two-handed signs:

(i) **The Dominance Condition and the Symmetry Condition** (see 1.1, Bat- tison, 1978).

(ii) **The Selected Finger Constraint** (Mandel, 1981, as cited in Sandler, 2006, 1885) requires a maximum of one specification for selected fingers on the dominant hand in a sign.

(iii) **Prosodic constituency/Monosyllabic**: Most signs have only one movement and are monosyllabic (Coulter, 1982; Sandler, 1993 as cited in Sandler, 2006).

In addition, Brentari (1998, 46) defines a

(iv) **Contact** parameter for two-handed signs of type 3: the dominant hand may only contact the non-dominant hand at eight specified places.

1.3 Linguistic properties of letter names in an inter- and cross-modal perspective

Letter names, i.e., the pronunciation of a language’s graphemes in isolation, are a special class of units. By their very nature, they are no proper words or names but the constituents of the latter. The relation between letters (or, more precisely, the sounds from which they derive) and words is that of “duality of patterning” (Hockett, 1960; van der Hulst and Mills, 1996). This means that infinitely many words can be generated from a finite set of elements, the phonemes or, in our context, graphemes. Graphemes make up what we call an “alphabet”. This word already hints at one strategy of how to name graphemes: in the Greek alphabet, each letter has a proper (though irrelevant) name that starts with that letter, i.e., “a=alpha”, “b=beta”, etc. The word “alphabet” just denotes the beginning of that list. Another, more widespread and simple strategy, is to use the graphemes themselves as names. This strategy, however, runs into difficulties exactly because graphemes are not words and therefore do not adhere to phonological well-formedness constraints on words. In particular consonants inevitably miss the minimal prosodic requirements necessary to form a phonologically licit smallest unit of a language: “n” or “t”, for example are not possible words. In order to satisfy the constraints on a minimal prosodic word for consonantal letters, an epenthetic vowel is inserted, either before or after the consonant. Thus, “n” becomes [en] and “t” becomes [ti:], in English – whose homonym ‘tea’ is a proper English word.
In spoken Turkish, the same strategy is used; however, the epenthetic vowel may differ in terms of type and position. Thus, in Turkish, “n” is [ne] and “t” is [te]. Sequences of letter names that become proper words are called “acronyms”, as, for example, ‘AIDS’, or ‘NATO’. Acronymy is a quite productive process of word formation in spoken languages.

The sign languages of the world also differ with respect to their manual alphabets, as will be discussed in the following section 2, with TİD as our reference language. Again, the challenge that letter names pose to sign languages is common to all of them as well as to spoken languages and has led to common strategies to overcome it, one of which is movement epenthesis. Letters and their names thus constitute a particularly interesting data class for exploring the interface between phonetics and phonology in signed languages in general and TİD in particular.

2. The TİD manual alphabet

TİD has a bimanual alphabet like British Sign Language (BSL), but different from it as well as different from the unimanual alphabets of e.g., American Sign Language (ASL), French Sign Language (Langue des signes française, LSF), or German Sign Language (Deutsche Gebärdensprache, DGS). Historically, the TİD manual alphabet had been preceded by a unimanual alphabet based on the LSF one. This alphabet was used at Yıldız School for the Deaf in Istanbul that was run by an Austrian educator, Ferdi Garati, from 1889-1926 (Haydar, 1925; Busse, 1994; as mentioned in Miles 2009, Betten, 2009, and Taşçı, 2011). In the 1940s, the school moved to Fatih and was renamed Fatih School for the Deaf (Özyürek, İlkbaşaran and Arık, 2005). Note that after the foundation of the Turkish Republic in 1923, in the course of Atatürk’s language reform, the old Arabic script had been replaced by the Latin script. Due to this change, the deaf manual alphabet was in need of revision, too. Therefore, probably in the 1940’s or 1950’s, the present form of the TİD manual alphabet was introduced at Faith School for the Deaf and other Turkish deaf education institutions (Zeshan, 2003, 46).

The TİD manual alphabet is “dactylogical,” that is, based on the fingers (gr.-lat. “daktylus”) which imitate the form of the Latin block letters (Sutton-Spence, 2006, 469). Overall, the TİD manual alphabet has 29 manual letter signs which are visually modeled from the Turkish alphabet (see Figure 2). In the TİD manual alphabet, the letters J and Y have a “tracing movement” similar to the movement in the ASL letters J and Z, however, performed on the non-dominant hand and not in the air. The dot on the “ı” (İ), Umlauts
(Ö and Ü), and cedillas (Ç and Ş) in TİD are produced with finger snapping which may be considered as hand-internal movements. Other than these, only Ğ (soft G) has a further hand-internal movement, namely, moving the thumb of the dominant hand up and down repeatedly (wagging). Note that in contrast to unimanual alphabets like ASL in bimanual alphabets like TİD the single letters are relatively large and there are big differences in the single handshapes. They are typically signed in the waist region where interlocutors may still perceive them quite well with peripheral vision (Sutton-Spence, 2006, 469). One-handed manual alphabets mainly overlap with the handshape inventory of the sign language, whereas two-handed alphabets only overlap with their handshape inventory to the extent that the alphabet also has one-handed letter signs (Sutton-Spence, 2006). Some letters in TİD (C, I, L, O, (P), U, V) are one-handed, indeed, and at the same time also handshapes in TİD.¹⁰

Figure 2. The TİD Manual Alphabet (see also the videos for each letter in the appendix) (all pictures are taken from the viewer’s perspective)
In general, we observe five kinds of fingerspelled letters in the TİD manual alphabet:

(i) **1-handed letters (static):** C, I, L, O, P, U, V

(ii) **two-handed letters, type 1 (symmetric, both hands static):** B, M, (W, X)\(^{11}\)

(iii) **two-handed letters, type 2 (same handshape, both hands static):** G, S, T, K-İ\(^{12}\)

(iv) **two-handed letters, type 3a (different handshape, both hands static):** A, D, E, F, H, N, R, Z, K-A, (Q)\(^{13}\)

(v) **two-handed letters, type 3b:** letters that are originally one- or two-handed and that receive a movement of some sort through the dominant hand, e.g., a tracing movement (J, Y), a secondary hand-internal movement, or a finger snapping. Originally one-handed letters that thus become two-handed are İ, Ç, Ü, Ö, J, Y; originally two-handed letters are Ğ and Ş.

All types of 2-handed signs, namely Battison’s type 1, 2, and 3 are present in the TİD manual alphabet. In our classification, type 3a signs are most frequent. However, they are all static. Only type 3b letters have a movement of some kind.

2.1 Do TİD manual letters violate phonological well-formedness conditions?

In the following, we are testing whether one- and two-handed TİD fingerspelled letters may violate various phonological constraints: hand dominance (2.1.1), contact (2.1.2), and prosodic constituency (2.1.3).

2.1.1 Hand dominance

One-handed TİD letters (C, I, L, O, P and V) are produced with the non-dominant hand. This is quite surprising given that one-handed TİD signs are always signed with the dominant hand and the dominant hand is readily available for signing one-handed TİD letters. So why should they nevertheless be signed with the non-dominant hand? This may be due to the fact that during the course of fingerspelling it would be hard to change the dominance back and forth between the dominant and the non-dominant hand when fingerspelling one-handed and two-handed letters. We suppose that fingerspelling one-handed TİD letters with the non-dominant hand reflects a generalization
across the TİD manual alphabet, owing to the fact that it comprises one- and two-handed letters. Note that in one-handed letters that have two-handed variants with diacritics (cedilla) or one or two dots, as in C/Ç, İ/İ, O/Ö, and Ü/Ü, the base letter must be signed with the passive non-dominant hand and the active dominant hand adds the cedilla and the dots by finger-snapping, respectively. In those minimal pairs, changing the dominance for the base letter from dominant (as in C, İ, O, Ü) to non-dominant (as in Ç, İ, Ö, Ü) would result in an inconsistency within the pair. This generalization also requires one-handed letters with no two-handed counterparts to be signed with the non-dominant hand, in the first place. As a result, all TİD signs are signed with the non-dominant hand which produces the entire letter (as in one-handed letter signs) or it provides the static base of the letter to which the dominant hand actively adds the remaining part of the letter by making contact with, adding a finger-snapping, or a tracing movement to the sign (as in two-handed letter signs).

It should be noted, however, that the dominance condition and the prosodic condition interact in a highly lawful way: If there is a movement in the letter, it is always carried out with the dominant hand, never with the non-dominant one. Also, “transitional” movements, by which the dominant hand adds its part of the letter to the non-dominant hand, as in static two-handed letters (type 3a), may count as movements in this respect. This regular behavior of the dominant hand shows that movement constitutes dominance (as opposed to a static posture of the hand), in a very basic physical sense. The linguistic system can then exploit this basic regularity, and may further refine it, in terms of phonological rules that hold for a particular sign language.

For two-handed letters of Battison’s (1978) type-3, the dominance condition is violated insofar as the handshapes of the non-dominant hand do not only come from the set of unmarked handshapes in TİD shown in Figure 3 (see Kubus, 2008):

![Figure 3. The narrow set of unmarked handshapes in TİD (Kubus, 2008)](image_url)
In A, K, M, N, and Y, the V-handshape is used on the non-dominant hand; in F and J the L-handshape is used, and R has a TİD P-handshape on the non-dominant hand. Lastly, H does not conform to any handshape at all.

2.1.2 Contact

The dominant hand may generally contact the non-dominant hand at any contact point in order to convey the iconic shape of the corresponding written letter. In two-handed TİD signs, as in other sign languages, the two hands can make contact with each other only at specific contact points which are phonologically constrained (Brentari, 1998; Sandler and Lillo-Martin, 2006). In two-handed TİD letters, however, the two hands may contact each other at phonologically licensed as well as unlicensed locations. Mostly, they adhere to phonologically licensed contact points, which are the following three:

(i) **Finger tip:** D, E, F, K-A, K-I, M, N, (R), S, T, Z, Q, W

(ii) **Middle knuckle:** A, H, (R)

(iii) **Base knuckle of index finger:** D, E, F, K-A, K-İ, Z

However, there are also letters that show odd contact points, such as H, R, B, Y, and X (see Figure 2). In H, the index finger of the dominant hand crosses horizontally over the vertically extended index and pinky finger. The index finger of the non-dominant hand is thereby contacted at the middle knuckle, the pinky finger, however, at a point between the middle and the upper knuckle. One could argue that there is only one contact point per letter and the proper one is the one for the middle knuckle. However, the fact that there are various contact points is an oddity already, which re-occurs in the letter R. Here, three fingers make contact at one point, namely the fingernail of the index finger of the dominant hand and the fingernail of the middle finger of the non-dominant hand at (around) the middle knuckle of the non-dominant hand. This is a quite complicated letter. The contact of the fingernails is otherwise not observed in proper TİD signs (except for some iconic signs related to nails, e.g., “nail polish”). In B, also the fingernails of the index fingers and thumbs of the two hands make contact. In Y, the contact point is between the base knuckles of the index and the middle finger, where the perpendicular line of the letter Y is traced downwards. In X, the two index fingers cross between middle and upper knuckle.

Summarizing, most contact points are also phonologically licit: finger tips, base and middle knuckles. Others, however, are phonologically illicit: between knuckles, at fingernails. Moreover, more than two selected fingers
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may share a single contact point. Taken together, these observations are consistent with the view that contact is not fully constrained phonologically, but guided phonetically, in TİD letters. Under the hypothesis that contact is driven by iconicity of the resulting letter shapes, we would expect to see a mixture of well-formed and ill-formed contact points – which is borne out by the data. This does not mean that the contact points are completely random. They are not. Rather, most of them are anatomically motivated, mostly making recourse to the knuckles and the fingertips. This fits with a picture where the set of phonologically selected contact points is a proper subset of the wider superset of phonetically motivated ones.

2.1.3 Prosodic constituency

TİD letters do not have to form a minimal prosodic unit, that is, a movement may be missing for a single letter. Since they are letters and not proper signs one may be inclined not to apply any prosodic constraint in the first place. Some one- and two-handed letters (our types 1, 2, and 3a) do not have movement, indeed, and only type 3b has various kinds of movement (see section 2). The set of TİD letters with movement (type 3b) comprises: İ, Ç, Ü, Ö, J, Y, Ğ, and Ş. Two of them, J and Y, show a tracing movement which depicts (a part of) the letter. This movement is more in the service of iconicity than in the service of a phonological requirement. As a matter of fact, it renders the otherwise static letter dynamic, but more epiphenomenally. Otherwise, J would be too similar to L. They only differ in their hand orientation: in L, the palm of the hand is facing, in J the back of the hand (see Figure 2). V is oriented on the X-plane with the back of the hand facing, while Y is oriented on the Y-plane. Ğ shows what can best be described as a hand-internal secondary movement, a wagging with the first section of the thumb of the dominant hand. In the remaining letters, İ, Ç, Ü, Ö, and Ş, the dominant hand adds one or two finger snaps to indicate the dot(s) and the cedilla. Although these additional movements fulfill the prosodic requirement of a minimal prosodic unit, they are quite different from regular movements. In particular the finger snaps only convey the movement and are not combined with any other phonological feature of the letter. There is still no movement in the overall two-handed letter. In Ş and Ğ, where the snapping and the wagging are conveyed with the dominant hand, that at the same time also forms a handshape of some sort, the combination with the movement is even odder in that parts of the hand (which clearly do not belong to
the “selected fingers” as in a genuine sign) which happen to be suitable are used for the snapping/wagging. The resulting letter is more a “kludge”, an idiosyncratic *ad hoc* formation, than a well-formed sign.

It has been argued that some letters (i.e., type 3b) do have movement and thus do not violate the prosodic constraints of a proper sign. Even in two-handed letters of type 3a, one may be tempted to also diagnose a movement since the dominant hand actively adds one part of the sign through a movement; however, this movement is not lexical, but just transitory, not even epenthetic. The contact, however, is salient and pronounced. The dominant hand does not just touch the non-dominant hand but makes a short and firm single contact. This salient contact differs from that found in usual TİD signs, e.g., from TAVUK ‘chicken’, a Battison type-3 sign where the index finger of the dominant hand contacts the palm of the non-dominant hand (repeatedly) somewhere in the middle (see Figure 1c). The selection of the exact location of the contact may follow from (i) the highly restricted location of the contact, typical of TİD letters, where contact with the non-dominant hand is mainly specified in terms of the knuckles, and (ii) the restriction of a single contact. Therefore, the dominant hand “knows” exactly where it should contact the non-dominant hand and makes sure that this single short contact becomes as salient as possible. Transition and tracing movements (as in type 3a and b letters) may be only phonetically specified. Actually, as long as TİD letter signs are still outside the core lexicon, there is no need to conform to any linguistic constraint. We argue below that it is only when TİD letters are integrated into the TİD lexicon that lexical movements are added to make the initialized signs phonologically well-formed. When letters (and numbers) in sign language are intended to be used in a sign, movement epenthesis (by minimal epenthesis or full epenthesis with primary and secondary movements) is common and the best way to conform them to a proper sign.

Sutton-Spence (2006) points out that the manual alphabets for sign languages have been constructed for raising the literacy of deaf signers in the 1600s, and that they are fairly artificial. They may therefore start out outside the phonological and lexical system of the sign language. From this perspective, TİD fingerspelling can be viewed as phonetic rather than phonological, at least in the earlier stages of its inception. However, this does not mean that fingerspelled letter signs are not related to phonological parameters at all. To the contrary, there are various signs that borrow fingerspelled letters, as in initialized signs, to which we will turn now.
3. The use of fingerspelled letters in TİD signs

Fingerspelling may violate phonological well-formedness conditions in terms of hand dominance, contact, and prosodic constituency, as pointed out in the previous sections. However, when signs are derived from fingerspelled letters, they start to conform to the phonological rules.

As we mentioned, one-handed letters in the TİD manual alphabet are signed with the non-dominant hand. However, when one-handed TİD fingerspelled letters are used as handshapes of lexical signs, they are signed with the dominant hand. For example, CEVAP ‘answer’ is signed with the dominant hand using the TİD C-handshape and with a path movement. The C letter becomes phonologically well-formed by adapting to two main phonological constraints, namely dominance and prosody: (i) one-handed signs are signed with the dominant hand and (ii) a path movement is added (through movement epenthesis) in order to obtain a prosodically well-formed sign.

Some letters have unusual contact points which may not be used in a sign (see section 2.1.2). Therefore, the finger configuration of a one-handed sign whose handshape is derived from a TİD letter may change to make it compatible with phonological requirements on contact with a phonologically specified contact point. For example, the P-handshape in the handshape inventory and the P letter in the manual alphabet differ in interesting ways (Figure 4).

![Figure 4. (a) The P-handshape in the TİD handshape inventory (signed with the dominant hand) and (b) the P letter in the TİD bimanual alphabet](image)

In the letter P (signed with the non-dominant hand, see Figure 4b), the middle finger is bent and contacts the straight index finger somewhere in the middle (at or slightly below the middle knuckle). In the P-handshape (signed with the dominant hand, see Figure 4a), the index finger is bent and contacts the middle finger at around the middle knuckle. Obviously the P letter is related to the P-handshape. Thus, there exist initialized signs for words starting with P (e.g., PSİKOLOJİ ‘psychology’ in which the dominant hand (with the P-
handshape) contacts the right forehead laterally with a short reduplicated movement; see video in the appendix). These signs, however, do not make use of the letter P but of the P-handshape. The reason may be the fact that the P-handshape is already in the handshape inventory of TİD; hence there is no reason to use the letter P as a handshape. Moreover, it is actually hard to produce physically. The bending of the longer middle finger of the non-dominant hand and the contact at around the middle knuckle of the index finger, as in the letter P, are somewhat more challenging movements than the bending of the shorter index finger of the dominant hand and the contact at around the middle knuckle of the middle finger, as in the P-handshape. A reason why there is no reverse adaptation of the letter P to the P-handshape may be that the P-letter – though harder to produce – is more iconic, that is, it resembles the letter P more, physically, through the more pronounced rounding which is possible with the middle finger. Also, the letter P was probably contrived independently from the P-handshape, as part of the overall TİD alphabet, and therefore has retained some degree of autonomy. We therefore have to revise our previously made claim in section 2, that one-handed TİD letter signs serve at the same time as TİD handshapes slightly. This is true except for P. When P is used in initialized TİD signs, the P-handshape (see Figure 4a) rather than the letter P (see Figure 4b) is used. That the P-handshape is a regular handshape used also for non-initialized signs can be seen in signs such as KA VÅGA-ETMEK ‘quarrel’ (see video in the appendix).

As for prosodic constituency, there are various kinds of phonological processes by which one-handed and two-handed TİD letters may contribute to the TİD lexicon. In producing initialized signs, the strategies are mostly adding a path, an arc, or a hand-internal wrist movement to the letter. For example, the L, which is one of the one-handed TİD letters, has three different initializations: “Path movement”: LAZIM ‘need’ (Figure 5a), “arc” movement: LİSE ‘high school’ (Figure 5b), and “wrist movement”: LOKAL ‘association’ (Figure 5c) (Kubus, 2008).

Figure 5. (a) LAZIM ‘need’ (b) LİSE ‘high school’ (c) LOKAL ‘association’ (see videos in the appendix)
Two-handed TİD letters may similarly engage in initializations. A lexical movement of the dominant hand or a reduplicated and therefore more pronounced contact of the dominant hand with the non-dominant hand satisfies this basic requirement. Small epenthetic contact movements are used in TEŞEKKÜRLER ‘thanks’ with the T-letter (Figure 6b) and in FEDERASYON ‘federation’ with the ‘F’ letter (not shown, but see video in the appendix). “Path movements” are used in TAKSİ ‘taxi’ with the T-letter (Figure 6a), in DOLMUŞ ‘minibus’ with the D-letter, and in SORU ‘question’ with the S-letter (not shown, but see videos in the appendix).

Another use of fingerspelling is to form derivational morphemes adopted from spoken Turkish (Kubus, 2008). There are two such morphemes in Turkish: (i) -CI15 (-c1, -ci, -cu, -cü, -ç1, -çi, -çu, -çü) provides the meaning “seller of something” to the root and is equivalent to the –er suffix in English and (ii) –LI (-lı, -li, -lu, -lü) conveys the meaning of “belonging to something”, “place of origin” or “being endowed with something, containing something”. From these sets, TİD realizes -C-I/-C-U and -L-I/-L-U (see Figure 7a and b):

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**Figure 6.** (a) TAKSİ ‘taxi’ (b) TEŞEKKÜRLER ‘thanks’ (see videos in the appendix)

**Figure 7.** (a) the suffix -C-I (b) the suffix -L-I (see videos in the appendix)
TİD uses these suffixes in the same meaning as in spoken Turkish, where they are widely used; however, in TİD, they occur less frequently. Since the letters L, C, I and U are one-handed, it is easy to combine them, as in ANKARA^L-I ‘from Ankara’ or İSTANBUL^L-U ‘from Istanbul’. Between these two letters (C-I and L-I), a forward path movement is added, following the movement epenthesis rule which makes the suffix prosodically well-formed (see Figure 7 a+b). The movement change between the two letters occurs during the forward path movement. Note also that the letters of the suffix are signed with the dominant hand and not with the nondominant hand – as one-handed TİD letters normally are. These examples of fingerspelled morphemes in Figure 7 resemble most closely to the many examples of initially fingerspelled words in ASL that become contracted in the course of language change, such as N-O or J-O-B (Emmorey, 2001, 20).

Short fingerspelled sequences may also be used as abbreviations for words such as P-J (‘proje’ (‘project’)) or C-C (‘Coca Cola’, Taşçı, 2011).

Summing up, the change of dominance of one-handed TİD letters, the peculiar state of the letter P, initialized one- and two-handed signs and the contraction of fingerspelled derivational suffixes in TİD indicate that phonological well-formedness conditions of lexical signs have to be met when TİD letters become integrated into the TİD lexicon. Hence, phonetics eventually conforms to phonology. This line of reasoning is similar to Padden’s (1998) and Brentari and Padden’s (2001) adaptation of Itô and Mester’s (1995) “core-periphery” structure where native words that fully adhere to the phonological constraints of the language reside in the center and foreign loan words at various distances from it in the periphery (as summarized in Emmorey, 2001, 18ff.). Dynamically speaking, the periphery corresponds to the outskirts of the “basin of attraction” and the center to the attractor itself. Padden and Brentari (2001), however, did not consider single fingerspelled letters, as we do here, but whole fingerspelled words, as they gradually undergo prosodification on their way from the periphery to the core. We were looking closely at single TİD manual letters for two reasons. The first reason is that these letters are predominantly bimanual and can thus be checked as to their adherence to the constraints on the use of the two hands, as in two-handed signs. The second reason is that there are actually few signs in TİD that derive from fingerspelling of the letters of the respective word, in contrast to the rich set of such words in ASL, for example. Fingerspelled words are rarely used in TİD and native signers use relatively little fingerspelling overall. This may be due to the fact that Deaf Turkish people mostly have difficulties in reading and writing. Native TİD users generally fingerspell when they want to sign their names and those of specific places, as well as words which
do not have a proper sign (yet). It may also be that a bimanual dactylological alphabet is simply not suited to form signs from – if already a single letter can be quite complex and behaves like a little bimanual sign itself. As a consequence, the resulting whole word would almost inevitably violate the prosodic constraints. Consistent with this idea is the observation in Kubus (2008) that only short free and bound morphemes are fingerspelled, such as U-N ‘flour’ and the derivational morphemes -L-I and -C-I, which, in addition, become contracted into a single syllable.

4. Summary and conclusion

All tests for violations of phonological well-formedness in TİD manual letters were positive to varying extents. Some of the phonological constraints may not, some may be fulfilled, among them those that are fulfilled in a more coincidental or epiphenomenal way, as in the case of various sorts of contact points, unmarked handshapes for the non-dominant hand, and transitory movements in type 3a bimanual letters which could arguably fulfill a minimal prosodic requirement. However, we also found that some very basic constraints are strictly fulfilled, namely the fact that movement is always a matter of the dominant hand (for letters of type 3a and b). Others are mainly fulfilled, as with the predominant choice of motivated contact points. We conclude that TİD manual letters are best to be described phonetically where phonetics is considered as a superset of anatomically and physically motivated features from which the phonology of a sign language may select a proper subset of phonologically licit features for linguistic purposes.

In this article, we have explored the lower and upper limits of the phonological requirements on well-formed (one- and) two-handed TİD letters and signs formed from them. On the one hand, TİD letters typically fail to achieve basic and minimal phonological requirements on hand dominance, contact, and prosody. This, however, does not seem to be problematic as long as they remain outside the TİD lexicon. If, however, they are to be used as handshapes or as signs (as in initialized signs), they need to shift their hand dominance (one-handed letters swap dominance when used as a handshape in a TİD sign), selected fingers and contact (as with the letter P), or be augmented with a movement of some sort (primary or secondary). If, on the other hand, a sequence of TİD letters is used as a morpheme or word, this sequence typically exceeds the prosodic limits of a phonological word. As a consequence, the fingerspelled word or morpheme needs to be contracted in order to keep within the limits of a well-formed word (Hohenberger, 2008).
TİD, in the course of its history, has successfully resolved those “interface” problems between phonetics and phonology, through constant accommodation of requirements from both sides – “inside out” (from phonetics to phonology) and “outside in” (from phonology to phonetics). Here we have discussed the shift from a system based on phonetic regularities (the TİD bimanual alphabet) to a system based on phonological constraints (the TİD core lexicon). Yet the rift between the two must not be blurred. When conflicting requirements between phonetics and phonology compete, rather striking symmetry breaks in favor of phonology may occur, as in the discrete shift of hand dominance or switch of fingers. These adaptations of TİD letters to signs can also be understood in terms of a movement from the periphery to the core of the TİD lexicon. Placed at the periphery initially, TİD finger-spelled letters have found their way into the TİD lexicon, although opportunities of integration may be fewer as compared to other sign languages, partly due to the historical and educational situation in Turkey, partly also due to the dactylological and bimanual nature of the TİD alphabet.
Notes

1. We would like to thank two anonymous reviewers and Rachel Channon for their valuable comments on earlier drafts of this chapter.

2. Although the TİD alphabet is called “bimanual”, some letters only use one hand, as will be discussed in detail in section 2.

3. We will mainly be concerned with the role of single TİD letters or short derivational suffixes as they enter the TİD lexicon and not with fingerspelled words which are extremely rare in TİD (see section 3; see also Taşçı (2011)).

4. Battison (1978) determined these phonological constraints by considering only ASL. However, they seem to be universal and therefore also applicable to other sign languages including TİD. There exist examples in TİD for each of Battison’s categories; hence it can be assumed that TİD follows the symmetry and dominance condition, as well. However, the set of passive handshapes defined in the Dominance condition is not universal and may thus differ between sign languages. Kubus (2008) listed the following unmarked handshapes found in the non-dominant hand in Type-3 TİD signs: B, A, A-bar, S, F (TİD-O), 1 and 5 (see section 2.1.1 and Figure 3).

5. Sandler and Lillo-Martin (2006, 223) have revised Mandel’s original definition insofar as they refer to the morpheme and not to the sign anymore as the domain of this constraint. In the context of our paper this refinement is irrelevant, though.

6. This section has been inspired by the comment of an anonymous reviewer of an earlier draft of this chapter to whom we are indebted for pointing out inter- and cross-modal aspects of “letter names”.

7. These letter names mostly have no meaning in Greek but were taken over from the earlier Phoenecian alphabet where, for example, “aleph” means ‘ox’ and “bet” means ‘house’ (http://en.wikipedia.org/wiki/Greek_alphabet).

8. There are three other letters, W, Q, and X, which, however, occur very rarely in Turkish and therefore also in the TİD alphabet. W and X are type 1 letters and Q is a type 3a letter.

9. In section 3, we argue that the letter P is different from the Phandshape. Therefore, strictly speaking, the letter P is not within the set of TİD handshapes.

10. The defined handshapes that are found in the TİD handshape inventory are not necessarily related to initialized signs, as in: C-/U-handshape: DERNEK ‘association’; I-handshape PAZAR ‘Sunday’; L-handshape: FESTİVAL ‘festival’; P-handshape: KAVGA ‘quarrel’ (see also section 3); V-handshape: SERBEST ‘free’.

11. See footnote 8.

12. There are two variants of K, the Istanbul variant K-İ, which is a type 2 letter, and the Ankara variant, K-A, which is a type 3a letter. In Figure 2, both variants are depicted.
Here, we would like to relate our findings to the SignTyp database. It includes 6 different languages (ASL, Japanese Sign Language, Sign Language of the Netherlands, New Zealand Sign Language, Finnish Sign Language, and Korean Sign Language) and 9 datasets (2 languages, ASL and Finnish Sign Language, have datasets from different time periods). In this database, when the handshape of the non-dominant hand differs from that of the dominant hand, the distribution is as follows: B (flat hand unspread with thumb in palm or next to index): 58.3 % (of a total of n=2004); S (fist with thumb grasping fingers): 7.4 %; A (fist with thumb next to index): 1.5%; Index (index extended, all other digits closed): 6.1%; C (all fingers curved, thumb opposed and curved and no contact): 4%; O (all fingers contact thumb in circular O shape): 2.3%. Therefore the total of all “Battison” handshapes amounts to 83.8%. The remaining 16.2 % comprise other handshapes. Channon (2004) suggest that the Dominance Condition with respect to handshapes may not be so much a constraint as a set of constraints which result in a distribution where the “Battison” handshapes predominate but others are also possible. She further argues that the non-dominant handshape is a result of phonetic, phonological and iconic factors: 1) several simple phonetically based constraints (be perceptually salient, be physically easy, be cognitively easy to produce), 2) the requirements that the phonological place (or occasionally places) be contacted, and 3) in a few cases, a requirement to be iconic. We owe this information entirely to Rachel Channon.

In Turkish linguistics, capital letters in –CI and –LI are used as abstractions from the concrete instantiations of the consonant and the vowel in the suffix. Depending on the preceding consonant, the consonant C can surface either as [c] or as [ç], that is, accommodation with respect to the feature “voice” takes place. Depending on the vowel feature of the preceding stem, the vowel I can surface either as [ı], [i], [u], or [ü], according to the rules of vowel harmony. In the terminology used here, however, –C-I and –L-I are used as glosses. Note that in TİD, only –L-I/-L-U and –C-I/C-U exist. This is because the letters for the other two vowels, İ and Ü, and for the consonant Ç, involve both hands. Since, however, the hand dominance has switched from the non-dominant to the dominant hand it is no longer available for adding the necessary finger snaps. Furthermore, the lexical path movement and the hand-internal letter movement would clash.

A short history of TİD and the educational system of the Deaf in Turkey is provided by Zeshan (2003).

Note that U-N ‘flour’ is very short in the first place and therefore a good candidate for lexicalization. In smooth signing, the two letters become contracted into a single syllable whereby the change between the two letters occurs during the orientation change of the hand.
The phonetics and phonology of the TİD bimanual alphabet

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Appendix:

All letters of the TİD alphabet and the following TİD morphemes and words can be seen as videos on the accompanying CD:
C-I, C-U, DOLMUŞ, FEDERASYON, KAVGĂ, LAZIM, L-I, LİSE, LOKAL, L-U, PSİKOLOJİ, SORU, TAKSİ, TEŞEKkürLER, U-N.
Child-directed signing as a linguistic register

Ginger Pizer, Richard P. Meier, and Kathleen Shaw Points

1. Introduction

Here we consider child-directed signing as a register that must be described linguistically. Following a recent definition, “a register is a linguistic repertoire that is associated, culture internally, with particular social practices and with persons who engage in such practices” (Agha 2001: 212). All aspects of language are potential contributors to such a repertoire, whether words, pronunciations, prosody, or sentence types. The features of a register are not random; rather, some “seem to facilitate speedy communication; other features apparently serve to mark the register, establish feelings of rapport, and serve other purposes similar to the accommodation that influences dialect formation” (Ferguson 1994: 20). In the case of child-directed signing, the status of infants as novice language users and the requirement of visual attention for access to language combine to place specific demands on the register. The parent-child relationship allows a degree of physical closeness and emotional rapport not present in most signing between adults; these aspects of the communicative situation may affect the use of space and the amount of physical contact in child-addressed signing. To the degree that this register has become conventionalized, individual parents do not have to invent from scratch a way to sign to their infants. In this paper, we describe the formational features that we have observed in the signing that three deaf mothers addressed to their infants and consider possible motivations for those features of the register.

Research on register variation in signed languages has found that factors such as the degree of formality of a situation and the size of the audience addressed can affect signs’ size, speed, and degree of handshape assimilation (Zimmer 1989), as well as the amount and kind of constructed action used (Quinto-Pozos and Mehta 2010). Omission of the nondominant hand from non-alternating two-handed signs (“weak drop”) appears to be a feature of colloquial and/or rapid signing (Padden and Perlmutter 1987). Analyses of poetic signing in a number of languages have demonstrated register-specific
characteristics in phonology, the use of space, rhythm, and lexical choice (Blondel and Miller 2001 for French Sign Language; Klima and Bellugi 1979 for ASL; Russo, Giuranna, and Pizzuto 2001 for Italian Sign Language; Sutton-Spence 2001 for British Sign Language, BSL).

In many, but perhaps not all (Heath 1983; Ochs and Schieffelin 1984) spoken languages, child-directed speech—sometimes called “motherese”—is a distinctive register. The properties of child-directed speech include shorter utterances, with longer pauses between them. Child-directed utterances tend to be higher-pitched than adult-directed utterances; moreover the pitch contours of child-directed speech are likely to be exaggerated. Infants appear to prefer to listen to child-directed speech over adult-directed speech (Fernald 1985). However, child-directed speech is not simpler in all respects than adult-directed speech: for example, child-directed speech may be more varied with respect to sentence type than is adult-directed speech (Newport 1977). Speech addressed to young children may also have distinctive morphology: thus, Spanish diminutive morphology (compare, niña ‘girl’ vs. niñita ‘little girl’) appears to be more frequent in maternal speech addressed to three-year olds than it is in speech addressed to five-year olds (Melzi and King 2003).

The literature on the acquisition of a number of different signed languages reveals a consistent picture of child-directed signing (for ASL: Erting, Prezioso, and Hynes 1990; Holzrichter and Meier 2000; Launer 1982; Maestas y Moores 1980; for BSL: Harris et al. 1989; for the Sign Language of the Netherlands: Baker and Bogaerde 1996; and for Japanese Sign Language: Masataka 1992). Child-directed signing shows many similarities to child-directed speech. For example, child-directed signing tends to be larger and more clearly articulated than adult-directed signing. It also tends to be slower and to contain shorter utterances, and thus may be more readily segmented than adult-directed signing. Child-directed signing tends to be repetitive. Child-directed signing is also an affectively-laden register that may reinforce emotional bonds between parent and child; certainly it is often produced in an intimate context in which the child is seated on the parent’s lap. The result is that parent and child sometimes share a signing space. Like child-directed speech, child-directed signing is attractive to infants, irrespective of whether they have sign exposure or not. Masataka (1996, 1998) videotaped six-month-old infants (deaf and hearing) while they viewed a tape of seven sentences as addressed to adults or to infants. Both sets of infants were more attentive to the child-directed signing and displayed more positive affective reactions to it.
But some unique factors may also be at work in child-directed signing. In child-directed signing, parents accommodate the visual attentional capacities of their infants. Signing infants must know to shift their gaze between, for example, an object and the signed label for that object. These infants must therefore learn when to look at the signer. In turn, signing parents must know when to wait for their child’s visual regard, when to displace signs into their child’s visual field, and how to attract the child’s visual attention.

In sum, many discourse properties of child-directed language are likely common to speech and sign; for example, longer pauses than would be expected in adult-directed language may help the child segment the speech or sign stream. Both signing and speaking parents might scaffold the child’s language production by using utterance types that would tend to elicit further contributions from the child. However, as we suggested, child-directed signing may also have properties that are not true of child-directed speech. Characteristics of the articulatory system and of visual attention may help us to explain these properties of child-directed signing. In this study, we investigated the ways that deaf mothers modified their signs (in comparison to the citation forms of those signs) when addressing their deaf infants. Based on previous research, we expected sign modifications that accommodated the children’s visual attention and status as language-learners while showing effects of the physical proximity between parent and child.

2. Data and coding

We analyzed three mother-child dyads. Videotapes of mother-child interactions were made for all three children (pseudonyms Katie, Noel, and Suzie) at the approximate ages of 9 months, 13 months, and 15 months; Katie and Noel were additionally videotaped with their mothers at 17–18 months and 24 months. All three deaf girls have deaf parents and were acquiring ASL as a first language in the home. Each child has at least one deaf grandparent and therefore had access to a native-signing model in at least one of her parents. Katie’s and Suzie’s mothers have hearing parents, and Noel’s mother has deaf parents.

We analyzed 10 minutes of tape from each session. This span was not necessarily continuous, in that we disregarded periods of one minute or more when there was no interaction between mother and child. The 10-minute sections were chosen with a view to minimizing such gaps; i.e., we selected segments of video with a relatively high density of mother-child interac-
tion, rather than starting the segment at a predetermined time code. Using the ELAN annotation program, we transcribed all sign productions in the sample and coded them for place of articulation and for whether they had been modified in some way from their citation form. We excluded pointing signs (i.e., pronouns and body-part signs) from the quantitative analysis of sign modifications because it is difficult to distinguish between linguistic and gestural points, and because pointing signs may have a less certain citation form than do lexical signs. We coded for modifications in sign location by noting instances of displacement (producing the sign away from its citation-form position) and signing on the child's body (producing a sign such that the child’s body is used for its place of articulation). Modifications to sign movement included repetition (the cyclicity of the sign is increased); lengthening (the sign is held or produced slowly, increasing its duration); and enlargement (the movement excursion of the sign is increased). Additional modifications for which we coded were molding (moving the child’s hands to make her produce the sign) and whether the mother leaned into the child’s visual space across a span of signs, rather than sitting or standing upright. Previous research did not lead us to expect modifications to maternal handshape, so we did not devise a code specifically for handshape changes, and we did not discover a need for one while coding.

All maternal signs were also coded for whether the child had visual access to them. In a separate coding pass, we coded the child's eye gaze, or where she was looking at any point in the interaction. It is important to note that even when a child was not focusing on her mother’s face or hands, she may still have had visual access to the mother’s signs, as long as those signs were produced somewhere within her visual field. Finally, we coded the attention-getting cues produced by the mother, such as touching or waving at the child; we also coded whether those cues were successful in gaining the child’s attention. In this category of attention-getting cues, we included only those designed to draw attention to the mother, rather than cues, such as points, that the mother used to draw attention to an object or to another person.

3. Results

In our samples of child-directed signing, we identified 517 modified signs out of a total of 1114 lexical sign tokens: 46% of the mothers’ sign tokens were modified in one or more ways. As seen in Figure 1, the most frequent sign modifications were leaning into the child’s visual field and repeating
the sign (i.e., increasing the number of movement cycles). The least frequent modification type was molding: two mothers (Katie’s and Noel’s) occasionally manipulated their children’s hands to make the children articulate signs, but Suzie’s mother never did this. Because some sign tokens were modified in multiple ways, the number of modifications shown in this graph exceeds 517, the number of modified signs.

![Figure 1. Modified signs (n = 517) in child-directed signing. We report the frequency of seven modification types: leaning (LN); repetition (R); displacement (DIS); lengthening (L); enlargement (BIG); signing on the child’s body (SOC); and molding the child’s hand(s) (M).](image)

Figures 2 and 3 show the proportion of child-directed signs that were modified, as a function of the child’s age. A decline in modifications with the child’s age is evident for both Katie’s mother and Suzie’s mother; see Figure 2. However, much of this decline is attributable to a drop-off in the amount of leaning between the 9- and 13-month recording sessions for Suzie’s mother and between the 13- and 15-month recording sessions for Katie’s mother. Excluding signs whose only modification was leaning, the percentage of signs that each mother modified remained relatively stable across the period we studied; see Figure 3. The fact that modifications other than leaning continued throughout the period under study may indicate that the factors that elicit the register are similarly persistent at least until the child’s second birthday.

In the following pages, we discuss individual modification types.
On occasion, parents may adopt an overt teaching role and manipulate the child’s articulators to form a sign (Maestas y Moores 1980). For example, Noel (1;5,29) sat on her mother’s lap while her mother named the colors of the blocks on the floor in front of them. The mother picked up the blue block and, holding it in one hand, used her other hand to twist Noel’s forearm to form a facsimile of the sign BLUE, illustrated in Figure 4. She followed this molding with her own production of the sign.
As it happens, the early instances of molding in our data involved the molding of movement (as in the just-mentioned example) or location (as in Noel’s mother moving Noel’s hand to her forehead for an approximation of the sign HORSE at 1;2,20). In contrast, the last instances all involved the molding of handshapes of the manual alphabet (Katie, 1;11,12, 6 tokens). Given that young children’s accuracy in handshape production is low (Meier 2006), this possible change from molding location or movement to molding handshape may reflect a corresponding change in the mothers’ expectations for their children’s sign production as their children mature.

3.2 Signing on the child

In the episode described above when Noel’s mother was labeling colors, one of the blocks was orange. Unlike the ASL color signs for the other blocks (GREEN, BLUE, and YELLOW), which are produced in neutral space, the sign ORANGE is articulated at the signer’s mouth, as shown in Figure 5. If the mother had produced this sign in its expected place of articulation at her own mouth, it would not have been visible to Noel, who was seated on her lap. In this situation, Noel’s mother had a number of options. She could lean around the child, giving her peripheral visual access to the sign; she could attempt to draw Noel’s gaze up and backwards toward her face; she could dispense with contact and produce the sign in the neutral space in front of the child; or she could articulate the sign on her child’s mouth. In fact, all five tokens of ORANGE that the mother produced during this episode were signed on the child.
This strategy of signing on the child was used by all three mothers in the sample. About half of the tokens signed on a child were produced when the children were on their mothers’ laps, but all three mothers also signed on their children when facing them or when sitting next to them. With one exception, all tokens signed on a child were specified for contact with—or proximity to—the head or torso. As we will discuss in the next section, signs specified for contact were never displaced into neutral space (so this strategy was not available to make head- or torso-contacting signs visible to the child). However, other strategies for making signs visible to a child on the lap were occasionally used. For example, while Noel (1;1,12) sat on her lap, her mother juxtaposed the signs MOTHER and FATHER as articulated respectively on the child’s chin and forehead with those same signs produced at the expected locations on her own body; as she did this, she was leaning her head into Noel’s peripheral vision. Such juxtapositions were relatively infrequent when the child was on her mother’s lap: of 23 tokens signed on a child who was on her mother’s lap, only five—all during the same session—were alternated with signs in the expected location. However, when the mothers signed on their children with the two facing each other or next to each other (20 tokens), the mothers alternated signs on their children with signs in the expected location in a majority of instances (13 tokens or 65%). All three mothers produced such alternations.

A different class of signs that were sometimes produced with contact on the child’s body were pronominal points. As stated above, we did not include pointing signs in our calculations of sign modifications because of the difficulty of making a principled distinction between gestural and linguistic points. However, we noted a number of instances from both Noel’s and Katie’s mothers in which their pronominal points contacted the children’s
torsos. For example, Noel’s mother held Noel (1;2,20) on her hip while they looked at photos hanging on the wall. The mother signed the following (her gaze direction is indicated above the gloss):

(1)     photos               Noel
       POINT[photo] POINT-touch[Noel] NOEL
       ‘That’s you—Noel.’

     photos               Noel
       ALL[across photos] POSS-touch[Noel] NOEL
       ‘All of them are yours—Noel’s.’

The point and the possessive pronoun that touched Noel’s chest were smoothly integrated into the sentence. Such points with contact are different from other signs produced on the child’s body; these other signs are lexically specified for contact, while second-person points are not. Moreover, the contact was referential in the case of the pointing signs (including the possessive pronoun), but was not referential in the production of signs such as MOTHER or FATHER on the child. However, both kinds of signs that contacted the child’s body were likely made possible by the physical closeness between the parent and child, the resultant potential for their signing spaces to overlap, and the frequent use of touch in their interactions.

Signing on the child accommodates the child’s visual attention, especially when the child is on her mother’s lap (Harris et al. 1989; Waxman and Spencer 1997). When both mother and child are facing the same direction, signing on the child may ease the problem of visual perspective-taking in representing new signs (Shield 2010). In such instances, the child views the signs from the signer’s perspective, rather than from the addressee’s perspective. When parents juxtapose a sign on the child with the same sign articulated in its expected position, they produce a sample that not only provides two different visual perspectives on the shape of the sign, but that also provides tactile information about the sign’s place of articulation.

3.3 Displacement

A relatively common modification in child-directed signing is to displace a sign from its expected location. Such displacement may have two potential motivations: a sign may be displaced toward its referent, thereby enhancing the association between the two (Launer 1982), or displacement may be used
to move signs into the child’s visual field (Harris et al. 1989; Waxman and Spencer 1997). In an example of the latter function, Katie’s mother built a tower of stackable toys that Katie (1;1,5) was eager to knock down. The mother signed 8 tokens of \textit{wait}, a two-handed, neutral-space sign made with a 5-handshape (i.e., all fingers extended and spread) and a wriggling movement of the fingers. For all tokens, she stretched one or both hands forward, interposing them between Katie and the toy tower that the child was looking at, rather than producing the sign within her own normal signing space. (Naturally, when her mother briefly looked away, Katie immediately knocked the tower down.) [See video clip 1.]

It can be difficult to discriminate between the two possible motivations for displacement (spatially associating a sign with a referent, versus making the sign visible to the child). If the child is looking at an object, and the mother displaces her hands into the child’s visual field to comment on that object, then her signs necessarily move toward it. We had no examples in our sample where signs were displaced toward their referents in ways that did not also accommodate the child’s gaze. Interestingly, we saw cases where highly-repeated signs started out non-displaced, and the mother displaced them—while continuing to repeat—after the child initially failed to look (e.g., the sign \textit{no}, 9 cycles, last 4 displaced, addressed to Katie at 1;11,12; see video clip 2) or after the child had shifted her gaze away (e.g., \textit{toilet}, 8 cycles, last 2 displaced, addressed to Katie at 1;11,12). In these examples, both from the same book-reading session, displacement of the signs was unambiguously motivated by the child’s gaze direction; the fact that displacement also moved the signs toward the book the mother was talking about appeared to be incidental.

In our data, only neutral-space signs and signs specified for contact on the non-dominant hand were displaced (cf. Holzrichter and Meier 2000). As mentioned above, when signing in the expected position was not feasible for signs specified for contact, those signs were articulated on the child’s body rather than being signed without contact. This pattern in child-directed signing suggests a possible difference with other registers. For example, contact on the signer’s face is sometimes not achieved in deaf-blind signing (Mesch 2001), presumably because such contact would require a very long movement excursion of the addressee’s hand.

Harris et al. (1989) found a decline in the percentage of displaced signs (pooling the types of signs we coded as displaced with those we coded as signed on the child) as the children got older and more skilled at shifting attention back and forth to their mothers. In their data, out of all signs that were visible to the child (over 70\% of the total), three of the four mothers
displaced a majority of signs when their children were younger but switched to producing a majority in the expected location by the 20-month recording session. In our data, the percentage of sign tokens that Katie’s mother produced outside of the expected position showed a similar decline with her child’s age, moving from 31% at 13 months to 13% at 15 months and settling at 5-7% during the last two sessions. There was not a similarly clear pattern for Noel’s mother. (No comparison is possible with Suzie’s mother, because Suzie was only 15 months old at her last recording session.)

3.4 Leaning into the child’s visual field

Given that signs on the face or body are not displaced in child-directed signing, one way that parents make their signs visible (without signing on the child) is by leaning forward during a span of signs (cf. Harris et al. 1989). In the following example reported in Meier (2008), Katie (1;1.5) and her mother were looking at a picture book; see video clip 3. Mother and daughter were seated on the floor, with the mother behind and to the left of Katie. The mother’s left and right hands are indicated in the transcription as LH and RH, respectively:

(2) M’s gaze: book Katie book Katie
M’s posture: leaning in
LH: DUCK5x
K’s gaze: to book.........................to Mom...................to book.........to Mom

At the first token of DUCK (a one-handed sign articulated at the mouth that suggests the opening and closing of a duck’s bill), the mother leaned in, thereby making it possible for her daughter to see this sign that is articulated on the face. She continued to lean in for the remainder of the interaction. All three mothers used leaning in this way; as shown above in Figure 1, leaning was the most frequent method of sign modification.

3.5 Repetition

Maternal signs were coded as repeated if single-cycle targets had 2 or more cycles and multi-cycle targets had 4 or more cycles. For example, Suzie’s mother pointed to a red toy and then signed RED with six cycles; Suzie (1;1,11) shifted her gaze from the toy to her mother’s sign on the third cycle.
A possible motivation for increasing the cyclicity of a sign may be to repeat the sign until the child looks, as was perhaps true in this last example. However, as shown in Figure 6, for roughly half of the repeated tokens in our data, the child was already looking at the mother before she started to sign (Pizer, Shaw, and Meier 2007). Given that the mother already had the child’s visual attention in these cases, there must have been another reason for her to increase the cyclicity of these signs.

![Figure 6](image)

*Figure 6. Timing of child gaze at repeated signs in child-directed signing. (The 17-18 month data point for “Already Looking” had essentially no variance.)*

A second hypothesis is that increasing a sign’s cyclicity may be a way to induce the child to imitate the sign (Woll, Kyle, and Ackerman 1988). For example, Katie’s mother pointed to the book she and Katie (1;11,12) were reading and asked who was pictured; see video clip 4. Not receiving a response, she tapped Katie’s leg, pointed again to the book, and signed MOTHER with nine cycles. Katie pointed to the book on the first cycle of her mother’s sign, looked up on the second cycle, and signed MOTHER herself beginning at her mother’s seventh cycle. After the imitation, Katie’s mother nodded and moved on to the next page of the book. During this session, 59% of the mother’s repeated signs were followed by imitation from Katie (19/32).

The mean number of cycles for increased-cyclicity signs with multicyclic targets was between five and six for most sessions. The only exceptions were Noel’s mother at the 24 month session, when she produced only a single increased-cyclicity token with four cycles, and Katie’s mother, who exceeded that range at both the 9 month session (mean 10.2 cycles) and the 24 month session (mean 6.8 cycles). Her maximum number of cycles
showed a similar U-shaped pattern, with peaks of 15 cycles at 9 months and 13 cycles at 24 months. Although the number of cycles was similar at these two sessions, it is likely that her motivation for increasing the cyclicity of her signs was different.

One reason that increased cyclicity in child-directed signing is of interest is because of the existence of noun-verb pairs in ASL that are distinguished by cyclicity (e.g., multicyclic AIRPLANE vs. single-cycle FLY). Launer (1982) suggested that the maternal tendency to add repetition to non-repeated signs may affect children’s learning of the noun-verb distinction in ASL. Our data include instances of single-cycle verbs that have repeated movement in child-directed signing: e.g., both Suzie’s mother and Katie’s mother asked their daughters to sit on the floor using multicyclic tokens of sit.

Children tend to err in early sign production by adding repetition to single-cycle target signs in ASL (Meier et al. 2008) and BSL (Morgan et al. 2007). As Meier et al. observed, increased cyclicity in child-directed signing complicates the effort to separate motoric effects on children’s early sign production from environmental effects.

3.6 Lengthening

Like increased cyclicity, increasing the duration of a sign by slowing the movement or lengthening the final hold could be a way to continue a sign until the child looks. As with repeated signs, there were examples of a child looking halfway through a lengthened sign. However, analyses of the timing of the child’s gaze toward lengthened signs is very similar to the results for repeated signs: for lengthened signs as well, about half of the time the child was already looking at the beginning of the mother’s sign production.

Another parallel between lengthened final holds and increased cyclicity is that both may be used to elicit imitation from the child. During her last session, Katie (1;11,12) imitated 83% (25/30) of her mother’s lengthened signs (16 of them during a recitation of the manual alphabet). In total, during this session Katie imitated 41 signs that her mother had lengthened and/or repeated; she imitated only 18 signs from utterances in which her mother had produced no lengthening or repetition.

Phrase-final lengthening has been noted as a characteristic of ASL phonology/prosody (Brentari 1998; Perlmutter 1992), and almost all of the mothers’ lengthened signs were phrase final (albeit many were in single-sign utterances). Neither our study nor most studies of adult-directed signing have quantified sign duration, although, for example, Liddell (1984) has reported
evidence of lengthened final holds in isolated, citation-form signs. Analyses of sign duration in phrase-final and non-phrase-final position will be needed before we can state to what degree signs are lengthened in child-directed signing and what patterns that lengthening might follow.

3.7 Enlargement of signs

Some of the mothers’ signs were produced with a larger movement excursion than would be expected in adult-addressed signing. Such enlargement could possibly serve to emphasize a sign, making it particularly clear or salient to the child. One means of enlarging signs is proximalization, that is, using a joint of the arm or hand that is closer to the torso than would be expected. Holzrichter and Meier (2000) reported that, in child-directed signing, parents frequently added path movement at the elbow or shoulder to signs with hand-internal movement (e.g., RED OR ORANGE). A few instances of maternal proximalization were observed in the current sample. For example, Katie’s (1;3,0) mother signed BOOK with longitudinal rotation at the shoulder, rather than only rotation of the forearm as in the citation form of that sign.

Proximalization has been found to be characteristic of infant sign production (Meier et al. 2008). This fact raises the same question as discussed above for increased cyclicity: is proximalization in development driven by input factors or by infant motor development or by both? Further research analyzing whether there are systematic differences in how adults and children proximalize may contribute to answering this question. For example, Meier et al. (2008) noted that adults and children sometimes proximalize in different ways, with parents preserving the overall shape of signs whereas children may sometimes distort those shapes.

4. Conclusions

In this paper, we have observed features of naturalistic signing in mother-child conversations. Some features (e.g., displacement and leaning) arise from apparent attempts to accommodate the child’s visual attention. However, other modifications that may sometimes serve an attention-getting function (e.g., repeating or holding a sign until the child looks) were also frequently used when the child was already attending. In such circumstances, these modifications may sometimes serve to elicit imitation from the child, highlighting the parent’s and child’s respective roles as language expert and language novice. Instances of sign teaching through molding of the child’s
hands highlighted these same roles. The physical closeness between parent and child allowed the parent to share the child’s signing space and sign on the child’s body, providing the opportunity for the child to see and feel signs from the signer’s perspective.

To the degree that other signing situations share characteristics of parent-child communication, signing in those situations might be profitably examined to see if it exhibits the features described above. For example, we might expect commonalities with other situations in which the signer must accommodate the addressee’s attention (e.g., when the addressee is driving). Some features of child-directed signing that are tied to the problems of getting and maintaining a child’s attention may also characterize attention getting in other kinds of signed conversations. Coates and Sutton-Spence (2001) described turn-taking behaviors in casual BSL conversations among groups of friends. They observed that signers often start to sign without first acquiring the others’ attention; they may then 1) repeat signs after the others look, 2) start to form a sign and hold it until everyone looks, or 3) begin signing in the others’ line of sight, outside of the normal signing space, and return to the normal signing space after everyone looks. These attention-getting strategies resemble the repetition, lengthening, and displacement observed in child-directed signing.

Other features of child-directed signing might be shared with other intimate registers. Emmorey (2002) described an example of a signer moving her hands into her best friend’s signing space to refer to locations that the friend had set up; she observed that such sharing of signing space is rare and considered amusing. It appears that displacement into an interlocutor’s signing space or producing signs that contact the interlocutor’s body may violate common norms for adult-addressed signing; however, studies of signing between close friends or romantic partners may reveal whether intimate registers other than child-addressed signing allow such productions.

Variation in the size of signs and in the use of joints of the hands and arms has also been observed in adult-addressed signing; for example, Crasborn (2001) found proximalization to be characteristic of distance signing in the Sign Language of the Netherlands and distalization to be characteristic of whispering.

Understanding the properties of different sign registers will require transcription and measurement of the features noted in this paper (displacement, increased cyclicity, proximalization, sign duration, etc.). It is clear that these articulatory features will be useful in describing many sign registers, not just child-directed signing, and that the details of how signs vary within and across registers will likely provide crucial insights into the phonological structure and representation of signs.
Note

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Part II. Experiment
Sign language comprehension: Insights from misperceptions of different phonological parameters

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1. Introduction

Sign languages produced by Deaf people in everyday conversation differ in some interesting ways from spoken languages. Sign languages are perceived by the eyes and articulated through movements of the hands and the face, while spoken languages are perceived primarily by the ears and articulated through movements of the mouth and vocal tract. In spite of these fundamental differences in ‘signal properties’ the past 30 years of research on different sign languages has demonstrated that in several domains (e.g. comprehension, production and first language acquisition) there are remarkably similar patterns across the speech and sign modalities at both the behavioral and the neural level (Emmorey, 2002; MacSweeney et al., 2008). Through examinations of these similarities, and of differences between modalities, we are beginning to understand more about how sign languages and more generally the faculty of ‘language’ works.

The question we ask in this chapter is this: What parts of the sign guide sign recognition in Deaf people looking at the signing stream? We know that vowels and consonants have different roles in speech recognition (van Ooijen, 1996), so it is possible that the main parameters of signs contribute in different ways to their recognition. This question relates to an emerging area of sign language linguistics, which looks at the parameters of signs and how they combine (i.e., the phonotactics of sign language), and at how parameters contribute to how signs are perceived and understood. In this chapter we first outline some of this related research. We then describe our research on segmentation in sign language. In particular, we describe our methods based on a sign-spotting task (derived from the word-spotting task as developed for spoken language by Cutler and Norris, 1988). Using the sign-spotting task, we tested the segmentation of real signs embedded in nonsense contexts.
(Orfanidou, Adam, Morgan & McQueen, 2010). During the task participants sometimes misperceived nonsense signs as real signs, just as listeners sometimes misperceive spoken nonsense words as real words in the word-spotting task (van Ooijen, 1996). These misperceptions of nonsense signs as real signs can give us some important clues to what parts of the sign are important in sign comprehension.

2. The Phonological Structure Of Signs

The study of the phonological structure of visual-spatial languages such as American Sign Language (ASL) or British Sign Language (BSL) has revealed that they have a level of linguistic organization based on a set of parameters that are meaningless in isolation but become meaningful in combination. The main parameters of a sign identified by Stokoe, Casterline and Croneberg (1965) were handshape, movement, and location. Although there is no set of defined rules on sign well-formedness in BSL, studies in ASL sign phonology (Brentari, 1998; Sandler, 1989) agree that these three parameters must always be present in a sign. Others have suggested the addition of two other components: orientation (the direction in which the palm and fingers face) and facial expression (Liddell & Johnson, 1989).

The location parameter specifies where the hand is located in space in relation to the body (e.g., chest, nose, head, chin), the movement parameter describes how the hand moves in the sign space (e.g., arc, circle, and with internal movements such as wiggling fingers), and the handshape parameter indicates the form the hand itself takes (e.g., fist, flat hand or index-finger pointing). These parameters combine in rule-governed ways to create lexical signs with meanings (Brentari, 1998; Stokoe, 1960; Sutton-Spence & Woll, 1999). Based on these parameters, there are minimal pairs of signs which differ in only one parameter. For example, the BSL sign meaning NAME uses the same handshape and movement parameters as the sign AFTERNOON, but they differ in location. Path movements are considered to be the “vowels” of signs (Liddell & Johnson, 1989), and locations are considered to be the “consonants” of signs (Brentari, 1998).

Sign parameters are also implicated in sign comprehension and production. In particular, different parameters appear to contribute in different ways to sign processing (Carreiras, Gutierrez-Sigut, Baquero, & Corina, 2008; Corina & Emmorey, 1993; Corina & Knapp, 2006; Dye & Shih, 2006; Emmorey & Corina, 1990).
3. An experiment on sign segmentation and misperception

We began this research project by asking how sign comprehenders segment continuous signed input into discrete lexical units during sign comprehension. Much more is known about the segmentation and recognition of lexical units in speech than in sign language. In our research into sign language segmentation we therefore began by testing the predictions of a theory derived from research on spoken language segmentation. It has been proposed that listeners segment continuous speech so as to leave no residues that themselves are not viable words (Norris, McQueen, Cutler, & Butterfield, 1997). More specifically, according to the Possible Word Constraint (PWC), a lexical hypothesis is disfavored if the stretch of speech between the edge (the beginning or end) of that word and a likely word boundary does not contain a vowel. A stretch of speech without a vowel is not a possible word (in English and most other spoken languages) and thus cannot be part of a meaningful lexical parse. When listeners hear the phrase “sign comprehension”, for example, they will entertain not only the hypothesis that they might have heard “sign” but also that they might have heard “sigh” (for review of the evidence on the parallel evaluation of multiple lexical hypotheses during speech recognition, see McQueen, 2007). But the stretch of speech between the end of “sigh” and the likely word boundary between the [n] of “sign” and the [k] of “comprehension” does not contain a vowel; it is just the single consonant [n], which cannot itself be a word. The boundary between [n] and [k] is a likely word boundary because the sequence [nk] cannot occur within a syllable in English. Furthermore, listeners use such phonotactic restrictions to cue the location of word boundaries (McQueen, 1998). Thus, a spuriously embedded word such as “sigh” in “sign” will be disfavored, making it easier for the listener to reject “sigh” and hence recognize the word the speaker intended: “sign”.

The question we asked (Orfanidou et al., 2010) was whether sign comprehenders would have the same kind of segmentation procedure available to them, to help them segment continuous signed language into individual signs. There were two reasons to suppose that they would. First, in spite of the substantial physical differences between signed and spoken languages, sign comprehenders and listeners have the same computational problem to solve: How to segment meaningful units out of a quasi-continuous input stream? Since listeners appear to have a lexical viability constraint to help them segment speech, it was at least plausible that sign comprehenders would have a similar procedure to help them segment signed input. Second,
experiments across a variety of spoken languages (e.g., English, Norris et al., 1997; Dutch, McQueen, 1998; Japanese, McQueen, Otake & Cutler, 2001; Sesotho, Cutler, Demuth & McQueen, 2002) have repeatedly found evidence for the operation of the PWC. This is true even in languages where a subset of single consonants are closed-class words — as in Slovak, which has four vowel-less single-consonant prepositions (Hanulíková, McQueen & Mitterer, 2010). We thus asked whether the PWC does indeed apply in BSL.

3.1 How would the PWC apply to sign languages?

Our study into lexical segmentation (Orfanidou et al., 2010) investigated how Deaf BSL users perceive real BSL signs embedded in BSL nonsense signs. We adapted for use with BSL a method previously used to examine segmentation in the spoken-language domain: the word-spotting task (Cutler & Norris, 1988; McQueen, 1996). In word spotting, listeners hear a list of nonsense sequences, press a response button when they detect a real word embedded in the nonsense, and then say aloud the word that they have spotted. The target real words are not specified in advance, and so must be segmented and recognized just like words in normal continuous speech. For example, in the first test of the PWC, English listeners spotted words such as “apple” more slowly and less accurately in “fapple” than in “vuffapple” (Norris et al., 1997), even when the words and contexts were cross-spliced (e.g., the “apple” from “fapple” spliced onto the “vuff” from “vuffapple”, and the “apple” from “vuffapple” spliced onto the “f” from “fapple”), thus controlling for any acoustic differences between the tokens of the target words. In sequences such as “fapple” there is an impossible English word preceding the target “apple” (the single consonant “f”). Following the predictions of the PWC, word spotting was easier for contexts where the targets were preceded by possible words, as in “vuffapple” (“vuff” is not an English word, but could be).

In the sign language version of this task we created possible and impossible nonsense signs and paired them with real sign targets. Deaf BSL users saw nonsense sequences consisting of two signs. On some trials, the second sign was a real BSL sign. The participants’ task was to press a button when they spotted BSL signs, and then to sign them to camera. We predicted that, if BSL signers use a lexical viability constraint (i.e., a PWC procedure) in sign segmentation, then they would find it more difficult to spot a BSL sign in the context of an impossible nonsense sign (which is not a viable member
of the BSL lexicon), and thus should not be easily accepted as a residue in sign segmentation) than in the context of a possible nonsense sign (which is a potential BSL word, and thus a more acceptable residue). One possible difference with the speech situation is that both *fapple* and *vuffapple* are themselves possible words, whereas in sign a sequence of two signs probably cannot be seen as a single sign. Such a sequence could be two signs in the process of becoming compounds, but there are fairly strict limits on what can count as a simple sign (e.g., the sequence should usually involve not more than two changes). Nevertheless, the task in both modalities measures the ability of the participant to spot a real word or sign in a longer nonsense sequence, and hence whether this is easier or harder as a function of the residue that is left over. The fact that the complete sequences in the spoken modality are themselves possible words, while those in the sign modality probably are not, simply makes the task (across conditions) harder in the spoken modality.

The way the sign-spotting task was set up (i.e., the presence of nonsense signs in the materials) also gave us the opportunity to look at misperception errors of nonsense signs as real signs and thus to examine the role that each of the different phonological parameters of BSL play in sign recognition. This analysis paralleled previous analyses of misperceptions in spoken word-spotting. Van Ooijen (1996) found that misperceptions of spoken nonsense words more often involved a misperception of a vowel (e.g., listeners saying they heard “less” when they heard “feliss”) than a misperception of a consonant (e.g., listeners saying they heard “miss” when they heard “feliss”). Van Ooijen argued that consonants are therefore more important than vowels in constraining lexical access. Previous research on BSL and ASL (e.g., Dye & Shih, 2006; Emmorey & Corina, 1990; Hildebrandt & Corina, 2002), including developmental (e.g., Karnopp, 2002; Meier, 2000; Morgan, 2006; Siedlecki & Bonvillian, 1993) as well as neuropsychological studies (Corina, 2000), has found differences between parameters in sign comprehension and production. Would there thus be differences between parameters in sign misperceptions? If so, these differences would provide insights into the relative importance of different parameters during the recognition of lexical signs. The sign-spotting task methodology, new to sign-language research, therefore has the capacity to advance understanding not only of how continuous sign is segmented into discrete lexical units, but also of how sign parameters are used in lexical access.
3.2 Stimuli

We wanted to look at how signers perceive real signs in the context of nonsense signs. There were 32 real BSL signs: DOG, DUCK, NUT, LIGHT, EGG, WINE, CURTAINS, CASTLE, MOON, POLICE, HOUSE, TREE, MONKEY, TROUSERS, SHIRT, BANANA, AEROPLANE, SISTER, NAME, PIANO, ALARM, SPORT, WEEKEND, AFTERNOON, BOY, THEATRE, UNIVERSITY, GOLD, HOLIDAY, UMBRELLA, HOSPITAL, and BANK. There were two sets of signs which needed to be in the stimuli along with these target signs: possible nonsense signs and impossible nonsense signs. The possible nonsense signs were made by replacing one or two phonological parameters of a real BSL sign (i.e., handshape, movement, location and orientation). The possible nonsense signs were judged to be legal by four native signers of BSL. The impossible nonsense signs were illegal combinations of these phonological parameters (as outlined for ASL and potentially other sign languages by Brentari, 2006). These signs were judged to be illegal by four native signers of BSL. In order to make the impossible sign stimuli, we used illegal parameter combinations (i.e., phonotactically illegal combinations of handshape, movement, location and orientation). For example, it is extremely rare in BSL to see a non-compound lexical sign with a movement between two different phonological locations (e.g., from head to non-dominant hand). Both sets of nonsense signs included a variety of handshapes (marked and unmarked), locations (major body areas – head, trunk, neutral space, non-dominant hand – and specific locations within these major areas), and movements (straight, arc, circle and internal movements such as aperture changes). Ten of the nonsense signs in first position were disyllabic (i.e., had two movements; Brentari, 2006). In these cases, either the same movement was repeated, or a circle and straight movement were combined. There were no other combinations (such as straight and arc, straight and circle). We coded the stimuli in terms of these types of phonological complexity (i.e., in terms of which and how many phonological parameters they included: handshape, path movement, internal movement, location, orientation and one or two hands). The 32 pairs of possible and impossible nonsense signs (one pair for each target sign) could therefore be matched for complexity (for further details, see Orfanidou, Adam, McQueen & Morgan, 2009).

In addition to these 64 target-bearing sequences (32 targets each paired with a possible and an impossible nonsense sign) there were a further 64 filler sequences containing no real BSL sign (32 sequences of two possible nonsense signs and 32 sequences of an impossible nonsense sign followed
by a possible nonsense sign). The possible and impossible nonsense signs in the fillers were made in the same way as those in the target-bearing items.

All the nonsense signs were reviewed by four native Deaf signers of BSL and were judged by them as being nonexistent signs in BSL or in its regional dialects, and also as being possible or impossible. A Deaf native BSL signer (the first author) practiced each sign in isolation and then produced them in the specified two-sign sequences (either, for the target-bearing sequences, a nonsense sign followed by a real sign, or, for the filler sequences, a pair of nonsense signs). The materials were filmed in a professional studio with a blue background; video clips were then edited into separate files using iMovie software. The signer recorded the stimuli in a seated position. Video clips showed the signer’s head, his body from the waist up, and his arms. Figures 1 and 2 show examples of a possible nonsense sign and a real sign respectively. Further examples of stimuli can be viewed at: http://www.staff.city.ac.uk/g.morgan/sign_segmentation/clips.

Figure 1. Possible nonsense sign

Figure 2. Target sign – DOG
3.3 Participants

Fifty-two deaf BSL signers aged between 18 and 60 years took part. Twenty-nine were native deaf BSL signers (who had first been exposed to sign before age 5), 10 were childhood BSL signers (who had first been exposed to sign between age 6 and age 12), and 13 were adolescent BSL signers (who had not been exposed to sign before age 12). There were some differences in performance between these groups but in this chapter we will deal only with phonological parameter errors collapsed across all three groups (see Orfanidou et al., 2009 for the group differences).

3.4 Procedure

This study was carried out using DMDX (Forster & Forster, 2003) on a 19-inch computer screen. (DMDX is experiment-running software that controls screen and stimulus presentation and timing, and records responses and their timing.) The experiment started with a practice block which was followed by two blocks of the main experiment, each of which had 32 nonsense combinations (fillers) and 16 combinations of nonsense signs followed by a real BSL sign (target-bearing items). Participants were asked to press a button on a button-box if they saw a real BSL sign and then sign just the single sign that they thought they saw to a camera. Further procedural details can be found in Orfanidou et al. (2009, 2010).

3.5 Summary of results

Participants correctly spotted approximately 75% of the target signs (for comparison, participants in Experiment 1 in the Norris et al. 1997 study spotted approximately 60% of the targets with preceding nonsense contexts). As reported in detail elsewhere (Orfanidou et al., 2010), participants found it harder to spot real BSL signs embedded in nonsense-sign contexts which were impossible BSL signs (2742 ms and 25% error rate) than in nonsense-sign contexts which were possible BSL signs (2702 ms and 22% error rate). It appears that a lexical viability constraint is applied in sign segmentation, just like in the segmentation of spoken language. Here we report on the participants misperceptions of the nonsense signs as real BSL signs. A more extensive report of these misperceptions, including statistical analyses supporting the following summary, is given in Orfanidou et al. (2009).
Most false alarms were to nonsense signs in second position. However, although the target signs were always second in a pair of signs, subjects sometimes identified the first sign as a target sign. Note that they were not informed that only the second sign could be a proper sign. When subjects reported they had seen a real BSL sign when in fact it had been a nonsense sign, they changed some aspect of the sign in order to make it more like a real sign. We define here three types of major phonological parameter: Handshape, Movement, and Location (cf. Stokoe et al., 1965; Brentari, 1998). It is important to note that sign-internal movements (e.g., changes in aperture, wiggling, twisting, and bouncing) can be classified either as “Hand” parameters (Sandler, 1989) or as “Movement” parameters (Brentari, 1998). Here, we take the latter option, and classify internal movements along with path movements (i.e., straight, arc or circle movements). Analyses based on other categorisations of the data are given in Orfanidou et al. (2009).

We also defined five different types of error: Substitutions (substituting a parameter in the stimulus with a different one; e.g., an arc movement substituted by a straight movement); Omissions (omitting a stimulus parameter from the response); Reductions (reducing a parameter; e.g., a smaller movement); Additions (adding a parameter); and Fusions (blending of parameters across the two signs in the stimulus, e.g., blending a index-extended handshape with a pinky-extended handshape to produce an index- and pinky-extended handshape). There were very few fusions, so they were therefore omitted from the present analysis.

In summary, therefore, we looked at each of the participants’ false alarms in sign spotting and how a major parameter (handshape, movement or location) underwent substitution, omission, reduction or addition errors. We found differences between the three major phonological parameters in the four types of errors. This is shown in Table 1. Note that these errors were made when subjects attempted to repair a sign by making it into a real sign, regardless of whether the input was an impossible or a possible nonsense sign.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Substitution</th>
<th>Omission</th>
<th>Reduction</th>
<th>Addition</th>
<th>n</th>
</tr>
</thead>
<tbody>
<tr>
<td>Movement</td>
<td>22.3</td>
<td>53.1</td>
<td>12.0</td>
<td>12.6</td>
<td>341</td>
</tr>
<tr>
<td>Handshape</td>
<td>75.5</td>
<td>24.0</td>
<td>0.5</td>
<td>0.0</td>
<td>200</td>
</tr>
<tr>
<td>Location</td>
<td>15.1</td>
<td>69.1</td>
<td>6.6</td>
<td>9.2</td>
<td>152</td>
</tr>
</tbody>
</table>
3.5.1 Movement

Movement (path and internal movements) was the parameter most frequently perceived erroneously. The most frequent error type was omission, but substitutions were also quite common. The behaviour of the participants in these cases of substitution and omission was consistent with the phonotactics of BSL. For example, some combinations of path movements (e.g., arc plus straight movements) are not permissible in BSL. The path substitutions can thus be characterized as simplifications, in which a marked arc or circle movement was substituted by an unmarked straight movement, or as legalizations, where the misperception consisted of a permissible combination of path movements.

One reason why movement is more likely to be misperceived than location is that movement is more variable than location. Movements have different sizes and speeds (e.g., in different communicative settings) while locations are more fixed. Movements can also be reduced in magnitude when a signer copies the signs of the current conversational turn holder by way of feedback to the turn-holder. If sign comprehenders normally have to cope with variability in movements, then they may be more willing to change how they interpret movements, and thus more prone to movement misperceptions.

3.5.2 Handshape

The most frequent error type involving the handshape parameter was a substitution error, particularly where subjects replaced a more marked handshape with a less marked one. The fragility of handshape perception has been reported in several previous studies on sign language processing (Carreiras et al., 2008; Corina & Emmorey, 1993; Corina & Knapp, 2006; Dye & Shih, 2006; Emmorey & Corina, 1990). This is potentially related to the large inventory size and the reduced saliency of the handshape parameter, especially for complicated, marked handshapes, which are harder to perceive and to produce than unmarked handshapes. The substitution of a marked handshape with an unmarked one is an example of simplification, which has also been documented in developmental studies of speech (Smith, 1973) and sign (e.g., Morgan, 2006).

With respect to omission errors with handshapes, when there were two handshapes in the nonsense sign, one of those two handshapes was always deleted. Omissions of handshapes usually involved the second handshape in the nonsense sign, but sometimes an unmarked handshape was substituted
for the second handshape instead of being omitted. The behaviour of the signers in the present task is thus consistent with the phonotactic structure of BSL, which shows a preference for unmarked handshapes across the board (i.e., even when there are two handshapes in a sign).

3.5.3 Location

We found that the location parameter was the least affected major phonological parameter. As with movement, the most frequently occurring type of error was omission. In line with the phonotactics-based account, omissions of the second location in the nonsense sign resulted in an acceptable phonotactic structure.

As location had the fewest errors, it may be said that this is the least ambiguous parameter and that it is the most important parameter for sign recognition. This may be due to the fact that, from a perceptual point of view, the location of a sign is easier to perceive than its handshape and movement. Data from non-signers in a non-sign repetition task provide some support of this idea. Mann, Marshall, Mason & Morgan (2010) carried out a study where Deaf signing and hearing non-signing children were asked to repeat single legal nonsense signs and their productions were scored for accuracy. Non-signers were able to repeat location information without difficulty, but made more mistakes in repeating handshapes and movements. Location thus appears to be the easiest of the major parameters to perceive accurately for individuals who do not know sign language and for whom the task is thus purely perceptual. However, given that data from non-signers cannot be related in a straightforward manner to the behaviour of signers (for whom the task is not only perceptual but also linguistic), we will refrain from making any strong conclusions based on these data.

3.5.4 Sign legality

While participants often used phonotactic knowledge to correct illegal signs, this tendency cannot explain all of the data. In an additional analysis we examined only the errors that were made to signs in first position in the filler nonsense sequences (remember that half of these were impossible signs and half were possible signs). A purely phonotactics-based account of the process underlying sign misperceptions would predict that all false alarms would be in response to illegal signs (i.e., would be attempts to legalize the
input), and that no false alarms would be made to legal signs (because in these cases there is nothing to legalize). In contradiction of this prediction, we did not find significantly more errors for the nonsense signs in first position that violated phonotactic constraints of BSL (i.e., the impossible signs; 95 errors in total) than for nonsense signs that did not (i.e., the possible signs; 81 errors in total).

4. Discussion

The different levels of misperceptions of parameters possibly indicate that each of these parameters has a different role in the sign recognition process. In previous research involving priming tasks, inhibition between primes and targets sharing location (Carreiras et al., 2008; Corina & Emmorey, 1993) has been interpreted as evidence that location is present in the early stages of sign recognition. Location has also been found to be the first parameter to be identified in gating tasks (Emmorey & Corina, 1990; Grosjean, 1981), Corina and Knapp (2006). This suggests that the elements in words and signs that are recognized first may be more important for recognition than other elements.

Like vowels and consonants in speech, the sign parameters also differ in inventory size and saliency, as well as in articulatory variability. The BSL dictionary (British Deaf Association, 1992) gives an inventory of 57 different handshapes, but only 36 different locations, and 34 types of movement (including internal movements). Handshape is frequently involved in production errors (Hohenberger, Happ, & Leuninger, 2002) because of the combination of a large inventory size and the fine motor skills which are required to deal with the various hand configurations. These factors can lead to errors during sign production. Although there are no more movements than locations, researchers are not in agreement about how these movements are classified or categorized. The movement inventory is also greatly increased both because of the use of movement in classifier constructions for example (which lead to variations in speed, size and rhythm, which have morphemic status in BSL) and because of the use of movement in poetry (Sandler & Lillo-Martin, 2006). It is important to note, however, that analyses of effects of vowel inventory size in spoken-language processing (Cutler, Sebastián-Gallés, Soler-Vilageliu, & van Ooijen, 2000) have shown that the size of the vowel inventory does not change the amount of weight assigned to vocalic information in speech perception. It is thus less likely that parameter inventory size influences sign (mis)perception.
Perceptual saliency may provide another explanation for differences in perception accuracy of the parameters. The small articulators (hand, fingers) reduce the handshape parameter’s perceptual saliency, increasing the likelihood of errors. Movements on the other hand are easier to perceive and are considered to be a sign’s most sonorous element (e.g., Brentari, 1990; Coulter & Anderson, 1992; Perlmutter, 1992). For this reason they are more salient than handshapes and locations (but the combination of movement and location are possibly the most salient aspect of a sign; Corina & Knapp, 2006; Dye & Shih, 2006; Hildebrandt & Corina, 2002). The fact that salient movements were more often misperceived than less salient handshapes, however, makes it unlikely that saliency is the sole source of these parameter differences.

We have also suggested that amount of variability may be a possible reason for the observed differences in misperception rate across parameters. In particular, as noted earlier, movements are more variable than locations. But it has also been suggested that location is more variable than handshape (Emmorey, McCullough, & Brentari, 2003). Thus, while greater variability is associated with more errors in one case (movement vs. location), it is associated with fewer errors in another case (location vs. handshape). Again, it appears that variability is not the source of the parameter effect.

A more likely explanation for the difference in proportion of misperceptions across parameters is one based on perceptual ambiguity. The location parameter is the least ambiguous and can be recognized the fastest (Carreiras et al., 2008; Corina & Emmorey, 1993; Corina & Knapp, 2006; Emmorey & Corina, 1990; Grosjean, 1981). One reason why location may be relatively unambiguous is that it is a static parameter (i.e., it does not change over time). In contrast, movement may be more perceptually ambiguous, and thus recognized the most slowly (Grosjean, 1981; Thompson, Emmorey & Gollan, 2005), because it is a dynamic parameter (movements, by definition, change over time, so they will necessarily take more time to recognize). Consistent with this perceptual ambiguity account, it appears that the parameter that is recognized the fastest, location, is the least prone to errors in lexical access, while the parameter that is recognized the slowest, movement, is the most prone to errors in lexical access.

This may not be a complete account, however, since handshape, like location, is a static parameter that ought to be recognized relatively easily, and yet there are more handshape than location errors. One possible explanation for this difference is that, in spite of their static nature, handshapes are more perceptually ambiguous than locations (perhaps because, as discussed above, handshape information is perceptually less salient than location infor-
Another (not mutually exclusive) possibility is that location information constrains lexical search more extensively than handshape information, making recognition of sign location more robust. Once a major body location has been identified, all other locations are ruled out, helping narrow the search to the subset of signs in that particular location. Handshape (and movement) parameters do not constrain lexical search in this way. It appears that comprehenders of BSL indeed use location cues to narrow lexical search during sign recognition (Orfanidou, Adam, McQueen & Morgan, 2008). Future research will be required to establish which components (perceptual ambiguity and saliency, lexical constraints) contribute to the observed ranking of parameters in sign misperceptions.

It is important to note that while phonotactic knowledge appeared to be used regularly in the misperceptions, resulting in simplifications and legalizations which obeyed the phonotactic constraints of BSL, phonotactic legality cannot provide a complete account of the participants’ behaviour. As mentioned earlier, misperceptions of impossible signs were not more frequent than misperceptions of possible signs. It thus appears that while phonotactic knowledge was frequently used during the process of generating a misperceived sign, phonotactic irregularity was not necessary to trigger the misperceptions in the first place. In the real world of sign comprehension, where the input is presumably usually phonotactically legal, misperceptions can of course still arise. Imperfections in articulation, signal transmission and perception can all be sufficient to generate occasional misperceptions.

In conclusion, our data from errors in sign spotting are similar to errors in spoken language word spotting. Van Ooijen (1996) found that speakers changed the vocalic characteristics of the original stimuli most frequently, that is, that vowel changes outnumbered consonant changes. This finding is reflected in the present study, where there were more errors with movement, which is seen as vocalic (Liddell & Johnson, 1989), than with location, which is seen as consonantal (Brentari, 1998). It is important to recall that the results of the sign-spotting study also reflected a parallelism between signed and spoken language (Orfanidou et al., 2010). As for listeners of many spoken languages, comprehenders of BSL appear to be sensitive to a lexical viability constraint: The participants found it harder to detect real signs in impossible- than in possible-sign contexts. The PWC thus appears to be modality general: It is a language-segmentation procedure rather than only a speech-segmentation procedure. The sign-spotting and misperception findings together thus lead us to believe that there are basic, modality-independent distinctions in the signal properties of language and in the way those properties are used during language comprehension. The parallelism
presented here is that signers tend to preserve mostly location parameters while speakers rely on consonants. These phonological components, whether signed or spoken, appear to be more reliable in guiding lexical access in on-line language comprehension.

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Notes

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5. Note that words like ink or link are examples of [ŋk], not [nk].


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Lexical and Articulatory Influences on Phonological Processing in Taiwan Sign Language

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1. Introduction

In spoken language research, it has become clear that the phonological processing of a word is affected by such factors as phonotactic probability, neighborhood density, articulatory difficulty and lexical (token) frequency. Phonotactic probability and neighborhood density can be taken as measures of the typicality of a word. The first is an analytic measure in that it considers parts of a word (such as phonemes) and computes the probability that the parts (or a combination of parts) will appear in a given language. By contrast, neighborhood density is a holistic measure, reflecting how many similar words (“neighbors”) a target item has in the lexicon of a given language. These two measures are highly correlated with each other. Studies concerning their influence on phonological processing in spoken language include Vitevitch & Luce (1998, 1999), Luce & Large (2001), and Bailey & Hahn (2001). Articulatory difficulty - the idea that certain segments or sequences of segments are more difficult than others to articulate - is as controversial in spoken language research as it has been difficult to quantify. Attempts to do so suggest that it is connected to what articulators “want” to do, perhaps individually but especially in concert, how many articulators need to act if a particular sound or sequence is to be uttered, and even the kinds of muscular actions not produced in speech except in cases of extreme necessity (see for example Lindblom and Sundberg 1971, Gay, Lindblom and Lubker 1981, Ohala 1983, Westbury and Keating 1986, Browman and Goldstein 1992, Stevens 1971 to name a few). Despite this, a full understanding of articulatory difficulty remains elusive. Lexical (token) frequency has long been understood to interact with linguistic behavior from the phonological to syntactic and discourse levels (Bybee 2000, Bybee 2001) and beyond. Do these factors also affect phonological processing in sign languages? And if so, do they have independent effects? This study addresses these questions with an experiment on Taiwan Sign Language (TSL).
2. Preliminaries

Several methodological issues arose at the beginning of our work. First, articulatory difficulty and type frequency were shown to be related in Ann (2006), and thus were confounds. Second, since we do not have a large enough TSL corpus to analyze in order to establish the frequency of TSL signs, we had to find an alternative method. Next, we explain our measure of articulatory difficulty of TSL signs. Finally, we explain the reasons for the tasks we chose given our questions.

2.1 Articulatory difficulty and type frequency are related

Ann (2006) related articulatory difficulty of handshapes to frequency of occurrence of handshapes in TSL. Specifically, Ann (2006) found that the type frequency of a handshape (i.e. the number of signs in the lexicon containing the handshape) tends to be negatively correlated with its articulatory difficulty score (defined according to a physiology-based algorithm). To make this observation precise, we computed this correlation for the 48 handshapes in the TSL signs used in our experiment (reported below), using logarithms of the handshape type frequencies, following standard psycholinguistic practice (this transformation makes the frequency distribution more symmetrical; see e.g. Baayen, 2001). We found that the negative correlation between articulatory difficulty and log handshape type frequency was statistically significant ($r(46) = –.42, p < .05$) and surprisingly large (the $r^2$ value meant that 18% of the variance in handshape type frequency was accounted for by articulatory difficulty).

Handshape type frequency can be thought of as a measure of typicality, similar to phonotactic probability and neighborhood density for spoken languages. Thus its correlation with articulatory difficulty provides an important clue about the role of articulation in the coinage and evolution of signs.\(^2\)

While this correlation is theoretically interesting in its own right, it poses a potential problem for our current purposes. If we want to know if articulatory difficulty affects phonological processing, we cannot simply test for a correlation between articulatory difficulty and reaction times, since it could be that responses are faster to more typical signs, rather than being affected by articulatory difficulty itself.

One way to deal with this potential confound is to follow the lead of Bailey & Hahn (2001), who faced a similar problem in disentangling the
effects of the highly correlated phonotactic probability and neighborhood density measures in English. Their solution was to run a multiple regression analysis. The mathematics of multiple regression makes it possible to partition out the effects of one factor from the effects of another, assuming that the two factors are not completely confounded (e.g. $r^2$ close to 100%). Though correlated, articulatory difficulty and handshape type frequency are not fully confounded, so a regression-based approach may help to reveal if they indeed have distinct effects on phonological processing.

Since we are interested not only in articulatory effects, but also the effects of the lexical properties of the signs themselves, we used only real TSL signs in our study. Thus we must also consider the effects of sign token frequency, or how often the signers in our study have seen or used the signs before in their lifetimes. Token frequency has long been known to exert powerful effects in reaction time tasks (Rubenstein, Garfield, & Milliken, 1970; Whaley, 1978; Rayner & Duffy, 1986). This then raises the problem of how to estimate token frequency in a sign language, which we deal with in the next section.

2.2 Estimating sign frequency in TSL

In spoken languages, estimating token frequency is usually done by means of analyzing a large corpus of fluent language use. Baayen (2001) shows first, that the standardly-used corpora of major languages like English now contain millions of tokens, and second, that smaller corpora are always less reliable than larger ones. In the absence of a sufficiently large corpus for TSL, it is difficult to estimate the frequency of a sign.

We dealt with this problem by following a strategy described in Bates et al. (2003). That study found that frequencies estimated in one language can often predict response times in another (see also Dehaene and Mehler, 1992). For example, if one wants to predict how fast an English speaker will name pictures of objects, one can successfully use the token frequencies of the object names in Chinese. In our own experimental stimuli of 127 words, the (log) Chinese and the (log) English frequencies are well correlated ($r(125) = .57$, $p < .0001$, with 32% of the variance in one language’s frequencies predictable from the other. This surprising result comes about, Bates et al argue, because word token frequencies reflect how often the concepts named by the words are used in everyday life, and many concept frequencies are relatively invariant across cultures. Thus, in order to estimate the frequencies of TSL signs in the experience of TSL signers, we used the frequencies of their translations into Chinese (as estimated by the number of hits on Google,
computed in October, 2005). We assume that our choice of Chinese would tend to improve accuracy, given that the aspects of the cultures of hearing and deaf people in Taiwan are similar, and so they may be expected to share similar concept frequencies. As with all frequency measures, we then took the logarithm of the Chinese frequency estimates.

2.3 Articulatory difficulty in sign languages

It should not be surprising that the idea of establishing a metric for determining articulatory difficulty is not particularly well-studied for sign languages. However, the literature offers a (beginning) assessment of what is difficult to articulate (Mandel 1981). Signs are said to be made up of handshape, palm orientation, location and possibly movement (Stokoe, Casterline and Croneberg 1965, Battison 1978). Though signs have not been considered in their entirety, researchers have inquired into the relative ease or difficulty of the parts of a sign, for example, palm orientation (Crasborn and van der Kooij 1997) and handshape (Ann 2006). In the present study, we computed the overall articulatory difficulty for a sign as the sum of the physiology-based ease scores of Ann (2006) of each component handshape. This measure ignored other articulatory properties of the signs (movement, location, orientation) and made the convenient (if questionable) assumption that a two-handed sign with identical handshapes doubled the articulatory difficulty.

2.4 Perception and production tasks

Because phonological processing involves both perception and production, we therefore decided on two tasks, one primarily concerned with each of these. The purpose of the experiment involving these tasks was to investigate the independent contributions of sign token frequency, handshape type frequency, and articulatory difficulty on reaction times.

For perception, we chose the same-different matching task, since as Vitevitch & Luce (1999) and others have argued, this task taps a relatively early stage of phonological processing, and thus is less influenced by the other factors (e.g. semantics) affecting the lexical decision task. In this task, pairs of stimuli (e.g. signs) are presented, and participants must quickly decide if they are the same or different. Both “same” pairs and “different” pairs
are presented, though responses to the “same” pairs are the primary focus of analysis, since these involve only one item (e.g. a sign), with its own particular properties (e.g. token frequency).

For production, we chose the elicitation imitation task, in which the participant is presented with a word that the participant is asked to repeat as quickly as possible. This task allows more flexibility than the picture naming task (used by Bates et al., 2003), since the concepts associated with the words need not be concretely picturable. It clearly has a perceptual component as well (i.e., processing the stimulus), but presumably the response cannot begin until something about the production form has been mentally prepared as well.

In both tasks, the measure we are interested in is the time it takes to begin a response, not the duration of the response itself. Thus reaction times should reflect purely mental processes, not articulation. Hence, if we find that articulatory difficulty slows reaction times in the production task, this would not be a trivial matter of finding that articulatorily difficult signs are harder to articulate. Rather, it would imply that articulatorily difficult signs take longer to prepare in the mind, a potentially much more interesting finding.

3. Methods

For both tasks, instructions were given in TSL by a fluent signer. The experiment was controlled by E-Prime (Schneider, Eschman, & Zuccolotto, 2002). In order to ensure accurate measurements of responses using this software, we converted each video into a series of still images, each lasting 120 ms (approximately eight frames per second) before giving it to the coders. This degraded the quality of the video by slowing down the movements, but the signs were still fully recognizable. Sign durations ranged from 1200 to 3240 ms (mean 2154, SD 385).

Stimuli for the two experiments were taken from the Taiwan Sign Language Online Dictionary (Tsay, Tai, Lee, Chen and Yu 2009), which consists of short videos illustrating nearly 3000 lexical items including each of the signs in Smith & Ting (1979, 1984), with adjustments and additions based on other sources as well as recent fieldwork. All are signed by the same deaf male signer.
3.1 Participants

Forty fluent deaf signers who use TSL as their primary means of communication performed both perception and production tasks. Participants’ ages ranged from 20 to 61 at the time of testing (mean 44, SD 10.4). Both genders were represented equally. All were from central to southern Taiwan with most of them living in the cities of Changhwa, Chiayi, Tainan, or Kaohsiung. Participants were paid for their help.

Sixteen participants attended deaf schools; the remaining subjects did not respond to that question on the form they were provided. Twenty-three participants had signing relatives (including parents, spouses or siblings). The age at which participants first learned TSL ranged from 1 to 20 years old (mean 10, SD 3.9). The majority first learned TSL by age 10, but only one participant started learning TSL by age 1 (the second youngest age was 7). Thus, we consider most of the participants non-native signers. It is by now well-established that nativeness in a sign language affects how signs are processed (e.g., Mayberry & Fischer, 1989). Hence, we included age of acquisition (i.e. the age at which participants were first exposed to TSL) as a numerical factor in our analyses to see if it modulated the effects of the other factors (e.g., whether articulatory difficulty affected processing more strongly depending on the age that the signer acquired TSL).

3.2 Materials

Since this experiment used a multiple regression design, it was important to choose a variety of representative materials so that effects of the various factors could be distinguished from each other.

Token frequency, handshape type frequency, and articulatory difficulty were first computed for each sign that appeared in Smith & Ting (1979, 1984). Sign token frequency was estimated via the frequency of the Chinese translations, as described above. The overall handshape type frequency for a sign was the sum of the type frequencies for the component handshapes, where these type frequencies were the number of signs in Smith & Ting (1979, 1984) containing these handshapes. The overall articulatory difficulty for a sign was the sum of the difficulty score (the ease scores of Ann 2006) for each handshape in the sign.

In an attempt to balance sign token frequency, handshape type frequency, and articulatory difficulty in the materials, signs were cross-classified as high or low according to these three measures (above and below each meas-
ure’s median) so that roughly equal-sized subsets could be collected for each combination (high token frequency-high type frequency-low articulatory difficulty, low token frequency-high type frequency-low articulatory difficulty, and so on). To keep the experiment to a reasonable length, we selected 127 items from the lexicon that met these criteria as best we could. One of these items had to be dropped in the analyses, since through an oversight it contained a configuration (crossed fingers) not given an articulatory difficulty score in the Ann (2006) system.

In the production (elicitation imitation) task, all 127 items were shown, but in the perception (same-different matching) task, a subset of 114 was selected to be shown in 76 pairs. The 38 “same” pairs (the same video shown twice) were chosen so as to give roughly equal numbers of combinations of the three measures (as described above). In particular, 20 of the signs had both low or both high values for handshape type frequency and articulatory difficulty, and 18 had opposite values for them. The remaining 76 signs were then paired up to create “different pairs”, choosing signs that matched each other as much as possible in low-level visual details, such as lighting.

We expected that response times might be affected by duration of the videos themselves, which might also partly correlate with at least some of our independent variables. In spoken languages, higher frequency words tend to have fewer segments (Zipf 1935), and it is also known that in fluent speech, the segments themselves are shortened more in higher-frequency words (Bybee 2000). These generalizations meant that we expected sign duration to be negatively correlated to sign frequency. At the same time, we expected sign duration to be positively correlated with articulatory difficulty, assuming that harder signs require more time to articulate. To reduce the influence of such possible confounds, we included video duration (as a measure of sign duration) as an independent variable in our analyses, so that its effects could be factored out in the regression.

3.3 Procedure

We were unable to use the reaction time measurements automatically recorded when participants lifted their hands off the keyboard, since all but one of the participants failed to understand the instructions; most failed to press the space key at the beginning of a trial, or pressed it again after the trial began. Hence we were forced to estimate reaction times from the video recordings of the task itself, which showed the onset of actual signing. The onset of a sign was defined to be the video frame in which the first handshape of the
sign was fully articulated, as determined by non-native research assistants. Naturally these measurements were far less accurate than we’d have liked; even under ideal conditions, our video camera could not measure durations less than 33 ms (1000 ms / 30 frames per second), and additional challenges came from properly defining and identifying the onset of a sign.

Nine participants were dropped from analyses, seven because they performed the task incorrectly (in addition to the problems noted above), one because the hand movements were too small to identify the initial hand-shapes in the video records, and one because of the loss of the video analysis. This left 31 participants for analysis, 17 who performed the perception task first, and 14 who performed the production task first.

Due to experimenter oversight, the order of the two tasks was not counterbalanced across participants, but as we will see in the analyses, task order had no effect on the results.

3.3.1 Same-different matching task

During this task, each participant faced a computer screen, with fingers poised over keys marked YES (on the right) and NO (on the left). In each trial, a “+” symbol first appeared in the center of the screen for 1 second (to focus attention), immediately followed by the first video of the pair. When this was finished, a blank screen was shown for 50 ms, followed by the second video. Participants were asked to press, as quickly and accurately as possible, the YES key if the two signs were identical, and NO otherwise. Reaction times were measured from the onset of the second video to the onset of the key press. After a practice session with three same pairs and three different pairs, the experiment proper began. 76 pairs of videos (38 same pairs, 38 different pairs) were presented in random order. The task was broken into two blocks of trials with a brief rest between them. Participants generally required five to ten minutes to complete the task.

3.3.2 Elicitation imitation task

During this task, participants faced a computer screen, with fingers pressing down the space bar. They were asked to view digital videos of TSL signs produced by a native TSL signer. Participants were asked to lift their hands from the keyboard as soon as they recognized the sign on the screen and to sign it themselves. Reaction time was measured both at the lift-off of the
hands from the keyboard, and at the onset of the first handshape of the target sign in the video recording. However for the reasons noted above, only the latter measure was used in the analyses reported here. In each trial, a “+” symbol first appeared in the center of the screen for 1 second, immediately followed by the video. A video record of each trial was also made (using a Sony TRV-30 camcorder, recording at the NTSC standard of 29.7 frames per second), showing both the onset of the stimulus on the computer screen and the participants’ actual signing. 127 signs were presented in random order, broken into two blocks with a brief rest in the middle. Participants generally required ten to fifteen minutes to complete the task.

4. Results

Reaction times in both tasks were analyzed using multiple regression. The most important independent variables were (log) sign token frequency, (log) handshape type frequency, and articulatory difficulty, but for the reasons explained in 3.1, we also included the participants’ age of acquisition of TSL, as well as the durations of the stimulus videos. Because these variables showed some correlation with each other (most notably, the significant correlation between articulatory difficulty and handshape type frequency), we first computed the VIF (variance inflation factor, based on $r^2$) for each variable to confirm that these correlations didn’t cause cross-variable confounds. The largest VIF was 1.22 for duration, well below the conventional threshold of 5. Thus we can be reasonably confident that effects of the different predictors are indeed independent of the others.

In order to take both cross-participant and cross-item variation into account in the regression analyses, we used a technique called linear mixed effects modeling (LME; see Baayen 2008). Results reported below are for the by-participants-and-items statistical models, which always provided a significantly better fit to the data than the simpler by-participants-only models, and significance is based on $t$ values assuming infinite degrees of freedom given the large number of observations (well over 1000).

4.1 Results for same-different matching

An initial LME analysis showed that the order in which the tasks were performed had no direct effect on reaction times in the perception task, as
well as no indirect effect via interaction with other factors. Age of acquisition similarly had no direct or indirect effect. Thus in the LME analysis reported in Table 1, these two factors are left out.

### Table 1. By-participants-and-items LME analysis of reaction times in the same-different matching task

<table>
<thead>
<tr>
<th>Coefficient</th>
<th>$SE$</th>
<th>$t$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chinese token frequency (log)</td>
<td>−3.723</td>
<td>23.192</td>
</tr>
<tr>
<td>Handshape type frequency (log)</td>
<td>−23.823</td>
<td>10.683</td>
</tr>
<tr>
<td>Articulatory difficulty score</td>
<td>27.896</td>
<td>9.395</td>
</tr>
<tr>
<td>Stimulus sign duration</td>
<td>0.343</td>
<td>0.043</td>
</tr>
</tbody>
</table>

Note. $SE$: standard error. $t$: t value.
* $p < .05$

All effects went in the expected directions, as shown by the signs of the coefficients. The positive correlation between stimulus sign duration and reaction times presumably merely means that participants needed some time to recognize the stimuli before they could respond to them, which took longer for longer signs. Of greater theoretical relevance were the effects of the other three factors. These effects are illustrated in Figure 1, which shows the independent contribution of each factor in the LME with other factors held constant (note that lower values on the $y$ axis imply faster responses).

### Perception results

![Figure 1](image-url)

**Figure 1.** Independent contributions of log frequency of Chinese translations of the TSL items, log handshape type frequency, and articulatory difficulty scores, to reaction times in the matching task.
Higher sign token frequency was associated with somewhat faster responses, though this effect was not statistically significant. Two possible explanations for this null result come to mind. One is that our Chinese-based frequency estimates did not reflect TSL frequencies well enough. Another is that the TSL signs, being taken from an introductory textbook (the only lexicon currently available), were all relatively common and thus did not differ enough in frequency to make detection of a significant frequency effect possible. Nevertheless, the frequency effect did trend in the expected direction.

Handshape type frequency was significantly negatively correlated with reaction times, indicating that responses were sped up (shorter reaction times) for more typical signs (with higher handshape type frequencies). Articulatory difficulty was significantly positively correlated with reaction times, indicating that responses were slower for more difficult signs. These results imply that both handshape type frequency and articulatory difficulty affect perceptual processing, and do so independently of each other, as well independently of sign frequency. We return to this point in section 5.0.

### 4.2 Results for elicitation imitation

Despite the limitations in our measurements, the results were quite straightforward. As with the perception task, task order and age of acquisition had no direct or indirect effects on reaction times in the production task. Hence they are left out of the analysis reported in Table 2.

<table>
<thead>
<tr>
<th></th>
<th>Estimate</th>
<th>SE</th>
<th>t</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chinese token frequency (log)</td>
<td>−28.105</td>
<td>14.938</td>
<td>−1.882</td>
</tr>
<tr>
<td>Handshape type frequency (log)</td>
<td>−19.331</td>
<td>6.258</td>
<td>−3.089*</td>
</tr>
<tr>
<td>Articulatory difficulty score</td>
<td>9.615</td>
<td>4.431</td>
<td>2.170*</td>
</tr>
<tr>
<td>Stimulus sign duration</td>
<td>0.093</td>
<td>0.024</td>
<td>3.841*</td>
</tr>
</tbody>
</table>

Note. $SE$: standard error. $t$: t value.

* $p < .05$

The effects again all trend in the expected directions. Once again, the effect of sign frequency did not reach statistical significance, though this time it came quite close ($p < .07$), perhaps because of the much greater number of
items in the production task compared with the perception task (over three times as many). The regression lines computed in the LME analysis for the three theoretically relevant factors are shown in Figure 2.

**Production results**

![Figure 2](image)

*Figure 2.* Independent contributions of log frequency of Chinese translations of the TSL items, log handshape type frequency, and articulatory difficulty scores, to reaction times (handshape onset times) in the shadowing task.

### 4.3 Cross-task comparisons

In order to help us understand what differences the task made in the influence of sign frequency, handshape type frequency, and articulatory difficulty on processing time, we conducted a further LME analysis, this time adding a factor representing the task (perception vs. production), and looking for interactions with it. This analysis was conducted using only the 24 signers who gave usable data in both tasks and the 38 items used in both tasks. Again, task order and age of acquisition had no significant effects, so they were removed from the analysis.

The tasks didn’t differ in overall reaction times, but aside from sign frequency, the tasks did differ significantly in how reaction times were affected by the factors shown in the preceding tables. There were significantly stronger effects of stimulus duration ($t = 4.09, p < .05$) and articulatory difficulty ($t = 2.45, p < .05$) in the perception task than the production task, while the effect of handshape type frequency was marginally stronger in the production task than in the perception task ($t = -1.96, p = .05$). This difference in strength may relate to the difference in reaction time measure-
ment sensitivity across the two tasks (1 ms. accuracy for perception vs. over 33 ms. accuracy for production), though an alternative interpretation will be noted in the discussion section.

5. Discussion

In both tasks, response times showed independent effects of token frequency (frequent signs were responded to more quickly), handshape type frequency (more typical signs were responded to more quickly), and articulatory difficulty (difficult signs were responded to more slowly).

Surprisingly, the cross-task analysis showed that the effect of articulation was stronger in the perceptual (same-different) task than in the production (elicitation) task. As noted above, this counterintuitive result could be due to differences in measurement sensitivity across the two tasks, but a more interesting possibility relates to the observation that the same-different task required holding the first sign in memory, whereas the elicitation imitation task did not. Wilson and Emmorey (1997) found that ASL signers hold signs in working memory using a visuospatial motoric code, analogous to the articulation-based phonological loop used by oral language speakers. Our study may have inadvertently provided new evidence for this phenomenon.

Token frequency effects were weakest in both tasks. This isn’t surprising, given the problems in estimating TSL frequency and the relative uniformity of frequencies in our lexicon of mostly common signs. Nevertheless, handshape type frequency sped up responses, regardless of the task. These results were consistent with those of Carreiras, Gutierrez-Sigut, Baquero and Corina (2008) who found frequency effects in lexical decision tasks that were only significant for non-native signers. This is consistent with spoken language research on the effects of phonotactic probability and neighborhood density. But further work would be necessary to define and distinguish these two measures in sign languages.

The articulatory difficulty effect was most important finding. Our study demonstrates that articulatory difficulty of handshapes does play a role in online phonological processing in TSL, independent of the typicality and frequency of signs in the TSL lexicon. Moreover, this articulatory difficulty effect is active inside signers’ minds, since the effect was observed in the time needed to prepare a response, prior to making the physical response itself.
Notes

1. This work was supported by a sabbatical grant to Jean Ann from Chiang Ching Kuo Foundation and by a grant from National Science Council, Taiwan (94-2411-H-194-016) to James H.-Y. Tai and Jane Tsay. We would like to thank the following people for a great deal of assistance with our research: Lee Hsin-Hsien, Lin Fang-Yu, Chang Feng-Ru, Su Shiou-Fen, Ku Yu-shan, Ku Hsiao Yue-hsia, Chiangsheng Johnson Yu, Jenna Fosco and all of the members of the deaf community in Changhwa, Taichung, Chiayi, Kaohsiung and Tainan who supported our efforts by agreeing to participate in these studies. We also thank three anonymous reviewers for their help.

2. Crucial to our chapter is the distinction between typicality and markedness. Language users learn about typicality through their experience with their language. Markedness does not have to do with language experience. Rather, it is connected to cross-linguistic, universal or innate properties.
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When does a system become phonological? Potential sources of handshape contrast in sign languages*

Diane Brentari and Petra Eccarius

1. Introduction

This chapter addresses how a phonological system might emerge in a sign language; in other words, it asks the question, “What are some potential paths to phonological contrast?” Distinctive contrasts (those that achieve minimal pairs) and allophonic alternations (those used in phonological rules) are the two most commonly studied types of distributions in phonological systems. Both exist in sign languages, but we will argue that we can learn a great deal about how the human mind comes to create phonology if we look beyond these types of distribution, (i.e., those most common in spoken languages). In particular, we will describe two phenomena, one involving a grammatical interface between morphology and phonology and the other involving a grammatical interface between phonetics and phonology. We propose that the interfaces are a good place to look for the seeds of phonology in homesign systems and in young sign languages. We use language internal evidence, crosslinguistic data, and data from homesigners.

The general argument is as follows. Distinctive and allophonic distributions are common in spoken languages but not in sign languages (Brentari & Eccarius 2010, Eccarius & Brentari 2008). A distinctive distribution is a case where unrelated lexemes are distinguished by the presence or absence of a feature or feature structure. For example, in English /b/ in “bit” (verb/past tense) and /p/ in “pit” (definite noun) are distinguished by [voice]. In ASL, car (noun) and which (wh-word) is a similar case of distinctive contrast in which two unrelated lexical items are distinguished by the absence or presence of the extended thumb. It has been observed that sign languages have very few minimal pairs, even in well-established sign languages (van der Kooij 2002, van der Hulst & van der Kooij 2006, Eccarius 2008). Van der Hulst and van der Kooij (2006) argue that this is due in part to phonetic possibilities; there is a larger number of different articulators and a larger perceptual space that contribute to the phonological system compared with that of
spoken languages. They argue that it may also be due in part to iconicity; meaning and form are more often related in signed than in spoken languages (Padden 1988, Meir 2002, Aronoff et al. 2005, Brentari in press, Wilbur 2010, P. Wilcox, 2005, Russo, 2005, Taub, 2001, Cuxac & Sallandre 2007). The other common distribution found in spoken languages is an allophonic distribution, in which a structure is predictable and captured by rules or constraints; in its most canonical form, the context for the application of a rule is also phonological. There are sometimes exceptions to allophonic elements in spoken languages, but these operations are largely obligatory. Aspiration in English is a good example of this because the [spread glottis] feature appears only in the context of the beginning of a syllable when followed by a vowel. A purely allophonic distribution in many sign languages is that of the Handshape Sequencing Constraint, which requires open and closed variants to vary predictably within a single monomorphemic sign (Sandler 1989, Brentari 1998). However, despite their existence in sign languages, purely allophonic distributions that are not optional are also relatively rare in sign languages (Brentari & Eccarius 2010, Eccarius & Brentari 2008).

The relative rarity of distinctive and purely allophonic behavior in well-established sign languages might suggest that the first indicators of phonology would not appear as distinctive or allophonic distribution, but rather as interface phenomena—between morphology-phonology and phonetics-phonology. We define an interface phenomenon as one that must refer to more than one grammatical component. We consider these analyses to concern interface phenomena because the phonology must refer to other grammatical components. In the first study we argue that the morphological status of handshape across different parts of the lexicon can affect the number and location of distinctive contrasts in the phonology, potentially affecting featural representation. We also argue that systematic phonetic variation based on the origin of signs may be a first step towards a phonological distinction, similar to the way that socio-phonetic variation can lead to historical change (Yu 2007). In the second study we argue that a morphological distinction between two handshape types grounded in iconicity (object handshapes and handling handshapes) provides the environment for a phonological distribution of handshape, and that this distribution is beginning to appear in homesigners.

We have chosen to focus on handshape for two reasons. First, of the parameters of a sign (handshape, location, movement, orientation, nonmanuals), handshape has a well described set of features on which there is agreement among models, hence there is a well developed literature of what is and is not phonological (e.g., Brentari 1998, Sandler & Lillo-Martin 2006
Second, handshape is the parameter on which gesturers, signers, and homesigners differ the most, and so would be most likely to display featural differences of the sort we are investigating here (e.g., Singleton et al. 1993, Schembri et al. 2005).

An introduction to two fundamental aspects of handshape in sign language phonology is necessary in order to proceed. First, handshape behaves differently across the lexicon of a sign language (Brentari & Padden 2001). Figure 1 illustrates the three grammatical components proposed for sign languages—the core component, the foreign component, and the spatial component. The circles partially overlap across components in historical origins as well as synchronic morphological and phonological properties. For example, the handshape inventories of the three components overlap considerably, but there are some differences as well. Core forms are lexical forms that would be listed in a dictionary as stems. Foreign forms have forms derived from an external source (e.g. written systems, another sign language, even a gesture from the surrounding spoken language community). Spatial forms include classifier constructions, which are productive polymorphemic forms, containing a verbal root (a movement) and a handshape affix that represent morphosyntactic properties of the arguments. Examples from each component with the same handshapes—in this case, \( \text{O} \) and \( \text{F} \)—are also shown in Figure 1.

![Figure 1](image)

*Figure 1.* The core, foreign and spatial components of the sign language lexicon, with examples using the same phonological handshapes O and F (cf. Brentari & Padden 2001).
The second aspect of sign language phonology that will serve as background for this chapter is the basic structure of handshape. The main components of handshape are given in Figure 2. The features of joints and selected fingers will be the focus of this work. The first study focuses primarily on joint features, and the second study focuses on selected finger features.

2. Differences in contrasts and Phonetic targets across Sub-components of the Lexicon

This study is taken from Eccarius (2008) and Eccarius and Brentari (2008). The purpose of the investigation was to determine whether joint features are perceived the same way across the lexical components shown in Figure 1. Specifically, we wanted to know if 1) the number of distinctive contrasts and 2) their phonetic targets would be consistent across lexical components for ranges of handshapes common to all ASL lexical components. Differences such as these could affect the number of features required for the representation in the foreign, core, and spatial components of the grammar.

Although the original study examined additional handshapes, here we focus on the results of two handshape ranges, which we refer to as the O and F ranges (see Figure 3). These groups were chosen because the handshapes within them are relatively common handshapes (Hara 2003) for which the feature [+contact] (contact with the thumb) could be held constant while altering the joint positions of the selected fingers (either all fingers in the O group or just the index finger in the F group). The visual effect of leaving [+contact] constant while varying the joint positions is a variation between round and flat shapes so that there are at least 3 distinguishable handshapes for each range: Round-O/Round-F, Mid-O/Mid-F and Flat-O/Flat-F.
In our attempts to identify phonological contrasts across the lexicon in these handshape ranges, we first looked for differences in meaning based solely on handshape variation (since differences in meaning indicate distinctive contrast). However, because sign languages tend to have very few minimal pairs (even for well established contrasts), determining contrasts via meaning differences was not always straightforward. For example, there is a known meaning distinction in ASL between Round-O and Flat-O in classifiers used to describe round and flat shaped objects (e.g. the description of a cardboard tube vs. a sheet of cardboard, see Figure 4 in the next section). However, we could find no such minimal pairs in the foreign component or in core lexical items. It was unclear whether the missing forms were the result of contrast differences across the three lexical components or were merely due to large accidental gaps.

This imbalance in lexical competition throughout the lexicon has the potential to affect signers’ responses in meaning identification tasks. Along these lines, Allen and Miller (2001) conducted a series of perceptual rating tasks on spoken English and found that the location of category boundaries for voice onset time between /p/ and /b/ shifted as the result of a lack of lexical competition (testing word vs. non-word status, e.g. beef vs. peef), indicating that the location of a contrast could be affected if no competition was present. However, they also found that the mapping of “best exemplars” within those boundaries remained comparatively stable regardless of the presence of competition. For that reason, we also included a form-rating task, which mapped (at a very basic level) the phonetic target preferences for forms within the same meaning group. This helped us determine how good a fit each phonetic variant was for the meaning chosen, thus beginning to establish the best phonetic exemplars within categories and helping to further identify the existence and location of meaningful contrasts.

Two competing hypotheses existed for this study:

Consistent Contrast Hypothesis: (Round-O and Flat-O) and (Round-F and Flat-F) are contrastive pairs across the ASL lexicon. The absence of minimal pairs in one part of the lexicon is accidental.
Variable Contrast Hypothesis: (Round-O and Flat-O) and (Round-F and Flat-F) are contrastive pairs only in the spatial lexicon of ASL. The absence of minimal pairs in the core and foreign lexicon is not accidental: the forms are not contrastive in these parts of the lexicon.

If the Consistent Contrast Hypothesis is correct, then we would expect the phonetic targets for those contrasts to remain constant across components. For example, if the Round-O vs. Flat-O contrast found in the classifiers persists throughout the lexicon of ASL, and those handshapes are highly rated as exemplars for the members of that contrast, we would expect the same handshape preferences to be found for items from other lexical components, regardless of whether or not there was a minimal pair available. In other words, for a core sign without a corresponding minimal pair (e.g. TEACH, Figure 1), signers would rate either Round-O or Flat-O as highest, matching one of the best exemplars from the classifier contrast. Conversely, if the Variable Contrast Hypothesis is correct, and either member of the pair were equally acceptable in the foreign and core components, OR we found phonetic targets for TEACH that were different from that of the classifiers, it would be an indication that the phonological contrast is not homogenous cross-componentially, and that a more complicated phonological relationship may be at play in the ASL lexicon.

2.1 Participants

Twelve Deaf adult, native or early learners of ASL participated in this experiment. All were students or employees at Gallaudet University at the time of testing.

2.2 Stimuli and procedures

The stimuli relevant to this work consisted of video clips of signs chosen to represent the three lexical components of the ASL lexicon. Each ‘sign’ was produced by a Deaf signer three times using each of the variants from the handshape groups—one with the round handshape (Round-HS), one with the intermediate handshape (Mid-HS), and one with the flat handshape (Flat-HS)—while the values for movement and location remained the same (see Figure 4 for an example). These three signed forms constituted one ‘item’ for purposes of comparison, and there were three items included for each of the lexical components—foreign (in this case, all were initialized signs),
core (lexical items) and spatial (classifier handshapes). As much as possible, items were balanced with regard to place of articulation, movement, orientation, and sign type (one handed, symmetrical two-handed, etc.). For each item, there was at least one, and sometimes more than one, attested meaning, depending on the contrast number and location per handshape group (e.g. the foreign and core items in Figure 4 each have one attested meaning—OPINION and TEACH respectively—while the classifier item has two: long-thin-round object and long-thin-flat object).

The combination of variables (handshape group, handshape variant, lexical component), and multiple items within each component resulted in 54 stimulus clips from the O and F groups. These test stimuli (in addition to those for the other handshapes tested in the larger study) were then added to distracter signs, which were balanced across the lexical components and used a variety of handshapes, some well-formed for their signs and others not (so that distractors as well as test stimuli would receive a variety of goodness rankings).

Each video clip was embedded in a pair of PowerPoint slides. The first slide of the pair addressed the meaning-choice task. Participants were asked,
“What is the best English meaning for this sign?” Two possible meanings were provided (along with the possibility of supplying a meaning that was not provided). In cases where a minimal pair was available (e.g. round vs. flat objects for the classifiers), both meanings were provided as possible choices. In cases where there was only one possible meaning for a given item across handshape variants (e.g. TEACH), the second choice provided was the English gloss for a sign that was a minimal or near-minimal pair and differed in handshape alone if possible (e.g., TEACH vs. PAY-ATTENTION). The second slide addressed the form rating task. Participants were asked to “Please rate the handshape for this sign” on a five-point scale from very bad (1) to very good (5).

2.3 Results

The results for both the O and F handshape groups are presented in Figure 5.3

![Figure 5](image_url)

Figure 5. Results for the meaning choice task for O (top left) and F (bottom left) groups, and for the form rating task for O (top right) and F (bottom right) groups. The graphs of the meaning choice task show the average proportion of round (vs. non-round) responses for each of the three handshape variants. The graphs of the form rating task show the average “goodness-of-fit” rating for each variant.
2.3.1 The Meaning Choice Task

Because the test items differed in the number of ‘correct’ meanings possible for a given handshape range, only the responses for one meaning were used for statistical comparisons. In cases where there was no minimal pair, the meaning used was the only ‘correct’ meaning for the signed form. However, where a minimal pair did exist (e.g. for classifier forms), the meaning response analyzed was the choice expected for the rounder of the two endpoints (e.g. ‘cardboard tube’ instead of ‘sheet of cardboard’). Results of the meaning choice task report the average proportion of times the round meaning was chosen for each of the three handshapes (Round-HS, Mid-HS, and Flat-HS) across the three components, and a Fishers Exact Test was used to determine significance.

For the O (top left) and F (bottom left) handshape groups, the items from the foreign and core lexical components do not show a significant difference from one another in the proportion of round responses across the three handshapes (i.e. all handshape variants elicited the same meaning response). However, the items from the classifier component for these groups differed significantly from the core and foreign forms for the proportion of round responses at Mid-HS and Flat-HS, the intermediate and flat forms ($p < .01$, $\alpha = .05$) (i.e. some proportion of non-round meanings were chosen for these handshape variants).

2.3.2 Form Rating Task

Results of the form rating task report the average “goodness-of-fit” rating (1-5) for the three handshapes in the core and foreign groups. As previously indicated, the rating task was used to help locate contrasts in the absence of meaningful competition, therefore the classifier group is not shown because there was a clear meaning contrast between round and flat handshape versions. For the rating task, a Mixed Model ANOVA with a Bonferroni adjustment of $a = .0167$ was used to determine significance.

The first thing to note is that all handshape variants (round, mid or flat) were considered acceptable for both core and initialized signs: on the 1 to 5 rating scale, all O and F handshape variants received an average rating of above 3. However, the acceptance rating for Flat-O in initialized signs was significantly lower than it was in core signs: for the Flat-HS in the O Group only (top right) a significant difference was found for form rating responses between core and initialized items ($t = 3.74$, $df = 197$, $p < .01$).
2.4 Discussion

Significant differences in the meaning choice task (supported by the form ratings) provide evidence for the number of distinctive contrasts, which was our first research question. For stimuli in the two handshape groups (O and F), the classifier component for all groups demonstrated a progressively lower proportion of round meaning responses on the Mid-HS and Flat-HS. In other words Mid-HS and Flat-HS elicited different meanings than Round-HS for classifiers, but crucially all three handshape variants elicited the same meaning responses for core and foreign (initialized) forms. These results suggest that certain changes to the features needed in each component may be warranted: the feature [+contact] may be sufficient to define each phonemic category (O and F) represented by these handshape ranges for core and initialized forms, making the features used to distinguish flat from round (e.g., flexion of the intrapharangeal joints) unnecessary in these components for handshapes with contact. (Future work can determine if this is actually the case.) Conversely, these joint features are needed in the classifier component, where a morphological contrast between Round-HS and Flat-HS exists.

With respect to the form rating task results, we found that phonetic targets were not always stable across components. While all handshape variants were rated relatively high across the core and foreign items (suggesting that a distinctive contrast does not exist), there was a significant difference in the average suitability rating of Flat-O for initialized signs as compared to core signs, suggesting a phonetic target closer to the round end of the handshape range in the foreign component (at least in forms borrowing a fingerspelled O). However, this kind of phonetic difference was not found when comparing core and foreign forms in the F handshape group. Why could this be? The joint configurations for these handshapes are the same—they only differ in the number of selected fingers. One possibility is that the phonetic targets are influenced by the iconic relationship between the borrowed orthographic letters and their representative handshapes. The letter O is round and therefore has the potential to elicit the phonetically rounder handshape variant, while the handshape used to represent the letter ‘F’ has no iconic link to the written letter, and is therefore immune to such external influence.

This study has implications for two theoretical domains. The first is Dispersion Theory (Flemming 2002). The principle of Maximum Dispersion within this theory proposes that, ceteris paribus, when forms express a meaningful difference (as they do in the classifier system here) the system is more well formed if the phonetic targets are as far away from one another as
possible (fully round vs. fully flat). Again, all things being equal, when forms do not express a meaningful difference (as in the core and foreign components most of the time) there would be no need for the form to gravitate to either end. Our results support the principle of Maximum Dispersion because in the core and foreign components flat, mid and round forms are almost equally acceptable except when iconicity interferes. Indeed, if anything, the mid form appears to be slightly preferred to the more extreme flat and round forms, although this difference in preference is not significant in this data.

This work also has implications for a second theoretical area, namely socio-phonetics, where sub-phonemic systematicity has implications for the emergence of a phonological system. Trends in sub-phonemic perception can have important implications for historical change in a phonological system. Using Exemplar Theory, Yu (2007) has demonstrated that sub-phonemic systematicity can help us better understand the historical phenomenon of near-merger in Cantonese. We add to this work considering the systematic difference in phonetic preference among the subcomponents in the experiment on ASL. While this experiment included no data from homesign or emerging sign language systems, the implications on the emergence of phonology are as follows. As the vocabulary grows in a new system, one mechanism that might be employed by the system to keep track of the source of the form is a difference in phonetic target. In other words, while there is a great deal of variability in homesign and young sign systems (e.g., Coppola & Senghas 2010, Aronoff et al. 2008), two signs—one originating in the gestures of an adjacent hearing community and one created within the community itself—might have different phonetic targets. Moreover, this sub-phonemic type of systematicity might well appear in a single user before it manifests itself in a whole community. The distribution of phonetic targets might not count as “phonology” by some definitions, but it might be the type of socio-phonetic phenomenon that could be a precursor to a phonological alternation.

3. **Handshape production in gesturers, signers, and homesigners**

This study is taken from Brentari, Coppola, Mazzoni and Goldin-Meadow (in press). The purpose of the study was to investigate how gesturers, signers and homesigners use handshapes to describe objects and how objects are handled, particularly in the area of *selected finger* features. First we studied whether gesturers and signers used handshapes in the same way, and then we examined whether homesigners looked more like gesturers or more like signers in their pattern of productive handshape use.
The morphological categories for Object and Handling might or might not be paralleled by a corresponding phonological pattern. For example, if the following hypothetical set of handshapes—comprises a particular classifier type in a sign language, the set would form a phonological class because the handshapes in the set share a phonological property (they are all fully extended) and form a natural class. New handshapes that enter the set would be predicted to be fully extended as well. In contrast, if the following handshapes—comprise the classifier type, the set would not form a phonological class as there is no common property that the handshapes share. In this event, the handshapes would constitute a morphological but not a phonological class. Because the phonological patterns are associated with specific morphological categories, the study we are about to describe concerns a morpho-phonological phenomenon, as described in the introduction.

For this study, we will refer to “finger groups” rather than individual handshapes, and use the abbreviation set T (thumb), I (index), M (middle), R (ring) and P (pinky) to create group names. For example, the finger group-IM represents the Index and Middle finger group that includes the whole range of joint configurations for handshapes using the index and middle fingers, e.g., , , , and . The thumb is ignored in designations of finger group unless it is the only digit selected. We classified finger groups into three levels of finger complexity based on several criteria.

**Low complexity** finger groups have the simplest phonological representation (Brentari 1998), are the most frequent handshapes crosslinguistically (Hara 2003, Battison 1978, Eccarius and Brentari 2007), and are the earliest handshapes acquired by native signers (Boyes Braem 1981). These three criteria converge on these selected finger groups: finger group-IMRP, finger group-I  and finger group-T . Interestingly, these three groups of selected fingers have also been found to be frequent in the spontaneous gestures that accompany speech (Singleton et al. 1993, Goldin-Meadow et al. 1996) and in child homesign (Goldin-Meadow et al. 1995).

**Medium complexity** finger groups include one additional elaboration of the representation of a [one]-finger handshape, either a branching structure or an extra association line. A branching structure elaboration means that the single selected digit is not on the ‘radial’ (thumb) side of the hand, which is the default position for all finger groups, e.g., in the finger group-P the selected finger is on the ‘ulnar’ (pinky) side of the hand, and for the finger group-M is ‘middle’. An extra association line elaboration means that there is an additional finger selected, as in finger group-IM, where two fingers are extended rather than one. These are also the next most frequent
sets of selected fingers after the low frequency selected finger groups (c.f. Hara 2003).

High complexity handshapes would include all other handshapes, such as three selected fingers or two non-contiguous selected fingers. Examples would be finger group-IMR \( \overline{\text{I}} \) and finger group-IP \( \overline{\text{P}} \). These are the least frequent sets of selected fingers (Hara 2003) and can exhibit a wide range of further elaborations of the representation.

In sign languages, ObjectHSs, or handshapes that represent objects, show a higher degree of selected finger complexity than HandlingHSs, or handshapes that represent how objects are manipulated. Data from American, Swiss German, and Hong Kong Sign Languages (ASL, DSGS, and HKSL) shows that whole entity classifiers, which is one use of ObjectHSs (Engberg-Pedersen 1993) have a larger set of finger distinctions and more finger complexity than HandlingHSs. This set of classifiers includes semantic and some SASS classifiers in Supalla’s 1982 system. Eccarius (2008) and Brentari and Eccarius (2010) have found that ObjectHSs and HandlingHSs differ in their distribution of finger and joint complexity (Figure 6).

<table>
<thead>
<tr>
<th>Complexity level:</th>
<th>Finger contrasts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Object CL-HSs</td>
<td>1 1 1 2 2 3 3</td>
</tr>
<tr>
<td>Handling CL-HSs</td>
<td>1 1 1 2</td>
</tr>
</tbody>
</table>

Figure 6. Handshapes found in Object (whole entity) and Handle classifiers in ASL, HKSL, and DSGS (cf. Eccarius 2008). The finger complexity score for each handshape is listed below it.

A task was designed to elicit handshapes that represent either an object or a hand manipulating an object with three goals in mind: (1) to replicate the finger complexity patterns found by Eccarius (2008) and Brentari and Eccarius (2010) in signers using an experimental probe; (2) to use the same probe to determine whether hearing individuals asked to describe objects using only their hands and no speech would display the same or different finger complexity patterns; (3) to see whether the home signers pattern like gesturers or like signers.
3.1 Participants

The participants in this study were adults from 5 groups and 3 countries (age range: 22-55). The language groups were ASL, Italian Sign Language (LIS), spoken English, and spoken Italian; all participants were native users of the language in question. In addition there was a group of four Nicaraguan homesigners. The three American (i.e. English-using) gesturers were graduate students at Purdue University, and the three native ASL signers were from the greater Chicago area. The three Italian gesturers were students at the Università di Firenze, and the three native LIS signers were from the greater Milan metropolitan area. Four homesigners in Nicaragua also participated in our study. At the time of the study, they were 20, 24, 29, and 29 years old, and they displayed no apparent cognitive deficits. The homesigners did not know each other, did not interact regularly with other deaf people, and were not part of the Deaf community in Nicaragua that uses Nicaraguan Sign Language (Coppola 2002).

3.2 Stimuli and procedures

The stimuli consisted of 121 photographs or short movie clips (henceforth vignettes). Eleven objects were used in the vignettes: airplanes, books, cigars, lollipops, marbles, pens, strings, tapes, television sets, and tweezers. The shape of the hand used by the actor in the vignettes was intentionally ambiguous and could be represented by finger groups IMRP ꝰ, IM ꝰ, or I ꝰ. The objects exhibited a range of colors, shapes, and sizes. Each object was portrayed in 10 conditions of 2 types: Agentless: 5 conditions depicting a stationary object or an object moving on its own without an agent, and Agent: 5 conditions depicting an object being moved by the hand of an agent (Figure 7).

The gesturers were instructed to “describe what you see using your hands”. Signers were instructed in sign to “describe what you see.” The instructions to the homesigners involved indicating the computer screen and indicating with gestures that they should describe what they see. Data collection sessions were videotaped, then captured using iMovie and clipped into individual files, one file for each vignette description. The video files containing the participants’ responses were transcribed using ELAN (EUDICO Linguistic Annotator), a tool developed at the Max Planck Institute for Psycholinguistics, Nijmegen, for the analysis of language, sign language, and gesture. Three data sets were selected for analysis: the “falling” condition (#5) for all 11 objects, and the “airplane” and “lollipop” objects for all 10 conditions.
The falling condition provides opportunities to produce an unaccusative-like construction depicting a theme moving without an agent. Responses to the objects “airplane” and “lollipop” were analyzed because they tend to elicit high complexity handshapes. We focused on the gestures and signs used to describe the objects, their manipulation, and their spatial arrangements. Gestures and signs that were used to label the object or describe its color or number were not included in the analyses, as they are not comparable to productive classifiers, the focus of our study.

Each handshape was first coded according to meaning type: (1) ObjectHSs represented the whole object, part of the object, or its physical characteristics, such as size and shape; (2) HandlingHSs represented the manipulation or handling of the object. Participants also produced a number of handshapes that were not relevant to our analyses and thus were excluded: the index finger or neutral handshape was used to trace the object’s path or indicate its location; the whole body was used to substitute for an object in motion (e.g., falling off the chair to indicate the object falling); a lexical sign in LIS or ASL rather than a classifier form was used (relevant only to signers). We included in the analyses only handshape types that matched the intent of the stimulus, that is, ObjectHSs that were produced in response to Agentless stimulus events, and HandlingHSs that were produced in response to Agent

<table>
<thead>
<tr>
<th>Agentless scenes</th>
<th>Agent scenes</th>
</tr>
</thead>
<tbody>
<tr>
<td>2. [object] on table upside down</td>
<td>7. Put [object] on table upside down</td>
</tr>
<tr>
<td>3. Multiple [objects] on table (regular arrangement in row/s)</td>
<td>8. Put multiple [objects] on table (regular arrangement in row/s)</td>
</tr>
<tr>
<td>5. [object] falling</td>
<td>10. Demonstrate function of [object]</td>
</tr>
</tbody>
</table>

Figure 7. Description of the 10 conditions in which each of the 11 objects appeared (top), and examples of two airplane vignettes (a frame from the Agentless condition #3 and a frame from the corresponding Agent condition #8).
stimulus events. These criteria resulted in 595 handshapes across the four language groups.\(^5\)

Each handshape was then assigned a finger complexity based on the criteria described in Figure 6. Low complexity handshapes were assigned a score of 1; medium complexity handshapes were assigned a score of 2; high complexity handshapes were all remaining forms, and were assigned a score of 3. A handshape was given an extra point for complexity if there was a change in the selected fingers used over the course of the gesture or sign, e.g., it began with finger group-IMRP and ended in finger group-I. Thus, finger complexity values ranged from 1 to 4.

3.3 Results

Results will be reported first for the gesture/sign comparison in Section 3.3.1. The results on the gesture/homesigner/sign comparison will be reported in Section 3.3.2.

3.3.1 Gesture vs. Sign

Finger complexity was averaged for each participant, and then again for each language group. A Mixed Linear Model was used that allows grouping of interdependent samples. Group (Sign, Gesture), Country (US, Italy), and Handshape Type (Object, Handling) were treated as fixed effects, and Participant and Stimulus Item were treated as random effects. Figure 8 displays the estimated mean finger complexity for ObjectHSs and HandlingHSs for signers and gesturers by Country.

The model revealed a significant interaction between Group and Handshape Type, indicating that the signers and gesturers differed in their patterns of finger complexity for ObjectHSs vs. HandlingHSs (see Figure 8).

Specifically, signers showed significantly higher finger complexity for ObjectHSs than for HandlingHSs, \((t(5) = 7.35, p < .001)\), whereas gesturers showed the opposite pattern, lower finger complexity for ObjectHSs than for HandlingHSs, \((t(5) = -3.81, p < .05)\). The main effect for Country was marginally significant, indicating that signers and gesturers from the US tended to produce higher finger complexity than signers and gesturers from Italy \((t(10) = -2.02, p = 0.064)\). However, the lack of interaction between Country and Handshape Type \((t = -0.915, p = .38)\) indicates that the overall
pattern in finger complexity for the different Handshape Types did not differ by Country. Post-hoc contrasts indicated significant differences between signers and gesturers in both Handshape Types: signers showed higher finger complexity for ObjectHSs than gesturers, $t(10) = 4.16, p < .05$, and lower finger complexity for HandlingHSs, $t(10) = -5.05, p < .001$, than gesturers. There were no other significant effects.

Figure 8. Estimated mean finger complexity for ObjectHSs and HandlingHSs in signers and gesturers by Country. Signers in both countries replicated previous cross-linguistic findings (higher finger complexity for ObjectHSs than for HandlingHSs) (Eccarius 2008, Brentari & Eccarius 2010). Gesturers in both countries showed the opposite pattern (higher finger complexity for HandlingHSs than for ObjectHSs). The estimated values provided by the model reflect the effects of removing covariates (such as stimulus item and participant) and, in this sense, provide a more accurate picture of the underlying patterns in the dataset than the observed values. Because these are estimated values provided by the model, their values can be less than 1, which was the minimum finger complexity value assigned in our system.
3.3.2 Gesture, Sign and Homesign

The observed average finger complexity for ObjectHSs and HandlingHSs for each homesigner is displayed in Table 1.

Table 1. Observed average finger complexity for each individual homesigner and the group average for all four homesigners.

<table>
<thead>
<tr>
<th>Homesigners</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>Group average</th>
</tr>
</thead>
<tbody>
<tr>
<td>ObjectHSs</td>
<td>1.87</td>
<td>1.55</td>
<td>1.50</td>
<td>1.36</td>
<td>1.57</td>
</tr>
<tr>
<td>HandlingHSs</td>
<td>1.46</td>
<td>1.00</td>
<td>1.43</td>
<td>1.58</td>
<td>1.37</td>
</tr>
</tbody>
</table>

The homesigners displayed individual variation in how they used finger complexity across the two handshape types. Three of the four homesigners displayed higher finger complexity in ObjectHSs than in HandlingHSs, the signers’ pattern. However, the fourth homesigner displayed the gesturers’ pattern, producing higher finger complexity in HandlingHSs than in ObjectHSs.

To compare the homesigners’ performance to the performances of the signers and gesturers, we contrasted the 156 observations from the Nicaraguan homesigners to the 595 observations from the native signers and gesturers described in Study 1 (a total of 751 observations) using the Mixed Linear Model described in Study 1. Because the factor Country (US, Italy) revealed no significant interaction with Group (Sign, Gesture) in Study 1, this factor was ignored in this analysis. Figure 9 shows the estimated mean finger complexity for ObjectHSs and HandlingHSs in homesigners, signers, and gesturers (collapsing across country).

The homesigners displayed a marginally significant tendency to produce more finger complexity in ObjectHSs than in HandlingHSs, $t(3) = 2.31$, $p = 0.10$. To situate the homesigners’ levels of finger complexity within the levels for the other two groups, we conducted the following post-hoc pairwise comparisons. Homesigners did not differ significantly from signers on finger complexity in either ObjectHSs, $t(8) = -1.02$, $p = 0.34$, or HandlingHSs, $t(8) = 1.6$, $p = 0.15$. And they did differ from gesturers: they displayed significantly lower finger complexity than gesturers in HandlingHSs, $t(8) = -2.62$, $p < .05$), and higher finger complexity than gesturers in ObjectHSs, $t(8) = 2.24$, $p = 0.055$. Thus, the homesigners’ finger complexity levels were closer to the signers’ levels than to the gesturers’ levels.
3.4 Discussion

The results for the ASL and LIS signers replicate previously found patterns (Eccarius 2008, Brentari and Eccarius 2010), and illustrate the morphophonological distinction in finger complexity for ObjectHSs vs. HandlingHSs described in Section 1.1.3. All six of the signers, regardless of country, displayed a higher finger complexity in ObjectHSs than in HandlingHSs. We have thus succeeded in creating a reliable experimental task that can be used to probe handshape use in groups who cannot provide grammaticality judgments. In addition, we show that the pattern previously reported for sign languages is not inevitable whenever the hands are used to communicate—the gesturers in our study did not show it and, in fact, displayed the opposite pattern, more finger complexity in HandlingHSs than in ObjectHSs. The different pattern found in gesturers vs. signers underscores the fact that different processes can be recruited when objects are represented in the manual modality. When gesturers view the vignettes containing an agent,
they replicate to a large extent the actual configuration of the hand in the vignette and, as a result, they display a fair amount of finger complexity in these Handle handshapes. They are using the hand to represent the hand, and thus are relying on an accessible mimetic process. In contrast, signers display more finger complexity in their Object handshapes, where handshapes take on the properties of the objects themselves. Gesturers do not use much finger complexity here, since properties of the object must be represented as abstract features of the hand. These hand-as-object representations seem to rely on a more abstract process than the mimetic process underlying hand-as-hand representations.

The discontinuity in finger complexity between gesturers on the one hand and homesigners and signers on the other provides clues to the changes that might have taken place in the evolution of the morpho-phonological system underlying handshape in sign languages. We see the first indicators of a phonologization process in the homesigners’ Object handshapes: homesigners increase finger complexity in their Object handshapes from the gesturers’ level to the signers’ level. We also see change in the homesigners’ Handling handshapes: homesigners decrease finger complexity in Handling handshapes from the gesturers’ level, although not yet to the signers’ level.

What accounts for the sign-like pattern observed in the homesigners? It is possible that the sign-like pattern that the homesigners display in their handshapes is the result of influence from Nicaraguan Sign Language (NSL). We think this possibility unlikely because none of the homesigners had regular contact with individuals who knew and used NSL. There are two factors that distinguish the homesigners from the gesturers: They have been using their gestures to communicate over a long period of time, and gesture is their primary means of communication. Although intertwined, these two factors can be distinguished and will be explored in future work.

Although homesigners have achieved sign-like levels of finger complexity in their Object handshapes, their Handling handshapes still appear to be in transition. Homesigners’ finger complexity levels in Handling handshapes are significantly lower than gesturer levels, but they have not yet fully decreased to the sign level. It is possible that achieving the sign level of finger complexity in Handling handshapes, which has the effect of maximizing the distinction between Object and Handling handshapes, may require a linguistic community where some sort of negotiation might take place. The homesigners’ regular communication partners are their hearing family members and friends, none of whom uses the homesign system as a primary means of communication. Thus, it is difficult to characterize home-
signers as having access to a shared linguistic community. Moreover, the homesigners do not know or interact with one another. There is consequently no pressure to arrive at the most efficient solution for a whole community. The fact that homesigners’ complexity level is closer to the gesturer level for Handling handshapes than for Object handshapes suggests that a shared linguistic community may play a important role in “losing” the hand-as-hand iconicity displayed so robustly by the gesturers.

4. Conclusions

The two experiments reported in this chapter serve as evidence suggesting that the most obvious elements of phonology—minimal pairs and phonological distribution—might not be the ways that an emerging phonology would first show itself. We have argued that interface phenomena may precede an autonomous phonological component. Two studies have been described that suggest that the first indicators of phonology might emerge at the grammatical interfaces between phonology and another component of the grammar.

In the first experiment involving both the morphology-phonology and phonetics-phonology interfaces, our results suggest that there can be both a different number of distinctive contrasts and different phonetic targets across lexical subcomponents. These subcomponents are based in part on their morphological and phonological behavior, so the sub-lexical phonetic properties described are relevant for both grammatical interfaces. The different distinctive contrasts and phonetic targets across the lexicon indicate a differential use of feature [flexed] at the intraphalangeal joints. Moreover, the number of contrasts and the preferred variants show sub-lexical systematicity that may be relevant for historical change.

The second experiment involving selected finger complexity addresses the morphology-phonology interface. It was found that the changes from gesture to homesign and from homesign to sign language involve not only loss of iconicity (Frishberg 1975) but also reorganization of phonological information over time. One reason that this occurs might be that the type of iconicity present in sign languages leads to early development (historically speaking) of a morpho-phonological interface. In other words, meaningful differences originating in iconicity are not completely lost but rather are both organized into productive morphological structures and subjected to phonological restructuring (e.g., by the differential use of selected finger features mapping to different morphology categories). This is true crosslinguistically in sign
languages, and as we have shown here, the Nicaraguan homesigners have begun to display a sign-like pattern in finger complexity distribution; in this sense, they can be said to display the seeds of morpho-phonological structure.

Thus far, there have been no minimal pairs reported in homesign or in Al-Sayyid Bedouin Sign Language (ABSL), the young sign language currently under investigation in Israel (Sandler et al. 2005, 2012, Israel & Sandler this volume). No doubt, given the relatively high levels of many types of variation found in homesign and young sign languages (e.g, Coppola & Senghas 2010, Aronoff et al. 2008), applying the type of investigation described in this chapter to those cases would involve teasing apart different patterns of variation—those that are within the individual vs. those that are within the community. It would be expected that hints of both uses of these interface phenomena would appear in a single system before appearing in a language as a whole, thus providing a way for us to track the path toward phonology first from a single individual and later into a community.

Notes

* This work was supported in part by National Science Foundation (NSF) grants to Brentari (BCS0112391 and BCS0547554) and by a Purdue Research Foundation Grant to Eccarius.
1. Extended methodology and results can be found in these two sources.
2. An ‘early learner’ is defined here as someone who learned ASL before age 5.
4. These expectations were formed solely on prior knowledge of ASL vocabulary and not on the experimental results themselves.
5. Importantly, if we include all handshapes regardless of the type of stimulus that elicited them (i.e., Object HSs produced in response to both types of stimuli, and Handling HSs produced in response to both types of stimuli), the results described below are unchanged.
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A phonological awareness test for deaf children using Brazilian Sign Language

Carina Rebello Cruz
Regina Ritter Lamprecht

Research on phonological awareness has been developed in different languages, because the ability to access knowledge and manipulate the segments (sounds) of a given oral language favorably impacts on the learning process of reading and writing of languages that are represented in an alphabetical code.

In the absolute majority of research on phonological awareness, informants hear and speak an oral language which has a written representation. Nevertheless, there has also been interest in investigating this ability in deaf informants, both users and non-users of a given sign language (Hanson 1989; Paul and Jackson 1993; Perfetti and Sandak 2000; Nielsen and Luetke-Stahlman 2002; Souza and Bandini 2007). Usually, the main purpose has been to investigate whether the development of phonological awareness in deaf individuals living amidst users of an oral language contributes to the literacy process of that written language, thus facilitating the learning of reading and writing and increasing the level of proficiency in them.

While research on the phonological awareness of hearing or deaf individuals using oral languages is found in the literature, research on the awareness of the phonological aspects of a given sign language, typically the native language of deaf individuals, is not easily found.

Nevertheless, research on phonological awareness of sign language users by way of an instrument which specifically considers a visuospatial system may contribute in several ways: i) to studies on the phonology of that language, ii) to studies on the language acquisition process of deaf children, and iii) to studies on the learning of a written alphabetical system. Light can be shed on questions like:

- Which is the adequate format for an instrument destined to evaluate phonological awareness in a visuospatial language?
- What aspects of phonology should the instrument test?
- Is it possible to determine typical/expected answers on phonological awareness in deaf children who acquire sign language early?
- Do deaf children who acquire sign language late, or deaf children who present some sort of language disability, have difficulty in their ability to think about their own language?
Do children who are stimulated to think about the phonology of their sign language benefit from this stimulation in their language acquisition process?

Is phonological awareness related to the learning process of a written first language even when it is non-alphabetical, like Sign-Writing, or of a second language, like the written representation of oral languages?

Here we are interested primarily in the first two questions: in the adequate format for an instrument to assess phonological awareness in a visuospatial language, and which aspects of phonology should be tested.

This chapter presents and discusses a phonological awareness test in Brazilian Sign Language (from now on LSB, for Lingua de Sinais Brasileira), taking into consideration one of the sublexical parameters of signs - the handshape.

Initially we describe the test and also the methodology for data analysis. We analyze the children’s performance according to their period of linguistic exposure1, and also differences between the answers given by children and by adults who took a pre-test.

Our results show that the period of linguistic exposure influences the children’s performance both as regards lexical knowledge and as regards their performance in tasks on phonological awareness of the handshape parameter.

The evaluation instrument, designed to be used with deaf children, was applied in a playful but at the same time efficient way and was considered adequate to measure phonological awareness of the handshape parameter.

1. The evaluation test: description and application

The test which we propose to use to evaluate phonological awareness of handshape (HS) in deaf children using LSB is a pioneer proposal for LSB.

It comprises two parts: in the first part, the children’s lexical proficiency is assessed, so as to be sure that the participants are familiar with the vocabulary which is going to be used (comprehension and production of the signs). In the second part, their phonological awareness of the HS parameter is assessed.

A linguistic test for children presents additional challenges to those inherent to any test for adults. Besides the linguistic questions which are at its basis, there are specific cognitive, maturational and psychological factors to be considered, namely:
A phonological awareness test for deaf children using LSB

- limitations in attention span and in physical capacity;
- vocabulary has to be age and development appropriate;
- words have to refer to concrete objects or animate beings, to be represented by easily recognizable pictures;
- directions have to be very clear and simple;
- application has to be playful and attractive to the participants.

A first version of the phonological awareness test was presented to five deaf adults who were native users of LSB. The purpose in conducting this pre-test with adults was: to initially avoid the specificities of interaction with children, being able to concentrate on the test itself (structure, wording of the orders, number of tasks, length, and so on); to assess the level of figure-match recognition; to check whether any signs evoke more than one item for a referent; and to select the production which is considered standard or most used by the children’s linguistic community, in the event of finding linguistic variation.

In accordance with the adult’s reactions, commentaries and difficulties in the pre-test, some adjustments were made and the instrument was then tested on fifteen deaf children aged between 6:0 and 11:1 who began their language acquisition in LSB between 0:0 and 4:1. These children attended a bilingual school for deaf people at the city of Porto Alegre, Brazil. The children have no visual, neurological or developmental disabilities, and they had average to good grades at school.

The school’s Board as well as the children’s parents and the adult deaf participants all gave their formal, written agreement to participation in the project.

1.1 Description and application of the Lexical Evaluation Test – LET

The purpose of the lexical evaluation test – LET – was to determine the children’s knowledge of the vocabulary which is used in the second part of the test, the phonological awareness test. Each child is checked whether he/she knows and produces the 120 signs of this test, and whether he/she knows the concept represented by the figures and is able to name it. This knowledge is a pre-requisite for the phonological awareness assessment since the signs and corresponding pictures are part of it, and it guarantees that the performance of the participants is examined exclusively as to phonological awareness of the HS parameter.

A hundred and twenty colored pictures on individual flashcards were used to evaluate lexical proficiency. These pictures represent the lexicon
to be tested, which was established according to the already mentioned
criteria: vocabulary has to be age and development appropriate; words have
to refer to concrete objects or animate beings that can be represented by
easily recognizable pictures. The vocabulary list contains many words iden-
tical to those existent in tests of spoken Brazilian Portuguese which also use
pictures to elicit children’s productions in research on phonological devel-
opment (Yavas, Hernandorena and Lamprecht 1992; Wertzner 2004). All of
them refer to a child’s universe, referring to family members, food, toys,
transportation, colors, numbers, animals, furniture and simple household
appliances.

Other criteria to choose signs for the test were: to have signs of different
categories and to have signs which share, or not, the HS parameter with
others, to give opportunity to questions about identical or distinct HSs.

After establishing the vocabulary list, we found that there was an unequal
number of signs in the four categories (1H1HS, 2H1HS, 1H2HS, 2H2HS). Due to the nature of the vocabulary itself there were more signs in certain
categories than in others (e.g. more 1H1HS, less 2H2HS).

Each participant was required to sign as many of these pictures as possible
in LSB. A camcorder was used to videotape the sessions. When the expected
sign was not produced by the subject⁶, the researcher used toys and objects
related to the picture in addition to making comments about the concept that
the picture and objects represented, with the purpose of clarifying and/or
promoting the appropriation of the meaning by the child. After one or two
interventions, the child was reassessed to determine whether he/she had
acquired the vocabulary.

After this short intervention on the lexical level all informants were able
to recall and to demonstrate understanding of the 120 signs.

1.2 Description and application of the Phonological Awareness Test – PAT

The purpose of the second part – that on phonological awareness – is to eval-
uate the participant’s ability to think consciously about the HS parameter.

The material used in the PAT consisted of 35 flashcards. A camcorder was
used to film the activities.

The evaluation comprised 5 demonstration tasks and 30 test tasks. These
were organized into five different parts, always taking in account linguistic
constraints on sign formation; LSB phonology; and studies on the acqui-
sition process of LSB phonology (Battison 1978; Ferreira-Brito 1995;
We describe the five different parts of the test and the signs with different formations which are in them.

**Part 1**

Signs produced with one hand and one handshape (1H1HS).

Example in LSB: GREEN

![Green Sign in LSB](image1)

**Part 2**

Signs produced with two hands and one handshape (2H1HS).

Most of the signs were completely symmetrical, while one of the signs had the same HS on both hands but other characteristics such as orientation or action were different.

Examples in LSB: TELEVISION and CHOCOLATE

![Examples in LSB](image2)

**Part 3**

Signs produced with two hands and two different handshapes on different hands (2H2HS).

Example in LSB: SLIPPERS

![Slippers Sign in LSB](image3)
Part 4

Signs produced with one hand and two sequential handshapes (1H2HS).
Example in LSB: LION

Part 5

Signs spontaneously recalled by the participant when shown a HS on a flash-card.

The participant was required to spontaneously recall all the signs he/she knew and remembered that can be produced with a given handshape.

Five handshapes were selected: [\textsuperscript{1}], [\textsuperscript{2}], [\textsuperscript{3}], [\textsuperscript{4}], [\textsuperscript{5}]. The first three HSs are documented in Karnopp’s (1999) longitudinal study as being acquired in different periods in LSB. The fourth handshape [\textsuperscript{6}] is part of the phonetic inventory of LSB although it was not identified in Karnopp’s study in the age range covered by that author. However, it is documented in studies by Bonvillian and Siedlecki (1996) and Boyes-Braem (1990) for ASL. The fifth handshape [\textsuperscript{7}] was chosen for the demonstration task for two reasons: because it allows the production of signs with one and with two hands, and because this HS is in the LET.

The number of tasks was different for different parts:
- parts 1 and 2: 1 demonstration task and 10 test tasks,
- parts 3 and 4: 1 demonstration task and 3 test tasks,
- part 5: 1 demonstration task and 4 test tasks.

The difference in the number of tasks per part is due to the difference in number of signs (according to their formation) in the lexicon to be tested, as mentioned above.

To assess phonological awareness in parts 1 to 4 (1H1HS, 2H1HS, 2H2HS, 1H2HS), each participant received detailed instructions to perform the tasks. The demonstration tasks allowed the children to be comfortable with the game they were asked to play, and helped the researcher to make sure that each of them understood clearly how the tasks should be performed.

In parts 1-3, the participant was required to compare the handshape of a given target-sign and the handshapes of three other signs. He/she was shown
a picture on a flashcard, produced the target sign, looked at some alternatives on that same card and chose the picture whose sign matched the handshape of the target-sign.

Figure 1 is an example of a flashcard with a task for part 2.

![Flashcard Example](image)

*Figure 1. Task corresponding to part 2: signs produced with 2 hands and 1 handshape – 2H1HS*

In this task the target-sign is the COMPUTER. The participant is required to compare the handshape of the target-sign and the handshapes of the signs: SOCKS, PRESENT and SHIP. Only the signs for COMPUTER and SOCKS have the same handshape, as can be seen in SignWriting below.

![SignWriting Examples](image)

In part 4, which has signs with handshape sequences (1H2HS), the participant was required to compare the final handshape of a given target-sign and the final handshape of three other signs: a rhyme task in sign language.

It was explained to the child that the target-sign had two parts (initial and final configuration), and it was also explained that the initial configuration could be seen in the photo at the side of the target picture but that the final configuration could not be seen (empty space at the side of the photo). The child was then told to compare the final configuration of the target-sign to
the final configurations of the alternatives on the flashcard. After comparing them, he/she then should choose the picture which had the same final configuration as the target-sign.

The participant looked at the target picture, produced the target-sign, looked at the alternatives and chose, among the alternatives, the picture whose sign had the same final handshape of the target sign.

Figure 2 is an example of a flashcard with a task for part 4. The final handshapes for the signs MOON and TOUCAN are identical, as can be seen in SignWriting below.

Figure 2. Task corresponding to part 4: signs produced with one hand and two sequential handshapes – 1H2HS

In Part 5, the participant was required to spontaneously recall any signs he/she knew and remembered at that moment that are produced with a given handshape when shown that HS on a flashcard. The signs could be of everyday usage or recently learned during the lexical evaluation test: there were absolutely no restrictions.
The pictures of the demonstration task are shown in figure 3

![Figure 3. Task corresponding to part 5: pictures used in the demonstration and test tasks](image)

2. **Coding for the Lexical Evaluation Test – LET – and the Phonological Awareness Test – PAT**

2.1 LET: data organization

The adults’ productions in the pre-test and the children’s productions in the LET were classified into five categories, as follows.

**Expected sign**

The sign produced by the participant matched the picture and the target which had been established. Example: the sign HOUSE was expected when the picture of a house was provided, and the participant (adult or child) produced the sign HOUSE. Phonological variation is an expected possibility in any language, and occurred with a few signs in this instrument. Example: TOOTHBRUSH may be produced with handshapes [a] or [b].

**Non-expected sign**

The sign produced by the participant matched the picture, but it did not match the target. Example: the picture of a man was signed as FATHER.

**Modified expected sign**

The sign produced by the participant matched the picture and the target, but a parameter was modified during the production. The modification was identi-
fied when comparing the sign produced by the child and the standard (adult) sign\(^8\). Example in LSB:
Signs KNIFE and BLACK produced by adults

![Signs example](image)

Signs KNIFE and BLACK produced by a girl and a boy

![Signs example](image)

Comment, classifier or mime

The participant produced a comment about a given picture, signing, for example, THE TEACHER HAS THE SAME!; or a classifier, as in manually representing the shape of the building in the picture he was shown; or a mime, as in doing the movement with his feet as though ‘kicking a ball’.

No sign

The participant did not sign or claimed not to know the sign to match the picture he was shown.

For the LET analysis, data were organized into four tables corresponding to the different handshape possibilities: one hand and one handshape (1H1HS); one hand and two handshapes (1H2HS); two hands and one handshape (2H1HS); two hands and two handshapes (2H2HS). LET data were
A phonological awareness test for deaf children using LSB

also distributed in tables corresponding to the five categories of productions: expected sign; non-expected sign; modified expected sign; comment/classifier/mime; no sign.

2.2 LET: comments on the data analysis

The pictures in the flashcards were found to be mostly age appropriate, clear and recognizable. Adult individuals in the pre-test signed 91% of the pictures and children signed 77.4% in accordance to what had been established as expected sign. Some pictures, nevertheless, were unsatisfactory because a number of children attributed one and the same non-expected sign to certain pictures, e.g. five children signed FATHER when seeing the flashcard for: man.

Differences stemming from phonological variation were found in the production of expected signs in adult data. Identification of phonological variation in LSB signs that make up the LET was very important, since variable forms in the children’s production were then considered expected signs in the analysis. Therefore, these were counted as correct lexical productions, unlike the productions with some other modifications at the phonological level. Nevertheless, if a child’s form is used less by the deaf community, the researcher demonstrated the prevalent (adult) sign, and required that this should be used in the tasks. In this way all the segments were the same for all participants, and correlated with the segments which were under assessment in the test. Among adults, in the pre-test, 15.8% of the signs were produced with some variation.

As to the free recall of signs from pictures of HSs, a qualitative difference was found between adults and children. The children produced all five categories of signs - expected signs, non-expected signs, no sign, modified expected signs, or comments/classifiers/mimes. The adults produced only the first three categories: expected signs, non-expected signs or no sign.

We looked in our data for the possibility of a relationship between the children’s production of signs and different shape complexity of signs. In the production of signs with 1H1HS, results showed more expected signs, less non-expected signs, still less modified expected signs and less production of comments/classifiers/mimes. On the other hand, in the production of signs with 2H2HS, results showed much less expected signs, more non-expected signs, more modified expected signs and more production of comments/classifiers/mimes. As for no sign production, there was only a small difference between these two shapes: 4.09% in signs with 1H1HS and 3.75% in signs with 2H2HS.
In table 1 we show percentages of usage in each of the two categories of signs – less complex and more complex – to contribute to the discussion about the possible relationship between the children’s production and different shape complexity of signs.

**Table 1.** Signs produced with 1H1HS and 2H2HS

<table>
<thead>
<tr>
<th></th>
<th>1H1HS</th>
<th>2H2HS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Expected signs</td>
<td>83.18%</td>
<td>68.33%</td>
</tr>
<tr>
<td>Non-expected signs</td>
<td>9.24%</td>
<td>15.83%</td>
</tr>
<tr>
<td>Modified expected signs</td>
<td>0.45%</td>
<td>5.41%</td>
</tr>
<tr>
<td>Comments/classifiers/mimes</td>
<td>3.03%</td>
<td>6.6%</td>
</tr>
</tbody>
</table>

The results of our LET confirm Karnopp (1994). In longitudinal research on children acquiring LSB, Karnopp corroborates Carter (1983) and McIntire (1977) when she finds that there are several different factors which may influence the production of HSs by deaf children. The most important ones are the complexity of the movement and the area in which the HS is articulated. Karnopp also found that 1H1HS signs were produced by all the children who were her informants, and in higher proportion than those produced with two hands. 2H1HS signs seem to be established earlier than 2H2HS signs.

The children in our study also produced more 1H1HS signs, and there were more modified signs in the production of 2H2HS signs, which are of late acquisition. Karnopp’s (1994) subjects and this chapter’s subjects can be compared even though they differ in some aspects, like beginning of language acquisition, chronological age and linguistic exposure period. But what they have in common is that they are still in the process of language acquisition, and that the language component which is analyzed is phonology.

Materials and procedures used in the evaluation of lexical proficiency proved to be efficient. They enabled the researchers to assess participants’ knowledge of vocabulary and of the form of production, and also gave participants an opportunity to acquire vocabulary or adequate production.

### 2.3 PAT: children’s strategies

During the PAT we observed that adults (in the pre-test) and children reacted in different ways while they executed the tasks. Different strategies were used to choose the alternative which was considered to be the correct answer.
Children’s performance was more variable, both in strategies as in achievement. They produced all six of the strategies listed below - a) to f) - while adults produced only the last three - d) to f).

Strategies employed only by children:

a) holding the HS of the target-sign in one of the hands, and to perform the alternative answer signs with the other hand - then compare both HSs;\footnote{11}
b) repeating the sign of alternative answers a few times before choosing among them;
c) producing the sign of some of the incorrect alternative answers using the HS of the target-sign; Strategies employed by both children and adults;
d) producing the target-sign, then producing the signs corresponding to each picture and eventually choosing among the alternatives;
e) producing the target-sign, holding the HS and then choosing the alternative answer;
f) producing or not producing the target-sign and then choosing the alternative answer after looking at the pictures.\footnote{12}

We will discuss some questions raised by the use of different strategies as well as by the greater number of strategies used by children than by adults, and the use of different strategies by some participants.

As for the fact that children employ strategies that adults don’t employ, attention is here called to two facts: in these strategies the HS stays the same; there is a tendency to repetition of signs. A question is raised: could expressive language (i.e., producing a sign with one’s hands) be a tool to help the child to identify the HSs he/she is shown, to compare them and to choose ‘the best”? This is a hypothesis to be considered, because expressive signed language was constantly present during the whole activity. In the other strategies this tool was very little or not at all employed. With little or no use of expressive language the task turned into a greater mental effort.

As for the distinct use of strategies among children, it may be said that all of them employed more than one strategy, and that some who had a shorter period of linguistic exposure had a preference for strategies (a) to (c). Others began by making use of these first strategies but very soon dismissed the use of expressive language. A possibility which can be thought of is that this variety in the use of strategies is related to a child’s linguistic level. On the other hand, it could indicate that a certain task calls for a more complex phonological analysis.
The analysis of the LET and of the children’s performance according to the period of their exposure to sign language suggests that the choice of strategies could be related to three reasons: to the level of language development, to signs of different shapes, and to the complexity of the tasks.

While performing the tasks, some children spontaneously expressed their views on the selection of answers, whereas others chose the correct alternative after producing the target-sign, according to the instructions they had received. This fact demonstrates that some of the children went beyond the task that was being given to them, since they made comments on certain aspects of their own language.

2.4 PAT: data organization and analysis

Data obtained for parts 1 to 4 of the PAT were organized in tables to be analyzed according to the level of complexity of tasks with differently formed signs (1H1HS, 2H1HS, 2H2HS, 1H2HS). Table 2 is an example of these tables.

Table 2. Answers given by the participants to tasks in part 2 (2H1HS) – Children

<table>
<thead>
<tr>
<th>Task 1</th>
<th>Alternatives</th>
<th>Target</th>
<th>Alternatives</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Tent</td>
<td>13</td>
</tr>
<tr>
<td>Bed</td>
<td>Bear</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Rain</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td></td>
<td>NA</td>
<td>0</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Task 2</th>
<th>Alternatives</th>
<th>Target</th>
<th>Alternatives</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Chocolate</td>
<td>13</td>
</tr>
<tr>
<td>Knife</td>
<td>Rice</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Library</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td></td>
<td>NA</td>
<td>0</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Task 3</th>
<th>Alternatives</th>
<th>Target</th>
<th>Alternatives</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Train</td>
<td>12</td>
</tr>
<tr>
<td>Donkey</td>
<td>Clouds</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Broom</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td></td>
<td>NA</td>
<td>0</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Task 4</th>
<th>Alternatives</th>
<th>Target</th>
<th>Alternatives</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Ball</td>
<td>13</td>
</tr>
<tr>
<td>Coconut</td>
<td>Umbrella</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Dress</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td></td>
<td>NA</td>
<td>0</td>
<td></td>
</tr>
</tbody>
</table>
By means of these tables we were able to analyze the children’s choice of answers, and also to determine if the tasks in parts 1, 2, 3 and 4 varied in complexity in phonological terms.

Data obtained for part 5 were organized in tables according to the different sign formations (1H1HS, 2H1HS, 2H2HS, 1H2HS) of the spontaneously recalled signs, permitting the comparison of the four handshapes which were being assessed.

<table>
<thead>
<tr>
<th>Task 5</th>
<th>Target</th>
<th>Alternatives</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Socks</td>
<td>12</td>
</tr>
<tr>
<td></td>
<td>Computer</td>
<td>Present</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Ship</td>
</tr>
<tr>
<td></td>
<td></td>
<td>NA</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Task 6</th>
<th>Target</th>
<th>Alternatives</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>House</td>
<td>13</td>
</tr>
<tr>
<td></td>
<td>Robot</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Monkey</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Balloon</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>NA</td>
<td>1</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Task 7</th>
<th>Target</th>
<th>Alternatives</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Videocassette</td>
<td>13</td>
</tr>
<tr>
<td></td>
<td>Television</td>
<td>Skirt</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Corn</td>
</tr>
<tr>
<td></td>
<td></td>
<td>NA</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Task 8</th>
<th>Target</th>
<th>Alternatives</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Towel</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>Car</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Kangaroo</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Alligator</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>NA</td>
<td>0</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Task 9</th>
<th>Target</th>
<th>Alternatives</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Football</td>
<td>12</td>
</tr>
<tr>
<td></td>
<td>Backpack</td>
<td>Rabbit</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Table</td>
</tr>
<tr>
<td></td>
<td></td>
<td>NA</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Task 10</th>
<th>Target</th>
<th>Alternatives</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Bus</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>Ox</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>King</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>Building</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>NA</td>
<td>0</td>
</tr>
</tbody>
</table>

Legend:
NA: no alternative

Correct alternatives are highlighted in bold.
Table 3 is an example of these tables.

Table 3. Signs produced in part 5: handshape $[\hat{\imath}]$ – Children

<table>
<thead>
<tr>
<th></th>
<th>1H1HS</th>
<th>1H2HS</th>
<th>2H1HS</th>
<th>2H2HS</th>
</tr>
</thead>
<tbody>
<tr>
<td>44 signs</td>
<td>9 signs</td>
<td>12 signs</td>
<td>4 signs</td>
<td></td>
</tr>
<tr>
<td>Modified expected signs</td>
<td>0.45%</td>
<td>Modified expected signs</td>
<td>5.41%</td>
<td></td>
</tr>
</tbody>
</table>

Differences in complexity can be found among tasks and parts. One example of this can be seen in the analysis of results according to the period of linguistic exposure (LE) (see graph 3). Part 4, the rhyme task, seems to be the less complex one since children with different lengths of time of LE reached 100% of correct answers.

Analysis of the children`s answers to the tasks proved to be very interesting. In table 2 there was a high level of correct answers (80%) in most of the tasks (1, 2, 3, 4, 5, 6, 7, 9). In case of incorrect choices, in 62.5% of them different children chose the same incorrect alternative. In task 5, for example, twelve children chose the correct answer SOCKS and three children selected the same incorrect alternative PRESENT. The option SHIP wasn’t chosen. Analyzing the parameters which constitute the signs of the incorrect answers, there is a similarity among them because both signs share location with the target-sign, as can be seen below.

<table>
<thead>
<tr>
<th>Computer -Socks (correct option )</th>
<th>Computer -Present (incorrect option )</th>
<th>Computer -Ship (incorrect option )</th>
</tr>
</thead>
<tbody>
<tr>
<td>■ HS</td>
<td>□ HS</td>
<td>□ HS</td>
</tr>
<tr>
<td>■ L</td>
<td>■ L</td>
<td>■ L</td>
</tr>
<tr>
<td>□ M</td>
<td>□ M</td>
<td>□ M</td>
</tr>
<tr>
<td>□ Or</td>
<td>□ Or</td>
<td>□ Or</td>
</tr>
<tr>
<td>■NM (not necessary)</td>
<td>■NM (not necessary)</td>
<td>■NM (not necessary)</td>
</tr>
</tbody>
</table>

Legend:

■ Parameter common to target-sign
□ Parameter not common to target-sign

Or: Orientation of the palm
NM: Non-manual features

HS: Handshape
L: Location
M: Movement
But preference for a certain incorrect option seems also to be related to other aspects of the signs. Both in the pair COMPUTER - SOCKS (correct option) and in the pair COMPUTER - PRESENT (incorrect option) hands are not in contact and each hand produces its movement in different directions, while in SHIP hands do have contact while the movement is in one direction only, as can be seen below in SignWriting.

The children looked at the two incorrect options and chose the one which had greater similarity to the target in terms of phonological characteristics. The same happened in other tasks: the preferred incorrect answer options were those that had greater phonological resemblance to the target, even though they did not share the target handshape similarity.

It is interesting to observe in task 10 of this same part 2 that, differently from task 5, seven children chose an incorrect option. Once again there was a clear majority: six of them chose one and the same incorrect alternative: KING. In this case, the correct pair OX - BUS shares the HS parameter, as can be seen below in SignWriting.

The pair OX-KING shares the same location but the pair OX-BUILDING doesn’t have any parameters in common, as can be seen below.
Results suggest that the children who chose the same incorrect option compared the location parameter and not the HS parameter. The preference for the same incorrect answer reinforces the hypothesis that children are conscious of the phonological aspects of the signs and that the incorrect choice wasn’t random. There is also the possibility that this task was more complex for two reasons: one incorrect alternative shared the location parameter with the target, and all alternatives were similar in terms of the fingers which have to be selected in the production of each sign.

Participants showed great interest and attention during the PAT. They liked the game they were asked to play. Our findings suggest that the material which was used and the procedures which were adopted provided adequate understanding of the test.

3. Analysis of children’s performance in the Lexical Evaluation Test and in the Phonological Awareness Test, according to period of linguistic exposure

Children’s performance in lexical proficiency and phonological awareness was evaluated according to the length of time of their exposure to LSB. Participants were classified in three periods of linguistic exposure (LE):

- < 4:6 years of LE = 3 children
- 4:6 to 6:6 years of LE = 7 children
- > 6:6 years of LE = 5 children.

As could be expected, participants with longer LE signed more pictures than participants with LE between 4:6 to 6:6 who, in turn, outdid informants with LE < 4:6.
Graph 1 shows that there is a relationship between length of time of LE and the participant’s level of lexical proficiency, considering 120 LSB signs. While the amount of expected signs tends to increase as the length of time of LE increases, there is a decrease in each of the other categories of signs individually. In other words, there is an enhanced knowledge of vocabulary and of more accurate productions. We see that linguistic knowledge grew in terms of vocabulary in a direct relation to the time of LE, in the same manner as happens with children who are exposed to oral languages and who develop a typical language acquisition process in that modality.

Legend:
ES: expected sign
NES: Non-expected sign
MES: Modified expected sign
C/CL/Mm: comment/classifier/mime
NS: No sign

Graph 2 shows the rise of the category of expected signs with the increase of LE, and the simultaneous, corresponding fall of all the other categories of signs taken together (non-expected signs, modified expected signs, comments/ classifiers/ mimes and no signs). As children have a longer span of LE, their vocabulary not only grows in quantity – which is shown by the increase in number of expected signs and the decrease in comments/ classifiers/ mimes and no signs – but also grows in quality, by more accurate productions – which is shown by the decrease in modified expected signs.
A certain amount of variability was found in the performance in phonological awareness tasks of participants who had the same period of LE. Additionally, the performance of one informant with LE > 6:6 was deemed discrepant from his peer group. Because of such discrepancy, data were analyzed two ways: with and without this participant.

In graph 3 the mean performance in parts 1 to 4 of the three groups of children, according to length of LE, is shown. It can be observed that the level of phonological awareness in LSB grows as the length of LE increases.

**Graph 2.** Increase of production of expected signs in the Lexical Evaluation Test, compared to all other categories of signs, according to length of linguistic exposure

Legend:
ES: expected sign
NES: Non-expected sign
MES: Modified expected sign
C/CL/Mm: comment/classifier/mime
NS: No sign

**Graph 3.** Mean of children’s performance on the PAT, according to length of linguistic exposure.
Table 4 shows these data in more detail.

**Table 4.** Percentage of correct answers in parts 1 to 4 of the PAT, relative to period of linguistic exposure

<table>
<thead>
<tr>
<th>Parts</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>LE</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt; 4:6</td>
<td>20 – 30%</td>
<td>20 – 70%</td>
<td>33%</td>
<td>20 – 100%</td>
</tr>
<tr>
<td>4:6 to 6:6</td>
<td>40 – 100%</td>
<td>60 – 100%</td>
<td>66 – 100%</td>
<td>66 – 100%</td>
</tr>
<tr>
<td>&gt; 6:6</td>
<td>30 – 100%</td>
<td>80 – 100%</td>
<td>66 – 100%</td>
<td>66 – 100%</td>
</tr>
<tr>
<td>&gt; 6:6 *</td>
<td>80 – 100%</td>
<td>100%</td>
<td>100%</td>
<td>66 – 100%</td>
</tr>
</tbody>
</table>

*Leaving out data of participant with discrepant performance.

In table 4, where one of the participants was left out, a gradual growth in performance can be seen. If that same participant is included, correct answers in parts 1 and 3 grew gradually or were the same. In part 4 the percentage of correct answers grows.

Interestingly, there were some children with less linguistic exposure who answered all questions correctly, while there were other subjects with longer exposure who didn’t.

The majority of children in all three linguistic exposure groups had 100% correct answers in part 4. Possibly this task is less complex; a study with a higher number of subjects and/or more tasks might explain these results better.

In part 5 the total number of signs which were spontaneously recalled by the children was 222 signs. These data were distributed in 4 tables according to the HS of the spontaneously recalled signs and according to the possibilities of production of signs with different configurations. Data for each linguistic exposure period were taken in account.
In Table 5 there is an example of one of these tables, according to period of LE.

**Table 5.** Signs produced in part 5, handshape [3/5], according to the period of linguistic exposure

<table>
<thead>
<tr>
<th>LE</th>
<th>1H1HS</th>
<th>1H2HS</th>
<th>2H1HS</th>
<th>2H2HS</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 4:6</td>
<td>4 signs</td>
<td></td>
<td>2 signs</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>4:6 to 6:6</td>
<td>18 signs</td>
<td>5 signs</td>
<td>5 signs</td>
<td>2 signs</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td>30</td>
<td></td>
</tr>
<tr>
<td>&lt; 4:6</td>
<td>22 signs</td>
<td>4 signs</td>
<td>3 signs</td>
<td>4 signs</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td>33</td>
<td></td>
</tr>
<tr>
<td>Total/handshape</td>
<td>69 signs</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

For our analysis, the number of signs produced with each HS in each period of LE was summed up and divided by number of children. The amount of signs spontaneously recalled and adequately produced by participants, for each LE, was:

- LE < 4:6: 18 signs, mean of 6 signs per participant
- LE 4:6 to 6:6: 92 signs, mean of 13.1 signs per participant
- LE > 6:6: 112 signs, mean of 22.4 signs per participant

Besides the gradual increase in the amount of signs which were produced there was also an increase in signs per category in the four HS categories, according to the increase in LE. This relationship can be seen in Table 5, above. The table shows very clearly that there is an important gain from the first group (<4:6) to the second group (4:6 to 6:6), both in the absolute number of signs and in the number per HS category.
Conclusions

We described and discussed the Phonological Awareness Test (PAT), designed for deaf children who are signers of LSB, as well as the Language Evaluation Test (LET), which is integral part of it.

The test is efficient, user friendly and opens the way to a great number of analyses. It is applicable to children in a playful, easy and attractive manner.

This research shows that deaf children have the ability to access their knowledge of the phonology of the language in which they sign, meaning that phonological awareness is not contingent on the modality in which language is expressed. A gradual evolution of this ability occurs in hearing as well in deaf children, and performance grows in all areas and parts which were tested according to longer exposure to language.

It is our belief that a validated test for the assessment of phonological awareness of a given sign language may contribute to investigations on the linguistic development of deaf children. It provides an instrument to check a child’s sensitivity to the phonological aspects of his/her own language, to identify the level of development of phonological awareness (typical/atypical, considering the period of linguistic exposure or age), as well as to follow up the evolution of this important linguistic skill. This instrument can also contribute to studies on sign language phonology and on other questions about phonological awareness of deaf children and adults which are without answers.

In schools for hearing children games, rhyming activities and songs which help the increase of phonological awareness are already everyday practice. It is necessary to consider whether in educational practice with deaf students this kind of activity should also occur or be emphasized, thus contributing to the linguistic development of deaf children.
Notes

1. Each of the participants had a different age at the beginning of exposure to sign language: since birth (0:0) or, the oldest, at 4:1. This was considered a very important factor for language awareness.

2. Years: months

3. At their school, LSB is the native language of the majority of the students and constantly used by the children and teachers; written Brazilian Portuguese is taught as a Second Language.

4. Reliability of the children’s data is guaranteed by the fact that the first author has been a speech and language therapist at the school for 15 years.

5. Data about the subjects’ age, beginning of language acquisition (production), period of exposure to LSB, general health conditions, as well as about the parents and the parents’ learning and use of LSB were considered because our purpose was to create a test of phonological awareness for deaf children with typical development in terms of language acquisition.

6. For example: the participant was expected to represent the figure of a whale with the sign WHALE, but one of the children used the sign FISH, which was not expected.


8. These modifications seem to be repair strategies (also known as substitution processes), very common in phonological acquisition.

9. The possibility of modifications at the phonological level - repair strategies/substitution processes - was raised since the children were still in the language acquisition process in LSB, which includes phonological acquisition.

10. Karnopp’s (1994) informants were four deaf children born of deaf parents, aged between 2:8 and 5:9. They were exposed to Brazilian Sign Language (LSB) from birth.

11. Signs produced with 1H1HS.

12. Some of the children looked at the flashcard and indicated their choice by pointing or by putting a plastic token on the picture.

13. Alternative NA was added to the tables because some of the informants declared that all the three answer options were incorrect.
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Phonological category resolution in a new Sign Language: A comparative study of handshapes*

Assaf Israel and Wendy Sandler

Stokoe’s (1960) demonstration that the words of sign languages are constructed from a discrete and finite list of meaningless units — that they have phonology — dispelled the myth that sign languages were comprised of iconic gestures, holistic in form. But do the meaningless units that Stokoe identified exist at the inception of a new sign language? Or does it take time for a phonological system to self-organize? More specifically, how does a language develop phonological categories? The answer to this question cannot be discovered empirically in spoken languages, as they are all very old. But sign languages arise anew wherever a community of deaf people forms, and, as new languages, they have much to teach us about the emergence of linguistic form.

The present study grew out of observations on the part of the research team investigating Al-Sayyid Bedouin Sign Language (ABSL), a new sign language that arose spontaneously in an isolated desert community about 75 years ago. The investigators saw unexpected variation in sign production across the village – both in the choice of lexical items and in the form of the same lexical item (Aronoff et al 2008). Following up on this observation, we conducted a detailed analysis of the form of ABSL sign productions in isolation and compared them to those of two other sign languages with different social histories, American Sign Language (ASL) and Israeli Sign Language (ISL; Israel 2009).

In the present paper, we focus only on the handshape category, and demonstrate how our investigation confirmed the initial impression of considerable variation within this category. We adopt a comparative method that enables us to quantify the amount of variation in the three sign languages. The results reveal a cline, with ABSL exhibiting the most variation in the formation of handshapes, ISL next, and ASL showing the least variation across signers. Taken together with other evidence, we hypothesize that ABSL signers are often aiming for a holistic iconic image, and that discrete phonological categories are not yet robust in the language.

We begin with a description of ABSL in section 1, and illustrate with some of the variation in sign production that was discovered in the broader ABSL research project (Aronoff et al. 2008; Sandler et al. in press). We then turn to the
study of handshape (following Israel 2009), coding and analyzing handshapes in 15 signs for ten signers in each of the three languages. Section 2 describes the handshape features of interest, and the methodology of the study is the topic of section 3. Results and discussion follow in section 4. In section 5, we consider some explanations for differences across languages, including language age, community size and other social characteristics. While our results suggest that ABSL may not yet have formed discrete phonological categories, there is some evidence pointing in the direction of formal organization, which we mention briefly in section 6. Section 7 is a summary and conclusion.

1. Al-sayyid Bedouin Sign Language

The young village sign language that is our focus here took root in the Al-Sayyid Bedouin village in the Negev Desert of present day Israel, when four deaf children were born in a single household about 75 years ago. Today, there are about 150 deaf people in the village.¹

ABSL functions as a fully fledged language, used for a range of social interactions, for instructions and plans, personal histories, folk remedies, national insurance, childcare, or how to cajole a husband. Among the grammatical features that have been found in the language are a robust word order within the clause and the noun phrase (see Sandler et al. 2005) and a kind of size and shape classifier affixation (Meir et al. 2010; Sandler et al. 2011).

At the lexical level, the research team investigating ABSL observed a surprising degree of variation in lexical items themselves. Even signs for everyday items sometimes have several variants. In addition, across tokens produced by different signers there is variation in sublexical components, and that is the object of study here. This sublexical variation seemed greater than what we would expect in more established sign languages, such as ISL and ASL. Moreover, tokens seemed to vary in features that are potentially contrastive in established sign languages. One example is variation in place of articulation found in different tokens for ABSL DOG shown in Figure 1.

![Figure 1](image.png)

**Figure 1.** Variation in location across ABSL tokens for DOG. Variant (a) is articulated in neutral space, variant (b) in front of the mouth.²
One might be tempted to compare this to different pronunciations of words such as English \textit{route}, [rut] and [raut]. In the English example, while the vowels are potentially contrastive (cf., boot [but] and bout [baut]), we tend to associate the two forms of \textit{route} with different varieties or dialects. However, in the case of ABSL, the different signers whom we have recorded are members of the same extended family within a small, closely-knit community, and we suspect that the variation is not ‘sociolinguistic’ in the normal sense of subgroups within a language community. Rather, it seems to us that this variation is an indication that the ABSL lexicon has not yet developed discrete, meaningless formational categories. A perhaps more basic reason for suspecting that, currently, formal categories do not exist in ABSL is the fact that no minimal pairs have surfaced in all the ABSL data collected to date. Apparently, it takes time for users of a new language to converge on a fixed set of meaningless primitives for forming lexical items.\footnote{3}

In order to test the hypothesis that distinct formational categories are not yet defined in ABSL, we recorded and analyzed both the amount and type of variation in languages with different social characteristics. The current study, taken from a larger project (Israel 2009), focuses on one sublexical component – hand configuration. In the next section, we discuss briefly the internal structure of this component as a way of introducing the phonetic features that we will use for the coding of signs. This will be followed by a discussion of the measures of variation and the way to compare them across languages.

2. Sublexical structure in sign language: hand configuration

A considerable portion of the sign language phonology literature has been dedicated to the lexical representation of hand configuration. In this study, we adopt finger selection features from an early detailed model of hand configuration (Sandler 1987; 1989). That model proposed a hierarchical representation of feature classes, in which the handshape is determined by selected finger features together with subordinate categories of finger position and orientation features. The model was later further developed (Sandler 1993, 1995, 1996); and other models with changes and innovations were proposed (e.g., van der Hulst 1993; van der Kooij 2002). In this study, we adopt the features and categories informed by these models that are shown in Table 1. The phonological status of different subsets of these features, category membership, and hierarchical relations among the categories are

Table 1. Hand Configuration subcategories and features.

<table>
<thead>
<tr>
<th>Handshape</th>
<th>Subcategories</th>
</tr>
</thead>
<tbody>
<tr>
<td>Selected Fingers</td>
<td>[index], [middle], [ring], [pinky], [thumb], [any combination of fingers]</td>
</tr>
<tr>
<td>Flexion</td>
<td>[extended], [bent], [curved], [clawed]</td>
</tr>
<tr>
<td>Aperture</td>
<td>[open], [closed]</td>
</tr>
<tr>
<td>Spreading</td>
<td>[spread], [non-spread]</td>
</tr>
<tr>
<td>Unselected Fingers</td>
<td>[open], [closed]</td>
</tr>
<tr>
<td>Thumb</td>
<td>[extended], [opposed], [adducted], [crossed]</td>
</tr>
<tr>
<td>Orientation of palm,</td>
<td>[up], [down], [in], [out], [contralateral]</td>
</tr>
<tr>
<td>Orientation of metacarpals</td>
<td></td>
</tr>
</tbody>
</table>

Phonological representations by definition avoid phonetic features that are predictable, but as this study addresses convergence on the production of basic phonological elements, we are not concerned here with models of the internal organization of these features. Here we intentionally retain a certain amount of phonetic detail, since we are investigating a new language in which the phonetics/phonology distinction is not yet known, or, as we suspect, has not yet crystallized.

Figure 2. Four flexion positions in handshapes with all the fingers selected. The [extended] position has no flexion of the fingers; in a [bent] position, only the base joints are partially to fully flexed; in a [clawed] position only the non-base joints are partially to fully flexed; and in the [curved] position, base and non-base joints are partially flexed. Selected fingers that are fully folded into the palm, irrespective of thumb position, are coded as [closed].
The **finger selection** category is comprised of a set of five features – one for each finger: [index], [middle], [ring], [pinky] and [thumb]. As for **finger position**, we distinguish between the four different degrees of flexion (van der Kooij 2002) illustrated in Figure 2 using handshapes with all four fingers selected.

Specification in underlying representation has been argued to be redundant for most other hand configuration features, namely the configuration of unselected fingers (Corina 1993), the posture of the thumb (shown in Figure 3) and the spread/non-spread configuration of the selected fingers (van der Kooij 2002). In the ‘extended’ configuration illustrated in Figure 2 the fingers are also ‘non-spread’; in the handshape with the adducted thumb (Figure 3e) the selected fingers are in a ‘spread’ configuration. Nevertheless, as already noted, our primary aim here is to record formational differences as a first step towards an analysis of phonological organization in ABSL, which may or may not currently have phonological categories, and we adopt these distinctions for this purpose alone. We make no a priori assumptions about the phonological status of these sublexical components.

![Figure 3. Thumb position features.](image)

The last component of hand configuration in our coding system is orientation. We specify orientation with the following features: [up], [down], [in] (faces signer’s body), [out] (faces away from signer), and [contralateral]. These features are used to specify two degrees of freedom: the side faced by the palm of the hand and the direction in which the hand’s metacarpal bones
(i.e., the bones connecting the wrist and MCP joints) point, as illustrated in Figure 4.

![Figure 4. Degrees of freedom in the representation of orientation. The figure shows the position of the hand in the ISL sign SUNDAY. The hand is oriented so that the metacarpal bones point upward (specified as [up]), and the palm faces the contralateral side (specified as [contralateral]), as indicated with solid arrows.](image)

3. Methodology

Ten signers from each language (ABSL, ISL and ASL), each signing 15 signs, provided the data for the study.

Participants

**ABSL**

The signers included in the study are members of an extended family, six of them members of the same immediate family. The reliance on sign language as the means of communication within the family ensured that the signers chosen are highly proficient in ABSL. There was a wide distribution of ages among the subjects: two second generation signers were between 40 and 50 years old at the time of videotaping; one signer was about 28 years old – a young second generation signer. Of the third generation participants, four were between 20 and 30 years old, and three were between 7 and 12 years old.
While many hearing people know ABSL well and use it daily within deaf families, all ABSL participants in the study were deaf. The oldest two, Th. and A-B., were born in the second generation of deaf people in the Al-Sayyid village. The rest of the participants represent the third generation of deaf people, all of whom are attending school in a nearby village, where ISL signs are used by the teachers. At school, children from Al-Sayyid interact with deaf children from other villages in the area. However, the majority of second generation deaf people and the hearing signers in the Al-Sayyid village have had little direct exposure to ISL, and we infer from this that the communication among family members takes place in ABSL. In the study, each signer signed to another ABSL signer while being videotaped.

In order to compare variations across the three sign languages, group sizes were balanced, so that each of the ISL and ASL groups also numbered 10 signers each.

**ISL**

All ISL participants were deaf signers who learned the language at an early age (by the age of six) and have been using it continuously since. The ISL group was formed in such a way that it would be as analogous as possible to the ABSL group, both linguistically and socially. Thus, all ISL participants were from the same small geographic area, the city of Haifa. This was intended to result in data that are maximally lexically unified. In addition, of the 10 participants, four were members of a single immediate family (cf. the six same-family members in ABSL), two of them one generation older (the two parents), aged 45 and 50. The ages of the other participants were 40, 38, 37, 32, 21, 21, and 14. All ISL participants have had formal education.

**ASL**

The group of ASL signers was less homogenous than the other two language groups. All 10 participants were “recruited” while spending leisure time on the University of California, San Diego campus. All, except for a single participant (who acquired ASL from a deaf parent), were deaf, and the only requirement for participation was a perceived high level of ASL proficiency. No information regarding participants’ (original) area of residence, educational background, etc. was collected. The ages of the two youngest
participants are between 20 and 30 years (the exact ages were not recorded). The other participants were 32, 33, 35, 41, 42, 43 and 54 years old. Three participants acquired ASL from deaf parents, and the rest began acquiring the language by the age of six.

3.1 Stimuli and procedure

Citation forms were elicited from participants using pictures of objects presented on a computer screen using Microsoft Powerpoint software. The pictures presented single objects with which participants were familiar, such as common animals, furniture, types of vehicles, fruits, etc.

Each participant was seated opposite another signer of the same language, and next to the computer used for the presentation of pictures. Participants were instructed to look at the computer screen and then to sign to their interlocutors their sign(s) for the presented object. The presentation of pictures on the screen was controlled by a researcher, so that one picture was presented at a time, and the next picture was presented after the sign was produced clearly by the participant. Since the younger ABSL participants knew some ISL, they were explicitly asked to use only their native (i.e., ABSL) signs. If a participant produced an ISL sign, he or she was asked to sign again, using the local sign.

The total number of elicitation pictures presented to each signer was 35. Of these, 20 were eliminated, for reasons such as the following: signers presented a description using a sequence of signs rather than a lexical item; in a few cases, a lexicalized and potentially reduced compound was produced by some signers; signers did not use the same lexical item for the concept (e.g., a bit in the mouth vs. legs straddling an object for HORSE; or, in the case of ASL, fingerspelling was used instead of a sign, a common strategy in that language). The total number of signs included in the analysis is 15, as noted above.

The list of lexical items in the study is given in Table 2. The first 11 items are shared by all three language sets, and the remaining 4 items overlap only partly, because of the constraints just mentioned on which signs were accepted for analysis in each language. In any case, a lexical match of the three language sets is not critical, since the same concept may reflect different attributes of an object in different sign languages in any case. What matters is sublexical variation for the same form within a language.
The lists of signs in Table 2 were not compiled with the intention of representing the entire range of handshapes found in each of the languages. Rather, these signs were chosen primarily as a random sample of items that symbolize highly familiar real-world objects, with the assumption that such signs are very frequent in the language and therefore are highly conventional in form. In other words, we expect the amounts of cross-signer variation recorded in the production of these signs to represent the minimal amounts of variation found in these languages.

**Table 2.** The lexical items represented in the collected data.

<table>
<thead>
<tr>
<th>Item number</th>
<th>ABSL; ISL; ASL</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>LEMON</td>
</tr>
<tr>
<td>2</td>
<td>SCORPION</td>
</tr>
<tr>
<td>3</td>
<td>TOMATO</td>
</tr>
<tr>
<td>4</td>
<td>CARROT</td>
</tr>
<tr>
<td>5</td>
<td>COW</td>
</tr>
<tr>
<td>6</td>
<td>DONKEY</td>
</tr>
<tr>
<td>7</td>
<td>FORK</td>
</tr>
<tr>
<td>8</td>
<td>LEAF</td>
</tr>
<tr>
<td>9</td>
<td>DOG</td>
</tr>
<tr>
<td>10</td>
<td>GOAT</td>
</tr>
<tr>
<td>11</td>
<td>TRAIN</td>
</tr>
<tr>
<td>12</td>
<td>WOMAN</td>
</tr>
<tr>
<td>13</td>
<td>TELEVISION</td>
</tr>
<tr>
<td>14</td>
<td>BROOM</td>
</tr>
<tr>
<td>15</td>
<td>BROOM</td>
</tr>
<tr>
<td>16</td>
<td>STUFFED</td>
</tr>
<tr>
<td>17</td>
<td>GRAPE LEAVES</td>
</tr>
<tr>
<td>18</td>
<td>FLOWER</td>
</tr>
<tr>
<td>19</td>
<td>FLOWER</td>
</tr>
<tr>
<td>20</td>
<td>GARLIC</td>
</tr>
<tr>
<td>21</td>
<td>CUCUMBER</td>
</tr>
<tr>
<td>22</td>
<td>CAT</td>
</tr>
</tbody>
</table>

Items 1 – 11 were elicited from signers of all three languages, and (12 – 15) are items not shared across the three languages.
3.2 Measuring variation

The essence of variation is the existence of different variants of the *same* item, which, in our case (i.e., at the sublexical level), is a single lexical item. Therefore, for each language, variation is measured first for each of the 15 lexical items separately, and only then are these measures combined to get an indication of the amount of variation at a more global level. This methodology is detailed here.

For the analysis, we use two measures which we believe capture the essence of variation in a way that is both transparent and simple: *number of variants* and *mode*. These measures correspond to two important aspects of variation: the range of the distribution and the extent to which the data are concentrated or spread within this range.

We begin with number of variants. Recall that in the current analysis, for each token, the hand configuration component is specified in terms of discrete phonetic features which cannot be considered in terms of higher or lower values. This method of coding is comparable to specifying the features [high] [mid] and [low] for vowels, rather than measuring their formant frequencies, since features are discrete whereas frequency is measured along a continuous scale. Therefore, for our purposes we may define the range of variation in hand configuration as the number of different features found across tokens.

To make this measure clear, let us consider a hypothetical situation in which we have two different sets of ten tokens each for the sign FORK. For each set of tokens, Figure 5 shows a distribution of features within the subcategory Selected Fingers (SF). We can see that in the first set of tokens (represented by Distribution A) there are two different finger selections: [I+M] ( ConfigureServices Location ) and [I+M+R] ( ConfigureLocation ). In the other set of tokens (represented by Distribution B) there are three different finger selections, [IMR], [IM] and [I] ( ConfigureLocation ). In other words, there are two different variants of SF in the first set of tokens and three variants of SF in the second set. That is, the range of variation in SF is wider in the second distribution. The number of different values for selected fingers found within a set of tokens is therefore an indicator of the range of a distribution.
A comparative study of handshapes

Distribution A:

<table>
<thead>
<tr>
<th>Signer</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>F</th>
<th>G</th>
<th>H</th>
<th>I</th>
<th>J</th>
</tr>
</thead>
<tbody>
<tr>
<td>Category</td>
<td>I+M</td>
<td>I+M</td>
<td>I+M+R</td>
<td>I+M</td>
<td>I+M+R</td>
<td>I+M</td>
<td>I+M+R</td>
<td>I+M</td>
<td>I+M</td>
<td>I+M</td>
</tr>
</tbody>
</table>

Distribution B:

<table>
<thead>
<tr>
<th>Signer</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>F</th>
<th>G</th>
<th>H</th>
<th>I</th>
<th>J</th>
</tr>
</thead>
<tbody>
<tr>
<td>Category</td>
<td>I+M</td>
<td>I+M</td>
<td>I+M</td>
<td>I+M+R</td>
<td>I+M</td>
<td>I+M</td>
<td>I</td>
<td>I+M</td>
<td>I+M</td>
<td>I+M</td>
</tr>
</tbody>
</table>

Figure 5. Different amounts of variation indicated by the number of variants produced for the same lexical item: wider range of SF variation in Distribution B.

The other measure we use – the *mode* – provides information about the spread (or dispersion) of a distribution. This measure counts the total number of tokens that exhibit the most frequent feature or, as in the case of SF, feature set (see Footnote 4). Consider the distributions in Figure 6. Since in each distribution there are two different feature sets realizing the SF category, both distributions have the same range of variation (*number of variants* = 2). However, in Distribution A, eight out of ten tokens have the same feature set [I+M], whereas in Distribution C the two feature sets are distributed more equally across tokens: six tokens have the feature set [I+M] and four tokens have the feature set [I+M+R]. We may say that in Distribution C tokens are more “spread out” – i.e., they vary more – compared to tokens in Distribution A. The frequency of the modal feature – i.e., the number of tokens in which the most frequent feature is found – therefore captures an important aspect of variation that escapes the *number of variants* measure. For further discussion of the advantages and disadvantages of this method, see Israel (2009).

Distribution A:

<table>
<thead>
<tr>
<th>Signer</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>F</th>
<th>G</th>
<th>H</th>
<th>I</th>
<th>J</th>
</tr>
</thead>
<tbody>
<tr>
<td>Category</td>
<td>I+M</td>
<td>I+M</td>
<td>I+M+R</td>
<td>I+M</td>
<td>I+M+R</td>
<td>I+M</td>
<td>I+M+R</td>
<td>I+M</td>
<td>I+M</td>
<td>I+M</td>
</tr>
</tbody>
</table>

Distribution C:

<table>
<thead>
<tr>
<th>Signer</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>F</th>
<th>G</th>
<th>H</th>
<th>I</th>
<th>J</th>
</tr>
</thead>
<tbody>
<tr>
<td>Category</td>
<td>I+M</td>
<td>I+M</td>
<td>I+M</td>
<td>I+M+R</td>
<td>I+M+R</td>
<td>I+M</td>
<td>I+M+R</td>
<td>I+M</td>
<td>I+M</td>
<td>I+M+R</td>
</tr>
</tbody>
</table>

Figure 6. Different amounts of variation indicated by the frequency of the modal feature in a set of tokens for the same lexical item: more dispersion in Distribution C.
The ultimate aim of this study is to use the measures of variation calculated for individual lexical items to arrive at a more global measure of sublexical variation within a language, to which we turn now.

3.3 Beyond the single lexical item: a global measure of variation

The first step then is to average all the measures obtained for the same phonological category across lexical items within the same language. This is exemplified with hypothetical data in Table 3.

Table 3. Average mode and average number of variants as global measures of variation in phonological category X.

<table>
<thead>
<tr>
<th>Category X</th>
<th>Item 1</th>
<th>Item 2</th>
<th>Item 3</th>
<th>Item 4</th>
<th>Item 5</th>
<th>Item 6</th>
<th>Item 7</th>
<th>Item 8</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mode (%)</td>
<td>95</td>
<td>80</td>
<td>100</td>
<td>87</td>
<td>80</td>
<td>93</td>
<td>84</td>
<td>100</td>
<td>89.88%</td>
</tr>
<tr>
<td>Number of variants</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>3</td>
<td>1.63</td>
</tr>
</tbody>
</table>

Recall that the first stage in the analysis was to calculate the mode for each lexical item separately. In the above table, 95% represents the mode of the set of tokens produced for Item 1. 80% was the mode of all the tokens elicited for Item 2, etc. Once the averages of all the modes and numbers of variants have been calculated (rightmost column), we will already have reached a more global representation of variation, since for each phonological category we are left with two measures per language: (1) average mode and (2) average number of variants. Now it is possible to compare the values of each of the two measures of variation across languages. For example, if the average mode calculated for Thumb Position is 90% for language A and 95% for language B, we may say that with respect to this measure of variation, language A shows more variation in thumb position than language B. The two languages will also have to be compared with respect to the average number of variants for this feature.

The average measures calculated for subcategories may be considered together in order to characterize the degree of variation within the major category of hand configuration. We achieve this by calculating the average of the averages of each of the seven HC subcategories.
4. Results and discussion

As can be seen in Figure 7, in all subcategories of this component, mode values were lowest in the ABSL data. That is, as indicated by this measure in the data collected for this study, for each subcomponent of Hand Configuration, the amount of variation is greatest in ABSL. For the categories Thumb, Unselected Fingers, and Orientation, we find a cline of mode values from ABSL through ISL to ASL. No difference between ISL and ASL was found for Flexion and Aperture. Finally, Selected Fingers and Spreading varied in the ASL data more than in the data collected from ISL. Overall, when the mode values are averaged over all seven subcategories, the global amounts of variation form a pattern in which ABSL and ASL have the highest and lowest amounts of sublexical variation, respectively, with ISL somewhere in between.

This picture of the differences across the three languages is made clearer by the second measure of variation – the number of variants. Figure 8 shows that in five of the seven hand configuration subcategories the average number of variants is highest in ABSL. The only subcategory for which the number of ABSL variants measured was the lowest is Spreading. As the figure shows, the ABSL > ISL > ASL cline indicated by the mode measure for Thumb, USF and Orientation is also indicated by the average number of variants. Overall, this cline emerges as a global pattern indicated by both the Mode and the Number of Variants.
In order to check whether the differences found are statistically significant, a Kruskal-Wallis test was performed on the data. A highly significant difference was found between the degree of variation in thumb position in ABSL and those measured for ISL and ASL. This was found for both the mode measure (p<0.001) and the number of variants (p<0.01).

It appears that the subcategories for which the ABSL > ISL > ASL cline was found, namely Thumb, USF, and Orientation, also exhibit more variation than other categories within ABSL. We propose that the relative amounts of variation measured for these three sublexical categories are especially suggestive of the qualitative differences across the three languages because the phonological status of these components, if any, is marginal. Specifically, the position of the unselected fingers is highly predictable in established sign languages, and handshapes are not distinguished by this feature. Similarly, the position of the thumb is often predictable (van der Kooij 2002), and there are very few cases in which contrast is based on thumb position. Finally, as argued by Crasborn (2001), it is most likely that orientation is lexically specified in relative terms (see Crasborn & van der Kooij 1997; Crasborn 2001), and that variation in absolute orientation (coded in this study) is non-distinctive and often predictable from the lexically specified parameters, such as the part of the hand which contacts the place of articulation.

We suggest that the development of systematic lexical representation targets first those features which contribute most to the distinction between different lexical items, with other features being consistently incorporated.

Figure 8. Average number of variants within each subcategory of Hand Configuration.
A comparative study of handshapes

into lexical representations at a later stage. In the case of sign language, the features which contribute most to the overall configuration of the hand are SF, Flexion and Aperture. Thus, we propose that because ABSL is in the early stages of developing a phonological system – our main conclusion here – it exhibits a greater degree of cross-signer consistency with respect to these features. The production of Thumb, USF, and Orientation features, which are least consistent across ABSL signers, gradually becomes more uniform as the language develops, as exhibited by the measures calculated for ISL and ASL (discussed below). It seems that cross-signer convergence on the production of phonologically marginal features is a more stable correlate of a language’s developmental stage.

To help conceptualize the differences across the three languages, Figure 9 and Figure 10 present the range of average mode values and of average number of variants for each language shown discretely and feature by feature in Figure 7 and Figure 8 above.

![Figure 9. Ranges of average mode values.](image1)

![Figure 10. Ranges of average number of variants.](image2)
The range measure shows clearly the differences among the three languages with respect to both the size of the range and its location along the Y-axis. As for the mode (Figure 12), in ASL, its values are distributed within the smallest range, about 17 percent. Like ASL, ISL’s maximum value is 100 % (representing a subcategory with zero variation), but its range of average modes is wider than that of ASL – about 23%. Finally, ABSL’s average modes spread over 27 %. Moreover, unlike ASL and ISL, none of the average modes calculated for ABSL reaches 100%. In other words, there is not a single subcategory of Hand Configuration in which there is no variation across ABSL signers in the study. Figure 10 shows similar differences in the range of average numbers of variants. Examples of variation in ABSL are shown in Figure 11.

Figure 11. Examples of hand configuration variation in ABSL.
The robustness of the cross-linguistic differences reported on here is further supported by results from two additional analyses of variation along features of location and movement – the two other major parameters of sublexical form. Using the same methodology, Israel (2009) found the same cross-linguistic pattern of variation, namely ABSL > ISL > ASL, for both Location and Movement. It is therefore not only the Hand Configuration component which varies to different extents, but the entire form of lexical items.12

Certainly, there must be some phonetic variation in any language (see Crasborn 2001), and indeed, the most established of the three languages studied here, ASL, does exhibit some variation. However, assuming that all languages eventually develop lexicons with highly conventionalized forms, the consistent cline of variation found in Israel (2009) and partially reported here suggest that ABSL, ISL and ASL are currently situated at different points along this conventionalization continuum. In the next section we brieﬂy discuss the possible contributions of four different factors to the development of regularity in new languages.

5. Three different sociolinguistic backgrounds

We would like to put forth the hypothesis that, in the early development of a sign language, an aggregate of sociolinguistic factors affects the convergence by signers on a relatively fixed set of forms used as lexical items. Underlying this hypothesis is the assumption that convergence – i.e., transition from more to less variation – is universal and characterizes the emergence of any new language. In each case of language emergence, however, the social and linguistic settings, which have an impact on the way language develops, are unique. Our hypothesis incorporates the following factors: a) relation to other languages, b) the language’s age, c) the size of the community, and d) the existence of prescriptive norms. In this section we discuss the possible influence of these factors and relate it to the case at hand.

A new language may come to life in one of two settings: within a community whose members have no language at all, and within a community whose members use different languages but none of which is shared by all. The languages that emerge in settings of the latter type are known as pidgins and, when passed on to children, as creoles. Even though these languages are fundamentally distinct from any of the languages used natively by the original members of the community, there is no doubt that some grammatical elements are borrowed from native languages into the pidgin and preserved in
the creole (e.g., McWhorter 1997). This means that, compared to a language developed by people who know no language at all, pidgins and creoles get a head start.

The study of ISL and ASL has shown that both of these languages developed in ways that resemble pidginization and creolization, with contributions from German Sign Language, and other sign languages of Europe, North Africa, and elsewhere in the case of ISL (Meir & Sandler 2008), and influence from French Sign Language and local American varieties in the case of ASL (Woodward 1978; Fischer 1996). Therefore, in both cases, at the outset, experienced signers who had been using signs skillfully and consistently made a contribution. In contrast, ABSL has emerged in a relatively isolated community and for many years was developed by deaf people who had no knowledge of any other language. It is reasonable to believe that for such signers it takes longer to converge on a single form for each concept.

If conventionalization is indeed gradual, then we expect forms to be produced more consistently across signers as the language gets older. A language’s age may be measured not only in years but also in the number of generations of users that have acquired it. Young children have the capacity to acquire and build upon the language as it is passed on to them from a previous generation, or cohort, as in the case of Nicaraguan Sign Language (Senghas, Coppola, Newport & Supalla 1997; Senghas 2003; Senghas, Senghas & Pyers 2005). It is likely that children play an important role in the process of convergence by taking the language a step closer to fully conventionalized production of lexical items. In our case, ASL is the oldest language, which, according to our hypothesis, explains the fact that it exhibits the least amount of sublexical variation. However, since ABSL and ISL are of the same age but vary to different extents, it is clear that this factor by itself cannot predict differences in the amount of variation.

The size of the community in which a language develops may be another factor affecting the amount of variation. Trudgill (1995) suggests that within a small and isolated community there is likely to be a large amount of shared information, making variation more easily tolerated. This may well be the case within the community of Al-Sayyid. When much of the background information is shared by interlocutors, it may be sufficient for a signer to produce a token that approximates the overall image which is conventionally associated with the target concept in order for communication to succeed.

Metalinguistic awareness may have a strong impact on language production. One aspect of such awareness is the idea that some forms are “better” or “more appropriate” than others, and that certain forms are “correct” and others are “incorrect”. Usually, these concepts are shaped by authoritative
sources, such as schools, books, interpreters, and other influential individuals, and are often associated with formality. On this basis, it is reasonable to distinguish between languages used in formal settings, such as ISL and ASL, and languages whose users are not subject to prescriptive pressure because it is never used formally, such as ABSL. Thus, in both the ISL and ASL communities there are Deaf organizations which organize formal meetings and sign language courses; social interaction and public events in Deaf clubs; dictionaries; Deaf theater and dance groups; and sophisticated interpreting, including academic material for university students. Finally, following linguistic studies on both languages, the status of both languages – mainly within, but also outside the Deaf communities – has risen considerably, which may somewhat ironically add to the pressure for standardization. In both ASL and ISL communities, dictionaries, sign language instruction, and interpreter training programs exist, which may have the effect of establishing norms to some extent. Such norms may in turn considerably reduce the variety of alternate forms, thus contributing to more consistent signing. In the ASL community, the normative sources just mentioned have longer histories and are therefore more established compared to ISL, which could partly explain the differences in the amount of variation found between the two. In Al-Sayyid, where deaf people are integrated into the larger hearing community, none of these sociocultural developments has taken place, and, to the best of our knowledge, the language is only used in informal, everyday settings.13

We propose that all of the sociolinguistic factors just discussed played a role in the cross linguistic differences found in this study. Table 4 shows that each language has a different aggregate of these factors (population numbers are approximate). According to the discussion in this section, the sum of factors is most conducive to convergence in ASL and least conducive to convergence in ABSL.

The hypothesis developed above is motivated by the amounts of variation measured in this study. In order to test this hypothesis further, it is necessary to measure variation in additional sign languages with different aggregates of sociolinguistic factors. We leave this investigation for future research.

Table 4. A summary of cross-linguistic differences along sociolinguistic parameters.

<table>
<thead>
<tr>
<th></th>
<th>ABSL</th>
<th>ISL</th>
<th>ASL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Contribution from other languages</td>
<td>–</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Age in years</td>
<td>~75</td>
<td>~75</td>
<td>~200</td>
</tr>
<tr>
<td>Size of deaf signing population</td>
<td>~150</td>
<td>~10,000</td>
<td>~500,000–1,000,000</td>
</tr>
<tr>
<td>Prescriptivism</td>
<td>–</td>
<td>+</td>
<td>+</td>
</tr>
</tbody>
</table>
6. Seeds of phonological form in ABSL

ABSL is a language by any functional measure. Conversations about any topic relevant to the community take place in real time with no apparent effort or hesitation. Humor is conveyed, stories are told. There is a shared vocabulary. Even the variation that we find in the lexicon is apparently well tolerated if ease of communication is any indication, possibly suggesting that the language simply has synonyms.

Minimal pairs are a standard indication of duality of patterning: two distinct levels of structure, one meaningless (a phonological level) and one meaningful (Hockett 1960). As we have said, no minimal pairs have surfaced yet in investigations of ABSL. However, contrast is not the only measure of duality. The isolation of discrete, meaningless units systematically in processes such as assimilation, epenthesis, or deletion, also provide evidence for a formal system of this kind. The ABSL team has identified the seeds of phonology by observing the occurrence of such processes under particular circumstances (Sandler et al 2011).

One example is assimilation of handshape within one family in a compound that is lexicalized. The compound, CHICKEN^OVAL-OBJECT = EGG, is signed with regressive assimilation of handshape from OVAL-OBJECT to CHICKEN across members of this family. The assimilation is countericonic and systematic within the family, indicating that the handshape is functioning as a meaningless and abstract formational element (see Sandler et al. 2011 for illustrations).

Another indication of the emergence of phonological form is the addition of movement to movementless signs on the part of some third generation signers (see Sandler to appear). This is particularly interesting because, while the movement category often contains very little phonological information, in established sign languages, signs must have movement to be well-formed (Wilbur 1987; Sandler & Lillo-Martin 2006). In ABSL, movementless signs do exist. But among some third generation signers with deaf parents, the addition of movement has been observed. For example, to the sign for GOAT, which depicts the horn of a goat on the side of the forehead, these young signers add a tapping movement. As with assimilation, the process of movement epenthesis results in a countericonic image, and seems to be fulfilling a phonological function, such as providing a minimal amount of salience to a syllable-type unit. These and other closely observed phenomena show us how ABSL is moving toward phonological organization.
7. **Summary and Conclusion**

This study has shown that sign languages differ in terms of the amount of variation in the form of sign production across a community. The amount of variation in the category of handshape in a new language with little outside influence is shown to be greater for nearly all subcategories of that class than in languages with different social histories. In particular, we find a cline of regularity in form across ABSL, ISL, and ASL, such that ABSL shows the most variation, ISL next, and ASL shows the least amount of sublexical variation. The results reported here are from the first cross-sign-language study of phonetic variation and, as such, we hope it will pave the way for other, larger-scale studies in the future.

Undoubtedly, the small scale of this study requires that we adopt a careful interpretation of the cross-linguistic differences in the amount of hand-configuration variation. Nevertheless, there is additional evidence in support of our interpretation, detailed in Israel's (2009) broader study, such as the amount of variation across languages in the other major formational categories, as well as the differences in the amount of variation when whole tokens are considered.

Specifically, regarding quantitative analysis of the other categories, Israel found that Location and Movement also exhibit a greater amount of variation in ABSL compared to ISL and ASL. In addition, when the forms of tokens were considered as bundles of features from all three major sublexical categories – Handshape, Location and Movement -- highly significant cross-linguistic differences which correspond to the ABSL > ISL > ASL cline emerged. In that analysis, tokens that were different in one or more sublexical features were considered different variants of the same lexical item, and the average number of variants per item was calculated for each language. ABSL was found to have about 6.47 variants per lexical item on average, compared to 4.67 variants in ISL and 2.07 variants in ASL, a striking difference that is statistically significant.

These and other related results mentioned above support the suggestion that, while ABSL functions fully as a language with certain grammatical regularities, it appears not to have developed robust phonological categories. We find in addition that differences in social factors such as language age, size of community, and normative pressures that hold between ABSL, ISL, and ASL, correlate with differences in the amount of variation across these languages.
Notes

1. For a detailed account of the social setting in which ABSL arose, see Kisch (2000).
2. Figure 1 is taken from Aronoff et al. (2008).
3. Models of linguistic communication proposed in a number of computational studies produce gradual convergence across different “language users” (see, for example, Barr 2004; Hutchins & Hazlehurst, 1995)
4. The coding system differs from the model in that when more than one finger is selected in a handshape, this selection is treated as a single feature set. For example, [I+M] and [I+M+R] are two different feature sets.
5. It should be noted that these different degrees of flexion are not necessarily distinctive in any of the three languages studied here. See Crasborn (2001) for a discussion on non-contrastive variation between [bent] and [extended] finger flexions in Sign Language of the Netherlands.
6. The handshapes in Figure 3b and 3c illustrate an ‘opposed’ thumb position with an ‘open’ and ‘closed’ Aperture specification, respectively.
7. It should be noted that neither the grade school teachers nor the other children use Israeli Sign Language. Instead, the teachers use signs from ISL that they learned in a brief course, and the children integrate these into whatever signing they bring with them to the school. This means that the only influence from ISL is lexical, and not grammatical, and that the children do not have a real ISL model at school.
8. Naturally, there are a few regional lexical differences in ISL. We attempted to avoid lexical variation by choosing signers from the same area.
9. We are grateful to Carol Padden and Deniz Ilkbasaran for collecting the ASL data used in this study.
10. Fingerspelling is the use of handshapes which represent letters of the alphabet to spell a word borrowed from a spoken language.
11. As explained in section 2, in order to determine whether variation in certain hand-configuration features was influenced by variation in other features, we examined each case of variation in relation to other relevant formational aspects, as discussed by Crasborn (2001). We found that, in the data collected for all three languages, some of the differences in flexion indeed resulted from variation in other features. Removing those cases of variation from the analysis reduced the cross-linguistic differences in mode measures for this feature, but it did not affect the qualitative ranking of mode values across languages.
12. In this study we did not include non-manual components, such as facial expressions and mouthing, which in some languages may be part of the lexicalized form.
13. A dictionary of ABSL signs is being compiled at the Sign Language Research Lab in Haifa. At this point, however, the dictionary is not available to ABSL signers.
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American Sign Language Tone and Intonation: A Phonetic Analysis of Eyebrow Properties

Traci Weast

1. Introduction: what the eyebrows reveal

Interpretations of eyebrow movement contribute to one of the strongest debates in current signed language literature. Do eyebrows represent syntax or intonation? How does eyebrow movement interact with emotion? ASL eyebrow analysis to date is limited to recording only impressions of eyebrow height or muscle movement. Could greater detail on eyebrow movement provide insight into the interpretation of eyebrows? Through the first quantitative analysis of eyebrows in signed languages, this chapter demonstrates both syntax and intonation, clarifies the co-effects of the emotional and linguistic expressions through eyebrow height, and introduces eleven properties of eyebrow movement in ASL. Eyebrow behavior in ASL questions is compared to the behavior of pitch in some tone languages, where emotional prosody, grammatical intonation, and syntax can all overlap through one change in pitch. Similarly, in the data, one change in eyebrow height simultaneously conveys emotional prosody, grammatical intonation, and syntax in ASL questions.

2. Nonmanuals of the face

Eyebrows are one of several nonmanual channels which convey information beyond the manual signs. Nonmanuals of the face can be separated into the lower face and the upper face. The lower face includes channels such as the lips, tongue, and cheek muscles. The lower face nonmanuals attach to individual signs to convey morphological and lexical information (Liddell 1980, 2003). For example, in ASL they can generate a minimal pair, such as in the sign NOT-YET. NOT-YET is produced with the tongue protruding during the sign, while the same hand sign without the tongue protrusion creates the sign LATE. Tongue movement can also signal adverbial information in ASL,
such as the ‘th’ shape that is added over signs to indicate a state of being ‘careless’. For example, signing DRIVE and the vehicle classifier with the ‘th’ tongue shape means ‘driving carelessly’, while the same sign without this nonmanual loses the careless meaning.

The upper face nonmanuals include channels such as the eyes and eyebrows. Directed eye gaze in ASL can signal referents such as subject or object. Eyebrow movement is considered to extend across phrases in several types of constituents in ASL, such as topicalized elements, yes/no questions, wh-questions, conditionals, and relative clauses (Liddell 1980, Baker-Shenk 1983, Neidle et al. 2000).

3. Current methodologies and research on ASL eyebrows

Eyebrows are considered to play a role through similar patterns in several signed languages. For example, eyebrows are raised in yes/no (polar) questions of Israeli Sign Language (Nespor & Sandler 1999) and several signed languages in a cross-linguistic study (Zeshan 2004). This is not universal, however, as Croatian Sign Language lowers the eyebrows for yes/no questions (Kuhn and Wilbur 2006). The question, then, is how to capture the information eyebrows convey in order to examine these language-specific differences.

Thus far, ASL eyebrow analysis has used impressionistic or qualitative methodologies. One common method uses the Facial Action Coding System, FACS (Ekman et al. 1978), and records impressions of muscle movements. This method was first applied to ASL by Baker (1976). Such research influenced subsequent ASL curricula (e.g. Signing Naturally Lentz et al. 1988), with general findings that eyebrows raise in yes/no (polar) questions and lower in wh- (content) questions (Baker 1976; Liddell 1980; Baker-Shenk 1983).

Another common method uses SignStream™ transcriptions (Neidle et al. 1997) or similar recording methods. With SignStream™, impressions of eyebrow heights are recorded on a 4 point scale: raised, raised -, lowered -, and lowered (Neidle et al. 1997).

Eyebrows in ASL are considered to spread across groups of signs, and are not considered associated with any particular manual sign (e.g. Emmorey 2002, Aarons 1994). Brow furrowing (brows coming together) is often used to describe eyebrow behavior in wh-questions, and is not separated from lowering in ASL FACS analysis (Ekman et al. 1978), a distinction shown to be important later in this chapter. These current methodologies provide a
glimpse of eyebrow movements, but these impressions create variable results which also fuel the debate.

When Baker (1976) first observed the strong correlation between eyebrow movements and yes/no questions, she labeled the eyebrows as raised. At the same time, she recorded that 30% of sentences did not appear to show these raised eyebrows. In part to explain these potential exceptions to the general pattern, many researchers turned to investigate whether raised eyebrows are obligatory or not, and whether they reflect syntax or intonation.

3.1 Do eyebrow movements represent syntax or intonation?

Researchers currently debate interpretations of the upper face nonmanuals, and eyebrows are a central part of the discussion: do eyebrows best compare to pitch in the intonation of English, or do eyebrows represent aspects of syntax? The upper face nonmanuals are considered comparable to English prosody and intonation by several researchers of different signed languages, such as Israeli Sign Language (Nespor & Sandler 1999), American Sign Language (Reilly et al. 1990; Brentari 1998), and British Sign Language (Atkinson et al. 2004). For example, Sandler and Lillo-Martin (2006) conclude that raised and lowered eyebrows in ASL questions represent intonational tunes, and that a pragmatic force creates the question nonmanual marker, not the syntax.

An alternative account for the upper face nonmanuals (including eyebrows) is that they reflect the syntax and can serve as facial morphemes, particles, or clitics (Stokoe 1978, Baker & Padden 1978, Liddell 1980, Baker-Shenk 1983, Neidle et al. 2000). For example, Aarons (1994) states that yes/no questions show the obligatory eyebrow raise over the c-command domain of the Complementizer, and spreads obligatorily over the entire IP (clause) because it is not associated with any lexical material in the Complementizer.

Perhaps the most extensive examination of eyebrows in ASL can be found in Wilbur’s work (Wilbur 1994b, 1995, 2000, and 2003). Wilbur and Patschke (1999) searched for a unified account and concluded that only a syntactic analysis explains all occurrences of raised and lowered eyebrows in ASL. Furthermore, while most of the debate considers all upper face nonmanuals as either intonation or syntax, Wilbur’s work extends this debate to allow for a layering, where multiple channels function independently. While still analyzing eyebrows as syntax, for example, Wilbur considers many other simultaneous upper face nonmanuals to represent functions such as intonation or prosody (e.g. eyeblinks, Wilbur 1994). This notion of layering suggests
that different morphological, syntactic, prosodic, and semantic functions can co-occur when distributed to distinct channels (Wilbur 2000, 2003).

3.2 Distinction between grammar and emotion in nonmanuals

These channels also include emotional nonmanuals that co-occur with linguistic nonmanuals. Emotional expressions are generally considered to be universal involuntary expressions and eyebrows play a significant role in conveying emotion (Ekman & Friesen 1978). In addition, eyebrows can convey linguistic information in both spoken languages (Ekman 1979) and signed languages (Baker 1976). Are there distinctions, then, in how the brain organizes these emotional and linguistic expressions in language?

Brain imaging shows distinct functions between grammatical and emotional facial expressions. In spoken language, both emotional and linguistic information is predominantly controlled by separate hemispheres in the brain: linguistic centers located mostly in the left hemisphere, and paralinguistic centers for emotional communication in the right hemisphere (Segalowitz & Bryden 1983).

Similar distinctions are seen between linguistic and emotional nonmanuals in signed languages (Corina et al. 1999). Researchers imaging the brain hemispheres during signing (Bellugi et al. 1989) found emotional facial expressions show additional right hemisphere activation, the same hemisphere as emotional spoken language, while linguistic ASL facial nonmanuals show additional engagement of the left hemisphere, activating the language centers of the brain. Both linguistic and affective facial expressions are distinct, then, evident by timing and distribution in signed languages (Baker & Padden 1978; Liddell 1980; Coulter 1978, 1979; Baker-Shenk 1983; Bahan 1996; Veinberg & Wilbur 1990; Wilbur 2000, 2003).

Signed language research on eyebrows in questions has focused on neutral sentences, but one study (de Vos 2006) recently used FACS to examine emotional questions in a different sign language, Sign Language of the Netherlands, Nederlandse Gebarentaal (NGT). De vos (2006) concluded, based on muscle impressions, that eyebrows show somewhat conflicting results: sometimes the grammar overwhelms emotion, removing emotional expressions, while other times the emotion overwhelms the grammar, removing the linguistic eyebrow movement.

What about ASL? Would quantitative measurements show more regular patterns? The emotional expression of anger includes lowered eyebrows (Ekman & Friesen 1978). If a signer is angry and producing raised eyebrows
during a yes/no question in American Sign Language, how will the raised eyebrows be influenced? When emotions use similar facial muscles as linguistic expressions, as in this example, can the two distinct functions be observed through a phonetic analysis? These first data of emotional ASL questions allow such an observation, and reveal complex layering, where both emotional and linguistic eyebrow movements co-occur.

3.3 A layered perspective

Rather than two divergent paths in the debate, new quantified data suggests that researchers on both sides of the debate can be on separate paths going the same direction. Not all differences will be resolved, but a new framework can broaden the discussion. In this investigation, the eyebrows are seen to simultaneously represent both syntax and intonation. To explore how this is possible, the following is a brief comparison to tone languages.

In tone languages, such as Thai, lexical tones create minimal pairs. For example, a fall from the highest-to-mid trajectory for the word *Kha* means ‘to kill’, while a rise from mid-to-high *Kha* means ‘to trade’. Emotion is then simultaneously conveyed within each required pitch trajectory’s tone latitude (Ross et al. 1992). Too low or too high and the lexical tone is altered, but within a range, the emotion is allowed to vary the tone while not removing the lexical material. Tone languages, then, can have a lexical tone over a word and simultaneously expression emotional intonation through the same use of pitch. Tone languages can also allow pitch to create question distinctions. For example, in Igbo, a question beginning with a pronoun will place a low tone on the pronoun, and without this low tone, the question becomes a statement (Green 1949). Additionally, some tone languages can incorporate grammatical intonation such as focus and other prosodic cues that are then simultaneously overlapped onto the lexical tone (Lindau 1986).

I argue that ASL nonmanuals show some similarities to pitch in tone languages, especially in regards to eyebrow height. Nonmanuals that are attached to lexical items, such as the lower face adverbials, can be analogized to syntactic tone attached to syllables in tone languages. For ASL, this chapter demonstrates that eyebrow height attaches to lexical items in questions, allows both syntactic and intonation types of spread across constituents, and further allows emotional states to influence this eyebrow height without removing the linguistic distinctions (Weast 2008a, 2008b).
4. Methodology

Participant demographics of the six consultants: each is at least second generation Deaf, with one consultant fourth generation Deaf. They all learned ASL as a first language from their parents. Consultants (C1 - C6) were ages 21-51, and there were two males and four females. While all six currently reside in either north or central Texas, three had previously graduated from Gallaudet University, located in Washington D.C.

4.1 Data and collection

For this study, each sentence set includes one sentence unit (or group of signs) and each sentence unit is then signed in three sentence types: a yes/no question, a wh-question, and a statement. Next, each of these sentence types for this one sentence unit is also signed in five emotional states. Sentence sets and sentence set types were created by a native Deaf consultant, and also verified by consultant signers. A modified elicited approach was used to collect the questions and statements, in order to not restrict the natural nonmanuals and sign movements. This permitted consultants to sit back comfortably in their chairs and to relax while signing, and to sign in normal space, rather than asking them to limit their range of motion for the camera. The consultants were then videotaped from approximately waist level so as to include the entire sign space. A Panasonic 3CCD PV-GS320 digital video camera was placed on a tripod at eye level exactly 1.5 meters in front of the seated consultant as measured from the camera to the consultant’s nose.

To help become comfortable with signing in front of the camera, prior to collecting the scripted data, consultants first signed two short stories. They were also videotaped answering questions to confirm eligibility for the study, and both the interview and narratives were examined in data analysis to confirm that the range of eyebrow heights in the scripted data was similar to the range of eyebrow heights in the unscripted conversational data.

One sentence set example used the signs NOW and RAIN, differentiated only by nonmanuals between the statement “It is raining now.” and the yes/no question “Is it raining now?” For the wh-question, a wh-word was added, to sign the English equivalent of “Where is it raining?” Each sentence set was then given a scenario to situate the emotional settings, and help frame similar
interpretations of sentence sets. For example, for this sentence set, ideas included planning a fun picnic but now it rains (sad), leaving the car window open with important papers in the car but now it rains (angry), and so on.

Consultants each signed six target sentence sets using neutral and the emotions happy, sad, angry, surprise. There were a total of fifteen sentences for each sentence set, with five sentences signed as a yes/no question for each of these five emotions, five signed as a wh-question for each emotion, and five signed as a statement for each emotion. The six sentence sets contain a total of 90 sentences per consultant, further signed with three renditions each, so that the middle rendition could be selected whenever possible, consistent with traditional phonetic analysis. With six consultants, this resulted in a total of 540 sentences (middle renditions) for the data. Only the first three sentence sets were selected for analysis, which resulted in 270 sentences for the final data of this investigation.

During data collection, the sentence types were elicited by holding up cards. For example, if a sentence was to be signed as a happy yes/no statement, the card was seen as in Figure 1, similar to the method used in Baker & Padden 1978.

![Sample card seen by consultants listing emotion and sentence-type.](image)

The cards similar to Figure 1 were also mixed into random orders. As signing continued for about an hour, this allowed consultants to view cards and not be influenced by expressions from an interlocutor. After signing, consultants viewed their own sentences to verify the target emotions were achieved, and also recorded impressions of signing from other consultants.
4.2 Measuring instrument and procedure for analysis

Figure 2 shows the measurement tool and facial landmarks for recording values. This includes detail on the application of this digital tool that is new to the field of ASL research. Figure 2. Screen Calipers™ tool by Iconico; facial landmarks image (Clapham et al. 2006).

Outside the field of signed languages, hand calipers have been used frequently for facial measurements, and Clapham et al. 2006 investigated their accuracy in comparison to newer digital technology. The results of their study showed the measurements from SO to IO (seen in Figure 2) were accurate in tests of variance with p-values <.05 for both hand calipers and measurements of still frames in Adobe Photoshop. Correlation scores, however, showed digital measurements were overall more accurate. One possible explanation is that individuals may move or alter expressions when a physical tool is placed over their faces. Any such movement would most certainly be repeated and even magnified in a signed language study of subtle facial movements. For ASL, then, the combination of a caliper tool and digital images proved to be an ideal and novel combination. This was found in a digital version of calipers, seen in figure 2.

This online version of the caliper instrument called Screen Calipers™ (Iconico) was located and applied for the first time to signed language research. This tool is traditionally applied to engineering, medicine, and other scientific projects. The standard version is free, but the upgrade was purchased for an affordable $30 (USD) for the ability to move 360 degrees as needed during analysis. The tool was situated on the face using points A, B, and C in Figure 2, situated into the SO, LC, and IO locations respectively.
With this tool, all 270 sentences at 30 frames per second were stopped at least every 3 frames (and more often if there appeared to be a change), and eyebrow heights were recorded by hand. In total, over 3500 measurements required more than 170 hours to code, including over 39 hours of training the tool to each face prior to coding. The Screen Calipers™ tool was used to generate pixel measurements. Pixels are units of small dots relative to screen size, measured in increments of 1 pixel (px) at a time. Researchers can replicate similar measures by using the same screen size in this study, and the same distance from the camera to the signer during data collection. For analysis, the computer screen was obscured so that only the upper face was visible during coding of the facial measurements, recorded based on time stamp.

5. Statistical results

Table 1 shows the range of eyebrow heights in the data for each signer (C1-C6) in terms of pixel measurements. Each signer showed the same individual range in both the natural and elicited data.

<table>
<thead>
<tr>
<th>Consultant</th>
<th>Min. brow Height in Pixels</th>
<th>Max. brow Height in Pixels</th>
</tr>
</thead>
<tbody>
<tr>
<td>C1</td>
<td>1</td>
<td>13</td>
</tr>
<tr>
<td>C2</td>
<td>3</td>
<td>15</td>
</tr>
<tr>
<td>C3</td>
<td>1</td>
<td>13</td>
</tr>
<tr>
<td>C4</td>
<td>2</td>
<td>13</td>
</tr>
<tr>
<td>C5</td>
<td>1</td>
<td>13</td>
</tr>
<tr>
<td>C6</td>
<td>2</td>
<td>14</td>
</tr>
</tbody>
</table>

In Table 1, all consultants show a 12 pixel range for eyebrow height, except Consultant 4 (C4), who shows an 11 pixel range for eyebrow height in all data.

For comparison across signers, it was initially hypothesized that consultants would show great variability in pixel ranges because of physiological differences across individuals. For example, perhaps one signer might range from 5-16 pixels when signing while another might range from 1-10 pixels. The eyebrow heights, then, were to be set to zero, to compare change in heights across consultants.
Instead, as seen in Table 1, all six consultants ranged within 1-3 pixels of each other from both maximum and minimum height levels. With such a similar range of production in this study, there was no need to limit the results by setting values to zero. Rather, the raw values of eyebrow height were used in all statistical tests and contour charts of measures.

**Property 1 emotional organization:** The ranges of eyebrow height are organized by emotional state.

Figure 3 shows overall emotional eyebrow heights, and question distinctions that are often made within these emotional levels. A mixed model analysis was performed using SAS software for the onset, maximum, and minimum eyebrow heights for each sentence. All three showed similar patterns, and these patterns are seen in the results for maximum values of each sentence in Figure 3.

![Figure 3](image)

Figure 3. Eyebrow height for ASL questions and statements with added emotion: maximum values for all 270 sentence samples. Yes/no questions (Y/N), wh-questions (WH), and statements (DECL): mixed model means across (left to right) surprise, happy, neutral, sad, and angry.

The boxes represent the 25th to 75th percentile of means, with the 50th percentile at the line. The whiskers show the distribution of values in the means for all sentences. Looking at the overall distribution in Figure 3, it becomes apparent why curricula continue to teach only the basic “eyebrows raised” or “eyebrows lowered” for questions: neutral yes/no questions and
neutral wh-questions are spread farthest from their respective statements, appearing as a degree of extreme raising or lowering. The picture becomes less obvious, however, when noting the spread in emotional question distinctions. The mean maximum eyebrow heights in ASL sentences make significant distinctions between yes/no and wh-questions with \( p < .05 \), but make no distinctions between questions and statements within emotions.

In Figure 3, eyebrows raise for neutral questions on average 21% from statements, and lower 30% from statements, generally the largest extremes. Notice, however, that when emotion is added to the conversation, there is a much tighter distribution. For example, while on average angry yes/no questions reach higher heights of raised eyebrows than angry statements, there is only a subtle raising, and angry wh-questions are only slightly lowered from angry statements. Also, compared to neutral state, many sad and angry yes/no questions may not even employ eyebrow heights as high as the ‘lowered’ wh-question in neutral.

In Figure 4, the mixed model data show type-by-emotion interaction which further demonstrates that emotions do influence the linguistic question distinctions.

![Figure 4](image-url)

**Figure 4.** ASL Eyebrow MAX height from Least Squares Means (LSM). Categorical distinctions: sad and angry are different from positive emotions.

Figure 4 shows the difference in mean eyebrow maximum values for eyebrow height. The minimum and onset values are also categorically similar to each other for the three sentence types across the same data set of emotions. All five emotions are statistically significant (\( p < .05 \)) from each other, except for surprise and happy (no difference, \( p = .9632 \)). There is generally no difference between sad and angry for eyebrow height, but the
data do show a categorical distinction which ranks these negative emotions together as statistically lower than the other emotions. The type by emotion results show a $p < .05$ difference exists between sad and angry and all other emotions in the data, in all sentence types, with only two exceptions, seen in Figure 4 in the small box. The two values that do not show this categorical distinction represent a surprise wh-question and a neutral wh-question. For both of these values, there was a significant difference for all of the comparisons except two, which were when comparing the surprise and neutral wh-questions against neutral statements or against each other. Therefore these two are excluded from the grouping. Perhaps a larger study could resolve these exceptions and show they too will fit into the categorical ranking.

The overall declination of eyebrow heights and distinctions between positive and negative emotional states reveal the first property, that the ranges of eyebrow height are organized by emotional states.

With such variability from emotional states, then, are there any consistent patterns produced by eyebrow height to distinguish between question types and statements in American Sign Language? Consistent distinctions do exist, but are found when looking not at the range of eyebrow height, but at both the timing and spread of raised and lowered eyebrows.

6. Contour results

The results focus on both raised and lowered eyebrows, but not furrowed eyebrows, because of the variable nature of furrowed brows revealed in the data. For example, brow furrowing was frequently omitted from wh-questions, depending on the emotion and sentence type combination.

Contour charts plot the raised and lowered eyebrows over the entire sentence and reveal a bigger picture of eyebrow behavior in signers.

**Property 2 height change at boundaries:** Eyebrow height changes either at lexical boundaries or with sign movements.

Figure 5 shows statements of one sentence set for one consultant signing in the five emotional states. Each mark across the x-axis represents three frames, and the y-axis shows the pixel heights for each measurement.
Figure 5 reveals the second property of eyebrow movement. When the eyebrow levels change, as seen in the Figure 5 line values, the raising or lowering occurs either at lexical sign boundaries, or in timing with sign movements.

**Property 3 Declination In Statements:** Eyebrow height shows a declination effect in simple statements.

Figure 5 also shows the third property of eyebrow movement: a declination effect in statements, visible with an overall lowering by sentence-final position. This can be analogized to the declination of pitch in the intonation of spoken languages. The data also show a frequent sentence-medial rise, visible in angry and happy in Figure 5. However, Figure 6, shows a striking difference for wh-questions.

**Property 4 wh-word lowering:** Eyebrows show a subtle lexical lowering (at least 1 pixel) over wh-words.

Bracing wh-questions, with wh-words in both initial and final position, occurred in some sentences in the data. Figure 6 reveals two examples of signed bracing wh-questions, in the emotions happy and angry.

Figure 6 shows the fourth property of eyebrow movement: a subtle lexical lowering over WH words. Wh-words such as the sign WHERE in Figure 6 show a consistent lexical lowering of at least (and often exactly) one pixel across all 90 wh-questions in the data across emotions. This occurs regardless
of positioning in the sentences. This obligatory lexical signature for lowering can then be compared to syntax.

Property 5 wh-constituent end lowering: Eyebrows lower at least 1 pixel (subtle lowering) over an element at the end of a wh-constituent.

Not only is there a lexical attachment of lowering over every wh-word, but there is also at least a one pixel lowering over an element at the end of the wh-constituent. In Figure 6 this occurs over WHERE in sentence-final position. This is the fifth property of eyebrow movement.

In final position, this lowering occurs over a wh-word when available, but when one does not exist, the lexical lowering occurs over a substitute or non-overt wh-element. Thus, final position maintains this lexical lowering in the presence or absence of any wh-word. In contrast, when a sentence-initial wh-word is omitted, there is no lexical lowering assigned to any element in initial position. This lexical lowering, therefore, is triggered by the presence of a wh-word in initial position.

Property 6 narrow spread in bracing wh-questions: Eyebrows show an obligatory narrow spread of lowering in bracing wh-questions.

Figure 6 shows two examples of wh-word bracing where the sentence begins and ends with a wh-word. When a word such as the verb RAIN in Figure 6 is braced by wh-words, the eyebrows are raised only one pixel in the data. This
sixth property of eyebrow movement is what I call narrow spread, because the content between the wh-words receives an additional lowering that limits the eyebrow raise to only about one pixel above the wh-word height. This occurs in all of the sentences with bracing wh-words, and is syntactic because limiting the raising is associated with a specific type of grammatical word, a wh-word, regardless of emotional context.

**Property 7 wh-constituent variable lowering:** There is a variable broad spread of eyebrow lowering over the entire wh-constituent.

Another eyebrow property, the seventh property, includes a variable broad spread of lowering over wh-questions in the data. This is what was seen in Figure 3 with the statistical means where wh-questions are generally lower than corresponding statements and yes/no questions. This broad spread can be omitted, possibly by speaker intent or emotional state. While in Figure 6 C1 showed an angry wh-question ranging from 3-4 pixels, in Figure 5, C1 showed an angry statement ranging from 1-3 pixels, lower than the wh-question. While many of the 90 wh-questions maintained an overall lower height range than statements, this pattern was not consistent, therefore the overall broad spread of lowering best corresponds to intonation, that can vary based on pragmatic or other effects. The wh-questions are normally lowered, but the degree to which they lower varies. They are also signed in a brow range lower than the statement range, but this can also vary.

![English Translation: “Where is it raining?”](image)

*Figure 7. C6 eyebrow height in wh-questions sentence-final for Set 1*
Figure 7 shows examples of wh-questions without bracing wh-words, with only wh-words in sentence-final position. In the absence of an initial wh-word, the additional narrow spread is not triggered, so the sentence shows a declination similar to statements until the wh-word occurs. Without the sentence-initial wh-word, the sentence often begins at a higher pixel range of eyebrow height when compared within similar emotional states. Once the wh-word occurs such as in the lowest contour of angry in Figure 7, whatever follows the wh-word will retain the narrow spread of lowering, such as in this tag question of the particle of indefiniteness (part:indef, Conlin et al. 2003) that only raises one pixel after the wh-word. While the narrow spread does not occur in Figure 7, the overall broad spread of lowering still exists with simultaneously a lexical wh-lowering.

**Property 8 y/n variable broad raising:** There is a variable broad spread of overall raised eyebrows across the entire yes/no constituent.

Figure 8 shows height in yes/no questions. Yes/no questions reveal the eighth eyebrow property. Figure 8 shows a broad spread, but of overall raised levels across the constituent. These values are not always higher than the corresponding statements or neutral conversation, however, so this broad spread of eyebrow ranges behaves similar to intonation. For example, in Figure 8, the neutral yes/no question is signed with raised eyebrows at higher levels than all other emotional states, including surprise and happy.

![Figure 8](image_url)

*English Translation: “Is it raining?”*

*Figure 8. Eyebrow height in yes/no questions, C1 Set 1*
Property 9 y/n obligatory narrow raising: There is an obligatory narrow spread of raised eyebrows in yes/no constituents, with a rise of at least one pixel at some point and to the end.

Additionally, a further property of eyebrows, the ninth property, includes narrow spread of eyebrow raising in the yes/no questions as seen in Figure 8. Yes/no questions in the data either show a rise to a sentence-final level, as in surprise and neutral in Figure 8 above, or a lexical lowering in the sentence prior to a final rise of at least one pixel, which remains until sentence-final position as in happy, angry, and sad in Figure 8. This consistent narrow spread of eyebrow raising corresponds to syntax.

Also, while statements frequently show a sentence-medial rise, yes/no questions often show a lexical lowering over a particular sign, usually a verb such as RAIN in Figure 8, but not always. Whether this is merely an effect of the sentence-final rise, or an independent phenomenon, is the subject of future research.

7. Other lexical attachment in all sentence types

Property 10 variable focus lowering: Lowered eyebrows show variable lexical attachments across sentence types, potentially as an expression of stress or focus (e.g. NOW).

The data show additional lexical attachment that occurs in both statements and questions, and which can be either syntactic or intonational in nature. For example, across all six consultants, the sign NOW showed a lexical attachment of eyebrow lowering that coincides with the vertical lowering of the two hands in the second part of the sign. This did not occur in every instance of the sign, but when present, gives the appearance of an effect of stress or emphasis, perhaps added as a focus or intonational component of the language. This type of variable lexical attachment across sentence types is the tenth property, potentially as an expression of stress or focus.

Property 11 obligatory lexical lowering: Lowered eyebrows show obligatory lexical attachments across sentence types, such as a subtle lowering of at least one pixel over the N in the lexicalized sign #WHEN.
An eleventh property shows an obligatory lexical attachment across sentence types. In the data, for example, there was a lexical attachment for eyebrow lowering which occurred over the N in the lexicalized sign #WHEN. This appears to be obligatory in the data, as the subtle lowering of at least 1 pixel occurred in every instance of the sign, across all consultants. This correlates to a syntactic attachment of eyebrow lowering. This could either be a lexical syntactic lowering that is not fully realized until the final letter N, or some type of morphological lowering attached to the final element of the sign.

8. Conclusion: properties of eyebrow movement

This chapter introduced eleven properties of eyebrow movement. These properties show behavior that corresponds to intonation, syntax, and emotional prosody. The following is a summary of the properties, grouped by sentence type:

General Properties
1. EMOTIONAL ORGANIZATION: The ranges of eyebrow height are organized by emotional state.
2. HEIGHT CHANGE AT BOUNDARIES: Eyebrow height changes either at lexical boundaries or with sign movements.

Statements
3. DECLINATION IN STATEMENTS: Eyebrow height shows a declination effect in simple statements.

Wh-Questions
4. WH-WORD LOWERING: Eyebrows show a subtle lexical lowering (at least 1 pixel) over wh-words.
5. WH-CONSTITUENT END LOWERING: Eyebrows lower at least 1 pixel (subtle lowering) over an element at the end of a wh-constituent.
6. NARROW SPREAD IN BRACING WH-QUESTIONS: Eyebrows show an obligatory narrow spread of lowering in bracing wh-questions.
7. WH CONSTITUENT VARIABLE LOWERING: There is a variable broad spread of eyebrow lowering over the entire wh-constituent.
Yes/No Questions
8. Y/N VARIABLE BROAD RAISING: There is a variable broad spread of overall raised eyebrows across the entire yes/no constituent.
9. Y/N OBLIGATORY NARROW RAISING: There is an obligatory narrow spread of raised eyebrows in yes/no constituents, with a rise of at least one pixel at some point and to the end.

Other Lexical Properties
10. VARIABLE FOCUS LOWERING: Lowered eyebrows show variable lexical attachments across sentence types, potentially as an expression of stress or focus (e.g. NOW).
11. OBLIGATORY LEXICAL LOWERING: Lowered eyebrows show obligatory lexical attachments across sentence types, such as a subtle lowering of at least one pixel over the N in the lexicalized sign #WHEN.

The data distinguish between questions and statements across emotions, showing that emotion does not remove linguistic eyebrow height. The data show, for example, that eyebrows in wh-questions can simultaneously alter the height for stress or focus on a particular sign, may show or omit overall lowered levels in a wh-constituent (aspects of intonation), will produce subtle lowering over every wh-word and show a further lowering between bracing wh-words (both obligatory aspects of syntax), all while maintaining an overall range of height that is organized around emotional states.

Therefore, the layered functions of ASL eyebrows are not best compared to pitch in English, but instead function similar to pitch in tone languages. The data show that one nonmanual, the eyebrow channel, can simultaneously function as syntax, grammatical intonation, and emotional prosody in one change of eyebrow height. This corresponds to how pitch functions in some tone languages, where grammatical intonation, emotional prosody, and tone all co-occur through one change in pitch. This expands the theoretical debate on nonmanuals from the assumption of a mutually exclusive analysis of either syntax or intonation, to a more defined question of when syntax and intonation can or cannot co-occur in signed languages, and the interaction of emotional and grammatical effects. The introduction of affordable quantitative measurements also broadens the options for future research.
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Wilbur, R. B.  

Wilbur, R.B.  

Wilbur, R. B.  

Zeshan, U.  
Part III.  Theory
Are dynamic features required in signs?¹

Rachel Channon and Harry van der Hulst

1. Abstract

This chapter argues that dynamic features are required in signs, even though they are not used in spoken languages. Hayes (1993) and others (e.g. van der Hulst 1993) have argued that they should also be eliminated from signs. But at least one dynamic class node, pathshape, is here shown to be required. This opens up the possibility that other dynamic class nodes and features are available as well, since no absolute ban on such features can be maintained. We understand dynamic features to be basic gestalt-like shape concepts that have no internal structure.

2. Dynamic features

The literature on the form of signs contains proposals for dynamic features² such as ‘downward’ or ‘upward’ for directions, ‘zigzag’ or ‘curved’ for path-shapes, ‘rotate’ or ‘pivot’ for orientation changes, and ‘wiggling’ or ‘hooking’ to describe movements of the fingers. Most models use at least one or two dynamic class nodes or features such as [pathshape] or [repeat].

But are these kinds of features really needed? Since the advent of autosegmental phonology, dynamic features for spoken languages such as [delayed release] or [prenasal] have been considered superfluous because such features could be replaced by a sequence of two values for one static feature ([−continuant] → [+ continuant]; [−nasal] → [−nasal]), or by an incompatible feature combination that requires phonetic sequencing (e.g. [−sonorant, +nasal]) for prenasalized stops). On this basis Hayes (1993) proposed removing dynamic features from sign representations.

If dynamic features for pathshapes are not used in representing signs, movements must be computed as interpolations between static points. Even the most complex movement can be understood in this way if there is no limit on the number of points that can be specified. For example, a videoclip of a person signing is actually a set of static snapshots (which the mind interprets or integrates into a moving representation). One might argue that dynamic
characteristics are not fundamental properties of a geometric representation of a path, but rather derivative, gestalt or integrative notions. From this perspective therefore, the static ‘digital’ representation of movement as a set of points along a line may seem simpler, more accurate, and more fundamental.

Nevertheless, this chapter argues that dynamic features are a necessary part of the phonological representation of a sign. The primary focus here is on pathshape and secondarily on repetition features. Other arguments for specific dynamic features have been made in Channon 2002b and Mak and Tang (this volume) for repetition, Channon Crain 1996, Channon 2002a (arguments for direction features and the use of dynamic features in general), and Corina 1993 for a dynamic handshape change feature.

The chapter is organized into two major sections. The first section explains dynamic features and gives two detailed examples for a dynamic single segment model. The second section is a comparison of the two logically possible models: a dynamic model which allows dynamic features, and the non-dynamic model (anything else). The goal is to show that using a dynamic model produces simple phonetically based representations while a non-dynamic model results in logical absurdities, arbitrary phonological constraints, and excesses (such as huge numbers of segments and features for a given sign) that do not occur in the dynamic model. Note that occasionally arguments are simplified by making reasonable but unproven assumptions about sign languages. The simplifications are allowable because they are only used to make the model argued against (the non-dynamic model) more likely. All sign language examples that follow are from ASL, but the characteristics discussed are fundamental properties of representations which surely apply to all natural sign languages. For example, it is unlikely that there are sign languages without circular pathshapes, and it is unlikely that one sign language would use interpolation and arbitrary locations (as discussed below) while other languages used pathshapes.

Frequency values from the SignTyp database are used throughout the chapter. This database, which was created under NSF grant 0544944, consists of annotations for 9 datasets of 6 languages (two languages have multiple datasets of signs collected at different points in time) with a total of 11,956 signs as shown in Table 1. These were originally separate datasets from different coders using different annotation systems, which were converted to the SignTyp coding system and structure and added to the database. Some datasets are more complete than others, in part because some contained more information and in part because conversion is not yet complete for all datasets. More information and a download are available at http://www.ldc.upenn.edu/signtyp/downloads/.
Are dynamic features required in signs?

### Table 1. SignTyp database

<table>
<thead>
<tr>
<th>SIL Codes</th>
<th>Sign language</th>
<th>Dataset (original coder or source)</th>
<th>Signs</th>
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</thead>
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<td>ase</td>
<td>American</td>
<td>Hara/Stokoe</td>
<td>1890</td>
</tr>
<tr>
<td>ase</td>
<td>Old American</td>
<td>Long</td>
<td>1549</td>
</tr>
<tr>
<td>ase</td>
<td>American</td>
<td>Rozelle</td>
<td>656</td>
</tr>
<tr>
<td>dse</td>
<td>Netherlands</td>
<td>SignPhon</td>
<td>3080</td>
</tr>
<tr>
<td>fse</td>
<td>Old Finnish</td>
<td>Rozelle</td>
<td>609</td>
</tr>
<tr>
<td>fse</td>
<td>Finnish</td>
<td>Rozelle</td>
<td>354</td>
</tr>
<tr>
<td>jsl</td>
<td>Japanese</td>
<td>Hara</td>
<td>2516</td>
</tr>
<tr>
<td>kvk</td>
<td>Korean</td>
<td>Rozelle</td>
<td>614</td>
</tr>
<tr>
<td>nzs</td>
<td>New Zealand</td>
<td>Rozelle</td>
<td>688</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td></td>
<td>11956</td>
</tr>
</tbody>
</table>

3. **What are dynamic features?**

Dynamic features are characteristics of motion such as direction, pathshape, repetition, size, speed, tension, or change in shape or orientation. These features occur over a discernible period of time. While motion cannot be directly seen in a snapshot, there is a way in which at least pathshape and repetition are potentially atemporally visible. Imagine standing on top of a building and looking down at a landscape with a circular path that you plan to walk on. You can see your future path³ as an atemporal whole, without regard to direction or where you plan to begin or end on the path. Similarly, visual perception of repetition can be atemporal as in looking at a garden or work of art and easily picking out various types of repeated elements. These repeated elements can be perceived without any ordering or temporal reference (such as to when the items were placed in position). Contrast this with possible auditory dynamic features: although one may speak of a voice as falling or rising and can perceive that some sound has been repeated, these perceptions have a metaphorical quality to them (in that a term like ‘rising’ refers to an upward movement, and so on) and/or are clearly accompanied by an understanding that time is involved. This difference in visual and audible perception may be reflected in the proposed difference in the use of dynamic features in sign and speech⁴.
A significant characteristic of many dynamic features is their ability to sequence static (i.e. non-dynamic) features. Referring back to the analogy of a person observing a path from above, if you know that you will walk around the path clockwise and know either your beginning or ending point, then for any two points along the path, you can determine their sequence – which point you will pass through first or second. Similar sequencing information is available through phonological features such as *down*, *opening*, or *pronating*. If there is a location on the *chin* and the *chest*, and a direction *down*, then the two locations must be sequenced *chin* → *chest*. If there are two handshapes such as an *open spread* hand and a *fist* and a handshape change feature *opening*, then the two handshapes must be sequenced *fist* → *open spread hand*. If there are two orientations of the palm such as *palm facing floor* and *palm facing up* (with elbow flexed) and an orientation change feature *pronating* then the two orientations must be sequenced *palm facing up* → *palm facing floor*. While there are a few exceptions, dynamic features usually cannot sequence more than two features, but as has been noted by a number of phonologists, signs rarely have more than two distinct values of any particular feature type: for example not more than two distinct locations (Wilbur 1993).

Although dynamic features can sequence static features, it appears to be even more common that they allow for the omission of static features. For example, if there is a location on the chest and a direction *out*, then it is clear that the hand begins at the chest and moves out, but no final location needs to be specified. There simply is a location where the movement takes place. Likewise, if there is a dynamic orientation feature *pronating*, then the hand must begin in a neutral or supine position and move to a pronated position, and neither the initial nor final orientation of the arm needs to be specified.

When static features are omitted, the resulting locations, orientations, handshapes and other characteristics will be somewhat vague or allow for several similar choices: if location is chest and direction is out, then the final location of the hand is somewhere out from the chest, but it could be a very short or very long distance out without changing the meaning of the sign. In the second example in the previous paragraph, the initial and/or final orientations may vary considerably, providing that it allows for a pronating action of the arm. As discussed in more detail below, this is in fact what is often seen in signs – that while some static features are relatively fixed, others may vary considerably, because these characteristics are not a part of the phonological representation but are the result of dynamic phonological features. One important characteristic of the dynamic model is its ability to explain this difference between more fixed and more flexible characteristics. More
examples are given below in the sample signs.

As a consequence of the nature of dynamic features and especially this sequencing ability, representations using dynamic features are normally extremely simple and all non-compound signs can be represented within a single segment.

3.1 Examples of single segment dynamic representations

Although the primary point of this chapter is to show the representational problems that occur when dynamic features are not allowed, it may be helpful to show some of the positive results of using them. This section shows that the dynamic model allows compact non-redundant representations because many characteristics can be determined by implication from other features, or by assuming the unmarked or phonetically determined value of a feature. The model used here assumes a single segment representation with dynamic features as in Channon 2002a. Two examples with accompanying explanations are given: KNOW and PLEASE.

In what follows, omitted values are sometimes referred to as implied and sometimes as default, although it is not clear that there is any real distinction between these two terms. Implied is used when there is a clear physical explanation for why a particular characteristic is omitted, and this explanation depends on the value of a feature(s) in the representation. Default is used when the value is omitted primarily because it is by far the most common value in SignTyp, either overall, or for a pertinent subset (such as most common orientation for signs overall or most common orientation for signs made in a particular location). Most or all defaults probably have a physical explanation although not necessarily an implicational explanation. Note that both default and implied values can be overridden by specifically adding some marked value to the representation.

3.1.1 Representation example: KNOW

Figure 1 provides the illustration for KNOW and Figure 2 the full dynamic representation. Even this representation is simpler than what would be seen in most multisegmental models, but it is still redundant.
A word description of Figure 2 is: KNOW is made at the ipsilateral side of the forehead. The hand touches the location with the pads of all fingers. The palm faces the body. The handshape has all fingers extended and unspread, with the thumb extended. Omitted information includes: repetition (none), pathshape (none), second hand (none) and nonmanual expression (none).

Figure 3 shows a non-redundant representation with simplified location information, contacting part information retained, and no specifications for handshape, movement or orientation. The claim is that deleted information falls out from various default values and implications. The following explanations discuss all characteristics in turn, and give the reasoning behind what information is kept or removed. (The focus of this chapter is primarily on redundancy and dynamic features, so few supporting arguments are provided for the chosen dependencies, which are tentative and may need revision.)

3.1.1.1 Location

Forehead is shown as a dependent of SideOfHead because in many cases, KNOW is actually performed lower on the head but always on the side. This effect can be explained as a deletion of forehead, leaving SideOfHead.

Ipsilateral is considered redundant because it is (by definition) the closest location to the acting hand, and therefore on the face, this is the easiest side for the hand to contact. However, the data from SignTyp is slightly ambiguous on this issue. SignTyp currently has two datasets that specify locations
in sufficient detail to be of use in this question: the SignPhon NGT and the Long ASL datasets. If all signs with information about locations are included, as in Table 2, then the preference for ipsilateral locations as opposed to central or contralateral is clear. If only signs made on the body are included, as in Table 3, or only signs made on the head, as in Table 4, the preference for ipsilateral is still clear. But if only signs made on the forehead are considered, as in Table 5, the situation is a little murkier. The SignPhon data maintains the ipsilateral preference, but the Long data shows a preference for a central location as opposed to an ipsilateral one. More data is certainly needed to resolve this variability, but it seems likely that the Long data represents a younger, as well as a more formal, language set, where there is an opposing tendency to symmetry and centrality which over time, gives way to the physically easier and visually clearer peripheral locations. A picture and description of the sign KNOW from the Long data (Figure 4) shows that in this early 1900s incarnation of ASL, the sign was made centrally (and with a much flatter handshape than is the norm now).

**Table 2.** Laterality preferences for all locations

<table>
<thead>
<tr>
<th>laterality</th>
<th>Long</th>
<th>SignPhon</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>ipsilateral</td>
<td>61.7%</td>
<td>78.5%</td>
<td>77.7%</td>
</tr>
<tr>
<td>center</td>
<td>23.0%</td>
<td>15.9%</td>
<td>16.2%</td>
</tr>
<tr>
<td>contralateral</td>
<td>15.3%</td>
<td>5.6%</td>
<td>6.0%</td>
</tr>
<tr>
<td><em>n</em></td>
<td>222</td>
<td>4566</td>
<td>4788</td>
</tr>
</tbody>
</table>

**Table 3.** Laterality preferences for all body locations

<table>
<thead>
<tr>
<th>laterality</th>
<th>Long</th>
<th>SignPhon</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>ipsilateral</td>
<td>60.5%</td>
<td>61.1%</td>
<td>61.1%</td>
</tr>
<tr>
<td>center</td>
<td>26.5%</td>
<td>29.1%</td>
<td>28.7%</td>
</tr>
<tr>
<td>contralateral</td>
<td>13.0%</td>
<td>9.8%</td>
<td>10.2%</td>
</tr>
<tr>
<td><em>n</em></td>
<td>185</td>
<td>1153</td>
<td>1338</td>
</tr>
</tbody>
</table>

**Table 4.** Laterality preferences for all head locations

<table>
<thead>
<tr>
<th>laterality</th>
<th>Long</th>
<th>SignPhon</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>ipsilateral</td>
<td>63.7%</td>
<td>96.6%</td>
<td>90.1%</td>
</tr>
<tr>
<td>center</td>
<td>35.5%</td>
<td>0.0%</td>
<td>7.0%</td>
</tr>
<tr>
<td>contralateral</td>
<td>0.8%</td>
<td>3.4%</td>
<td>2.9%</td>
</tr>
<tr>
<td><em>n</em></td>
<td>124</td>
<td>502</td>
<td>626</td>
</tr>
</tbody>
</table>
Table 5. Laterality preferences for all forehead locations

<table>
<thead>
<tr>
<th>laterality</th>
<th>Long</th>
<th>SignPhon</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>ipsilateral</td>
<td>36.4%</td>
<td>96.3%</td>
<td>87.1%</td>
</tr>
<tr>
<td>center</td>
<td>63.6%</td>
<td>0.0%</td>
<td>9.8%</td>
</tr>
<tr>
<td>contralateral</td>
<td>0.0%</td>
<td>3.7%</td>
<td>3.1%</td>
</tr>
<tr>
<td>n</td>
<td>44</td>
<td>243</td>
<td>287</td>
</tr>
</tbody>
</table>

Thus, although overall, there is a preference for ipsilateral locations, more data is needed. For now, *ipsilateral* is considered the default location, while leaving open the possibility that it is a true phonological feature and must be included in the representation.

### 3.1.1.2 Contact part and type

Contacting part is included. Contact type is omitted based on two reasonable assumptions. First, if there is a contacting part, then there must be contact with the specified location(s). Second, the unmarked contact type is assumed to be with the hand moving toward the location(s) and lightly touching or tapping it.
3.1.1.3 Orientation

All orientation information is omitted because it is implied by the contacting part (fingerpads). Two basic orientations are observed: the palm faces the body and the fingers point either up or toward the body. These two orientations are the physically easiest orientations for this sign. Other orientations of the hand would be impossible with fingerpad contact or would require unnecessary expenditures of energy or move the arm into uncomfortable positions:

- Palm facing out toward the viewer: Impossible if the fingerpads must contact the forehead.
- Fingers pointing contralaterally: Requires an awkward twist of the wrist and/or raising the entire arm out of neutral position which is less energy-efficient.
- Fingers pointing down: Less energy-efficient since it would require raising the elbow to about head height.

Note that the absence of a feature for a particular representation does not imply that it is always absent. So while impossible orientations are of course ruled out (for signs with the same handshape and location), orientations that are less energy efficient are not ruled out for other signs. But if such an orientation does occur, it must either be specified in the sign or be predicted by some other combination of characteristics. For example, the marked orientation of ASL LION (hand with spread, extended fingers pointing down traces a “mane” from forehead toward back of head) must be a part of the representation. As another example, suppose that a sign is made with the extended thumb contacting the forehead. In this case, the unmarked orientation would be for the palm to face contralaterally (as in FATHER and other signs).

The reader can easily verify these unmarked orientations even without any knowledge of sign languages. Simply touch the forehead with the pads of all fingers or with the tip of the thumb and observe which orientations are possible and which ones are easy.

3.1.1.4 Fingerset and posture

The fingerset and posture are redundant, because the contacting part implies fingerset, posture (and orientation). Note that the reverse is not true: fingerset, posture and orientation do not imply contacting part: the given fingerset and
orientation could have a contact point on the heel of the hand, the entire surface of the palmside of the hand, the palm of the hand or the entire surface of the fingers.

Given that fingertips is the contacting part, the fingerset must be IMRP (index middle ring and pinky) acting as a unit. Finger posture is slightly more variable. Possible postures are: extended, bent, hooked, curved and closed⁶. Closed and hooked handshapes are eliminated because they do not allow the fingerpads to contact the forehead. Curved, bent and extended handshapes all allow contact with all the finger pads, and all these postures are seen. Note that omitting finger posture from the representation is therefore not only possible, but more accurate, since it allows for the actual posture variation.

Although contacting part does not always predicts the fingerset and posture, it is likely that for signs that contact the body, the contacting part may be included in the representation far more often than other handshape information. Contacting part is more constraining and predictive than the notion of selected fingers. Selected fingers lightly constrain but cannot predict the contacting part for most signs. For example, even a relatively restricted handshape such as the F hand (index and thumb contact, middle ring and pinky extended) has more than one possible contacting part in ASL: in the sign CAT, the fingertips contact, in the sign IMPORTANT the sides of the fingers contact and in the sign COUNT the side of the thumb contacts. And of course, more common handshapes, like the flat hand, have many possible contacting parts.

Contacting part may sufficiently limit the choices of fingerset and posture that in conjunction with unmarked choices for thumb posture, digit crossing and spreading (see below), no further information about the hand is needed - as in KNOW. But there are certainly signs with contact where the limitation is insufficient⁷, and further phonological features must be included. And signs without contact, and therefore no contacting part, would usually need to include handshape features.

### 3.1.1.5 Finger spreading

Unspread fingers is assumed as the default spreading value, based on Table 6 which shows that unspread is strongly preferred for handshapes with all fingers acting together in an extended, bent or curved posture.
Table 6. SignTyp spreading values for strong IMRP handshapes with extended, bent or curved postures

<table>
<thead>
<tr>
<th>Strong handshapes</th>
<th>n</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>unspread</td>
<td>3944</td>
<td>73.3%</td>
</tr>
<tr>
<td>spread</td>
<td>1435</td>
<td>26.7%</td>
</tr>
<tr>
<td>Total</td>
<td>5379</td>
<td>100.0%</td>
</tr>
</tbody>
</table>

3.1.1.6 Thumb

The thumb has several elements:
- Posture: which if any knuckles are flexed.
- Contact point: where the thumb contacts the fingers (tips, pads, palm side of fingers, etc.)
- Crossing: whether the thumb is underneath the fingers (when the fingers are not extended)
- Opposition: the large knuckles of the thumb move it into opposition with the plane of the fingers them

The default values for extended, bent or curved handshapes can be assumed to be uncrossed with no contact point. A hooked posture of the thumb is difficult and is rarely seen except when the fingers are hooked. An opposed thumb posture is a bad choice for any sign on the forehead since one runs a risk of poking the thumb into the eye. A posture with the thumb folded into the palm is physically possible, but there are several objections. First although the achieved posture is not dangerous to the eye, moving into such a posture as the hand moves toward the forehead could be risky. Secondly, the posture appears to be physically slightly more difficult than either an extended thumb or a thumb next to the index. Thirdly, this thumb posture is uncommon - it constitutes only 3% of thumb postures for strong hands with unspread IMRP handshapes with extended, bent, or curved postures. When a posture is uncommon, it suggests that for it to appear, it needs to be phonologically specified.

This leaves two choices: the extended thumb or the thumb next to the index. While both appear to be acceptable for KNOW, observation suggests that the extended thumb is more common. Table 7 shows the preference patterns by spreading choice for strong handshapes in signs with all fingers selected (IMRP), with bent, curved or extended finger postures. Although the
numbers are small, unspread IMRP signs with bent or curved postures prefer the thumb closed next to the index, but for all other combinations of posture and spreading, the preference is for an extended thumb.

The apparent unspread nature of KNOW may actually be better understood as an indeterminate element – that the absence of a spread value in Figure 3 does not equate to a default value of unspread, but rather the hand is neither spread nor unspread. Phonetically, this appears to be an unspread handshape, but it is actually the resting position of the hand when no choice has been made – the fingers slightly but inconspicuously separated, neither widely spread nor tensely contacting each other. In this default position, the thumb will be slightly extended in the same plane as the palm. In other words, the most accurate way of understanding both spreading and thumb posture in KNOW is to say that they are unspecified (as in the representation) and the resultant handshape has the phonetically most relaxed choices for both spreading and thumb posture, which happen to closely resemble the phonological choices of unspread handshape and extended thumb. For now however, it seems sufficient to show that in this sign, thumb posture is not fully determined, and can vary between at least two positions – next to the index or extended in the same plane as the palm.

Table 7. Thumb posture data for strong hand in SignTyp

<table>
<thead>
<tr>
<th>Finger Posture</th>
<th>Finger spreading</th>
<th>n</th>
<th>% thumb extended in same plane as palm</th>
<th>% thumb closed next to index</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bent</td>
<td>Unspread</td>
<td>346</td>
<td>33.8</td>
<td>66.2</td>
</tr>
<tr>
<td></td>
<td>Spread</td>
<td>44</td>
<td>50.0</td>
<td>50.0</td>
</tr>
<tr>
<td>Curved</td>
<td>Unspread</td>
<td>183</td>
<td>10.9</td>
<td>89.1</td>
</tr>
<tr>
<td></td>
<td>Spread</td>
<td>137</td>
<td>99.3</td>
<td>0.7</td>
</tr>
<tr>
<td>Extended</td>
<td>Unspread</td>
<td>2184</td>
<td>90.8</td>
<td>9.2</td>
</tr>
<tr>
<td></td>
<td>Spread</td>
<td>976</td>
<td>95.6</td>
<td>4.4</td>
</tr>
<tr>
<td>Total</td>
<td>Unspread</td>
<td>2713</td>
<td>83.6</td>
<td>16.4</td>
</tr>
<tr>
<td>Total</td>
<td>Spread</td>
<td>1157</td>
<td>94.3</td>
<td>5.7</td>
</tr>
<tr>
<td>Total</td>
<td>Spread &amp; Unspread</td>
<td>3870</td>
<td>86.0</td>
<td>14.0</td>
</tr>
</tbody>
</table>
3.1.2 Representation example: PLEASE

The second example is PLEASE (or ENJOY), which will be further referenced in the second part of this chapter. The sign is shown in Figure 5 and the proposed dynamic representation in Figure 6. PLEASE moves the palm side of the hand on the chest in a repeating circling pathshape.

![PLEASE in a dynamic model](image-url)

**Figure 5.** PLEASE in a dynamic model

![PLEASE - dynamic model representation](image-url)

**Figure 6.** PLEASE - dynamic model representation

**Location.** It is not necessary to specify the location in any more detail than chest. The hand moves through various points of the chest, but these are all predictable from a circular pathshape.

**Handshape and orientation.** Fingerset, posture, thumb values, and orientation can be deduced from the contacting part. If the strong hand contacts the chest with the palm side of the hand, the orientation will have the palm facing the body as required to produce this contact. For the same reason, the hand must be flat. The lack of spreading is the default value (as in KNOW). The thumb must be either next to the index or extended in the same plane, with essentially the same reasoning as in KNOW.

**Contact type.** It is possible that an additional feature is required: type of contact which would be specified as rubbing or continuous. It is omitted here because this can probably be deduced from the pathshape and location. If the
hand circles on the chest and there is contact, the natural contact type would be continuous. Nevertheless, if it were shown to be necessary, a contact type could be added to PLEASE. This would be the case if a sign were found that contacted the chest in a circular path but had a vertical or horizontal path. Such a sign would be similar to HAPPY° which moves in a vertical plane contacting the chest briefly as it moves up repeatedly. However, HAPPY does not have a circular path, so it is not the minimal pair needed to show that contact type is required for PLEASE. So unless this type of sign is identified, contact type is not needed here.

**Direction.** A direction feature is omitted on the grounds that there are no minimal pairs in ASL caused by a change in the direction of a circle, and that the default circling action in the lateral plane is an up-contralateral-down-ipsilateral motion.

### 3.2 Example summary

To sum up, representations for signs in a dynamic model vary in two significant ways: the number and kind of features. The simplest signs such as KNOW and PLEASE have a minimal representation of a few features. Others may have more numerous features, but even these complex signs have many omitted characteristics.

The specific features required or omitted vary from sign to sign. Brentari & Eccarius (this volume) propose something similar when they observe that in the core lexicon, signers do not distinguish between flat and circular postures of the thumb and fingers in O and F handshapes, although they do distinguish between these versions for flat or rounded classifiers, or (for O handshapes only) when it is an initialized sign. In other words, something that is a phonetic variant in one situation becomes a phonological distinction in another.

Most parameters have little detail. Very few signs (probably none) have a fully specified handshape indicating exactly how the knuckles of each digit behave and the relationship of thumb and finger. Different dynamic features appear in different signs, and most signs probably have no or only one dynamic features. The assumption is that dynamic features (like static features) have a cost, and probably are more costly than static features, but no research has been done yet on this issue.

The dynamic model per se does not require that features/characteristics be left out of the representations for a particular sign. Any sign could be represented with full details about location, handshape, orientation, movement,
contact and non-manuals similar to KNOW in Figure 2. But with dynamic features, it becomes possible and reasonable to simplify the representations as shown in Figure 3.

The point is worth stressing, because the proposed simplified representations shown above may turn out to be incorrect in some or even many details. But even if the current choices are incorrect, this still would not invalidate the argument for a dynamic model. Features for a particular sign or a group of signs might need adjustment, but the choice of features and the choice of model are separate (though related) inquiries.

Does the use of dynamic features necessarily imply a single segment model? If the model does not use dynamic features, a multiple segment representation (or at least a representation with timing units of some kind) is absolutely required in order to temporally order features. But if the model uses dynamic features, the answer becomes more complex: a single segment model becomes possible but ruling out a multisegment model is a matter of multiple arguments. Each argument alone might not be sufficient to show that a single segment model is required, but the cumulative weight of various arguments may be more persuasive. In many signs, no significant problems can be shown regardless of whether a multisegment or single segment representation with dynamic features is used. However, Channon 2002a has shown that for significant sets of signs, a multiple segment model produces peculiarities, excessive feature cost, overgeneration of representations for the same sign, overgeneration of unattested forms, and logical absurdities. Two arguments are summarized here:

1. Signs with reversing movement where the reversal is meaningful require only a change of feature to produce the change in meaning in the single segment model. An example is STATUS-CHANGE (or IMPROVE/GET-WORSE) which contacts the arm repeatedly while moving up or down to indicate improvement or deterioration. But in a multisegment model, the change in meaning requires a reversal of segments, such as $S_1 \rightarrow S_2 \rightarrow S_3$ switching to $S_3 \rightarrow S_2 \rightarrow S_1$, a method of producing meaning change never seen in spoken languages (dog is not the opposite of God).

2. In other signs, such as DEAF which can be signed by contacting the ear and then the mouth OR the mouth and then the ear, a multiple segment model must use two distinct representations ($S_1 \rightarrow S_2$ and $S_2 \rightarrow S_1$) for the same meaning, and therefore overgenerates representations. The single segment model uses only one representation which has no direction feature. Because there is no segmental sequence and
no sequence provided by a direction feature, the particular direction that occurs in the utterance will be determined by phonetic or sociolinguistic factors, by contiguity (previous or succeeding signs), personal preference, or even chance.

See Channon 2002a and 2002b for fuller explanations of these arguments as well as many other arguments for a single segment model.

Even when a single segment model is shown to be required, the exact nature of the model is still an open question. Van der Hulst (1993) and Channon (2002a) provide somewhat different versions of a single segment model. The Channon model is used here, but this choice is not justified beyond what has already been said. Many issues about the correct phonological model for signs remain to be resolved. Here, the primary goals are to show that dynamic features both simplify and are required in the representation of many signs.

4. **Required dynamic features: Pathshape and repetition**

Two dynamic features or feature groups are commonly used by sign language phonologists: pathshape and repetition. For example, Brentari (1998:50) uses several such features which she calls movement shape: [circle], [straight], [arc], [tracing] as well as repeat and alternating features. Sandler (1993) has [arc] and [redup] features, the model of van der Hulst (1993), Crasborn (2001) and van der Kooij (2002), uses “manner features” similarly, Hansen (this volume) uses [oscillating] and various circling features, Mak & Tang (this volume) have two repetition features [repeat] and [return], and Channon (2002a and 2002b) uses [repeat], several values of [pathshape] and other dynamic features. Although Liddell and Johnson (1989) do not use a repetition feature, they do have some pathshapes.

Pathshape (and concomitant repetition issues) has been selected as the “poster child” for dynamic features because of this use. Other dynamic features, such as direction (Channon Crain 1996, Channon 2002a) or handshape opening/closing (Corina 1993), are not as widely accepted.

In spite of the common use of dynamic repetition and pathshape features, there has not been much discussion of why dynamic features as a class are needed, what problems occur if they are not used, and what the implications for segmental structure are if they are used. One discussion is in Padden & Perlmutter (1987). Although they adopted a segmental approach, they have an interesting appendix pointing out the problems with alternating and
Are dynamic features required in signs?

trilling for such an approach. They observe that trilled movement, which has an indefinite number of repetitions, must be represented as a dynamic feature [trill] instead of a series of segments because otherwise it “would lead to the absurd result that the phonological representation consists of a different number of segments in different performances of the sign”. They note also that a multisegmental representation is problematic with dynamic features because they cannot be associated with a single segment. They show that alternating in the Liddell & Johnson (1984) model is not a feature, but a characteristic of the temporal arrangement of the segmental tiers of the two hands, and that therefore if alternating signs change to trilled signs, this change cannot be easily represented as a change from [alternating] to [trill]. Instead it requires wholesale changes to the structure of the sign, and peculiar complex rules that specify that signs with a particular temporal arrangement of the segments of each hand tier change to a sign with a single H segment and a feature [trill].

The problem of multiple representations with a “different number of segments in different performances” is discussed at greater length in Channon 2002a and 2002b. Channon 2002b argues that a repetition feature is required primarily because number of repetitions is not contrastive in signs (except for some classifier predicates where it is iconic). Repetition most commonly occurs just once, but two or more repetitions are also well formed utterances. A model with a repetition feature can use one representation for all of these forms. But a model without one overgenerates representations: every utterance with a different numbers of repetitions must have separate representations, even though such utterances are all considered to be the same sign. In 2002a she shows that many other sets of signs also overgenerate representations, in a multiple segment model and this problem is best resolved by using direction features and a single segment model.

Generating non-contrastive but separate representations for the same sign is one type of overgeneration. The second type is overgeneration of forms that do not exist in the language. An example of the second type is that any multisegmental model (dynamic or non-dynamic) for sign languages predicts that forms should exist in the language with indeterminately long location sequences, or more generally, indeterminately long segment strings. Examples of such strings are nose-ear-forehead-mouth, or ear-nose-forehead-chest-mouth-ear. But sign languages exhibit a systematic gap - these long location strings do not exist in simple signs, even though such sequences would be perfectly acceptable in strings of signs. Even compounds show only very restricted location strings. Therefore multisegmental models of signs overgenerate non-existing forms (see Channon 2002a for further discussion).
4.1 Representing pathshape with multiple locations along the path: interpolated locations

If all paths were single straight lines, then a pathshape feature would not be needed. But in fact there are many other possible paths including cross-shaped, rectangular, 7, arc, semi-circle, circle and spiral path.

A non-dynamic model can only represent a pathshape by listing points along the path. Of course, for any line or line segment, there are an infinite number of possible points, making it impossible to actually specify every point along the path. So any nondynamic model must use interpolation to describe pathshapes. Straight lines, 7 paths, arcs, semi-circles and circles are considered below in turn. Other possible paths are omitted from consideration to make the argument simpler – the logic of the argument is not affected.

**Straight lines.** The number of points and the type of interpolation (straight or curved) for all possible pathshapes must be established. For a straight line, the beginning and ending points have a natural salience that make them suitable to select as the phonological locations required by the non-dynamic model. A first approximation of an Interpolation Constraint might be:

1) If all phonological locations are collinear, then the interpolation method is linear.

**7 pathshapes.** The naturally salient points for a 7 pathshape (two straight line paths joined at a somewhat acute angle) would be the two end points and the point at the angle. The Interpolation Constraint is still linear, but needs adjustment:

2) If there are either two or three distinct phonological locations, then the interpolation method is linear.

Note that a repetition of the same location does not count as distinct. For example *aab, aba, abab, abba* all have only two distinct locations.

**Arcs.** To distinguish arcs from straight lines or 7 shapes requires a different number of distinct phonological locations. The smallest possible set of distinct locations is 4. The question now arises: which 4? The beginning and ending points of an arc are naturally salient, but where should the other two points be located? In an arcing sign such as DAY, the hand moves in
a smooth, continuous curve from start to finish. If there were four salient points, one would expect to see a movement which would look something like the following: the hand moves smoothly from the beginning point to a point along the arc, pauses, moves to a second point along the arc, pauses, and moves to the final point of the arc. Since this is not what is seen, and there is no other natural indication of salience, then the two interior locations must be arbitrarily selected.

For arcs, semi-circles and circles, a curvilinear interpolation method will be needed. The adjusted Interpolation Constraint is:

3) If there are either two or three distinct phonological locations, then the interpolation method is linear. If there are four distinct phonological locations, then the interpolation method is curvilinear and the path is an arc.

**Semi-circles.** Again, a distinct number of phonological locations is required, and since 2, 3 and 4 have already been used, the next possible set is 5. Again, as with arcs, there are only two naturally salient locations, so three interior locations must be arbitrarily selected. The Interpolation Constraint is now:

4) If there are either two or three distinct phonological locations, then the interpolation method is linear, otherwise it is curvilinear. If there are four distinct phonological locations, then the path is an arc. If there are five distinct phonological locations, then the path is a semicircle.

**Circles.** The smallest number of distinct locations available is 6, so the circle must have 6 locations along it. Since a circle has no naturally salient points, all 6 locations must be arbitrarily selected (as shown in Figure 7). The final Interpolation Constraint will look like:

5) If there are either two or three distinct phonological locations \(a, b\) and \(c\), then the interpolation method is linear, otherwise it is curvilinear. If there are four distinct phonological locations, then the path is an arc. If there are five distinct phonological locations, then the path is a semicircle. If there are six distinct phonological locations, then the path is a circle.

Note that 5) must be a phonological constraint, because there are no possible phonetic characteristics that explain such a magical set of inferences.
4.2 Problems of a nondynamic model

The remainder of this chapter focuses on the sign PLEASE as an example to show the implications of rejecting dynamic pathshape and repetition. PLEASE was shown above in Figure 5 with its accompanying dynamic model representation in Figure 6. The same sign is shown below in Figure 7 as understood in a nondynamic model, and one of its possible accompanying non-dynamic representations is shown in Figure 8. Note that an additional representation with even more segments is required for every additional repetition of the circling movement. Since this is a circling sign, constraint 5) above requires that six arbitrary phonological locations on the chest be selected to allow for a circling pathshape.

Figure 7. PLEASE in a non-dynamic model
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As the two representations (Figure 6 and Figure 8) show, both models have one similarity: they each specify that chest contact is made with the palm side of the hand. The models differ as shown in Table 8.

**Figure 8.** Nondynamic representation of an utterance of PLEASE with one repetition of path

Abbreviations: S=segment, up=upper, ip=ipsilateral, mi=middle, ce=center, co=contralateral. Note: The nodes suprasegmental, segmental, Repeat1 and Repeat2 are for convenience of grouping only and are not assumed to be a real part of the representation. The placement of Repeat2 below Repeat1 is only because of space constraints.

As the two representations (Figure 6 and Figure 8) show, both models have one similarity: they each specify that chest contact is made with the palm side of the hand. The models differ as shown in Table 8.
### Table 8. Differences between nondynamic and dynamic models

<table>
<thead>
<tr>
<th>Nondynamic model</th>
<th>Dynamic model</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Arbitrarily selected contacting part.</strong> When the palm contacts and circles on the chest, different parts of the hand contact different parts of the chest. For example, at the highest point of the circling action, the index contacts the upper chest, but the pinky contacts the mid-chest (exact contact points may vary in different performances). Therefore, in order to correctly specify the location, the part of the strong hand that contacts the locations is arbitrarily selected as the large knuckle of the index. The selection is arbitrary because nothing in the handshape marks out the index or its knuckle (in contrast to a handshape such as index finger extended from a fist where the index is clearly distinct from the other fingers).</td>
<td>Contacting part not needed.</td>
</tr>
<tr>
<td><strong>Six arbitrary and complex locations on the chest.</strong> Once this contact part has been selected, then six arbitrary locations must be selected, using the magical Interpolation Constraint in 5) above. Note the complex subspecifications of these location features.</td>
<td>One location: chest. No subspecifications required.</td>
</tr>
<tr>
<td><strong>Multiple noncontrastive representations per sign.</strong> This is the first type of overgeneration mentioned above. Because the number of allowable repetitions is indeterminate, this means that there are an indeterminate number of separate representations.</td>
<td>One representation per sign.</td>
</tr>
<tr>
<td><strong>Many features and segments.</strong> PLEASE as shown with one repetition has 59 features: 52 location nodes and 7 contact nodes/features. There are 12 segments. For each additional repetition, 26 location features and 6 segments must be added, so feature and segment count is even higher for the other representations for this sign.</td>
<td>4 features, 1 segment.</td>
</tr>
<tr>
<td><strong>Multiple segments.</strong> A absolutely required to temporally order the changing static features. In this particular representation of PLEASE, the changing features are the location specifications.</td>
<td>One segment.</td>
</tr>
<tr>
<td><strong>Suprasegmental features.</strong> In the representation in Figure 8 contact features are assumed to be hierarchically placed between the root and the segmental level. This reduces the number of features per sign, but it assumes that there is a mechanism that would spread or associate the contact features</td>
<td>Not required.</td>
</tr>
</tbody>
</table>
with all segments. Problems with this method would occur if contact features changed during the sign, as in PANCAKE where the contact changes from the back of the hand to the palm of the hand, or if the sign changed between contact and noncontact with the location as in a sign like HAPPY. The problem is that the suprasegmental spreading of the contact features would have to be directed to specific segments and not automatically spread to all segments. A suprasegmental level such as this would require considerable theoretical support to justify such a change. A second alternative would be to reinsert the suprasegmental elements in the segmental area, arbitrarily associated to one of the 12 segments. A third alternative would be to add these features to each segment, greatly increasing the number of features and the redundancy of the model.

Table 9 gives side-by-side word descriptions based on the two phonological models to demonstrate the differences in complexity and arbitrariness.

**Table 9. Description of PLEASE in two different models**

<table>
<thead>
<tr>
<th>Nondynamic model (one-repeat version)</th>
<th>Dynamic model (any number of repeats):</th>
</tr>
</thead>
<tbody>
<tr>
<td>The palm-side big knuckle of the index of the flat hand contacts the upper ipsilateral chest, then the high upper center chest, then the upper contralateral chest, then the mid contralateral chest, then the low center chest, then the mid ipsilateral chest, then the high upper center chest, then the upper contralateral chest, then the mid contralateral chest, then the low center chest, then the mid ipsilateral chest.</td>
<td>The palm-side of the hand contacts the chest and moves in repeated circles on it.</td>
</tr>
<tr>
<td>Inferences: Because there are six locations arranged equidistantly on the chest, the pathshape is circular by phonological constraint 5) above.</td>
<td></td>
</tr>
</tbody>
</table>
5. Possible pathshapes: evidence from SignTyp

A possible objection to pathshape features is that there are too many and too complex pathshapes to be suitable as feature values. Suppose for example, that minimal pairs of signs existed that are distinguished solely by pathshapes which included such values as a random shape with five, six or seven protrusions as shown in Figure 9. There are surely cognitive limits on the shapes that a human being can visually grasp as a unitary phenomenon and distinguish from similar shapes, so if such minimal pairs existed, they would be a strong argument against dynamic pathshape features. The literature on visual perception suggest that complex shapes are decomposed into more elementary shapes using, for example, concave creases as points to cut up a complex shape into smaller less complex shapes (see, e.g., Hoffman 1998, chapter 4). It therefore seems reasonable to expect that the shapes that can function as features would be elementary shapes, or shapes with minimal complexity.

A reasonable expectation would be that except for iconic shapes, possible pathshape features would be roughly congruent with the set of shapes that are named in non-specialized spoken languages. This congruence would be expected because shapes that are named in the vernacular vocabulary of any language should roughly represent the limits of the average person’s ability to discriminate between different shapes. For example, English has shape words such as circle, oval, triangle, square, rectangle, line, point, and puddle, but it does not have single word descriptions to distinguish between the paths in Figure 9.

![Figure 9. Random complex pathshapes](image)

Of course, complex pathshapes do regularly occur in sign languages, such as pathshapes describing the path of a vehicle or the shape of a complex object. However, they only occur where there is strong iconic support for such a path, usually in classifier predicates. This exceptional behavior can be considered to be because in these signs, the pathshape itself is not stored as a feature. See van der Hulst & van der Kooij 2006 for further discussion of how iconicity is related to the phonology.

Table 10 and Table 11 shows the specific pathshapes found in SignTyp. The following notes about the data should help in interpreting the tables.
1. Only two datasets are included: the Long ASL data and the SignPhon NGT data, because these are the only ones that include information on compound status and pathshape.
2. Only non-compound signs were included.
3. *Straight then straight* and similar locutions in Table 11 could be either the result of drawing successive straight paths in some shape such as a triangle or square or a repeated straight line with the same spatial coordinates. These two types of repetition could not be separated out in the current version of SignTyp.

**Table 10.** Pathshapes found in SignTyp

<table>
<thead>
<tr>
<th>Dataset &amp; Language</th>
<th>Total signs</th>
<th>Noncompound signs</th>
<th>Signs with pathshapes</th>
<th>% of signs with pathshapes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Long ASL</td>
<td>1549</td>
<td>1120</td>
<td>151</td>
<td>9.7%</td>
</tr>
<tr>
<td>SignPhon NGT</td>
<td>3080</td>
<td>2811</td>
<td>859</td>
<td>27.9%</td>
</tr>
<tr>
<td><strong>Totals</strong></td>
<td><strong>4629</strong></td>
<td><strong>3931</strong></td>
<td><strong>1428</strong></td>
<td><strong>15.8%</strong></td>
</tr>
</tbody>
</table>

**Table 11.** Types of pathshape by dataset

<table>
<thead>
<tr>
<th>Path group</th>
<th>Pathshape</th>
<th>Long ASL Percent</th>
<th>SignPhon NGT Percent</th>
<th>Percent</th>
<th>Running total percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>arcs &amp; circles</td>
<td>arc</td>
<td>8.0%</td>
<td>55.8%</td>
<td>48.0%</td>
<td>48.0%</td>
</tr>
<tr>
<td></td>
<td>circle</td>
<td>60.8%</td>
<td>30.4%</td>
<td>35.4%</td>
<td>83.4%</td>
</tr>
<tr>
<td></td>
<td>2 circles</td>
<td>2.4%</td>
<td>0.0%</td>
<td>0.4%</td>
<td>83.8%</td>
</tr>
<tr>
<td></td>
<td>3 circles</td>
<td>0.0%</td>
<td>0.2%</td>
<td>0.1%</td>
<td>83.9%</td>
</tr>
<tr>
<td></td>
<td>semicircle</td>
<td>13.6%</td>
<td>0.0%</td>
<td>2.2%</td>
<td>86.2%</td>
</tr>
<tr>
<td>7 shape</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>cross or x shape</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Iconic</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>L</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Zigzag</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Examples of iconic paths include: outline of a statue, oblong shape, contours of a Christmas tree, shape of mountain, outline of priest’s clothing, shape of figure, question mark, and rectangle omitting one side.

Excluding the iconic pathshapes, the inventory of paths is relatively small and easily distinguished. It is not necessary to characterize the difference between two different circular/oval paths or variations in the productions of a cross shape; and the exact number of turns in a zigzag line is not counted. After all, the pathshape features, as phonological entities, generalize over an infinite number of variants; their denotations are not a precise iconic description of any specific actual path.

Of the 25 signs in SignPhon with more complex paths, most could probably be explained as having iconic elements, but further information is needed to determine this. The variation between datasets in both number |

<table>
<thead>
<tr>
<th>Multiple straight paths</th>
<th>Straight then straight</th>
<th>0.0%</th>
<th>3.9%</th>
<th>3.3%</th>
<th>96.4%</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Straight then straight</td>
<td>0.0%</td>
<td>0.3%</td>
<td>0.3%</td>
<td>96.7%</td>
</tr>
<tr>
<td>circular &amp; straight paths</td>
<td>arc then straight</td>
<td>0.0%</td>
<td>2.2%</td>
<td>1.8%</td>
<td>98.6%</td>
</tr>
<tr>
<td></td>
<td>straight then arc</td>
<td>0.0%</td>
<td>0.9%</td>
<td>0.8%</td>
<td>99.3%</td>
</tr>
<tr>
<td></td>
<td>straight then arc</td>
<td>0.0%</td>
<td>0.2%</td>
<td>0.1%</td>
<td>99.5%</td>
</tr>
<tr>
<td></td>
<td>arc then straight</td>
<td>0.0%</td>
<td>0.2%</td>
<td>0.1%</td>
<td>99.6%</td>
</tr>
<tr>
<td></td>
<td>circle then straight then straight</td>
<td>0.0%</td>
<td>0.2%</td>
<td>0.1%</td>
<td>99.6%</td>
</tr>
<tr>
<td></td>
<td>circle then straight</td>
<td>0.0%</td>
<td>0.2%</td>
<td>0.1%</td>
<td>99.7%</td>
</tr>
<tr>
<td></td>
<td>arc then straight</td>
<td>0.0%</td>
<td>0.2%</td>
<td>0.1%</td>
<td>99.9%</td>
</tr>
<tr>
<td></td>
<td>arc then arc</td>
<td>0.0%</td>
<td>0.2%</td>
<td>0.1%</td>
<td>100.0%</td>
</tr>
</tbody>
</table>
and type of pathshapes is also left unexplained here, but this would certainly be an important area for future research, to determine if these variations are true crosslinguistic variations, or effects of differences in coding strategies. Overall however the data supports the argument that pathshape features in signs are relatively simple and have a manageable number of values. There is therefore good reason to believe that possible pathshapes in signs form a small closed set which can function as features.

6. Conclusion

To summarize, the first part of this chapter showed that dynamic features, in conjunction with the omission of characteristics that are not phonological, make representations extremely simple. The second part showed that dynamic features for pathshape must be a part of the phonological model because without pathshape features, representations become psychologically unrealistic. A nondynamic model has the following problems:

1. **Too many features, too much detail.** A nondynamic model must use many more features, specified in much greater detail than in the dynamic model. The kind of detail used requires high levels of discrimination between similar features: for example the signer must discriminate between high upper center chest and mid ipsilateral chest.

2. **Arbitrary features.** There is nothing in the physical sign which indicates that the index finger has a special relationship with the chest location compared to the other digits or the palm or that the six selected locations are special.

3. **Indeterminate number of representations for one sign.** The nondynamic model has to repeat the six locations exactly as often as they are repeated, since it cannot use a dynamic [repeat] feature, so different numbers of repetitions generate different representations.

4. **Segment strings are too long.** Representations without [repeat] result in inordinately long location strings and other features.

5. **Magical inferences.** The nondynamic model requires inferences which are not phonetically sensible (if there are three locations, the path is angular, if there are six, the path is circular).

6. **Structural problems.** Features which do not change when the hand moves to a new location must either be repeated for each segment or moved to a suprasegmental position and some sort of spreading constraint must be invoked.
Thus, even though it is mathematically simpler to specify a path in terms of a finite number of points, it is much more likely that we mentally perceive and record the path as one of a small set of shapes: an arc, circle, spiral, cross, 7, or zigzag, with a default unspecified value of straight line for the majority of signs.

An additional result of accepting dynamic features is that a single segment representation becomes almost mandatory. This is because, as Padden & Perlmutter (1987) pointed out, it makes no sense to attach a dynamic feature to a particular segment when it applies to the entire sign. For example, if a circling pathshape occurs over the entire sign, but the representation had multiple segments, to which segment should the circling feature be attached? The presence of dynamic features therefore means that a single segment model is highly favored. Such a model might be similar to van der Hulst’s (1993) temporally sequenced single segment. Or it could be like Channon’s (1996, 2002a) segment which does not have internal temporal sequencing elements but assumes that whatever sequencing occurs is a result of dynamic features. Other arguments must be found to decide between these two models, and are not addressed here.

Hayes’ suggestion, then, to eliminate dynamic features cannot be fully followed, since at least pathshape and repetition are required. This opens the door to admitting additional dynamic characteristics. One might even say that the presence of two dynamic features raises an expectation that others also occur, since it would be surprising if only two features of an entire possible type were used. In particular, direction features and handshape opening/closing features become more likely and more reasonable.

If pathshapes had to be the result of interpolations between locations, it would mean that the mind is functioning like a digital machine in all respects—painstakingly linking locations together by calculating the paths between them. As an analogy, one might compare the nondynamic model to the connect-the-dots drawings given to children. A figure (e.g. of some kind of animal) is represented in terms of numbered dots and the child then has to connect the numbers in the correct order to see the figure. A nondynamic model claims that we mentally represent shapes in terms of a set of numbered points, rather than directly in terms of the shape itself. But if, as argued here, the mind is using pathshapes as basic concepts (as ‘gestalt’), it suggests that at least elementary, basic shapes can and should be represented holistically.
Notes

1. This material is based upon work supported by the National Science Foundation under Grant No. 0544944 to both authors. Any opinions, findings, conclusions or recommendations expressed in this material are those of the author and do not necessarily reflect the views of the National Science Foundation.

2. Pathshape could be considered a multivalent feature with values such as [arc/zigzag/circle] or a class node with dependent features [arc], [zigzag] and [circle]. Here, pathshape is referred to as a class node, but nothing in this chapter hangs on this distinction. Note that referring to a feature using a word such as zigzag does not mean that that shape features are mentally represented in terms of ‘words’. Rather the assumption is that the mental representation is in terms of articulatory instructions, and/or in terms of a ‘perceptual image’ of the shape. Of course, the same applies to spoken language features for which we also use ‘words’: here too the features are articulatory instructions and/or acoustic images.]

3. Of course, we can also visualize ourselves walking down the path over time in a particular direction as though watching a movie, but this is not what is meant here, but rather the direct immediate map-like perception of a path as a whole with a certain shape and direction. The difference between these two means of perception is the difference between driving by following instructions one at a time (turn left, then turn right…..) and driving by having a picture in one’s mind of the entire path to be followed as well as its relationship with the surrounding areas.

4. An interesting question for future research is whether the acquisition of dynamic features might be slightly delayed relative to static features. If the analogy in footnote 3 is appropriate, it often takes time to build up a map of an area, and many drivers begin by learning a route as a series of turns. Thus it might also be true that children might learn their first few signs as a series of arbitrary points in space. As they acquire the concepts of path and direction, these might then be used to acquire further signs, as well as to reanalyze those already acquired.

5. Characteristic: any feature can be a characteristic, but not all characteristics are features. Used when there is some doubt as to whether or not something is actually a phonological feature, or when considering both phonetic and phonological elements.

6. An extended handshape has no knuckles bent, a bent handshape has only the large knuckle bent, a hooked handshape has only the two smaller knuckles bent, a curved handshape has all knuckles flexed but not completely closed, and a closed handshape has all knuckles fully bent or closed.
7. For example, MOTHER contacts the chin with the thumb. Although some handshapes are ruled out, the fist and open hand seem almost equally likely candidates, so it is probably necessary to list something about the handshape. In this case, it may be sufficient to list spreading, because the fist cannot spread. Another example would be the two different forms of YESTERDAY, one with the fist, and the other (initialized) with a fist with the pinky extended. For this sign it would be necessary to exclude the open hand and for the initialized form to list the extension of the pinky.

8. The sign may also be slightly off-centered to the contralateral side for efficiency – to keep the elbow closer to the body. If this is correct, a simple phonetic constraint could produce this off-centered location.

9. HAPPY: The palmside of the hand with all digits extended and unspread repeatedly brushes upward on the chest with initial contact on the chest followed by an upward and outward movement which moves the hand out into space.

10. It should now be clear to the reader why other pathshapes are not considered – it would add more pathshapes to distinguish with different numbers of locations without changing the argument.

11. Notice that an additional arbitrary factor here is that these locations depend in part on the size of the particular hand and chest. For example, someone with an especially large chest and small hand might move the hand only in the mid area of the chest and therefore require a different set of features than the ones specified in the example.

12. If the model does not allow the feature omissions discussed in 3.1.2, then features for orientation, handshape, and other values would have to be added as well, further increasing the number of nodes.

13. PANCAKE (also KITCHEN): back of the strong hand contacts palm of weak hand, then turns over so that the palms contact. The handshape is all digits extended and unspread.

14. SignPhon was the only dataset that also listed the default straight path. This occurred in 1766 (62.8%) of all non-compound signs. An additional 186 signs (6.6%) of all non-compound signs had no path. These would be signs with hand internal motion, orientation change or similar situations where the action of the sign does not involve moving the hand from one location to another. This information is not available for the Long dataset which did not distinguish between straight paths and no path.

15. Almost mandatory: it might be possible to get around this by using a hybrid model with some kind of suprasegmental root node and internal segments. For example, in a manner similar to Sandler’s (1993) spreading handshape and location features, it could be argued that circling spreads to all segments.
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Van der Kooij, Els.  
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. 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.

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

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 in 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., ꞌ and ꞇ have one finger different, ꞌ and ꞉ 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 in the candidate set could represent the selected finger combinations in the handshapes 🖐️, 🖐️, 🖐️, 🖐️, 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.

(9) Example constraint ranking for HKSL

<table>
<thead>
<tr>
<th></th>
<th>MAXSF</th>
<th>*RING</th>
<th>ADJAC</th>
</tr>
</thead>
<tbody>
<tr>
<td>a.</td>
<td>✓9</td>
<td>**</td>
<td>*</td>
</tr>
<tr>
<td>(HKSL)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>b.</td>
<td>✓6!</td>
<td></td>
<td>*</td>
</tr>
<tr>
<td>(ASL)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>c.</td>
<td>✓5!</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(DSGS)</td>
<td></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.
A constraint-based account of distributional differences in handshapes

(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>![handshapes]</td>
<td>![handshapes]</td>
<td>![handshapes]</td>
</tr>
<tr>
<td>b. (ASL)</td>
<td>![handshapes]</td>
<td>![handshapes]</td>
<td>![handshapes]</td>
</tr>
<tr>
<td>c. (DSGS)</td>
<td>![handshapes]</td>
<td>![handshapes]</td>
<td>![handshapes]</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>![handshapes]</td>
<td>![handshapes]</td>
<td>![handshapes]</td>
</tr>
<tr>
<td>b. (ASL)</td>
<td>![handshapes]</td>
<td>![handshapes]</td>
<td>![handshapes]</td>
</tr>
<tr>
<td>c. (DSGS)</td>
<td>![handshapes]</td>
<td>![handshapes]</td>
<td>![handshapes]</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 inviolable.

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, IDENTSF, shown in (13). Unlike the 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 (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 DOCTOR and THOUSAND. These signs were originally borrowed from the initialized Old French Sign Language (OFSL) signs MÉDECIN and MILLE using ‘M’ handshapes (/thumb), but there seems to be a diachronic move toward the use of four selected fingers (fourth) as these signs lose their foreign status and their connection (i.e., Faithfulness) to the foreign, initialized forms.10 Tableaux (14) and (15) illustrate this lowering of rank for external Faithfulness to the fingerspelled letter ‘M’ (fourth) as contrasted with its two-fingered neighbor ‘N’ (second) (e.g., as in ASL’s minimal pair, DOCTOR vs. NURSE). In Tableau (14) (the original initialized ranking), the Faithfulness constraint IDENTSF is ranked higher than the Markedness constraints *RING and 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</th>
</tr>
</thead>
<tbody>
<tr>
<td>‘M’ ‘N’</td>
<td>SF:2</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>(OFSL)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>‘M’ ‘N’</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(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</th>
<th>IDENTSF</th>
</tr>
</thead>
<tbody>
<tr>
<td>‘M’ ‘N’</td>
<td>SF:2</td>
<td>* !</td>
<td></td>
</tr>
<tr>
<td>(OFSL)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>‘M’ ‘N’</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(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 ️ vs. ️) 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 relationship 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="image" alt="image" /></td>
<td><img src="image" alt="image" /></td>
<td><img src="image" alt="image" /></td>
</tr>
<tr>
<td>b.</td>
<td><img src="image" alt="image" /></td>
<td><img src="image" alt="image" /></td>
<td><img src="image" alt="image" /></td>
</tr>
<tr>
<td>c.</td>
<td><img src="image" alt="image" /></td>
<td><img src="image" alt="image" /></td>
<td><img src="image" alt="image" /></td>
</tr>
<tr>
<td>d.</td>
<td><img src="image" alt="image" /></td>
<td><img src="image" alt="image" /></td>
<td><img src="image" 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. Tableaux (19) and (20) show the cross-linguistic variation in such inventories for ASL, DSGS and HKSL. Interestingly, none of the three languages ranks Faithfulness to iconicity above all else (in this case, faithfulness to the infinite number of real-world surface-sizes 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>Infinite number of object thicknesses</th>
<th>*RING</th>
<th>MaxSS contrasts</th>
<th>Mindist = SF:2</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. (not attested)</td>
<td>![Image]</td>
<td>*</td>
<td>![Image]</td>
</tr>
<tr>
<td>b. ∈ (ASL)</td>
<td>![Image]</td>
<td>✓</td>
<td>3</td>
</tr>
<tr>
<td>c. (DSGS/HKSL)</td>
<td>![Image]</td>
<td>✓</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>Infinite number of object thicknesses</th>
<th>*RING</th>
<th>Mindist = SF:2</th>
<th>MaxSS contrasts</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. (not attested)</td>
<td>![Image]</td>
<td>*</td>
<td>![Image]</td>
</tr>
<tr>
<td>b. ∈ (ASL)</td>
<td>![Image]</td>
<td>*</td>
<td>![Image]</td>
</tr>
<tr>
<td>c. ∈ (DSGS/HKSL)</td>
<td>![Image]</td>
<td>✓</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; Stungis 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 conventionalized 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.
10. 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.

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

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

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ASL Movement Phonemes and Allophones

*Kathryn L. Hansen*

1. Introduction

The phonological movements of signed languages can be analyzed as independent phonemic segments, in contradistinction to “non-movement” phonemes (comprised of hand configuration, location, contact, and so on). Research is under way whereby the concept of the phoneme is being applied to the movement portion of American Sign Language (ASL). Thus far, approximately two dozen movement phonemes have been identified, with ongoing analysis expected to further refine this number. These movement phonemes are articulated through their respective allophones, whose phonetic factors are predictable from adjacent “non-movement” segments (analogous to syllable onset and coda). This chapter shares background information on sign language movements, briefly explains two views of the phoneme, and describes a method for segmenting signs. This chapter then shows how to determine phonemic contrast and offers examples of ASL movement phonemes with their allophones.

Movement phonemes refer to a phonological target while movement allophones are the phonetic manners of achieving that target. The relationship between these two is captured through the phonemic statement (irrespective of theoretical processes involved: rules, constraints, etc.). The phonological movement segment (conceived as an abstract mental representation) refers to the “type” of movement, which involves finger, wrist, and arm (path, arc, circle, and pivot) movements, as well as referring to the “direction” of the movement, which is the final target of what moves (such as the fingers being extended and spread, the palm facing downward, or the forearm having a sagittal orientation). Allophonic movements express the physical manner of achieving the target, such as wrist supination or pivoting the forearm forward then downward.

As the claim of this project involves the phonemic status of sign language movements, background information is provided in section 2, beginning with an overview of the role of “movement” in sign language phonological theory (2.1), followed by a short discussion of the concept of the
phoneme (2.2). Section 3 describes the methodology used for determining segments (3.1) and movement phonemes (3.2) in ASL. Section 4 offers a variety of movement phonemes with their respective allophones and the conditions under which the allophones occur. Section 5 concludes the chapter, summarizing the conditioning factors for the movement allophones, mentioning unresolved issues, and showing possible future applications of this approach.

2. Background

Stokoe (1960) identified three dimensions of contrast in his groundbreaking work: location, handshape, and movement (using current terminology). He considered these to be sign language equivalents of phonemes, which showed phonological contrasts similar to the phonemes of spoken languages. The constructs of location, handshape, and movement have remained within phonological theory, although they are now considered “parameters” rather than “phonemes”. Other parameters have since been noted, such as focus or contacting region (Battison 1978, Klima and Bellugi 1979, Mandel 1981), point of contact (Liddell 1984), palm orientation (Frischberg 1975, Battison 1978), proximity (Mandel 1981), and selected fingers (Mandel 1981).

2.1 Sign language movements

The formal study of sign language movement begins with Stokoe’s (1960) original analysis of movement as the sign language equivalent of a phoneme. He identified 24 movements, which included gross arm movements, wrist movements, and finger movements, as well as various interactions between the two hands. In Stokoe’s analysis, all movement types were classified as “movement” and were distinct from and independent of location and handshape.

In the 1980’s, Liddell and Johnson (Liddell 1983, 1984, Johnson and Liddell 1984, and Liddell and Johnson 1989) introduced the division of signs into “Movements” and “Holds”, with their corresponding segment types, M and H. The M and H segments occur along a syntagmatic axis, meaning that they are sequentially ordered relative to each other. Each H segment associates with one feature bundle that indicates the physical posture of that portion of the sign. The M segment associates with two feature bundles, capturing the postures at the beginning and at the ending of the movement. Because these
beginning and ending postures of the movement are identical to the adjacent H segments, they are conflated, with the result that the M segment associates with the feature bundles of the preceding and following H segments. The movement is the articulation between these two feature bundles, being interpolated from the two H segments. Modifications or further characteristics of the movement, such as finger wiggling, speed, tension, and shape, are captured by features within the M segment itself. Such features distinguish, for example, a path from an arc, since the beginning and ending postures of these signs would be identical between them while the actual movement differs.

This Movement-Hold model is based on the generative concept of feature bundles, although it has an element of autosegmental phonology through the M segment associating to two H segments. As autosegmental phonology became more widespread, sign language movements were represented by feature geometries, as with Sandler (1989). With a feature geometry, the sign as a unit is represented through class nodes that are organized around the articulators used in sign language. Certain class nodes associate with segmental units along a skeletal tier (which captures the syntagmatic axis). In Sandler’s model, these skeletal tier units are labeled “L” for “location” and “M” for “movement”. The movement segment carries features that modify the movement, such as [tense], [restrained], and [arc]. Path movements in an LML sign begin at one location (the first L) and end at a different location (the second L). Hand configuration movements divide into handshape change and orientation change. Handshape change is captured through two different feature values associated with the Fingers node. Orientation change is captured through two different feature values associated with the Orientation node. In both of these cases, the difference between the two feature values for the class node indirectly represents the movement.

The next major shift in representing sign language movements came with Brentari’s (1998) Prosodic Model. While also using a feature geometry, this model gathers the movements under one class node, the Prosodic Features (PF) branch of the feature tree. This collection of the movements under one label alludes back to Stokoe, who classified the movements as a single group. In Brentari’s model, the articulator node (capturing handshape) and the place of articulation node (capturing location) are subsumed under the Inherent Features (IF) branch. Thus a division is made, via the structure of the geometry, between the movement and the non-movement portions of the sign. The PF branch captures different types of path movements, orientation changes, and finger movements. Paths and finger movements are represented indirectly by interpolation whereby the value of a location or setting feature
(for paths) or of an aperture feature (for finger movements) in the PF branch differs from the value of its corresponding node in the IF branch. Orientation changes are represented by features capturing dynamic movements in the PF branch ([supination], [pronation], etc.). The path and finger movement features, then, represent static postures while the orientation features refer to dynamic movement. Path movements associate with two timing slots (x-slots) on a timing tier (the syntagmatic axis), one for the beginning and one for the ending of the path, while finger and orientation movements each associate with a single timing slot. The movements are unified within a single branch of the feature tree while varying in how they are treated within that branch.

The current proposal continues to develop the notion of phonological movements. Conceptualization of movement began as a “phoneme” occurring simultaneously with other “phonemes” of the sign, then shifted to a segment type, M, occurring sequentially with H (Hold) segments. After this, various feature geometries viewed phonological movement as changes in the feature values of class nodes, not being a segment type at all. Over time, then, movement was regarded less and less as a phoneme or as a segment in its own right, instead becoming the result of a change in feature values with the consequent interpolated movement. One common thread, however, involves movement as a separate aspect of the sign. For Stokoe, it was a separate phoneme. In the Movement-Hold model, Hold segments associate with one feature bundle while Movement segments associate with two. In feature geometries, the non-moving aspects are represented by one feature value per class node while the movements are captured by two feature values per class node, with one of these models capturing movement in its own branch. In the model proposed here, the distinction between movements and the non-movement portions is maintained, as well as the concept of sequentially-ordered movement segments. However, in this model, movement is not interpolated. Rather, it has phonemic status as a distinct segment type. If represented by a feature geometry, the movements and the non-movement segments would have separate root nodes along the skeletal or timing tier, with each root node having its own feature tree. Thus, a sign with three segments would have three root nodes and three feature trees. The innovation presented in this proposal is that movement segments are discrete syntagmatic phonemes, phonologically independent from the non-movement segments. The movements are not dependent on non-movement parameters: If the non-movement information were removed from the phonological system, the movement system would remain.
2.2 Phonemes

Phonemic status was attributed to location, handshape, and movement by Stokoe (1960). This status was the result of applying the structuralist method of phonemics to the manual communication system that became known as ASL. The term “phoneme” (or Stokoe’s analogue, “chereme”) was subsequently replaced by the term “parameter” as the American structuralist view of the phoneme was being questioned, in conjunction with the rise of generative linguistics, which disregarded the notion of the phoneme.

Structuralism has had two main schools of thought: American structuralism and European structuralism. Between these two groups, the notion of the phoneme differed. A simple description of the difference is that the European structuralists considered the phoneme to be a mental concept while the American structuralists viewed it as a family of phonetic segments. The European view stemmed from Saussure’s “sound image” as a mental construct of segmented speech (Anderson 1985) while the American structuralists were influenced by the theory of behaviorism, whereby mental constructs were disregarded; however, some American structuralists, notably Kenneth Pike and Edward Sapir, retained the phoneme as a mental construct. The American view included the condition of “biuniqueness”, which claimed a one-to-one correspondence between the spoken segment and the phoneme. Biuniqueness was later shown to be flawed (Chomsky 1964), and this played a role in the subsequent disregard of the phoneme as a phonological construct. This disregard can be seen in the shift of the representation of sign language movement, as shown above (including the shift of the term “phoneme” to “parameter”).

Fundamental to the structure of language, according to the European view, was the concept of oppositions (Trubetzkoy 1933[1969], Baltaxe 1978). The phonetic difference between two opposing (that is, contrasting) segments was the articulatory element or mark that distinguished them from each other. For example, in English, “zeal” and “seal”, which signify different concepts, differ only in their first segment (thus showing these two segments to be phonemic). The phonetic difference between these two segments is voicing: [z] is marked with voicing while [s] is not. The mark was the distinguishing feature, later to take on the name “distinctive feature”. (Herein, too, lies the beginning of the theory of markedness.)

Within generative phonology, oppositions do not play a role in the linguistic system (Chomsky and Halle 1968: 298). The contrastive phoneme was replaced by the non-contrastive “underlying representation”, and allophones were replaced by “surface representations”. The notion of biunique-
ness, a problem for American structuralism, was thereby eliminated, yet so was the notion of contrast within the phonological system, although the notion of contrast had not been problematic.

Returning to signed languages, Stokoe’s approach followed American structuralist methods. Stokoe noticed that certain signs which contrasted in meaning showed only one articulatory difference, which meant that that aspect of the articulation was contrastive. If we eliminate structuralism as a valid or viable form of analysis, then we invalidate Stokoe’s analysis, along with his foundational contributions to sign language linguistics. This is not a small matter. However, by combining the view that languages are structured as systems with the view of the mental construct of the phoneme as a unit in opposition to other phonemes, we can arrive at a definition of the phoneme that acknowledges the framework used by Stokoe while excluding its downfalls (such as biuniqueness).

The definition of “phoneme” offered here is as follows: The phoneme is a phonologically contrastive syntagmatic segment. The phoneme is phonological by being a mental representation, as opposed to a phonetic or articulatory expression. It is contrastive in that it is not predictable within a particular linguistic system, being distinct from other phonemes within the system. It is syntagmatic, occurring in a sequentially-ordered relationship with respect to other phonemes. It is a segment or segment-sized unit that is smaller than a syllable and larger than a feature, able to associate with syllable positions and being comprised of features. The allophone is the phonetic expression of the phoneme, conditioned by specific environments.

How phonemes are represented phonologically (e.g., feature bundles, feature geometry, base input for a constraint-based system) is not addressed in this chapter. The point is that sign languages have phonemes, specifically movement phonemes, irrespective of specific theoretical internal organization. Whether these phonemes equate with the root nodes of a feature geometry or some other system of representation is independent of the matter of phonemic movement and non-movement syntagmatic segment-sized units existing in sign language. However, if one were to consider a feature geometry (Sagey 1986), then the root nodes would carry the phoneme labels, and the class nodes and tiers would be based on the dimensions of contrast, as indicated by the respective linguistic system, with the features carrying only contrastive information. With this view, the feature tree would not necessarily be based on articulators but on dimensions of contrast, which ultimately refer to phonetic differences, since contrast is determined in part by the phonetics.
3. Methodology

The determination of phonemes and allophones is based on the distribution (and behavior) of phonetic segments within the linguistic system. Before determining phonemes, then, phonetic segments must be ascertained. For spoken languages, phonetic segments are recognizable because many spoken languages have been analyzed and described, showing cross-linguistic patterns in the dimensions of contrast that occur (major class, voicing, place of articulation, and so on). Such is not the case, at the moment, for signed languages. The analysis must begin at a more fundamental level. The sign language segment must be established (Section 3.1); then these segments may be analyzed for their phonemic status (Section 3.2). (Section 3.3 describes the data set used for this project.)

3.1 Determining segments

In discussing segments and syllables for signed languages, Wilbur (1990: 89-90) states that “the absence of a mechanically applied segmentation procedure does not necessarily rule out the possibility that a careful linguistic analysis could reveal phonologically significant segmental units….” She argues that “despite the difficulty of arriving at a segmentation, it exists and is in common use for spoken languages. That it has not been adequately done for signed languages does not mean that it is impossible to do” (p. 90). The current project shows her to be correct by introducing a method for determining segments in signed languages.

At a very basic level, any phonetic change that occurs during an articulation (whether signed or spoken) may be considered a change between two phonetic segments. This, then, is a starting point. Further analysis will show how the segments fit into the linguistic system.

Applying this to sign language, the basic approach for segmenting signs is as follows. Any sign that involves contact at one point in the articulation and no contact at another point in the articulation must, by definition, be comprised of two phonetic segments. The change between contact and no-contact shows a segmental difference at the phonetic level. This establishes two phonetic segments for any such sign. If a sign begins with contact, does not have contact during its movement, then ends with contact, three segments are involved, based on the two changes in the status of “contact”.
With phonetic segments being defined by change, what happens with movements? Movements involve a continuous state of change. One might argue that the changes within a movement constitute a vast number of separate segments, thereby invalidating the definition of phonetic segments (since a movement would consist of uncountable segments) or invalidating movements as segments (due to their constant changing). The argument against this is that the changes are continuous, not discrete (as a process rather than a state). With an infinity of postures within the movement, it is not possible to measure each and every one of them. (No level of measurement can capture all the minutiae of changes that are involved; regardless of the number of decimal places measured, there is always one more decimal place available to measure.) Rather, movement segments must be viewed holistically. On a perceptual level, a “path” movement is one movement; if it changes direction (perhaps from moving forward to moving downward), this is identifiable and perceptible and constitutes a change, signifying a different phonetic segment. When a movement stops, the constancy of moving is broken, and the existence of a separate phonetic segment must be considered.

Some signs have finger movement that results in the distal portion of the thumb contacting the distal portion of one or more fingers of the same hand (e.g., ASL TURN-OFF-LIGHT). Two changes are involved here: (1) finger movement changes to the fingers being static and (2) no contact between the thumb and finger(s) changes to contact between them. These changes coincide with each other in terms of timing along the syntagmatic axis. Since the changes co-occur, two segments are established.

In a sign such as BODY, four segments may be identified, with one possible transitional movement: (1) movement of both hands back (or in) toward the upper torso; (2) contact of the two hands with the upper torso; transition; (3) movement of both hands back (or in) toward the lower torso; and (4) contact of the two hands with the lower torso. The changes involve (1) movement without contact to contact without movement, (2) contact without movement to movement without contact, and (3) movement without contact to contact without movement. These three changes indicate four phonetic segments.

Some signs have no contact. Segmental analysis of such signs involves identification of the presence or absence of a period of no movement (stasis), when the sign is held in the signing space, either at the beginning or at the ending of the movement. Frame-by-frame video analysis may be required for this. If, for example, a transitional movement places a sign at the beginning of the sign’s movement, at which point the handshape is clear rather than blurry, then the hand is no longer moving; it is a phonetic segment, the beginning of the sign. As the hand moves, it blurs. Such a sign, with the description just
given, has two segments: (1) the initial static portion and (2) the movement portion. A similar situation would exist if the movement ended with a clear frame, indicating a static segment at the end of the movement.

If there is no stasis either at the beginning or ending of the movement, then an initial non-movement segment is assumed because the hand configuration must be specified, and this is part of the non-movement system, not the movement system. A non-movement segment must be involved, and the hand configuration exists at the beginning of the sign, so the onset of the sign is the non-movement segment. Segmentation of such signs is based on the structure of the system rather than on phonetic changes.

The movement of some signs occurs more than once. In cases of reduplication, the reduplicated portion simply occurs twice (or more than twice if reduplication exceeds two), and the reduplicated segments occur twice. In cases of uncounted movements (termed “oscillation” by Liddell 1990 and “trilled movement” by Padden and Perlmutter 1987), a separate mechanism exists to account for this, introduced in Section 4.1. In some signs, the articulators move simultaneously in opposite directions (such as one hand movement downward while the other hand moves upward, 180° out of synchronization with each other). This occurs when the syllable onset is one-handed and the movement is two-handed, with other conditions applying. (See Hansen 2006 for further details.)

3.2 Determining phonemes

Once the segments are identified, they are analyzed for their contrastive status within the phonological system. Implicit in the writings of Trubetzkoy (1969 [1939]), Pike (1947), and Jakobson, Fant, and Halle (1955) is the notion that discrete phonetic segments “default” to separate phonemes unless their distributions indicate otherwise. It is this distribution that must be analyzed. If two adjacent segments are identified in a language, whether spoken or signed (and every language has at least two phonetic segments which occur adjacent to each other), then a distributional analysis may determine if they are instantiations of the same phoneme or of different phonemes. The more phonetically similar two segments are, the more likely (or “suspicious”) they are to be allophones of the same phoneme. In the absence of evidence for allophonic distribution (in other words, if they are not allophones of the same phoneme), they may be considered distinct phonemes for the language under analysis. (At times, due to lack of data, determination of phonemic status may be suspended, pending further analysis.)
One guideline for identifying phonemes, proposed by Trubetzkoy (1969 [1939]), states that two adjacent non-identical segments, occurring within the same morpheme, are not members of the same phoneme. That is, for spoken language, a phonetic articulation of (monomorphemic) [dt] (which differ only in voicing) is not an instance of phonemic /dd/ or /tt/. The [d] and the [t] segments are instantiations of separate phonemes (perhaps /d/ and /t/, respectively). (With the phoneme being a phonological unit and the articulation being a phonetic unit, the phonetic unit is an instantiation of its respective phoneme.)

Trubetzkoy does not claim that [dt] cannot be an instance of a single phoneme. In English, the phoneme /d/ occurs as phonetic [dt] (shortened in length) insofar as it is partially devoiced when word-final. The matter of affricates is also not addressed by his claim; whether two adjacent phonetic segments pattern as an affricate is determined by the distribution and behavior of the segments within the system.

In support of Trubetzkoy’s guideline, we have the following example. One could assume that the phoneme /d/ has two allophones, [d] and [t]. [t] occurs when it follows [d] in the same morpheme. The notation to capture this is /d/ → [t] / [d] ___. (Elsewhere, /d/ → [d].) What would be the motivation for this? On what phonetic segmental or prosodic grounds could this be established? Cross-linguistically, consonant clusters tend to share voicing, rather than diverge in voicing. Devoicing of a segment because it is in a consonant cluster is unmotivated. Being unmotivated, any such rule could be posited: /g/ → [j] / [g] ___; or /r/ → [m] / ___ [r]. It could never be shown that [gj] is an instantiation of /gg/ or that [mr] is an instantiation of /rr/ (although it could be disproven by the existence of phonetic [gg] or [rr], which would be perceived as lengthened [g:] or [r:]). If timing slots and autosegmental phonology are assumed, then the presumed existence of two adjacent identical phonemes would actually be one phonological segment associating with two timing slots; it would involve only one phoneme, not two adjacent identical phonemes. There seems to be no motivation for identical (monomorphemic) phonemes to differ phonetically as a result of simply being adjacent to each other. Trubetzkoy’s guideline is accepted.

Pike (1947) provides a method for determining the phonemic (contrastive) nature of segments, one that does not rely on minimal pairs. This method is based on the distribution of phonetic segments and whether or not this distribution is predictable. If two (or more) phonetic segments complement each other in their distributions (explained below), then they may be considered separate instances of the same phoneme, with their phonetic differences corresponding with some factor in the environments in which
they occur. One tenet of this approach is that allophonic changes are motivated by segmental or suprasegmental (prosodic) factors. Another tenet is that the segments in question are phonetically similar. A third tenet is that the motivating factor is reasonable. (For example, devoicing of a voiced onset based on the voicelessness of a coda consonant that is two syllables away is not considered reasonable.)

A comparison of the distributions of two segments begins with noting the phonetic similarities and differences between the two segments in question. The similarities provide support for suspecting that the segments may be allophones of the same phoneme. The differences provide the impetus for ascertaining whether their respective occurrences can be predicted. If a phonetic difference correlates with some factor in the environment of these segments, then the phonetic difference is predictable from that environmental factor. In this case, the difference is not contrastive (phonemic); instead, the segments are allophones of the same phoneme.

Environmental factors involve segmental elements such as (for spoken language) nasality, manner, voicing, vowel height, etc., and (for sign language) handedness (whether one or two hands are involved in the articulation of a segment), proximity to place of articulation, forearm and finger postures, finger vs. metacarpal contact, place of articulation, movement type and direction, etc. Environmental elements may also involve prosodic or suprasegmental factors, such as stress or syllable position (for both signed and spoken languages).

Once the similarities and differences between two particular segments are noted, two token signs are selected that contain these segments (with one sign token containing one of the segments in question and the other sign token containing the other segment), controlling for identical environments as much as possible. If the environments are identical (which includes position within the syllable), then the signs form a minimal pair because the only difference between the two signs is the segment in question; in this case, these segments are contrastive (phonemic). If the environments are analogous (virtually similar) but not identical, a hypothesis is made that the difference between the two segments in question corresponds to a difference in the environment, such that segment A only occurs in environment X while segment B never occurs in environment X. A search is then conducted for words (signs) in that language that refute the hypothesis.

While hypothesizing that segment A only occurs in environment X and B never occurs there, if a search of the language reveals that segment A also occurs in environment Y (and not just in environment X), or else that segment B occurs in environment X (such that segment A is not the only
segment occurring in environment X), then the distributions of segments A and B overlap with respect to environments X and Y, and the hypothesis is refuted. If this situation occurs for each difference in the environments of the segments in question, then these segments are phonemic, not predictable. On the other hand, if the hypothesis is supported, then they are allophones of the same phoneme; the phonetic articulations of the phoneme are predictable from the environments in which they occur. (Detailed steps for the phonemic method are available in Pike 1947 and Hansen 2006.)

An example of contrastive distribution is shown in Table 1, involving arm pivot movements. The top row lists the initial postures of the forearm; the left column lists the targets of the pivot movement (resulting in a lateral, sagittal, or vertical forearm). (Note that the postures and targets are categorical. Phonetically, actual signs may show slight characteristics of more than one category.) The table has been simplified for expository purposes. (Some examples also have a path movement.) Considering the environments where each pivot direction occurs, there is overlap in the distributions, with each pivot direction occurring with at least two initial forearm postures. This distribution shows that pivot movements contrast (at least in this environment); they cannot be conflated into a single phoneme with predictable allophonic articulations based on initial forearm posture.

Table 1. Contrastive distribution of pivot movements: Rows contain data in multiple cells; conflation of columns would result in a loss of information.

<table>
<thead>
<tr>
<th>Initial Posture</th>
<th>Lateral forearm</th>
<th>Sagittal forearm</th>
<th>Vertical forearm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lateral pivot</td>
<td>AMONG$^5$</td>
<td>CLOSE-DOOR$^6$</td>
<td>DAY$^7$</td>
</tr>
<tr>
<td>Sagittal pivot</td>
<td>TRAVEL$^8$</td>
<td>LEND$^9$</td>
<td></td>
</tr>
<tr>
<td>Vertical pivot</td>
<td>BORROW$^{10}$</td>
<td></td>
<td>GOODBYE$^{11}$</td>
</tr>
</tbody>
</table>

For complementary distribution, Table 2 shows data for the fingers that move during finger movement (left column), based on the selected fingers (SF) (top row). The thumb has been disregarded because it belongs to a different system. Focusing on the movement, in considering which fingers move, the rows can be conflated into a single row with no overlap of data. In this example, the columns can also be conflated with no data overlap (such is not always the case). The table shows that the fingers which move are the fingers which are selected. Finger movement that is based on the fingers which move is not contrastive. If two signs each have finger curving, for instance, with only the index finger moving in one sign while all four fingers
move in the other sign, then the difference in the fingers which move is not a relevant factor for finger curving movement because it is predictable from the selected fingers. (Selected finger information is part of the non-movement system. Evidence for this comes from signs in which there is no finger movement yet the finger posture carries information.)

Table 2. Complementary distribution for which fingers move: Only one cell per row contains data; the columns may be conflated with no data overlap.

<table>
<thead>
<tr>
<th>SF Movement</th>
<th>Index finger</th>
<th>Index &amp; Middle</th>
<th>Middle finger</th>
<th>All four fingers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Index finger</td>
<td>ASK&lt;sub&gt;12&lt;/sub&gt;</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Index &amp; Middle</td>
<td></td>
<td>BOTH&lt;sub&gt;13&lt;/sub&gt;</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Middle finger</td>
<td></td>
<td></td>
<td>DOG&lt;sub&gt;14&lt;/sub&gt;</td>
<td></td>
</tr>
<tr>
<td>All four fingers</td>
<td></td>
<td></td>
<td></td>
<td>BETTER&lt;sub&gt;15&lt;/sub&gt;</td>
</tr>
</tbody>
</table>

Beyond the determination of phonemes and allophones, the dimensions along which the phonemes contrast (such as type of movement, direction of movement, handedness of movement, contact during movement, or place of articulation, proximity to a place of articulation, spreadedness of the fingers, etc.) are noted, and features to capture these contrasts are labeled.

3.3 Data

The data used for this project come from the book *Gallaudet Survival Guide toSigning* (Lane 1990). This book explains the articulations of 507 different ASL signs (nouns, verbs, adjectives, adverbs, negations, and prepositions) through verbal descriptions and line drawings. Since the signs were already selected and described, it was not necessary to create a word list, record a signer, download the files, and code them. The descriptions were entered into a Filemaker Pro<sup>16</sup> database which was designed for this project.

Some drawbacks of this approach became apparent while coding the data. The verbal descriptions and line drawings did not always correspond with each other, and sometimes the verbal descriptions and line drawings were inadequate. If there was a question about a phonetic articulation, it was not possible to review a recording of the sign. If time and resources are available, live recordings are preferred; however, even with the problems encountered in coding signs from this book, a system for the movement portion became
4. Results

This section presents numerous ASL movement phonemes that have been determined, along with their allophonic variations and the conditions under which the allophones occur. These are presented as modified phonemic statements, taking liberties in the format to save space (combining Pike [1947] and Chomsky and Halle [1968] and introducing new notations).

The list offers token movement phonemes for the different movement types and directions, not presenting the full list of contrastive movements. Two aspects have yet to be considered in more detail. Contact during movement has not been analyzed for each particular movement type and direction. However, contact during movement as a whole has been shown to be contrastive (Hansen 2006). Where it affects the phonetic movements, it is included as part of the movement phoneme; otherwise, it is omitted. Also, handedness (as defined in Section 3.2 and below in this section) is contrastive overall but has not been analyzed for the individual movement types and directions. Where it affects the phonetic movements, it is included as part of the movement phoneme; otherwise, it is omitted.

The format for the phonemic statement used here begins with the phoneme in slashes: /phoneme/, stated in prose, in the absence of a phonetic notation system that represents sign language segments. Following the phoneme is the first (or only) allophone, listed in square brackets: [allophone], stated as a prose description of its phonetic articulation. A slash (“/”) introduces the environment in which the allophone occurs. Onsets and codas are explicitly labeled for clarity, with an equal sign (“=”) indicating the relevant values. The blank line (“___”) shows where the phoneme appears with respect to the environment. Examples (ASL glosses) are then provided. Multiple allophones per phoneme are each listed in this fashion.

For example, the first phonemic statement in (1) below can be read as follows. “/Pivot, Lateral, No contact, One-handed/” means that the phoneme is one-handed, moving as a pivot from the elbow in a lateral direction with no contact during the movement. (Although the phoneme label contains several words, it is only one phoneme.) “[pivot contra then down]” means that this allophone is expressed as a pivot from the elbow that begins with the hand moving contralaterally and then the hand shifts to a downward direction, with the movement source still being the elbow, as a single movement. “/ Onset =
Forearm vertical ___” signifies that this allophone occurs in the environment (introduced by the slash) where the onset of the sign has a vertical forearm (for the active articulator). “Example: MISS” indicates that the sign MISS has this environment and this allophone.

Some explanations are in order. Abbreviated forms are used: “contralaterally” is shortened to “contra”, “ipsilaterally” to “ipsi”, “upward” to “up”, “backward” to “back”, and “downward” to “down”. If a movement segment is “two-handed”, then both hands move, regardless of handshape. If a non-movement segment is two-handed, then the two hands share all specifications (including handshape), being identical and bilateral. If a sign has a (phonologically) one-handed onset and a two-handed movement, the movement direction refers to the dominant hand (the one in the onset); typically, these are the signs that show alternating movement. Gaps exist in the allophone sets due to gaps in the data.

The phonemic statements begin with a discussion of /lateral pivot/. A detailed explanation of the terminology is found in Hansen (2006). Ex post facto recordings of the signs mentioned below accompany this volume.

4.1 /Lateral Pivot/

The class of /lateral pivot/ movements involves arm movement originating from the elbow that targets a lateral forearm posture (horizontal forearm with hand and elbow pointing generally ipsilaterally-contralaterally). (This posture may show phonetic variation in its degree of lateralness, being somewhat sagittal or somewhat vertical.) A pivot is distinguishable from a path by the presence of a change in the categorical orientation of the base knuckles (metacarpals). (Short pivots and short paths can be indistinguishable from each other.)

The movement of the ASL sign DAY has the phonological description /lateral pivot/ (Hansen 2006). This /lateral pivot/ contrasts phonemically with other pivot directions: /compact pivot/, as in BORROW, and /extended pivot/, as in LOAN. /lateral pivot/ also contrasts phonemically with other lateral arm movements: /lateral arc/, as in WE; /lateral circle/, as in LIBRARY; and /lateral path/, as in FLOOR.

Phonetically, DAY moves as a [pivot contralaterally then downward], where “pivot” indicates the type of movement, “contralaterally” states the first cardinal direction of the pivot, and “downward” indicates the following cardinal direction. That is, the movement begins with the hand and forearm heading in a contralateral direction, with the forearm rotating from the
elbow, and then, as the hand and forearm get lower, they move downward; hence, “contralaterally then downward”. The environment that conditions this particular phonetic execution of /lateral pivot/ is the vertical posture of the forearm in the initial position of the sign, which is the syllable onset, with the pivot being the syllable nucleus.

This allophonic articulation differs from the phonetic articulation of the /lateral pivot/ of READY (the version that occurs horizontally). This movement occurs as a [pivot ipsilaterally then backward]. (The articulation would move the arms toward the back if it were articulated for a full 90°. A similar situation exists for VERY, below.) The conditioning environment for the phonetic expression of the /lateral pivot/ of READY is the sagittal forearm of the segment at the beginning of the sign, in the syllable onset. Regardless of the initial forearm posture (vertical in DAY or sagittal in READY), a /lateral pivot/ invokes movement that results in the forearm having a lateral orientation (categorically, with physiological variation in the degrees of “lateralness”). DAY and READY differ in their phonetic articulations yet share the same phonological specification: a pivot movement to a lateral forearm.

While DAY begins with a vertical forearm and READY with a sagittal forearm, what happens if the forearm is lateral in the onset segment? How can a forearm that is already lateral be involved in a /lateral pivot/? In this case, there is still a phonological specification to execute a pivot movement. With the initial (onset) posture and target (movement) posture being the same, the arm moves by pivoting in place: the forearm oscillates (in this instance, shaking back and forth on the horizontal plane). This lateral pivot oscillation is exemplified by the sign AMONG. (AMONG also has a path movement, which does not oscillate. AMONG has two movement types in the same syllable. This is being called a “movement diphthong”. Path movements are immune to oscillation in movement diphthongs, suggesting that they are underspecified phonologically, having default values.)

The signs DAY and READY are each specified for a /lateral pivot/ and each begins with a vertical forearm, yet the phonetic directions of the pivots differ. In DAY, the arm executes a [pivot contralaterally then downward]; for READY, it makes a [pivot ipsilaterally then downward]. (As with READY, the movement in READY does not clearly articulate the second movement direction, which is “downward”, yet it would if the movement were articulated for a full 90°.) This difference (contralateral vs. ipsilateral) is due to the presence or absence of contact (or close proximity) between the dominant hand (H1) and the place of articulation in the initial segment. (If the elbow touches the back of the non-dominant hand in DAY, this contact is irrelevant since the elbow is not the hand; also, this contact does not seem to be required.) If the syllable onset
specifies proximity (including contact) between H1 and a place of articulation, then the /lateral pivot/ begins its movement ipsilaterally. Without this initial proximity, the /lateral pivot/ starts moving contralaterally. Three /lateral pivot/ phonemes are shown with their allophonic variations in (1) through (3).

(1) /Pivot, Lateral, No contact, One-handed/
   → [pivot contra then down] / Onset = Forearm vertical ___
      Example: MISS (as well as DAY)
   → [pivot ipsi then back] / Onset = Forearm sagittal ___ No coda content
      Example: THEY\textsuperscript{17, 18}
   → [pivot contra then back] / Onset = Forearm sagittal ___ Coda content
      Example: CLOSE-A-GATE
   → [pivot back-forward oscillate] / Onset = Forearm lateral ___ No coda content
      Example: AMONG

(2) /Pivot, Lateral, No contact, Two-handed/
   → [pivot ipsi then down] / Onset = Forearm vertical, Manner proximal ___
      Example: VERY
   → [pivot contra then down] / Onset = Forearm vertical, Manner non-proximal ___
      Example: DARK
   → [pivot ipsi then back] / Onset = Forearm sagittal, Manner proximal ___
      Example: READY
   → [pivot contra then back] / Onset = Forearm sagittal, Manner non-proximal ___
      Example: WIND

(3) /Pivot, Lateral, Contact, One-handed/
   → [pivot back-forward oscillate] / Onset = Forearm lateral, Manner proximal ___ No coda/second mora content
      Example: WASH
   → [pivot up-down oscillate] / Onset = Forearm lateral, Manner non-proximal ___ No coda/second mora content
      Example: DISCUSS
4.2 /Fingers Compact Flat/

The phoneme /fingers compact flat/ involves finger movement that targets closure of the selected fingers while not involving thumb movement. The designation “compact” reflects the closure while “flat” indicates that the thumb does not move. The allophones differ only in which fingers move, which is predictable from the selected fingers in the non-movement segment. A phonemic statement is provided in (4). (The examples also exhibit arm movement, which would associate with the syllable nucleus as a movement diphthong. The phonemic status of this diphthong as a unit is not yet determined.)

(4) /Fingers Flat, Compact/ → [α fingers close, not thumb]/ Onset = α SF ___
Examples: BECAUSE, BETTER, FAST, LEAVE, PREFER

4.3 /Fingers Extend Round/

The phoneme /fingers extend round/ involves finger movement that specifies finger extension. The “round” designation indicates that the selected fingers spread apart, and the thumb, if selected, moves in conjunction with the finger(s).

One allophone of /fingers extend round/ is articulated with [finger extension and spreading]. This entails simultaneous extension and spreading of the selected fingers, occurring when the fingers are not initially extended. A second allophone is articulated with [finger wiggling], as small rapid uncounted wiggling of the selected fingers, occurring when the onset has extended fingers. A phonemic statement is provided in (5).

(5) /Fingers Round, Extend/ (regardless of contact or handedness status)
→ [α fingers wiggle] / Onset = α SF, Finger height extended ___ No coda
   Examples: COLOR, DIRTY, FINGERSPELLING, FIRE, SALT, WAIT
→ [α fingers extend and spread] / Onset = α SF, Finger height non-extended ___
   Examples: BRIGHT, DON’T-LIKE, GROW, NOTHING, QUESTION (second syllable)
4.4 /Compact Rotation/

The phoneme /compact rotation/ involves “wrist” movement which targets a compact palm orientation. The “rotation” designation indicates that the forearm rotates, as opposed to the wrist bending (flexing). The term “compact” indicates that the rotation occurs in a supinating manner, resulting in the palm facing upward or backward, depending on the posture of the forearm. The allophones and conditioning environments are stated in (6).

(6) /Rotation, Compact/

\[\text{[wrist supination to palm back]} \] / Onset = Forearm vertical, Palm non-compact ___

Examples: FAMILY, SEEM

\[\text{[wrist supination to palm up]} \] / Forearm non-vertical (either onset or coda)

Examples: ALL, BOOK, HIRE, HOW, OPEN, TIRED

4.5 /Extended Flexion/

The phoneme /extended fexion/ involves wrist movement that targets an extended palm, which faces either downward or forward, depending on the forearm posture. The “flexion” designation indicates that the movement involves bending the wrist, as opposed to forearm rotation.

One allophone of /extended flexion/ is articulated with [oscillating wrist bend palmar]. This entails bending or nodding of the wrist with uncounted repetitions. The “palmar” description indicates that the palm of the hand bends toward the palmar side of the forearm. (Conversely, “dorsal” refers to the back of the hand bending toward the dorsal side of the forearm.) This allophone occurs when the forearm is vertical in the syllable onset and the palm orientation is extended (in this case, facing forward). A second allophone of /extended flexion/ is articulated with [oscillating wrist bend radio-ulnar]. This entails bending the wrist in a motion that alternates between moving toward the radial and ulnar sides of the hand, a “side-to-side” flexion. This allophone occurs when the initial palm orientation is extended (forward with a vertical forearm or downward with a horizontal forearm) with palmar contact at the hand location during movement. These and other allophones are listed in (7) and (8).
4.6 /Lateral Path/

The phoneme /lateral path/ involves straight (or basically straight) movement of the hand. The “lateral” designation indicates that the path movement occurs in a contralateral or ipsilateral direction, as opposed to forward/backward or upward/downward.

One allophone of /lateral path/ is articulated with an [ipsilateral path]. This entails a basically straight movement of the (dominant) articulating hand toward its ipsilateral side. Another allophone is executed with a [contralateral path], where the (dominant) hand moves toward its contralateral side. The conditioning environments for /lateral path/ allophones are shown in (9) through (12).
There is a problem with LEFT direction because the onset is non-proximal with the forearm vertical (non-lateral), so it is expected to move ipsilaterally yet it moves contralaterally. One possible phonological explanation for this is that LEFT might end with a hold in space, thus having a coda. The path movements in general invite further study.

(10) /Path, Lateral, No Contact, Two handed/

→ [contra path] / ___ Coda = Manner proximal
   Examples: HEAR, LAW, TICKET

→ [ipsi path] / ___ Coda = Manner non-proximal
   Examples: AND

(11) /Path, Lateral, Contact, One handed/

→ [ipsi path] / Onset = Manner proximal ___
   Examples: ARRANGE, FLOOR, MOVE, PRESIDENT

→ [contra path] / Onset = Manner non-proximal ___
   Examples: AFRAID, BRING, DO (first syllable), PARTY (first syllable)

→ [contra path] / ___ Coda = Manner proximal
   Examples: GAME, INTRODUCE, MEET

An apparent exception to (11) is if the movement occurs in the second syllable of the sign, in which case proximity in the coda results in an ipsilateral path, as in SCHEDULE, unless this second syllable begins with a proximal onset.

(12) /Path, Lateral, Contact, Two handed/

→ [ipsi-contra path oscillation] / Onset = Forearm lateral ___ No coda/second mora content
   Examples: BABY (contact in onset), ELECTRIC (no contact in onset)

→ [ipsi path] / Onset = Elsewhere ___
   Example: LEAD verb
4.7 /Lateral Circle/

The phoneme /lateral circle/ involves hand movement that targets a circular side-to-side motion. The “lateral” designation indicates that the circle contains or includes motions toward the ipsilateral and contralateral sides, while also including motion upward-downward or forward-backward.

One allophone of /lateral circle/ is articulated with a [horizontal counterclockwise lateral circle]. This movement entails a generally circular motion of the hand that occurs basically on the horizontal plane, moving counterclockwise as viewed from above. Another allophone of /lateral circle/ is articulated with a [vertical counterclockwise lateral circle]. This differs from the horizontal allophone in that the circular motion of the hand occurs vertically rather than horizontally, counterclockwise as viewed from the signer. Circle phonemes, allophones, and conditioning environments are offered in (13) through (16).

(13) /Circle, Lateral, No Contact, One handed/
→ [vertical circle counterclockwise] / Onset = Forearm vertical ___
Examples: FACE, MOUTH
→ [horizontal circle counterclockwise] / Onset = Forearm non-vertical ___
Examples: ABOVE, COLLEGE, BELOW

(14) /Circle, Lateral, No Contact, Two handed/
→ [horizontal circle counterclockwise oscillation] / Onset = Forearm lateral ___ No coda/second mora content
Example: TRA-VEL-AROUND

(15) /Circle, Lateral, Contact, One handed/
→ [horizontal circle counterclockwise] / Onset = Forearm sagittal, Manner proximal ___
Example: COFFEE
→ [vertical circle counterclockwise] / Onset = Forearm non-sagittal, Manner proximal ___
Examples: PLEASE, SORRY, USE
4.8 Oscillation

If a phonemic movement, as the syllable nucleus, specifies the very posture that exists in the syllable onset, then there can be no movement to that posture. However, there is a phonological specification for movement. To resolve this dilemma of moving to a posture where the articulator is already located, the articulator oscillates in place. Oscillation is invoked when the movement phoneme in the nucleus and the non-movement phoneme in the onset share certain phonological feature specifications. For finger movements, the finger posture is relevant. For wrist movements, the palm orientation is relevant. For arm movements, the forearm posture is the relevant factor.

Oscillation is precluded when there is phonological content in the coda or else in the nucleus as a movement diphthong. In other words, content in the second mora precludes oscillation (unless the first mora involves a path movement). For instance, the sign AND begins with a lateral forearm, which shares [lateral] and [arm] feature values with the /lateral path/ movement. This should induce oscillation. However, the sign ends with the fingers contacting the thumb (“distal thumb contact”). This distal thumb contact is specified in the coda. The movement does not oscillate due to content in the coda. (Support for distal thumb contact as a non-movement segment rather than as phonological finger movement comes from signs that exhibit distal thumb contact throughout the sign without finger movement, such as BUY and PUT, as well as signs that begin but do not end with distal thumb contact, such as GROW and BRIGHT.) Movement of the fingers to the final distal thumb contact is a phonetic effect of transitioning to the coda. In AND, oscillation is precluded by the coda content, the distal thumb contact. In other words, oscillation is precluded by a second mora in the syllable, path movements notwithstanding. (Perhaps oscillation behaves as a type of “vowel lengthening”, indicating that ASL prefers bimoraic phonetic syllables.)
5. Summary and conclusion

This chapter has argued that sign languages have phonemic segments, some of which are movements and some of which are non-movements. In support of this claim, ASL movement phonemes were presented with their allophonic variations, which correspond to the phonetic environments in which they occur. These phonemes and allophones were determined through the phonemic methodology of Pike (1947).

The conditioning factors for the movement allophones are summarized as follows. Finger movements are conditioned by the finger posture in the syllable onset. The selected fingers determine which fingers move. Wrist movements are conditioned by the palm orientation in the onset, in conjunction with the posture of the forearm. Pivot and circle allophones are conditioned by the posture of the forearm in the onset; pivots may also be conditioned by the manner (proximal, non-proximal) of the onset and the presence or absence of content in the second mora. Path allophones are conditioned by the manner of the onset segment, at times in conjunction with the forearm posture, or, if there is no onset, then the manner of the coda segment. Oscillation occurs for any movement type when the onset and nucleus share feature specifications between the relevant articulator and movement type and between the articulator posture and the movement direction. Oscillation is precluded if the coda contains phonological content or if there is a movement diphthong not involving a path movement.

Overall, allophonic variations for the movements of ASL are predictable from factors in the initial non-movement position, which is the segment in the syllable onset; from content in the coda segment; and from content in the second mora of a movement diphthong. This supports discrete syntagmatic movement and non-movement segments, as well as internal syllable structure along a syntagmatic axis (such as a skeletal tier, timing tier, or CV tier).

Several unresolved issues remain. The interpretation of the directions of path movements might not be correct. With natural signing, it can be difficult to determine if a path movement, for instance, is categorically [ipsilateral] or [extended] due to the physiology of having the two hands in contact with each other. A new system is being considered whereby the strict use of cardinal planes and axes is eliminated. Another issue involves wrist movements, which were difficult to analyze due to insufficient wrist movement data. The phonemic status of the various movement diphthongs has yet to be determined. The phonemic status of the non-movement segments is currently in progress. After the non-movement phonemes have been determined, at least as a first pass, it will be necessary to reconsider the phonological move-
ments in light of this newly-acquired information. In this case, some of the phonemes and allophones presented herein may be adjusted, modified, or refined as new evidence becomes available. Finally, frame-by-frame analysis of recorded live signing would help to identify possible static non-contact syllable onsets and codas, which would improve the accuracy of the environments for the allophonic variations.

The success of this approach suggests potential applications and benefits. If the phonemes of sign languages can be identified, then writing systems for sign languages can be based on phonemes rather than phonetic articulations, removing unnecessary elements and simplifying the writing systems. Allophonic notations could also be introduced in phonetic notation format. With such systems in place, syntactic and morphological analyses could be carried out by accessing the written form. This segmental approach could assist in addressing research areas such as agreement, determiners, affixation, classifiers, verb aspect, and so on. Besides research, books and other types of literature could be written in local sign languages by the respective Deaf communities. Already conceived and under discussion with computer programmers is the possibility of computer-generated animated signing read from phonemically-based written signed text.

The approach used for this analysis requires explicit phonological representations for contrastive movements, separate from phonetic movement information and distinct from phonological non-movement information. As shown here, considering the phonological systems of sign languages to be comprised of discrete movement and non-movement segments is a viable approach. Successful application of linguistic theory to both signed and spoken languages, as offered here, provides insight into language in general and into the similarities between the two modalities. To the degree that the segmentation of signs and the phonemic method are successful with signed languages, the concepts and methodologies are universally applicable across modalities.
Notes

1. With much gratitude to anonymous reviewers for extremely helpful comments. Special thanks to Bob Moore and others (who desire anonymity) for help with video recording and text editing.

2. TURN-OFF-LIGHT: Forearm horizontal and elevated, all fingers and thumb extended and spread, palm facing downward; fingers and thumb bend at metacarpal joint; thumb contacts distal portion of (some) fingers.

3. BODY: Path movement of both hands toward upper torso; for each hand, palmar side of all four fingers, extended unspread, contacts its ipsilateral chest; hands move away from body; both hands approach lower torso; for each hand, palmar side of all four fingers, extended unspread, contacts its ipsilateral waist area.

4. Transitional movements between signs, while being phonetic movements, are neither phonological movements nor allophones of movement phonemes. Thus, they are not part of this discussion.

5. AMONG: arm oriented laterally (elbow pointing ipsilateral, hand pointing contralateral), index finger pointing downward, approximating the finger tips of other hand, with all fingers extended and spread, palm back; arm moves contralaterally in a path while shaking back and forth (on horizontal plane) from the elbow.

6. CLOSE-DOOR: arm oriented sagittally, four fingers extended together, palm contralateral; arm pivots contralaterally and backward; palmar side of hand and arm contact dorsal side of other hand and arm, which is laterally oriented.

7. DAY: vertical arm, distal end of curved middle finger contacts distal thumb of same hand, index extended, other fingers closed, palm contralateral; arm pivots contralaterally and downward; palmar side of hand and arm contact dorsal side of other hand and arm.

8. TRAVEL: sagittal arm, index & middle fingers curved and spread, other fingers closed, palm down; path movement forward while arm oscillates (from elbow) side to side (on horizontal plane).

9. LEND: both arms vertical, index & middle fingers extended & spread, ulnar dominant hand (metacarpus) contacts radial non-dominant hand (metacarpus); both hands pivot forward and downward while maintaining contact.

10. BORROW: both hands sagittal, index & middle fingers extended & spread on both hands, ulnar dominant hand (metacarpus) contacts radial non-dominant hand (metacarpus); both hands pivot upward and backward while maintaining contact.

11. GOODBYE: arm vertical, fingers & thumb extended & spread, palm forward; arm pivots repeatedly from side to side (contralateral-ipsilateral).
12. **ASK**: index extended, forearm vertical, palm forward, dorsal side of finger near mouth; arm pivots forward & downward while index finger curves.

13. **BOTH**: index & middle fingers extended & spread, forearm vertical, dorsal side of fingers contact palm of other hand (with fingers nearly closed); hand moves downward while fingers come together, remaining extended.

14. **DOG**: distal middle finger contacting distal thumb of same hand, index extended, other fingers closed, forearm sagittal, palm up; middle finger closes repeatedly, rubbing contact with thumb during movement.

15. **BETTER**: all four fingers extended unspread, palmar side of fingers contact mouth, forearm oriented laterally; hand moves ipsilaterally and all four fingers close.

16. FileMaker Pro 7 software funded by National Institutes of Health Institutional Training Grant #T32 DC000030-14.

17. Lateral arm movements tend to displace the beginning location of the sign.

18. The pronoun system might be analyzable according to non-movement forearm posture (onset or coda) in conjunction with movement type (path, pivot) and direction and final holds. This system would eliminate referents located in space.

19. A fourth-generation native Deaf signer has informed me that this version of \textsc{left-direction} is not typical ASL but is a “hearing” version. Rather than a path movement, this sign is articulated with an oscillating compact pivot.
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Movement types, Repetition, and Feature Organization in Hong Kong Sign Language

Joe Mak & Gladys Tang

Abstract

Movement is one of the major phonological parameters in sign phonology. However, there has been a lack of consensus on how to characterize it, in particular, how to organize movement types and their associated features in a phonological representation. In this chapter, we revisit features involving repetitions in Hong Kong Sign Language (HKSL) documented in a HKSL dictionary (Tang 2007). We propose the features [repeat] and [return] to capture the different realizations of “repetitions” in the lexical signs of HKSL, which may take the forms of non-repeated movements, unidirectional repetitions, bidirectional repetitions, repeated local movements, returned movements and trills. We argue that repetition in HKSL involves a set of independent features which can occur at various nodes of the feature hierarchy. We propose that there is a Movement Feature (MF) node in the feature geometry under which path or local movements are grouped as sister nodes. Orientation and aperture changes are then sister nodes under the local movement node. Repetition features may occur at either the MF node or at the path or local movement node, but not lower down because they do not co-occur with either the orientation or aperture change terminal nodes.

1. Introduction

There have been a number of approaches to represent movement in sign language. Some researchers like Liddell & Johnson (1986), Perlmutter (1992), and Sandler (1989) treat movement as a segment. Some regard it as a specifying property of a syllable with an initial or final state (e.g. “timing units” in Wilbur 1993, “X-slots” in Hulst 1993). Following Stack’s argument (1988) that movement segments are redundant and movement can be viewed as a transition from A to B, Crasborn, Hulst & Kooij (2000:6) claim that there are no movement segments and all movement can be analyzed as a change
of feature values. They put forward the Dependency Phonology Model in which the class nodes Config, Orientation and SelFing are set up to host the sequence of terminal features, capturing the change of states in path, orientation and aperture respectively. By claiming that “signs are single segments”, Channon’s (2002) OneSeg Model claims that signs are single segments and proposes a set of structurally unordered, static (place, handshape, etc.) and dynamic features including pathshape (Channon & Hulst 2011, this volume), direction, and [repeat] features, with the number of repetitions in a sign being non-contrastive. Adopting a rather different approach, Brentari’s (1998:130) Prosodic Model captures the dynamic properties of movement by a set of prosodic features classified into class nodes Nonmanual, Setting, Path, Orientation and Aperture. This model also stipulates that there is a hierarchical organization of different types of dynamic changes, it reflects the organization of the executors (i.e. joints) and sonority hierarchy (i.e. prominence of corresponding joints). Therefore, in our attempt to revisit the movement parameter of HKSL, we adopt Brentari’s Prosodic Model and Sagey’s (1986) Articulator Model of feature geometry as the framework of analysis.

Various names have been used to capture repetition phenomena (e.g. [redup] in Perlmutter (1990), [repeat] and [TM] in Brentari (1998) and Tang (2007), [repeat] in Channon (2002), and [repeated] in Kooij (2002). Most analyses of repetition treat repetitions and trills as independent of each other even though they share similar movement properties.

We assume at the outset that the dynamic properties of movement in signs can be characterized by a set of features which may be categorized into natural classes (i.e. “movement types”). Just as Sagey’s (1986) Articulator Model of feature geometry groups place of articulation features like [±round] under Labial and [±anterior] under Coronal all under the Place class node according to the organization of the oral articulators, the classes for movement in sign language may stem from articulatory effects involving the various joints. These class nodes are organized into tiers and are related to each other. Just as manner features like [continuant] which characterize manners of articulation independent of specific articulators are discovered in spoken language, there may be independent features which characterize manners of sign articulation as well. Our study aims to categorize repetitions, trills and their associated features in HKSL, how they co-occur and organize themselves into tiers and whether this organization corroborates that of the PF node of the Prosodic Model. Brentari’s model uses an independent, articulator-free [TM] feature to capture trills, but we argue that trills are phenomena which can be characterized by two independent features [repeat] and [return], in
opposition to dependent features such as [open] and [close] that are defined by the finger joints and responsible for aperture change. Being independent manner features, they may be associated with different movement classes in the phonology of HKSL. We argue that positing these independent features allows us to capture repetitions at different levels of representations simultaneously, an intrinsic property of the signing modality. This means that even though repetition in our view is structurally ordered, its independent status allows it to occur at certain levels in the representation.

2. Characteristics of repetition

2.1 Directionality

Repetitions can be unidirectional or bidirectional. Newkirk ([1981] 1998:174-178) performed a descriptive analysis on reduplication patterns in ASL. What he calls “reduplication” includes repetitions within ASL signs, both inflectional and basic (i.e. lexically specified).

(1) Reduplication patterns in ASL (Newkirk 1998)

As observed in (1), repetitions in signs show up with different parameters. One of them is directionality. For examples, in ASL EXPLAIN and SWING...
contain bidirectional paths but with different shapes, straight or arc. ENJOY is not bidirectional but has a circular shape of movement. These signs have the common property that “the reduplicating unit … must begin in the same position in space, and in the same configuration of fingers, wrists, and so on each time it is repeated in order for the exact reduplication to occur”. The second group of signs, including APPROACH, POSTPONE\textsuperscript{[Augmentative]} and MINUTE-HAND-SWEEP, like the first group, also have different path-shapes, but contrasting with the first group, they are “reduplicated without returning to the initial starting point”.\textsuperscript{3} The final group involves signs with unidirectional repetition as in LOOK\textsuperscript{[Habitual]} and POSTPONE\textsuperscript{[Durational]}. It is different from the first and second groups by having “a linking movement complementary to the lexical movement … inserted to bring the active hand(s) back to the starting position for the next cycle”. Newkirk ([1981], 1998) provided further justification that the first half-cycle of the unidirectional repetition is lexical while the second is outside of the lexical domain. FINGERSPELL\textsuperscript{[Habitual]} in ASL is specified with a unidirectional path overlaid with the wiggling of the finger but the lexical movement occur only with the first half-cycle but not the remaining half-cycle which is merely a transition. In contrast, the wiggling of the fingers for the sign PIANO occurs in a bidirectional path movement in both the first and the returning half-cycles. In (1), he used solid arrows to represent “lexical” movement and the dotted ones to imply that the return of the articulator to the original setting is merely a “linking movement” (i.e. transitional movement) which is not phonologically specified.

Newkirk’s ([1981], 1998) did not propose any phonological features for directionality in repetitions. The Prosodic Model attempts to capture directionality in unidirectional and bidirectional repetitions by positing [repeat] as a heterogeneous path feature with diacritics rather than default values: [repeat]:identical (a unidirectional path), [repeat]:at 90º angle (a cross shape path), and [repeat]:at 180º angle (a bidirectional path).

2.2 Trills

Another form of repetition widely discussed in the literature is trills. Hulst (1993:217) defines trills as having “a rapidly repeated activity which can be executed during a path movement or while the hand is motionless, i.e. not moving along a path”. It is also called “trilled movement” or “secondary movement” by some researchers, and has different formal names in different frameworks: [\texttt{+trilled}] in Padden & Perlmutter (1987), [\texttt{trill}] in Sandler
Movement types, Repetition, and Feature Organization in HKSL

(1989) and (1993), [oscillated] in Liddell (1990) and Hulst (1993), [W] as the secondary movement feature for wiggling in Perlmutter (1992), and [TM] in Brentari (1996) and (1998). In this chapter we use the term “trills” rather than “trilled or secondary movement” because we do not posit “trills” as an isolated movement type but as a subtype of repetitions analyzable into a set of distinctive features. This is contrary to Brentari (1996) who considers trills and repetitions to be phonetically related but phonologically distinct.

There are several common properties of trills: 1) they are not restricted to a specific movement type because they “are produced at a variety of articulatory sites” (Brentari 1996:44, 1998:164), 2) they can be superimposed on signs with and without a path movement (Liddell 1990, Hulst 1993:217), and 3) trills co-occur only with paths or locations (Brentari 1996:51).

In the Prosodic Model, trills are perceived as having non-repeated counterparts and are symbolized with a prosodic feature [TM] directly under the PF node. Under a different approach, trills have been analyzed as iterated versions of local movements and reduplications have been accounted for by copying a skeletal template (Stack 1988, Sandler 1989, Liddell 1990). The templatic account can explain morphological reduplication because the templatic copying operates at the level of morphology; however, there is an inadequacy in explaining the non-morphological, lexically specified repetitions observed in Newkirk ([1981] 1998). In this chapter, we will argue for a unified account of unidirectional and bidirectional repetitions as well as trills by proposing two phonological features, one for repetition and the other for returning movement, both can be specified at the lexical level.

3. Analysis of movement in HKSL

3.1 Working assumptions

To offer a unified account of repeated unidirectional and bidirectional movements as well as trills, we propose to re-conceptualize the feature [repeat] and to introduce a new feature [return]. We argue that these two features will capture the various realizations of repetitions as reported in different sign languages and especially in HKSL. The working definitions of [repeat] and [return] are as follows:

(2) [repeat] – The movement in the articulation repeats itself, regardless of count. It refers to the commonly observed repetitions and trills in sign articulation.
(3) Movement that returns to the original configuration after displacement or any dynamic changes.

We also adopt the following definitions from Brentari (1998) to characterize the dynamic changes in HKSL:

(4) Path movement: Paths are articulated by shoulder and elbow joints, resulting in spatial changes of the hand in the signing space.
(5) Local movement: Orientation changes are articulated by flexion and extension of the wrist joints and rotation of the forearm. Aperture changes are articulated by finger joints.

Although these categories entail strong articulatory effects as they are defined in terms of the joints of the manual articulators, we argue that such characterization will ultimately enable us to capture systematically the different movement types as well as the associated patterns of repetitions. This path-local movement distinction has been widely observed by many researchers (Sandler 1987, 1989, Stack 1988, Liddell 1990, Hulst 1993:216, Brentari 1998:129,130, Kooij 2002).

A second level of categorization is based on the co-occurrence of these dynamic changes, yielding a distinction between simple and complex movement. Simple movement involves one dynamic change while complex movement is defined as having at least two different but simultaneous dynamic changes types.

3.2 Results

With these working definitions in place, we proceed to the analysis of movement in the lexical signs of HKSL. Our analysis is based on the distribution of movement types and repetition in the 1376 lexical signs documented in Tang (2007) and shown in Table 1. The great majority of the signs are monomorphemic; however, some are bimorphemic signs but their movements are so phonologically compressed that one complex movement results. Also, the signs may be one-handed or two-handed. As for the two-handed signs, either the movement of the dominant and non-dominant hand is identical due to the “symmetry condition” (Battison 1978) or the dominant hand moves and the non-dominant hand becomes the POA (place of articulation).
Table 1. Observations on movement types in HKSL based on Tang (2007)

<table>
<thead>
<tr>
<th>Type of movement</th>
<th>No movement</th>
<th>Non repeated</th>
<th>Repeated</th>
<th>Trills only</th>
<th>Trills plus non-repeated path</th>
<th>Trills plus repeated path</th>
<th>Totals</th>
</tr>
</thead>
<tbody>
<tr>
<td>No movement type</td>
<td>162</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>162</td>
</tr>
<tr>
<td>Path</td>
<td>349</td>
<td>156</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>505</td>
</tr>
<tr>
<td>Orientation</td>
<td>44</td>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>46</td>
</tr>
<tr>
<td>Aperture</td>
<td>22</td>
<td>7</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>29</td>
</tr>
<tr>
<td>Path\Aperture</td>
<td>133</td>
<td>22</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>155</td>
</tr>
<tr>
<td>Path\Orientation</td>
<td>94</td>
<td>19</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>113</td>
</tr>
<tr>
<td>Orientation\Aperture</td>
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<td>0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>6</td>
</tr>
<tr>
<td>Path\Orientation\Aperture</td>
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<td>1</td>
<td></td>
<td></td>
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<td>15</td>
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<tr>
<td>Other movement types</td>
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<td>317</td>
<td>20</td>
<td>8</td>
<td></td>
<td>345</td>
</tr>
<tr>
<td>Totals</td>
<td>162</td>
<td>662</td>
<td>207</td>
<td>317</td>
<td>20</td>
<td>8</td>
<td>1376</td>
</tr>
</tbody>
</table>

3.2.1 Signs with no movement

Out of 1376 signs in our analysis, 162 signs display a hold at POA rather than a path or local movement in the lexical entry. Under these circumstances, the well-formedness constraint in the phonological representation is satisfied by a transitional movement of the articulator to the POA. An example is the sign TOILET which is realized by a static handshape held at neutral space with “protruded lips”, as shown in Figure 1. For the signers with whom we have consulted, all agreed that TOILET is a static sign and the path of the articulator to the POA is meaningless and not part of the sign articulation. In contrast with the finding from previous research in ASL that signs are not well-formed without movement (Wilbur 1987, Stack 1988, Brentari 1990), these signs may suggest a typological difference on sign well-formedness. By the way, no movement signs in HKSL happen to be good evidence supporting movement as a category because all movement features as a whole can be totally absent in a sign.

Figure 1. TOILET
3.2.2  Simple and complex movements

(6) summarizes the co-occurrence pattern of movements in HKSL. Similar to reports from other sign languages, the three movement types can either occur independently or be combined with each other. Illustrations of the signs are found in Figure 2a-f. In Figure 2a-c, HIT, BUT and FLOWER have simple path, simple orientation change and simple aperture change respectively. Figure 2d-f show examples of complex movements: ADD, TELL and ROSE (i.e. the simultaneous combination of Path|Orientation, Path|Aperture and Orientation|Aperture movements respectively).6

(6)  Examples of signs with non-repeated movements (simple and complex)
3.2.3 Non-repeat, return, full repetition and trills

Signs marked “repeat” in Table 1 show full articulation during the repetition (referred to as “full repetition” in the subsequent discussion). This contrasts with “trills” in the last column where the movements are diminished and uncountable. In HKSL, trills may occur independently under path, orientation, or aperture changes. In complex movements, they may be combined with non-repeated and repeated path movement.

Table 1 also summarizes the results of signs showing repetitions in form of either ‘repeat’ or ‘trills’. The data shows that there are different types of repetitions in the language. Descriptively, all the signs in Figure 3a-d have aperture changes of the “5” handshape. However, FLOWER has a non-repeated opening movement, but FLASH contrasts with FLOWER in backtracking the movement to the original aperture. On the other hand, HONG_KONG contrasts with FLOWER in that HONG_KONG repeats the opening sequence twice with a transitional movement in between. Finally, PAGER is realized by trills between the opening and closing of “5” handshape without a specific end-state (i.e. the end-state is nondeterministic and without phonological significance).
The identification of these four independent realizations of repetitions in HKSL is based on “phonemic contrast”. The first type is “non-repeat”, which includes signs that have one movement type which does not repeat. This is a common sign type in HKSL as shown in Table 1. The second type is “return”, which requires a return of movement to its original state (path or handshape configuration) and this returning movement is part of the lexical specification. This is similar to Newkirk’s bidirectional type. The third type is “full repetition” which does not require the returning movement as part of the lexical specification and the final state of the second movement is identical to the final state of the first movement. The fourth type is trills. They refer to uncountable repetitions and the returning movement is part of the lexical specification. Another piece of evidence showing that “trills” are distinct from “full repetition” is that “full repetition” always has a specific end-state while “trills” do not. This can be shown by their different behaviour in phrase-final position where the signs are lengthened. Signs with “full repetition” lengthen themselves with a “hold” at the final state while “trills” just prolong as a whole.

In this analysis, we have attempted to distinguish two kinds of return in the signs of HKSL. Only those signs like FLASH or PAGER will be specified with the [return] feature in the lexical entry. Signs like HONG_KONG will have a [repeat] but not [return] feature because the returning movement is not part of the lexical specification. Adopting the feature [return] has an advantage over the feature “bidirectional” as proposed in Brentari’s model because bidirectional applies to paths only. In our proposal, [return] can capture either the “returning” of movement to the original setting of the “bidirectional” path or the original handshape configuration and orientation. [Return] can even capture “trills” which we assume are one type of repetitions.

Here we focus on the repetitions that lexically specify for a returning movement like EXPLAIN, SWING and ENJOY in ASL mentioned in (1), which we analyse as having both [repeat] and [return]; as well as those with transitional movement back to the starting position or configuration like LOOK\textsuperscript{Habitual}, POSTPONE\textsuperscript{Durational} and FINGERSPELL\textsuperscript{Habitual}, which have [repeat] but not [return]. However, we decide to leave the signs like APPROACH, POSTPONE\textsuperscript{Augmentative}, MINUTE-HAND-SWEEP and GRANDMOTHER in ASL aside because these signs, although specified with [repeat] without [return], must have additional “displacement” specification realizing as stepping through space after each iteration. Our preliminary conjecture is that these signs involve [repeat] plus additional setting changes and more research is needed to capture these signs adequately.
3.2.4  **Filling the gap of co-occurred orientation and aperture change with repetition**

As for the non-repeated signs, Table 1 shows that the movement types are combined to form complex movements in HKSL. However, those showing a combination of orientation and aperture changes are few and this complex local movement with repetition does not seem to occur unless there is also path movement as none shows this combination with repetitions. Although not included in Tang (2007), a variant of the sign FREE_OF_CHARGE subsequently identified in HKSL requires both orientation and aperture changes as well as repetition. This variant that we have uncovered in the course of time is shown in Figure 4, which does show this co-occurrence pattern.

![Figure 4. FREE_OF_CHARGE](image)

In this section, we have descriptively categorized the HKSL sign data in terms of movement types and repetition types. In what follows, we will put forward a formal analysis of the movement types as class nodes in the phonology of HKSL. We will analyze the nature and distribution of [return] and [repeat] in the movement types and how a combination of the values of these two features captures the four patterns of repetitions observed in HKSL.

3.3  **Analysis of movement types as class nodes**

Our analysis is couched within the general concept of feature geometry developed by Clements (1985), Sagey (1986) as well as Brentari (1998) that dependent features can be categorized into class nodes which in turn
may be organized hierarchically. In what follows, we will propose a Movement Feature (henceforth MF) class node under which there are Path, Local, Orientation and Aperture nodes in the feature geometry. (7) below offers a flat structure under the MF node (Structure I) which contrasts with Structure II which has a hierarchical organization of movement types, created by adding a Local node that groups orientation and aperture changes together. We will argue for Structure II based on analysis of [return] and [repeat] as independent, articulator-free features.

(7) Organization of movement class nodes

As mentioned, we call the class node formed from all movement features the MF class node. The co-occurrence patterns of the movement types shown in Table 1 suggest Path, Orientation and Aperture may appear on their own or combine with each other systematically, so they are shown as class nodes. As mentioned in Section 1, the definition of movement types is based on the involvement of the joints at different levels of realization. This is in line with the concept of “articulatory independence” (Halle 1982:98-99) because the three basic movement types are initiated by three sets of independently functioning joints: shoulder and elbow joints for Path, wrist joint for Orientation and finger joints for Aperture. Similar phenomena of “articulatory independence” have been found in spoken language where researchers refer to it as “co-articulation or multiple articulations”. This involves two or even three places of articulation in “complex segments”. Hence, in the “articulator tiers” and the “articulator node hierarchy” models developed by Sagey (1984, 1986:38), Labial, Coronal and Dorsal are not features but are class nodes immediately dominated by the Place class node. This motivates us to
propose a structure of basic movement types: Path, Orientation and Aperture as class nodes under the MF node, as shown in Structure I. The question is whether MF contains a flat or a hierarchical structure, (more specifically, whether there is a Local node), and whether [repeat] and [return] are articulator independent features, issues to which we now turn.

Independent, articulator-free features are those features which are not restricted to specific movement types. In what follows, we are going to show how [return] and [repeat] are specified in signs with single and complex movement types. Our observation is that the distribution of these articulator-free features is least restrictive in single movement types, as signs can be found which demonstrate either [return], [repeat] or a combination of both.

**Table 2.** Distribution of [return] and [repeat] over different simple movement types

<table>
<thead>
<tr>
<th>Patterns of repetitions with their features</th>
<th>Path</th>
<th>Orientation</th>
<th>Aperture</th>
</tr>
</thead>
<tbody>
<tr>
<td>Non-repeat : Ø</td>
<td>PUT</td>
<td>BUT</td>
<td>FLOWER</td>
</tr>
<tr>
<td>Return : [return]</td>
<td>RESUME</td>
<td>SHARE</td>
<td>FLASH</td>
</tr>
<tr>
<td>Full repetition : [repeat]</td>
<td>PRINT</td>
<td>MAID</td>
<td>HONG KONG</td>
</tr>
<tr>
<td>Bidirectional / Trills : [return] [repeat]</td>
<td>EARTHQUAKE</td>
<td>OR</td>
<td>PAGER</td>
</tr>
</tbody>
</table>

In Table 2, [return] and [repeat] feature specifications can be realized in all basic movement types. This observation offers some preliminary hints that they are articulator-free features. However, specifying [return] and [repeat] in complex movements leads to distributional constraints. In order to examine this issue, we analyze the patterns of co-occurrence between [repeat] and [return] within the possible movement combinations. The results are summarized in the following three tables, where each table corresponds to one of the three logical possibilities for complex movement: aperture and orientation (Table 3), path and orientation (Table 4), and path and aperture (Table 5).

Note that not all signs in the tables are lexical in nature. Some are overlaid with morphosyntactic features through movement modulations, and are underlined, to distinguish them from lexical signs. Because our data set has less than 2000 signs, it is possible that unattested combinations (marked by “*”) are merely accidental gaps. However, it seems more likely that these gaps are systematic, because as we will show that, the gaps can be explained by the combination of our proposed hierarchical structure for movement features, and constraints on where repetition features can and cannot occur in the structure.
Table 3. Distribution of [return] and [repeat] in Orientation|Aperture complex movements

<table>
<thead>
<tr>
<th>Orientation</th>
<th>Aperture</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>[return]</td>
<td>[repeat]</td>
<td></td>
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</tbody>
</table>

Table 4. Distribution of [return] and [repeat] in Path|Orientation complex movements

<table>
<thead>
<tr>
<th>Path</th>
<th>Orientation</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>[return]</td>
<td>[repeat]</td>
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<td>-</td>
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</table>
Table 5. Distribution of [return] and [repeat] in Path|Aperture complex movements

<table>
<thead>
<tr>
<th>Path</th>
<th>Aperture</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>[return]</td>
<td>[repeat]</td>
<td>[return]</td>
</tr>
<tr>
<td>−</td>
<td>−</td>
<td>−</td>
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<td>−</td>
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</table>

Taken together, some systematic patterns are found. Table 3 shows that the distribution of [return] and [repeat] in Orientation|Aperture complex movement is so restrictive that there are thirteen unattested combinations in this table. Note that all the twelve pairs with either [repeat] or [return] specified in different values have no attested signs in HKSL. The last unattested combination shows that trills specified with both [repeat] and [return] are not possible in complex movements involving Orientation and Aperture. Table 4 and Table 5 show that Orientation and Aperture share similar distribution of [return] and [repeat] when they combine to form complex movements with Path. For Path|Orientation and Path|Aperture, both tables show many attested forms except for rows 7, 10, 14 and 15. Taken together, these systematic distributions of [repeat] and [return] (henceforth [rp] and [rn] in some figures) in different combinations of Path, Orientation and Aperture support that Orientation and Aperture form a natural class on its own, namely Local movement. This observation also corroborates the claim made by Hulst (1993), Brentari (1998) and Kooij (2002) that Path movement forms its own class of movement while orientation change and aperture change form a class of Local movement. This is supporting evidence to justify that Path and Local (henceforth P and L in some figures) are sister class nodes under MF with Local having further subdivisions into Orientation and Aperture (henceforth O and A in some figures) as shown in Structure II of (7).
Recall that Table 4 and Table 5 show that Aperture patterns with Orientation when each combines with Path under different [return] and [repeat] specifications, we would expect that Path|Orientation and Path|Aperture share similar underlying structures. The signs in (8) show the possible structures of Path|Orientation movements. In (8), the sign ADD shows Path|Local movement without specifying for [return] and [repeat]. The next column of signs, including NAUSEATING, KOREA and RENOVATE, show that [return] and/or [repeat] are specified at the MF node. By inheritance, the features specified at MF are realized at both the Path and Local nodes. For the signs GOOD FIGURE, HILL and DEVELOP, the features [return] and/or [repeat] are specified at the Local node only. For signs like PREVENT, CULTURE and VARIOUS KINDS, the features are specified at the Path node only. These different distributions of features suggest that they may occur in three phonological domains – one dominated by MF node (i.e. including both Path and Local categories), the other two dominated by Local and Path class nodes. Crucially, [return] and [repeat] do not occur as dependents of Orientation or
Aperture. The conventional trilled movements in HKSL signs like RENOVATE, DEVELOP and VARIOUS_KINDS are represented by a combination of [return] and [repeat] features at MF, Local or Path nodes respectively.

The question is how to represent [return] and [repeat] in more than one phonological domain in one feature geometry. We assume that through dominance in a feature geometry, specification of [return] and [repeat] under MF affects other class nodes dominated by MF. (9) shows the three possible nodes at which [return] and [repeat] are specified. They are MF, Local and Path nodes. Cases I to III in (9) correspond to the distribution of the different repetitions expressed in terms of [repeat] and [return] in the current model, as shown in (8). These structures provide a structural account for the different domains of [return] and [repeat].

(9) The three possible domains of [return] and [repeat]

(10) shows the structures of the three attested combinations in Table 3.

It is observed that the realization of [return] and [repeat] in Orientation and Aperture are always identical, that is if Orientation is specified or not specified for [return], so is Aperture. (10) shows the structures of the three attested combinations in Table 3.
(10) Structures of attested Orientation|Aperture signs

\[
\begin{align*}
\text{ROSE} & \quad \text{WASTE\_EFFORT}^{[\text{Distalized}]} & \quad \text{FREE\_OF\_CHARGE} \\
\text{MF} & \quad \text{MF} & \quad \text{MF} \\
O & \quad L & \quad \text{[rn]} & \quad \text{[rp]} \\
A & \quad O & \quad A & \quad A
\end{align*}
\]

Signs in (10) show no Path class node because we assume that for complex movements involving both orientation and aperture changes with no path movement, the Path node is just not specified with Orientation and Aperture class nodes required. ROSE is not specified with any [return] and [repeat], while WASTE\_EFFORT\(^{[\text{Distalized}]}\) and FREE\_OF\_CHARGE are specified as having [return] and [repeat] respectively. That [return] and [repeat] have to occur in both Orientation and Aperture or neither implies that Orientation and Aperture nodes should get these feature specifications from one of their mother nodes, but this argument does not decide which mother node it should be, the Local or the MF node. We argue that these two features are specified at the MF rather than the Local node, as shown in (10). The evidence comes from the citation form WASTE\_EFFORT. In the underlying structures of the two signs, the path node is specified with [return] or [repeat] at the MF node. Distalization of WASTE\_EFFORT involves the delinking of Path node as shown in (11) below.

It is also noticed that only three of the four possible [return] and/or [repeat] specifications are shown here, that is, there is no [return] and [repeat] coexistence in Orientation|Aperture movement. We suspect that it is a lexical gap due to physiological constraint which prohibits trills from occurring when there are both orientation and aperture change.

(11) Derivation of WASTE\_EFFORT\(^{[\text{Distalized}]}\)

\[
\begin{align*}
\text{WASTE\_EFFORT} \\
& \quad \text{(distalization)} \\
\text{MF} & \quad \text{[rn]} \\
P & \quad L \\
O & \quad A
\end{align*}
\]
Until now, we have shown in (8) the structures of ten attested combinations of [return] and [repeat] in Path|Orientation movements as listed in Table 4. However, two other attested combinations in Table 4 are left untouched. They are represented by CL[An animate entity jumps summersault] in row 8 and DEVELOP[Reduplicated] in row 12. Interestingly, these two forms, together with their Path|Aperture counterparts CL[A 2-legged entity walks back and forth] and WALK[Reduplicated], represent classifier predicates and signs with aspectual modulation. These signs with rich morphology may have undergone morphological processes, bypassing the lexical constraints in HKSL phonology.

(12) Structures of signs with multiple [return] and [repeat] specifications

In (12), these signs with rich morphology can access more than one phonological domains. For instance, the classifier predicates can access both Domain_p and Domain_l, while the signs with morphological reduplications can access both Domain_M and Domain_L. All other signs in Table 4 and Table 5 should conform to the lexical constraints in HKSL phonology, if there are any. As it stands, one possible lexical constraint as observed in (8) is that a lexical sign may access only one of the three possible domains of [return] and [repeat] at a time.

4. Conclusion

This chapter offers some preliminary analysis of movement in HKSL. We have identified the co-occurrence patterns of movement types and four patterns of repetitions in the signs of HKSL. We have invoked the features [repeat] and [return] which we assume may occur in multiple phonological domains. These two features can account for the different patterns of repetitions in HKSL, namely non-repeated movement, unidirectional repetitions,
bidirectional repetitions, repeated local movements and trills. Invoking [return] enables us to distinguish returning movements between those that are required by the lexeme as part of the lexical specification and those that are transitional movements. Also, that [return] and [repeat] are perceived as features captures repetitions not only in path but also local movements. This differs from Brentari (1998) in which [repeat] is perceived as a path feature only. These finer distinctions can be adequately explained by a feature geometry that grouped Orientation and Aperture as sister nodes in a Local domain which itself is sister to the Path node and both are dominated by the MF domain in the structure. By formulating the lexical and post-lexical constraints of movement and organizing the MF classes in a hierarchical manner, a phonological template for HKSL results which we hope will encourage more in depth analysis in future research and potentially pave the way for the analysis of the morpho-phonology of HKSL.

Notes

1. The Prosodic Model views the root node of a feature geometry as dominating all feature specifications of a lexeme (Brentari 1998:25,26). This model distinguishes between Inherent Features (IF) which specify the fixed properties during the lexeme’s production and Prosodic Features (PF) which specify the lexeme’s dynamic properties (i.e. movements). In our chapter, we will leave aside the IF node and focus on the feature organization of the PF or Movement Features (MF). It is more appropriate to use the term MF rather than PF here because our investigation has not yet touched upon any prosodic constituent like syllable.

2. Movement features refer to those “distinctive features” which cross-classify the movement inventory and lead to lexical contrasts. According to Clements and Hume (1996), “class nodes” designate functional grouping of features into classes.

3. In ASL, the repeated arcs without returning to the original location is not necessarily inflectional as in POSTPONE[Augmentative] but can be lexical as in GRANDMOTHER (Rachel Channon, personal communication).

4. In this chapter, we are not focusing on showing the distinctiveness of the terminal features under class nodes of movement types but organization of the class nodes based on feature geometry. For discussion on the distinctiveness of terminal features hosted by these class nodes, readers can refer to Mak (In prep).
5. Most photos of signs illustrated in this chapter are extracted from Tang (2007). And those signs listed in Table 2 to 5 are supplemented with video clips included in this volume. We thank our deaf informants/models Kenny Chu and Pippen Wong for the photos and video clips.

6. In the following, the notation A|B is conventionally used to denote simultaneous co-occurrence of A and B.

7. Halle (1982:98-99) states that “consonantal occlusions are produced by three distinct active articulators: the lower lip, the front part of the tongue, and the tongue body. Since the position of each of these three articulators is independent of the other two, it should be possible to produce consonants with more than one occlusion.”

8. In these tables, “+” denotes presence and “−” denotes absence of the [return] and [repeat] specifications. The signs presented in these tables were collected from a deaf informant by asking him to provide as many possible signs of each type as he could. Therefore, some of these signs have not been documented in Tang (2007) and are not included in Table 1.

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