Chapter 14

The (early) history of sign language phonology

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1. Introduction[1]

This chapter addresses the history of sign phonology, focusing on its early phases.[2] There are several general reviews of sign phonology which capture the more recent developments in the field of sign phonology.[3] The organization is as follows. Section 2 briefly discusses misconceptions about sign languages that have stood in the way of developing sign phonology (and sign linguistics in general). Section 3 offers an introduction to the basics of phonological structure in signs. Section 4 and 5 discuss some early works (specifically Bébian (1825) and West (1960)) that developed notational systems, which fully (although often implicitly, as in Bébian's case) acknowledge that signs can be segmented into smaller, meaningless parts. In section 6, I introduce the seminal work of William Stokeo (Stokoe 1960), who is commonly mentioned as the first linguist to propose that signs can be analyzed into meaningless form elements, using modern linguistic insights. Section 7 reviews a number of early dissertations that were devoted to sign phonology, following Stokoe's lead. Section 8 discusses the work of Ursula Bellugi and Edward Klima (Klima and Bellugi 1979), while section 9 compares the negative reception of Stokoe (1960) to the positive reception of Klima and Bellugi (1979). Section 10 marks the transition from American structuralist linguistics to generative approaches. Section 11 deals with a new era in sign phonology, viz. the 'rise of sequential structure', discussing various strands of research that break with Stokoe's conception of the sign as a simultaneous bundle of properties. Section 12 reviews research (a) phonetic approaches, (b) so-called non-manual aspect of signs. (c) prosodic structure, (d) the role of iconicity, (e) the role of gesture, (f) acquisition, (g) the emergence of phonology in young sign languages, and (h) cross-linguistic work. Section 13 offers conclusions.

[1] I am grateful for comments on an earlier (for some much longer) version to Penny Boyes Braem, Diane Brentari, Rachel Channon, Susan Fisher, Shengyun Gu, Kathleeen Hall, Bob Johnson, Judy Kegl, Els van der Kooij, Susan McBurney, Richard Meier, Wendy Sandler, Ronnie Wilbur and Sherman Wilcox. All errors are my own.

[2] This chapter mostly deals English language publications in the US, which were influential in the rise and early developments of sign phonology. See McBurney (2012) for a geographically broader perspective on the discipline of sign linguistics. Most early work on other languages than ASL focussed less on theoretical issues and more on data collection, as well as analytic and descriptive issues (dictionaries, grammars), which is not to say that this work did not address fundamental issues with theoretical significance.

[3] See Corina & Sandler (1993), van der Hulst (1993b), Sandler (2012, 2017), Brentari (1995, 2011, 2012), Fenlon, Cormier & Brentari (2018), van der Hulst and van der Kooij (to appear). More specific reviews will be mentioned where I discuss different aspects of phonological structure; see section 1.2. Many dissertations (several of which will be discussed in section 7) also contain overviews.

2. What stood in the way of discovering sign phonology

Two misconceptions of sign languages have long stood in the way of viewing them as human languages that are on a par with spoken languages in terms of usage, functionality and grammatical structure: [4] (a) that there is no duality of patterning in sign languages and (b) that signs are mostly motivated, iconic gestures. These two misconceptions are interconnected in that both militate against the idea of submorphemic phonological compositionality. Additionally, for as long as we can go back in the historical record, the prevailing view on human languages has been **phonocentric**. Even though Socrates and some later writers occasionally remark that deaf people can communicate in signs (remarkably without the usual disclaimer that signs are inferior to speech), Aristotle set the tone for regarding *speech* as the only true expression of language that would enable people to learn and think. Perhaps due to his influence, the overwhelmingly prevalent idea among hearing people for a long time (indeed, still today for many) has been that *language equals speech* and that, therefore, sign is not (like) language, and in fact is an inferior communication system that is not worthy of studying, let alone that it would lend itself to linguistic analysis.

3. A brief introduction to sign language phonology

Here I summarize (rather than justify) what the reader must minimally know about the phonological structure of signs to understand the content of this chapter.[5] The production of signs uses the hands, the upper body (trunk, arms, head) and facial expression. Body and head posture can be grammatically relevant in discourse. Facial expression (especially the upperpart: eyes, eyebrows) is relevant syntactically. Facial properties can also be part of lexical contrast between morphemes (as in the sign HAPPY below where the signer has a happy face).[6] The manual part of signing concerns what the hands do and what 'shape' they take. Signs can be articulated with one or two hands. If one-handed (as in the sign ACCENT below[7]), the choice of hand (which will usually be the preferred hand, i.e. the hand dominantly used by a right- or left-handed person) is non-contrastive. In most, perhaps all sign languages, half or more of the signs are two-handed. When two-handed, both hands either function as 'twin' articulators (as in the sign ACTOR below) or one hand (usually the non-preferred hand) is the location for the active hand (as in the sign DISAPPEAR below).[8] The active articulator assumes a **handshape** that executes a **movement** at

[4] It is common to find a review of many more misconceptions about sign languages, such as the idea that all deaf people across the world use the same sign language or that sign languages are visual renderings of spoken languages. These misconceptions, including those mentioned in the text, have all been thoroughly debunked.

[5] General reviews of sign linguistics include Wilbur (1987) and Sandler & Lillo-Martin (2006).

[6] It will often not be so easy to find minimal pairs when facial properties (that are an essential part of the signs) are concerned. In general, minimal pairs even for manual aspects are not as frequent as they are in spoken languages. I will here not discuss why this should be so except for the suggestion that the greater array of phonetic means in the signed modality makes the occurrence of signs that differ in only one aspect less frequent, However, minimal pairs can be found; see Klima and Bellugi (1979) and Lillo-Martin and Sandler (2004) for relevant examples.

[7] The photographs are taken from an online resource (one of many > SHOULD PERMISSION BE REQUESTED): http://lifeprint.com/.

[8] In so-called classifier constructions, both hands can function independently. Classifier constructions use a handshape, or two, to represent an action of event. The location, movement and handshape are independently meaningful, i.e. usually analyzed as separate morphemes.

some **location**.[9] The location can be the space in front of the signer (called neutral space) or be a part of the body (such as head, trunk, neck, arm or (other) hand). The movement can be a movement of the whole hand along a path or it can be a local movement through rotation of the lower arm or closing/opening of the fingers. For each sign component, every sign language has a finite number of choices, comparable (with caution; see below) to the choice of vowels and consonants in spoken languages. The different choices can be further analyzed in terms of distinctive features that characterize the details (such as the specifics of the handshape or the shape of a path movement). Signs that consist of only a non-manual component are very rare, so the hand seems crucial. Various researchers have claimed that, with rare exceptions, all signs have a movement component. By necessity, all signs also have a location. In each sign, these three aspects occur simultaneously, and obligatorily. This fact has led to the initial belief that signs have no sequential structure, even though any sign with any movement has a durational aspect. Over time the need for sequential structure was established which invoked application of the notion syllable structure (see section 11). The fact that the structure of signs not only displays segmentation in terms of the three aspects, and within each of these in terms of finer feature distinctions, but also shows evidence for constraints on how these properties can be combined clearly confirmed to researchers that sign languages display a phonological organization that is very similar to that of spoken languages.

Fingerspelling forms an inherent part of sign languages that are used within cultures that have a written spoken language. Such languages contain a set of signs that represent letters of the alphabet or representations of other kinds of written units, such as characters for Chinese languages. By using these handshape words of the surrounding spoken languages can be spelled.

HAPPY ACCENT


ACTOR DISAPPEAR



[9] For each aspect of sign structure, there is a useful review. See Crasborn (2011) for two-handed signs; Brentari (2011) for handshape; Sandler (2011) for movement; Wilbur (2011) for syllable structure; Mauk & Tyrone (2012) for location.

4. The pre-linguistic era: Auguste Bébian

A French priest by the name of Charles-Michel de L'Épeé (1712-1789) is credited for being perhaps the first educator who understood that deaf people have 'some kind of' language of their own and he decided that it would be beneficial to use their sign language to teach them *written* French, thus moving away from a focus on the oralist goal of speaking and lip-reading. L'Epeé started compiling a dictionary of signs (which he did not finish), but his successor Roch-Ambroise Cucurron Sicard (1742-1822) did publish his own dictionary. Like so many others before him who had made lists of signs of whatever kind, he used *verbal descriptions* of how the signs are made, presumably because making drawings would be more cumbersome and costly.[10] Signs were thought of as holistic gestures, but spoken or written language simply cannot 'depict' a sign in an analog, holistic fashion, so verbal descriptions unintentionally suggested a partitioning of some sort which, then, prefigures a more formal partitioning that uses special symbols.[11]

It was Roch-Ambroise Auguste Bébian (1789-1839) who, working as a hearing teacher during Sicard's reign, recognized that signs can be analyzed using a finite set of smaller units for which he designed a notation system, consisting of 200 symbols. [12] The system was meant as the first **writing system** for a sign language (Bébian (1825); see Fischer (1995)).[13] It would seem that, just like the first phonographic writing systems for spoken languages implicitly acknowledges submorphemic phonological structure, Bébian's system anticipated the work by twentieth-century scholars which will be discussed in the following sections.[14]

5. La Mont West

La Mont West (1930-) is an anthropologist who wrote a dissertation about a sign language that had for centuries been used by various native American tribes (the Northern America 'Plains Indian Sign Language', PISL), who, speaking different languages, would communicate in sign across spoken language boundaries.[15]

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[10] For example, for the sign ACCENT such a verbal description could be: index finger extended, pointing to neck, moving to make contact.

[11] The use of verbal descriptions to represent 'signs' has a long tradition in the recording and promoting of both so-called monastic sign languages and rhetorical gestures that can or must be used in public discourse. See Kendon (1982) for a review of works on gestures and Umiker-Sebeok & Sebeok (1987) on monastic languages.

[12] Kendon (1982) mentions some early works on gesture in which formal notation systems were proposed. Indeed, he shows that throughout history there have been formal notation systems for body movements of various kinds (dance, mime or gesture). Also see Kendon (2002).

[13] Notation systems for bodily communication systems can be based on various principles. Usually the symbols are iconic in some way, unless for practical reasons the use of alphabetic symbols is preferred. A discussion of notation systems is beyond the scope of this chapter; see van der Hulst & Channon (2010).

[14] Bébian's emphasis on and study of natural French Sign Language was not consistent with the doctrines of de L'Epeé and Sicard, so he was fired from the *Institution Nationale des Sourds-Muets*, dying at the young age of 49 in Guadeloupe, his place of birth. Strikingly, rejection of those who study the natural languages of the deaf by those who control the education of the deaf is a recurrent phenomenon (see also section 6).

[15] See Davis (2010) for an introduction to the study of Plain Indian Sign Language. This language was a 'trade jargon', but West treats it as a full-fledged language. This language has in fact been acquired as a first language by deaf people in the tribes

The idea to investigate these systems linguistically (before they would become extinct) came from Alfred L. Kroeber (1876-1960). Kroeber (1958) discussed the urgency of describing the Plains Indian Sign Language, offering an extensive preliminary analysis that makes observations about the difference between one- and two-handed signs that has inspired later work by others on the phonology of American Sign Language (ASL). Kroeber was not sure that signs have a submorphemic structure, so he rejects an analogue to spoken languages phonemes. This claim is addressed in Voegelin (1958) who, making reference to the work that West was doing at the time, suggests that such a submorphemic structure might very well exist and he argues that a morphemic analysis cannot easily proceed without representing signs in terms of internal discrete structure, using some kind of notation system. He explains that a 'two-level' (phonological and morphological) analysis has the advantage of being able to more easily recognize recurrent morphemes in words, compared to prose descriptions of the articulatory properties of words. His argument for a phonological analysis and the development of a notation system is fully carried out in the work of La Mont West, which unfortunately is usually not mentioned at all in works that review the emergence of sign phonology, presumably because linguists do not know about it. In his unpublished 1960 dissertation (written after several years of fieldwork), West calls PISL "a natural language in every sense – a language amenable to analysis by the techniques of modern linguistic science" (see his page 1a). West was unaware of the work by Stokoe (see section 6), who was working on his discovery of phonology in sign language when West did his field work.

Being of the opinion that PISL is a fully-fledged natural language, West analyzed this language phonologically, morphologically and syntactically. He developed an explicit notation system. This system is non-iconic, using alphabetical letters and some additional diacritics. West analyzed PISL in terms of 82 'kinemes'[16], which he symbolized with 36 alphabetic symbols in combination with 5 diacritic marks, plus 5 dynamic markers.[17] Several of his observations strike a familiar tone to present-day researchers who work on sign languages used by the deaf. West recognized that the kinemes *can* be further analyzed in terms of features. It is very striking that West analyzed most signs that others, like Stokoe (in her work on American Sign Language, ASL) would analyze as monomorphemic, as having a complex morphological structure. Recognizing that the building blocks of signs often occur with recurrent meanings, he analyzes, for example, the sign meaning EAT as the simultaneous combination of at least four morphemes that recur in other signs (HOLD-IN-FINGERS+INSERT+REPEAT+MOUTH).[18] He then also recognizes that these morphemes often change their form depending on what they are combined with and he formulated a sophisticated set of rules that account for "morpho-kinemic alternations" to account for such variation in form. As I will note in various places in this chapter, his work anticipated many insights that were rediscovered in the study of sign languages. A full analysis of West's approach is desirable (as would be the publication of his thesis).[19]

[16] He took the term 'kineme', as the basic unit of a gestural system (as we will see in the next section, like Stokoe avoiding terminology from the analysis of spoken languages) Birdwhistle (1955) in his study if gesture. Birdwhistle referred to his approach as kinesics. (A related term 'kinematics' refers to the study of motion, while kinetics focusses on the forces that cause motion).

[17] West uses diacritics for finger positions (bending)/aperture.

[18] The highly complex morphological structure that results suggested to West that sign languages are 'polysynthetic' languages. West's recognition of meaningful parts is very similar to the proposal in Boyes-Braem (1981) and recent work by van der Kooij and Zwitserlood (to appear).

[19] West subsequently also did work on sign languages in Australia, where he extended his focus to mime and dance. In his last publication (West 1963), he calls for a unified approach to the study of sign, mime and dance without

6. William C. Stokoe

Like West, William Stokoe (1919-2000) showed that sign languages have a dual articulation, i.e. that signs which were thus far thought of as holistic forms associated with a meaning can be analyzed in *meaningless* parts, just like morphemes in spoken language can be analyzed into phonemes and features. Stokoe, graduated from Cornell University with a degree in English and a specialization in medieval literature.[20] In 1955, he was hired and appointed as the chair of the English department at Gallaudet College. While he knew very little about sign language when he joined the school, William Stokoe got interested in the way deaf students communicated among themselves and he decided to analyze the language using the methods of modern linguistics. Not having a strong background in theoretical linguistics, Stokoe took a summer course with George L. Trager and Henry Lee Smith, two leading structuralist linguists. Their ninety-page 'An outline of English Structure' (1957) exemplifies an approach to linguistic analysis which they apply to a portion of English grammar, for the most part the phonological and 'morphemics'. Following their methods, Stokoe conducted a detailed investigation of American Sign Language (ASL) (a name that he gave to the language of the deaf that he worked with), focusing on the phonological structure of signs. The results of this research were published in a 78-page paper. [21] Stokoe acknowledges the work of Bébian, but he had no access to the work by La Mont West. He does mention the papers by Voegelin and Kroeber. In a later publication (Stokoe 1966), having now seen West's dissertation, Stokoe acknowledges the similarities between his own work and that of West with respect to postulating a submorphemic segmentation and a set of symbols. Stokoe also discusses the pioneering work of Bernard Tervoort (1920-2006)[22] who analyzed the sign language of a group of Dutch deaf children, shying away from what we would call a phonological analysis.[23]

At the terminological level, underlining that the study of sign language form should not be seen through the prism of spoken language phonology, Stokoe suggested that the study of the perceptible form of signs would be called **cherology**, and what he took to be the basic units (handshape, movement, etc.) would be called **cheremes**; the Greek root *cher* (χείρ) means 'hand'. This terminological proposal had little impact because sign researchers quickly adopted the use of the analogous term 'phonology' for their field of study, and even the term 'phoneme' (for the simultaneous units handshape, movement and location).[24] Another crucial part of the story is that

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claiming that these are the same. According to a wiki page about him, he currently lives in Washington (https://en.wikipedia.org/wiki/La_Mont_West), apparently having withdrawn from academic work since his last publication in 1963.

[20] To get a good picture of the man and his work, see Maher (1996) and also Ruth Stokoe (1980). An excellent discussion of Stokoe's work, the historical context that preceded his work, its reception and its relation to the emergence of sign linguistics is McBurney (2001).

[21] Stokoe's seminal work was not published in 1960 as a book. It appeared as "*Studies in linguistics: Occasional papers (No. 8)*", which were distributed by the Department of Anthropology and Linguistics of the University of Buffalo. Since then is has been republished three times. In: in 1978 (Stokoe 1978) (in a revised version), and in 1993 (Stokoe 1993) and 2005 (Stokoe 2005) (both in the original version).

[22] Tervoort's work is also discussed by West.

[23] Tervoort (1973) is a review article of Stokoe (1972) in which he reflects on Stokoe's results. He expresses doubt that even Stokoe's work on ASL has delivered conclusive proofs that a sign language can be a 'true language'.

[24] Van der Hulst (1993b, 1995) takes issue with Stokoe's original claim that his major units compare to spoken language phonemes, pointing out that the major units compare more readily to different aspects of individual

Stokoe's idea to analyze signs in smaller parts necessitated the development of a **transcription system** for signs that could replace drawings or photos and which would be used in *A Dictionary of American Sign Language on Linguistic Principles*, co-authored with Dorothy C. Casterline and Carl G. Croneberg (Stokoe, Casterline & Croneberg 1965). From 1960 onward, Stokoe and his two co-authors, with a grant from the National Science Foundation (NSF), focused their energy on this dictionary project while others who were inspired by his work started researching syntactic structure.

The dictionary is known as DASL. It contains some 2500 signs, all presented in the notation system and provided with an English equivalent. The dictionary entries are arranged in accordance with the notation system, which specified the three major aspects in the order: location (tab), handshape (dez) and movement (sig). Within each unit, the distinctions are ordered as specified in a pre-given list. The location list, for example, starts with '0' (for neutral space), and the handshape list starts with the 'A-handshape' (see below for this term). The dictionary thus starts with signs made in neutral space with the A-handshape. The dictionary contains a listing and explanation of all the notation symbols, as well as several essays that comment on ASL syntax and various cultural and educational issues. That the dictionary entries were written in notation (with no picture or drawings included) testifies to Stokoe's conviction that ASL is not in some sense subordinate to English. This made DASL somewhat inaccessible to those not familiar with the notation system. Despite this, DASL left a mark on the history of sign phonology because many subsequent sign phonologists used DASL as their main source of data. See also Hochgesang & Miller (2016) for a publication based on the 50th anniversary of DASL with many testimonies by sign linguists and educators.

Stokoe's system contains a finite number of symbols for what he perceived as separate parts or 'aspects' of the sign: the handshape (19 symbols), the movement of the hand (24 symbols) and the location in front of or on the body (12 symbols). The symbols are partly iconic (for movement and location), but for handshape Stokoe used the letters ('A', 'B' etc.), when these handshapes were identical or very similar to the handshape used in the fingerspelling alphabet. See Wilbur (1979: Ch. 1), for a complete listing and discussion of the symbols. Subsequent work (Friedman (1977a), Battison (1977) and Newkirk (1975), among others) has proposed alternative (though not entirely different) inventories. [25][26] The ideas of Stokoe were further developed in the sense that his major units were decomposed into distinctive features for each of the major units. I will provide examples of such proposals in subsequent sections (see section 10).

From one angle, Stokoe's partitioning of the form of signs can be understood as a transcription system, designed for the practical purpose of allowing a compositional space-saving system of distinctive properties of signs that would replace holistic drawings. However, Stokoe clearly regarded the symbols as representations of the discrete units that 'realistically' constitute signs, even though, following the views of Trager and Smith, he was not a mentalist.

When he embarked on his work in the late 1950s and even after his ground-breaking 1960 publication, Despite the fact that he received an NSF-grant, Stokoe received very little further support or recognition. As carefully documented in McBurney (2001, 2012), only two reviews of

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phonemes such as laryngeal, manner and place, which leads to the suggestion that signs are monosegmental. This immediately accounts for the fact that aspects of signs are simultaneous, just like the different features of spoken language phonemes are. A monosegmental theory is also developed in Channon (2002).

[25] Friedman (1976), Mandel (1981) and Battison (1978) all provide reviews of Stokoe's proposals with various amendments and modifications.

[26] A computer usable font, called HamNoSys (Hamburg Notation System) has been developed that revises and Stokoe's system, moving it toward a universal transcription system for signs; see (Prillwitz et al. 1989).

his work appeared during the 1960s, one positive (Carroll 1961) and one rather skeptical (Landar 1960), neither convinced that Stokoe had made a conclusive case for recognizing ASL as a proper language.

At Gallaudet, the reception of Stokoe's work remained largely negative. Eventually, Stokoe was 'removed' as chair of the English department but was "allowed" to start a Linguistics Research Laboratory in 1971. In this environment, he continued his work with funding from various sources, attracting many young researchers, most of whom to become well-established sign language researchers. In 1972, he started the journal *Sign Language Studies* that (to the present day) became an outlet for publications of all kinds on sign languages, including theoretical work.[27] To publish this journal, he started a publishing company, Linstok Press, in 1972, which has also been an important outlet for work on sign languages.[28] Stokoe (1972) presented a detailed, updated book-length review of his 1960 work with chapters on phonology, lexicon, syntax, as well as general chapters and a chapter 'current sign language research' where we find few references to work stemming from Stokoe or people pursuing his ideas during the 1960s.[29]

During the 1970s Stokoe invites several young researchers to join his lab. This lead to a broadening of the topics being considered, such as sociolinguistic issues, which results in the first dissertation coming from this group (Woodward (1973)).[30] We also see work being done on non-manual aspects of sign language (Shenk-Baker 1983), on syntax, on acquisition, and on educational issues and Deaf culture. These and other contributions that deal specifically with sign phonology are reviewed in Stokoe (1980) where he also mentions the work done by another group of researchers lead by Ursula Bellugi and Edward Klima (see section 8). Meanwhile, research in other places has started as well (see, for example, Kegl & Wilbur (1976)).[31] During the 1970s Stokoe also shows a strong and continuing interest in the question of language evolution and the role of gesture as a predecessor to spoken language; see Stokoe (2001), Armstrong, Stokoe & Wilcox (1995) and Wilcox (2002). This broader perspective resulted from seeing language as a form of human culture. Subsequently, Stokoe identified more and more with anthropology.

In one of his last publications (Stokoe 1991), Stokoe takes a critical look at what sign phonology had become during the preceding period, opening his article with "Sign phonology can be as complicated as anyone wants to make it" (p. 107). He proposes a 'semantic phonology' which Armstrong & Karchmer (2009) have characterized as Stokoe's version of 'minimalism'; see also Armstrong and Wilcox (2009). The basic idea is that a sign represents an agent- verb structure with the hand being the agent argument and the movement plus location the 'predicate'. Thus far, this approach has not had a significant impact. It is not clear how a subject-predicate structure can be recognized in all signs. Likely, Stokoe's notion of semantic phonology is perhaps mostly relevant with respect to classifier constructions, although it was certainly not intended to be restricted to such constructions. Rather, Stokoe's idea was that in sign languages there is in fact no

[27] Theoretical work following generative approach was not so welcomed.

[28] In 1991 Linstok Press was purchased by Sign Media, which facilitated a wider distribution and presence to Linstok's scholarly publications.

[29] I'm convinced that I have overlooked work, so I stand to be corrected on this. Nevertheless, I think it is true that not very much was published during the 1960s. Stokoe did, however, invest considerable time and energy in getting his points across in the deaf community and among educators. Also, he and his collaborators worked on DASL, published in 1965, which was a very time-consuming project.

[30] There is also attention for the development of materials to teach ASL, which appeared only later (e.g. Baker-Shenk & Cokely (1980).

[31] McBurney (2012) provides an excellent overview of the development of sign linguistics in general, discussing work from both inside and outside the US.

meaningless level of analysis that is comparable to the phonology of spoken languages (Amstrong and Wilcox 2009: 413). This is of course an extremely strong departure from the initial position Stokoe took in his 1960 work. Nevertheless, the idea that parts of signs (held to be monomorphemic) have meaning resonates with West's approach discussed in the previous section as well as with idea in Johnston and Schembri (1999) who suggest that every 'manual gesture' has a literal meaning in which the hand represents itself or an object that resembles the handshape and the movement represent some action. There are also relations to the work of Boyes-Braem (1981) (see section 7) and Brennan (1990); see section 12d.

In the next section, I will briefly discuss five important dissertations that were written during the 1970s, which, while all clearly being based on Stokoe's seminal work (with acknowledgement by the authors, who in several cases spend time at Stokoe's lab), all come from the West Coast of the US.

7. Important early dissertations on sign phonology

During the second half of the 1970s into the early 1980s there was a first wave of very important dissertations that explored sign phonology, taking Stokoe's work significant steps further. These dissertations provide very detailed analyses of ASL phonology while continuing the structuralist approach that Stokoe had adopted, showing (despite claims to the contrary by some of their authors) little influence of the Generative Phonology which had been growing in popularity since the mid-1960s.[32]

Friedman (1976) aims at presenting a 'more complete' analysis of ASL phonology, taking into account iconic and scalar properties. This dissertation indeed offers a detailed inventory of distinctive units (handshapes, movements and locations) in ASL, with an account of allophonic variation. Reference to 'scalar' properties can be understood as involving gestural aspects.[33]

Battison (1977)'s objective is to show how the phonological constraints that can be observed in ASL signs drive the adaptions of fingerspelled words on their way toward monomorphemic signs.[34] Based on the initial observation in Voegelin (1958), which can also be found in Stokoe (1960), Battison formulates the **Symmetry Condition** (which states that in two-handed signs in which both hands are active, both hands have the same handshape and identical or mirrored movements) and his **Dominance Condition** (which states that in two-handed signs in which one hand, the non-dominant hand, acts as the location for the other hand, the non-dominant assumes a limited set of relatively non-complex handshapes, which are called unmarked). These two conditions have since been identified as valid for many sign languages and continue to be mentioned as important generalizations.[35] Battison essentially adopts the three Stokoe 'aspects'

[32] Friedman (1977b) is an important volume with contributions by Battison, Friedman, Mandel and others (which came out of a graduate seminar on sign language), which capture some of the results of the dissertations that are discussed in this section.

[33] The relationship between lexical properties of signs and co-sign gesture (analogous to co-speech gersture) has remained a subject of ongoing research; see Brentari and Goldin-Meadow (2017); see section 12.

[34] This dissertation from 1977 was published as a book in 1978. A new edition was published in 2003, with a foreword by Brentari, which highlights the proposals in and importance of this work in its historical and current contexts.

[35] Later works have proposed slightly different formulations or addenda. See the various review articles mentioned in footnote 3.

(handshape, movement and location) but adds orientation, adopting the term **parameter** for the parts of signs. Stokeo was never in agreement with this additional aspect.

The dissertation by Frishberg (1976) reports on changes in the phonological form of signs throughout the history of ASL.[36] The thrust of this work is that while iconicity is an obvious property of signs, especially directly after their formation[37], over time phonological constraints (or the processes motivated by them) cause signs to lose aspects of their iconicity in favor of being restructured in accordance with the phonological constraints at work in the language (such as the Symmetry and Dominance conditions).

Boyes-Braem (1981) discusses previous proposals and adds her own, proposing a set of 27 features for the 57 handshapes that she identifies for ASL.[38] The most striking and innovative proposal is the idea that one must distinguish two types of handshape features: primary, morpho-phonemic features and secondary, more purely phonological features.[39] Boyes-Braem proposed an explicit model to account for how aspects of a sign are meaning-bearing (and, usually, iconic with respect to the meaning that they express), where previous researchers had only pleaded for taking iconicity into account without developing explicit formal models. Boyes-Braem's work shows that iconic choices play a role in the formation of new signs, and she develops an explicit model that accounts for this role. Her proposal anticipates later developments that aim to account for the fact phonological building blocks are not all meaningless.[40]

Mandel (1981) offers the most extensive discussion of Stokoe's system and later modifications, presenting a rich overview of ASL phonology, phonotactics and morphophonology. Mandel argues for a 'redundant' rather than a minimal system of description, admitting many distinctions that are observationally present, which results in a great deal of redundancy in the analysis of individual signs.[41] Mandel is the first to propose the so-called **Finger Selection Constraint**, which captures that per monomorphemic sign only one handshape can be chosen with respect to which fingers are 'foregrounded' (which usually means 'extended').

The five dissertations reviewed here jointly present very extensive, impressive and detailed work on ASL phonology. Battison, Boyes-Braem, Frishberg and Mandel all explicitly state that they used the DASL corpus for their work. Friedman's work is also obviously based on that inventory, which is simply referred to as 'Stokoe (1965). The reliance of these dissertation not only on Stokoe's theoretical work, but also on the dictionary that he composed, once more underlines the important of Stokoe's work. Nevertheless, each dissertation offers much additional insight and new angles of analysis. A careful analysis and comparison of these works in terms of proposed distinctions and analysis is highly desirable because it is not obvious that later researchers have taken careful note of these works in all their richness (the present author included).

[36] The most important findings of this work are summarized in Frishberg (1975).

[37] It is virtually impossible for human beings to create a sign without invoking iconicity.

[38] See section 10 for further discussion of feature systems.

[39] An independent issue that comes up in proposing features, also prominent in spoken language phonology, is whether features are articulatory or perceptual. Boyes-Braem opts for perceptually-based features. See section 10.2.

[40] Another early dissertation that is relevant here is the study of Phyllis Wilcox (2000) of metaphor in ASL, who reviews earlier proposals. Brennan (1990) also shows how meaningful phonological building blocks play an active role in word formation in British Sign Language. In section 6, I also noted a relation to Stokoe's notion of semantic phonology. Taub (2001) is based on a dissertation from 1997, also offers a formal model to account for the incorporation of meaning-bearing, iconic elements in signs.

[41] In this, perhaps, he prefigured the phonetic approach of Johnson and Liddell discussed in section 11 and 12b.

Naturally there were many other important contributions during the 1970s, in all areas of grammar. Especially relevant to this chapter on phonology are studies that deal with the phonological aspects of morphological processes such as compounding (Klima and Bellugi 1979), reduplication (Fischer (1973)), Frishberg & Gough (1978) and aspectual and inflectional morphology (Klima and Bellugi 1979). Special mention should be made of Supalla & Newport (1978), whose work on ASL morphology was highly important, showing that nouns and verbs are phonologically distinct. Among other things, these authors demonstrated that lexical movements are nested within inflectional movements, which indicates a layering in the morphology and phonology, prefiguring the approach that became known as lexical phonology and morphology (Siegel (1974), Kiparsky (1982)). This idea is later also pursued in Padden & Perlmutter (1987).

In later decades many more dissertations followed on ASL and many other sign languages. I refer to the 'recent' overview articles mentioned in footnote 3 for references, although updated reviews are of course necessary.

8. Edward Klima and Ursula Bellugi

During the 1970s Ursula Bellugi, Edward Klima, both with dissertations from the Massachusetts Institute of Technology (MIT), and a team of researchers took the linguistic investigation of sign language in many new directions at the Salk Institute for Biological Studies (La Jolla, California), that was founded in 1963. Interested in the biological foundation of language, Bellugi hit on the idea to analyze the linguistic structure of American Sign Language (ASL), focusing on the psychological reality and neurological basis of this language. This work culminated in Klima and Bellugi (1979), *The Signs of Language* (SoL). This highly influential book contains various chapters that deal directly with the phonological organization of signs.[42]

Stokoe had shown that the phonological form of signs is compositional, but while it is possible to recognize and transcribe phonetic properties that function contrastively (in this case the shape of the hand, the movement of the hand and the body location at which the hand performs its action), it does not follow automatically that these distinctions have a reality in the mind of the signer in terms of storage in memory and language processing. Stokoe never addressed this question directly, no doubt influenced by the non-mentalistic philosophy of his Trager and Smith, but groundbreaking work on these issues was done by the Klima & Bellugi research group at the Salk Institute during the 1970s, involving, among others, a study of 'slips of the hand', and many experimental techniques and laboratory studies. The response to Klima and Bellugi (1979) in the scientific world, especially in psycholinguistic circles, was overwhelmingly very positive. Since its publication until the present day many linguists would say that this work convinced them that sign languages are 'real' languages, and that sign linguistics is a proper subdiscipline in the field.[43]

[42] The authors of this book explain that most chapters are based on previous working papers and articles that were authored or co-authored by members of the Salk research team. As detailed in McBurney (2001) (pp. 171-72), collaborating authors were Robbin Battison, Penny Boyes-Braem, Susan Fischer, Nancy Frishberg, Harlan Lane, Ella Mae Lentz, Don Newkirk, Elissa Newport, Carlene Canady Pedersen, and Particia Siple. Contributing researchers were Scott Liddell, Ryan Tweney, Helen Neville, Howard Poizner,Cheri Adrian, Madeline Maxwell, Darlene Scates, Sharon Newmann Solow, Richard Meier, Geoffrey Coulter, Richard Lacy and Birgitte Bendixen. Reportedly, not all of these researchers, who had authored or co-authored papers that found their way in the book, were happy with the loss of authorship in the book.

[43] There was cross-fertilization between the two research groups with researchers working at the Salk Institute spending time in Stokoe's lab.

9. The reception of Stokoe (1960) and Klima and Bellugi (1979) compared

I noted in section 7 that Stokoe's work did not receive a lot of attention in the linguistic world for quite some time. McBurney (1998, 2001) meticulously analyzes the reception of Stokoe's work, also in comparison with that of Klima and Bellugi, raising the question why Stokoe's work, while clearly foundational (and known to the Klima and Bellugi group), had so little impact, while SoL did so much to bring sign language into 'the purview of (psycho)linguistics' (which was Stokoe's goal) and within the broader arena of cognitive science. [44]

We have to take several factors into account:

1. What were the goals and result of the two works?
2. How were these goals and results presented to the intended 'audience'?
3. What was the linguistic climate?
4. What was the broader intellectual climate?

As mentioned in section 7, Stokoe set out to analyze the language that was used by the deaf students at Gallaudet, following the same methods of structuralist analysis that were being applied to spoken language. In this method language is analyzed bottom to top in terms of units and their combinations at a series of levels, starting with a phonetic analysis of the observable side of language, progressing to a phonemic analysis, to be followed by a morphemic and syntactic analysis. The result of Stokoe's work was an explicit taxonomic description of the signs of ASL, focusing on the phonemic analysis, specifically the manual aspects. The study also contained some remarks on morphology and syntax; Stokoe considered non-manuals a matter of syntax. His phonological analysis was written for an audience of linguists, assuming familiarity with the structuralist method and the terminology of linguistics. There is no 'rhetoric' to convince linguists of his analysis, which is simply presented to them, meant to speak for itself. In one favorable review of Stokoe's work, Carroll (1961), realizing that readers outside linguistics might need some background in linguistic terminology, explains in two pages what would be minimally required, something that Stokoe should have done. Aiming at linguists, Stokoe narrowed his audience. In fact, given that Stokoe wanted to also convince educators of the deaf, it is odd that he did not try harder to accommodate them in his book. Educators at Gallaudet and elsewhere did not understand the work with its 'complicated symbols' and terminology. But Stokoe also made it hard even for linguists by choosing new terms (chereme instead of phoneme, etc.) and opaque terms for his three aspects (*dez* for handshape, *sig* for movement and *tab* for location). Deaf people, with no knowledge of linguistics, had even less access to his analyses and moreover did not understand what this 'hearing person' was doing with their language, which they had been told by generations of hearing educators could not be analyzed in the same way as a spoken language.

For linguists, however, there was another factor that diminished their attention. Chomsky had published *Syntactic Structures* in 1957 (Chomsky 1957) and generative grammar was on the rise, the new thing to do. Structuralism was 'out', Chomsky was 'in'. Following the approach of Trager and Smith, Stokoe understood language to be a part of culture. As such, Stokoe's focus was on language 'performance' (despite his aiming at a phonemic analysis). With Chomsky the pendulum had swung to language 'competence'. Even though Stokoe was aware of Chomsky's

[44] This eventually changed and Stokoe ended up giving talks all over the world. See Maher (1996).

early work and liked the idea of formalization, he never got on board with the 'new linguistics', and therefore also not with the overall mentalistic focus that led to the cognitive revolution of the 1960s. His thinking and research started and was done before the breakthrough of generative grammar. It would seem that the 'timing' of Stokoe's 'book' could not have been worse. As already mentioned, the reception of SoL was quite different. Toward the end of the seventies, there was a willing audience for the results presented in this work that had embraced the new mentalistic way of looking at language. Klima and Bellugi's book was informed by and thus fit right into the Chomskyan view and the cognitive approach that had firmly established itself. Klima and Bellugi, being MIT graduates and working at the prestigious Salk Institute, were well-connected in linguistic and psycholinguistic circles. Studying the acquisition of sign language fit well with the focus on language acquisition in the generative and non-generative quarters. Their text was well-written, asking questions before answering them, and easy to understand for non-linguists. As carefully documented in McBurney (1998, 2001), the book was positively reviewed in many different journals.

Over time, the historical 'injustice' of neglecting Stokoe's contribution has been corrected. Today there is no doubt that Stokoe is the father of sign linguistics, who showed the way to all who followed. Klima and Bellugi's work was a shining highlight in developments during the 1970s and beyond, overshadowing not only Stokoe's work, but also much other work that was done in the 1970, as documented in Wilbur (1979), which offers a comprehensive and detailed discussion of sign linguistics, starting with Stokoe' work and continuing with the work of many others. In several ways, Wilbur's book has a wider scope than Klima and Bellugi (1979) and qualifies as the first comprehensive 'textbook' on sign linguistics. In a revised edition from 1987, Wilbur updates her state-of-the-art review by including the development toward the recognition of linear structure as discussed in section 11.

10. From structuralist linguistics to generative approaches[45]

The impact of generative phonology, already somewhat visible in the dissertations discussed above as well as in Klima and Bellugi's book is manifested in the attention to feature systems, phonological rules and the recognition of different lexical strata in work published during the late seventies and eighties. More generally, the attention has shifted to a mentalistic understanding of language, while strict bottom-to-top analytic procedures adhered in the preceding American Structuralist school were abandoned.

Wilbur (1987: Ch. 1) reviews various proposals for handshape feature systems: Woodward (1973), Kegl & Wilbur (1976), Lane, Boyes-Braem & Bellugi (1976b), Boyes-Braem (1981), Sandler (1987a, b, 1989), Corina (1989), Corina & Sagey (1989a, b). Movement features are proposed in Kegl & Wilbur (1976). Complete sets of features can be found in Sandler (1987b), Liddell & Johnson (1989) and Brentari (1990a, b), and later works such as van der Kooij (2002), Hansen (2006) and Cull (2014).[46] The question of feature systems for the major aspects of signs

[45] In this and the following sections, I include references that go beyond the 'early history of sign phonology'. However, I must refer to the general overviews mentioned in fn. 4 for more complete reviews of the later literature.

[46] Additionally, Battison, Friedman & Zambrano (1973) propose 10 features to distinguish 40 handshapes; Lane, Boyes-Braem & Bellugi (1976a), based on a visual perception experiment, propose 11 features for 20 handshapes; Stungis (1981) developed a feature system, using the same visual experiment data running them by new subjects who were asked to make similarity judgements.

continues to be a subject of interest. On the one hand this is a result of the fact that dealing with the sign modality is relatively new, but specific complicating factors play a role too. Firstly, there is the role of iconicity, which several studies discussed here grappled with (see section 12d). Given the pervasive role of iconicity, researchers ask whether all phonetic properties of signs must be captured in terms of potentially distinctive features, or be prespecified lexically as such (see van der Hulst and van der Kooij (2006). Additionally, as in spoken language where co-speech gesture can be universally observed, recognizing co-sign gesture raises the question of where to draw the line between lexical properties of signs and co-sign gesture (see Brentari and Goldin-Meadow 2017).

Wilbur (1978: 79) points out that Stokoe's analysis was empathically phonemic, treating various handshapes as variants of a single handshape (such as 'A' and 'S', a fist with the thumb next to the index finger and a fist with the thumb folded over the over fingers, respectively). However, he did not write rules that predicted the occurrence of allophonic variants from the phonological environment. The need to formulate explicit allophonic rules that use the features that characterize the handshapes, movements and locations of signs was established in Wilbur (1978), who explicitly argues for applying the generative approach that distinguishes underlying and surface forms to the study of sign phonology. However, as discussed in section 6, West (1960) also formulated many (in his term:) 'morphophonemic' rules to account for such allophonic variability in PISL.

There is a question about the 'status' of the phonological rules that these authors propose. When morphemes are combined, as in compounds or words in the sentence, various types of assimilations can take place. Arguably (at least in the view of the present author), these processes perhaps belong to the realm of phonetic implementation. Such rules could of course develop into obligatory 'phonological' rules that are triggered every time a compound is formed, but this does not appear to be the case. Rather, the effect of the phonetic processes is lexicalized on a compound-to-compound basis. Compounds gravitate toward the structure of monomorphemic signs, both phonologically and semantically, but they do so on an item-by-item basis, likely dependent on their frequency of use; see Bellugi (1976); Liddell & Johnson (1985); Sandler 1999). As a result, there is a noticeable absence of reports on 'phonological rules' that are comparable to phonological rules that occur in spoken languages which vary from rules that are dependent on lexical and morphological conditions (such as the notorious velar softening rules in English, exemplified in the pair in *electric – electricity*) to rules that apply generally when their phonological conditions are met (such as rules of vowel harmony) producing systematic allomorphic variation. At best, the allomorphy that results from having different forms of morphemes when free or in compounds in sign languages could be captured in lexical 'redundancy rules'. This raises the question why rules that account for allomorphy should be absent in sign languages. Perhaps this is due to the fact that for phonological rules (which can no longer be seen as part of the phonetic implementation system) only develop over considerable time with regular transmission from generation to generation within a language community that produces positive evidence for the relevant alternations. More often than not, deaf children learn sign language based on imperfect input (unless they having deaf parents who sign), which then causes them to spontaneously apply natural phonetic processes, rather than learning 'frozen' alternations that have emerged over generations of learners (as is the case in spoken languages). Secondly, another reason for the lack of obligatory allomorphic rules may be the relative absence of sequential structure due to low occurrence of concatenative morphology involving affixes, however such lack of linear structure would, in principle, not block allomorphic variation in the simultaneous parts of signs. Thirdly, another factor that may cause

an avoidance of systematic allomorphic change is that such changes would render the semantic function of phonological units opaque.[47] After all, if phonological features carry meaning, the form meaning relation would be disturbed, if such features are altered purely on phonological grounds.

While Stokoe's work (as is also clear from the lemma inventory in DASL) had largely focused on what one might called established, lexicalized sign, there grew a general agreement among sign phonologists that the lexicon contains different strata of signs which display different phonological properties. Johnston & Schembri (1999) offer an extensive and insightful discussion of different types of signs. Brentari & Padden (2001) propose a three-way distinction: a core lexicon (signs with submorphemic meaningless units, monomorphemic, often called 'frozen'); non-core lexicon (productive classifier constructions) and a non-native lexicon (fingerspelled words). They argue that these three strata must be separated in the phonological analysis. Different phonological generalizations obtain for these various strata. The phonological studies reviewed previously focus on the frozen ('monomorphemic') signs. Friedman (1977a), for example, excluded fingerspelling from her study of ASL phonology. Supalla & Newport (1978) found that the phonology of frozen forms is embedded in the phonology of productive formation that shows aspectual modification and inflection. The differentiation in terms of different lexical strata is also common for spoken languages, especially in lexical phonology/morphology approaches (see Kiparsky (1982)).

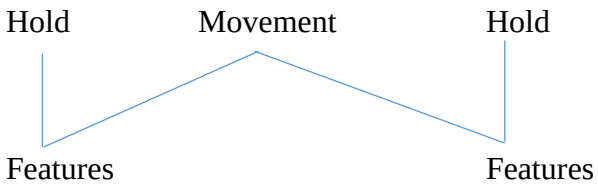
The analysis of fingerspelling (sometimes called **dactylology**) has also proven to be a fertile topic for phonological analysis. Battison (1978) was the first to study the manner in which fingerspelled words that are used recurrently will adapt to the phonological constraints that govern lexical signs. Liddell & Johnson (1985) also include fingerspelling in their analysis. Fingerspelling, because of its rapid execution, triggers many co-articulatory processes which have also been studied; see Wager (2012). Fingerspelled words (whether or not reduced and restructured) can acquire a holistic perceptual appearance (just like written words for spoken language); see Wilcox (1992). See Kean (2014) for a recent investigation of fingerspelling as it relates to an articulatory model of handshape. Wilcox (1992) and Kean (2014) look at the phonetics of fingerspelling. Padden (2006) concern the acquisition of fingerspelling. See Brentari (2001) for a collection of relevant studies, as well as Patrie & Johnson (2011), Wager (2012) and Keane & Brentari (2015).

11. The rise of sequential and multi-linear structure

Stokoe, and work following his lead, highlights the simultaneous nature of phonological sign structure as opposed to the linear, sequential structure of the phonemes in spoken languages. It was acknowledged that signs have a temporal duration, but such 'linear 'aspects were regarded as 'phonetic'. A major shift in phonological models of sign language occurred when researchers started drawing attention to linguistically relevant sequential properties. This shift has been documented in many reviews of sign language phonology and will only be briefly summarized in this chapter that is mostly meant to discuss the *early history* of sign phonology.

[47] Also see Sandler (2017) for this point.

The need for linear structure was first advocated in Supalla & Newport (1978).[48] These authors contrast FLY-THERE-BY-PLANE with FLY-BY-PLANE, showing that the first has a 'hold' i.e. a fix end location of the sign, while the movement in the second example is 'continuous'. They argue that there is a morphological rule that assigns a 'hold' to the endpoint of the first sign, which represents the end location of the flying event. Clearly, such a rule can only be formulated if there is such a thing as an 'endpoint' in the phonological representation, but no formal proposal is developed in their article. Newkirk (1981) looks at reduplication and observes that a sign with a bidirectional movement (abba) repeats the entire movement (abba-abba) while, the reduplication of a unidirectional movement (ab) leads to (ab-ab) with an inserted transitional movement from b to a in between. Such facts also cannot be described, let alone explained, without representing the beginning and end point of the movement. Building on these early studies, Liddell (1984a) offers a rigorous discussion of linear aspects of signs, providing additional arguments for such a move, involving among others the phenomenon of agreement. The sign GIVE involves a movement (representing the transfer of an object), but the direction of the movement for I-GIVE-YOU (away from the signer's chest toward the addressee) and YOU-GIVE-ME (from addressee to the signer's chest) is meaningful. One analysis is that this shows a morphological process involving the attachment of 'pronouns' (points in the neutral signing space) to the beginning and end points of the movement for GIVE. Phonological (or phonetic) arguments, for example involving the metathesis between the beginning and end points of different versions of signs, also call for linear structure. Unlike previous calls for linearity, Liddell proposes a formal model for the linear representation of signs. This model is further developed in Liddell (1984a, b, 1009b) and Liddell & Johnson (1985, 1989), and in a series of more recent articles that discuss detailed aspects of signs (Johnson & Liddell 2010, 2011a, b, 2012). In the model developed in Liddell & Johnson (1985, 1989) sequential feature bundles representing the handshape are associated in a one-to-one manner with these units:[49]



This model follows the theory of phonology advanced in Chomsky & Halle (1968) in representing the featural content of signs in terms of linear sequences of feature bundles. The novelty of their approach is that the feature bundles are linked to H and M positions. This creates a superficial resemblance to the autosegmental model that Goldsmith (1976) had developed for spoken language but the crucial difference is that the lines linking feature bundles to skeletal positions in this model are not the kinds of 'association lines' that can link a feature bundle to the beginning and final hold if it does not change during sign. Such multiple association is virtually mandatory

[48] I also refer to the abstract of a presentation at the 1977 LSA meeting: Ellenberger, R. 1977. Sequential Aspect of ASL Phonology. Chicago: Linguistic Society of America Annual Meeting, page 12. This abstract suggests that movement can be analyzed "as the predictable consequences of locations or handshapes', a view that predates Stack (1988), Hayes (1993) and van der Hulst (1993).

[49] Wilbur & Petersen (1997) provide argument against this model based on 'backward signing' because in such signing the movement occurs reversed, which suggest that movement is not an autonomous segment, but a transition between the beginning and end point of the sign.

in Autosegmental Phonology given the fundamental Obligatory Contour Principle that forbids sequences of identical features or feature groups. In violation of such a principle, Liddell and Johnson postulate separate feature bundles for the initial and final hold, even if these bundles are identical.[50]

Having provided the key arguments for introducing linearity into the representation of signs, and having developed an explicit model to capture sequentiality, Liddell and Johnson take on the notion of phonemic representation, rejecting it and proposing their own approach as aiming at a representation of the phonetic properties of signs. Liddell and Johnson argue that from an abstract phonemic representation (i.e. one that only captures contrastive properties) there is no way of telling directly what the phonetic realization of the signs is, which is of course a necessary consequence of the fact that a phonemic representations abstracts away from predictable phonetic details. Liddell and Johnson's solution to this problem is to abandon the notion of a phonemic representation,[51] instead presenting their work as "a segmental framework for the phonetic representation of signed languages" which is part of "a larger effort on our part to develop a theory of the phonetic structure of signs and to simultaneously create a tractable notation system consistent with that theory" (Liddell & Johnson 2011) (p. 408).

While the theory proposed in Chomsky and Halle (1968) explicitly limited phonological representation to a linear string of feature bundles (plus boundary symbols and syntactic bracketing), early on some researchers had pleaded for the recognition of syllable structure (Anderson 1969), Vennemann (1972)). As of the second half of the 1970s, we see the emergence of new theories which recognize the syllable (Kahn 1976) as well as a richer structure for phonological representations, such as Autosegmental Phonology (Goldsmith 1976), Metrical Phonology (Liberman and Prince 1977), non-concatenative morphology (McCarthy 1979) and Feature Geometry (Clements (1985); Sagey (1986)).[52]

Turning first to the potential relevance of a syllabic structure for signs, the earliest suggestion that ASL signs have CV-like syllable structure is Kegl and Wilbur (1976), who took facial expression to be the vowel analogue and handshape the consonant. This proposal did not involve the notion of linear structure. Chinchor (1978), followed by Coulter (1982) suggested that movement can be compared to a vowel, while the static elements of the sign (handshape, orientation and location) are like a consonant. A similar comparison can also be found West (1960). These early proposals too did not, however, appeal to a linear order of the C and V unit, which were said to occur simultaneously.

As we have seen, linearity is explicitly recognized in the HMH tier proposed in Liddell (1984a). Their proposal naturally suggested an analogy to the linear CVC structure that obtains in spoken languages. An extensive literature, pursuing this idea, follows: Edmondson (1986, 1990); Sandler (1987b, 1993); Wilbur (1987, 1990b, 1993); Perlmutter (1989, 1992, 1993)[53]; Brentari (1990a, 1993); Corina (1990); Blevins (1993); Brentari & Goldsmith (1993); van der Hulst

[50] Liddell (1990b) presents a autosegmental model in which features that remain constant throughout the sign are associated to all sign segments (HMH). To achieve this a postulate 10 separate tiers.

[51] They also question the whole notion of minimal pairs as being relevant to the study of sign phonology; Johnson & Liddell (2010) (pp. 248-253); see footnote 6.

[52] The model of Metrical Phonology (Liberman & Prince 1977) had less influence, although its offshoot prosodic phonology will eventually have an impact on the study of prosodic structure in sign languages; see section 12c. Miller (1991, 1996) applies the notion of foot structure to the rhythmic properties of sign.

[53] Perlmutter refers to the syllabic template as 'PMP' and he also proposes using mora-units.

(1993b); Hara (2003); see Sandler (2008)[54] and Wilbur (2011) for overviews. See Fenlon & Brentari (to appear) for various phonological arguments for syllables in signs.

Inspired by autosegmental phonology, feature geometry and templatic theories for non-concatenative morphology, and by the Liddell and Johnson model, Sandler (1986, 1987b, 1989, 1993) takes sign phonology three significant steps further. In her model, called the **Hand Tier Model**, one handshape structure is associated with both the beginning and end point of the sign 'skeleton' (LML), as well as the movement unit in between, using one-to-many association. This allows for an expression of the empirical observation that certain handshape properties of the sign remain constant during an entire sign, thus having scope over the entire syllabic skeleton (such as the choice of finger selection as part of the handshape). A similar autosegmental status is granted to the specification of the major location, which, as we have seen, is also constant for monomorphemic signs (Battison 1978). Secondly, Sandler takes into account the notion of **Feature Geometry** as developed by Clements (1985) and Sagey (1986). Based on assimilation data, Sandler proposes that handshape and orientation form a unit within the sign representation[55]. Thirdly, Sandler uses elements of the theory of **templatic morphology** (developed in McCarthy (1979)) and discusses a number of morphological processes in ASL and in Israeli Sign Language (Sandler 1990) which manipulate units in the sequential template.[56] Clearly, Sandler's model successfully connects sign phonology with the 'nonlinear' developments that had taken place in the study of spoken language phonology during the second half of the 1970s and early 1980s.

Later models that follow this 'multi-linear' trend are proposed in Brentari (1990a, 1998) (*The Prosodic Model*) and van der Hulst (1993a, 1995) (*The Dependency Model*), developed in van der Kooij (2002). Differences between these models lie mostly in the treatment of movement; see Sandler (2011). [57]

Finally, I note that the issue of simultaneity vs. linearity also manifests itself in the study of non-manuals, where the balance tips to simultaneity. Different non-manuals with their own function can occur simultaneously (such as a movement of the eyebrows and a tilting of the head). When similar linguistic functions are performed by aspects of intonation in spoken languages, these aspects necessarily occur in a linear sequence.[58]

12. Other domains of research

A complete historical review of all developments in sign phonology would have to cover several other areas of research. In this section I review research (a) phonetic approaches, (b) so-called non-manual aspect of signs. (c) prosodic structure, (d) the role of iconicity, (e) the role of gesture, (f)

[54] One of Sandler's arguments for syllables is reduplication in lexicalized compounds (Sandler 1989, 2008). The reduplicant is the final syllable. If the compound has reduced to one syllable, the whole compound gets reduplicated. If it is disyllabic, only the second syllable is reduplicated, whether the nucleus is path or internal movement.

[55] In a sense agreeing with Stokoe's assumption that orientation was not a separate major unit.

[56] Perlmutter (1989, 1992, 1993) also proposes a model that accommodates sequential aspects of sign formation, using the notation PMP. For comparisons of these various models see Perlmutter (1989), Liddell (1993) and, Sandler (1989, 1993) and Corina & Sandler (1993).

[57] A rather different and very original approach is taken in Uyechi (1994), where 'true' geometric notions are utilized.

[58] Of course, paralinguistic function can be manifested simultaneously with linguistic function in pitch contour, when for example a high tone, indicating 'focus' can be extra elevated to express excitement.

acquisition, (g) the emergence of phonology in young sign languages, and (h) cross-linguistic work.

a. Phonetic studies.[59] Arguably, the earliest work in sign phonology, including the 'pre-history', was primarily concerned with recording in notation systems what could be called phonetic details, although inevitably there was at the same time a sense of focusing on what is 'relevant'. The work of West and Stokoe introduces the *–etic* and *–emic* distinction, but the desire to be faithful to phonetic details has always there (partly because initial analyses cannot rely on knowledge of what is contrastive). Over time, starting with the work of Klima and Bellugi's group, sign phonetics, using instrumental techniques, has developed as an independent specialization, studying articulation and perception. The Klima and Bellugi group used several instrumental methods, including neurological studies and the use of lights attached to signers that could be tracked using a computer and visualization program; see Poizner, Klima & Bellugi (1987) and Emmorey (2002) for a comprehensive review. Early research on articulatory complexity (involving description of invisible muscle activity) was done by Ann (1992, 1993, 2006). Thus, even though Stokoe's early work in sign phonology focused on ignoring phonetic details and getting at phonemic distinctions, over time sign *phonetics* has gained solid ground as evidenced by more recent research (see Crasborn (2001, 2012), the latter for a recent overview). In section 11, I also mentioned the work of Liddell and Johnson (Johnson & Liddell 2010, 2011a, b, 2012) which advocates the idea that we should focus on an accurate phonetic description of signs, faithful to the way in which signs are articulated in full detail. Here, phonetics becomes a substitute for phonology, a trend that can also be witnessed in the study of spoken languages in so-called exemplar-based approaches which reject a 'symbolic' phonological representation in favor of phonetic exemplars; see Johnson (2005).

b. Non-manual aspects. The work on sign phonology that has been reviewed thus far is mostly about the manual aspects of signs. It has long been known, however, that non-manual aspects of the face, as well as of the head and the upper body, play an important role. Firstly, the lower face (lips, mouth, cheeks) can produce distinctions that can be lexically contrastive. A collection of studies devoted to such distinctions and possible feature systems is Boyes Braem & Sutton-Spence (2001).[60] More broadly, signs that corresponds to emotional states (anger, happiness) require a facial expression that corresponds to that emotion (which does not imply the person signing the word 'angry' is necessarily angry).[61] Another aspect that is occurs is the 'mouthing' of spoken language words; mouth gestures that are like co-speech hand gestures. Mouthing of spoken words, which may increase when signers address hearing people, is controversial in some countries because it is sometimes regarded as an intrusion of the spoken language; see Nadolske & Rosenstock (2007), Sandler (2009) and Bank, Crasborn & van Hout (2013, 2016) for recent studies. Early analyses of non-manuals on the upper face and involving head and body posture, regarded these aspects as 'being syntax (Stokoe 1966; Shenk-Baker 1983) or as part of the syntax (Liddell 1980), or remain neutral on this issue, focusing on the identification of the non-manual markers and their function/meaning themselves. Seeing non-manuals as part of syntax is not only

[59] See Crasborn (2012) for a recent review of phonetic work on sign languages.
[60] Very few signs consist of non-manual properties alone; see Dively (1996), who refers to those as 'non-hand signs'.
[61] Charlotte Baker-Shenk (1983) reports important early work on facial expression in ASL grounded in the Ekman and Friesen Facial action coding (Ekman and Friesen 1969); also see Grossman and Kegl (2006, 2007).

because it is a theoretically viable position, it should also be born in mind that the notion of a separate prosodic structure had not been developed for spoken languages; see (c) below.

c. Prosody. Much work has also been done on prosody and stress, going back to Bellugi (1976) and Friedman (1997). Friedman also discusses 'intonation' (referring to facial correlates) and contrastive stress. Subsequently, many studies have been published by Wilbur (1990a, 1999b) and Wilbur & Schick (1987) on phonetic correlates of stress. Also see Wilbur & Nolen (1986) for a phonetic study of ASL syllable structure. Rhythmic properties of sign utterances are studied in Allen, Wilbur & Schick (1991), Lupton (1993) and Miller (1996), the latter with reference to the notion of foot structure, borrowed from metrical phonology (Liberman & Prince 1977).[62] Earlier than all that work, West (1960) introduced notational symbols to indicate 'phrasing' (as distinct from syntactic structure).

In the study of spoken languages, during the 1970s came the advent of recognizing that words and larger units in spoken languages have a grouping organization, giving rise the idea that such groupings are represented in terms of a hierarchical structure, called the prosodic hierarchy (Liberman & Prince (1977); Selkirk (1980); Nespor & Vogel (1986)).[63] The argument for constituents like the syllable, the foot, the prosodic word, the prosodic phrase, the intonation phrase and the utterance was that phonological rules, phonetic lengthening effects and the spreading of intonational contours seem to make crucial reference to such units which, so it would seem, were not isomorphic to morpho-syntactic units.[64]

These ideas found their way into sign phonology in Nespor & Sandler (1999) who argued for the existence and linguistic relevance of prosodic structure in Israeli Sign Language, both for processes and for the analysis of non-manuals, leading to a host of further articles (see Sandler (2010) for details and a comparison of the direct and indirect reference approaches, as well as (Sandler et al. to appear)). Following that publication, arguments have been made for a prosodic word (Brentari (1998), Sandler (1999a, b)) and higher levels of phrasal prosody: the phonological phrase (corresponding roughly to the syntactic phrase), the intonational phrase (corresponding roughly to the clause), as well as higher, utterance- level constituents. (e.g., Nespor & Sandler (1999); Sandler (1999a, b), Sandler et al. (2011b); Boyes-Braem (1999); Sandler & Lillo-Martin (2006); Wilbur (1999a, 2000b); Fenlon (2010)). In most of the work on prosody, grammatical facial expression is understood to be the sign language equivalent of linguistic intonation in spoken language (Reilly, McIntire & Bellugi (1990); Nespor & Sandler (1999); Sandler & Lillo-Martin (2006); Dachkovsky & Sandler (2009); Cecchetto, Geraci & Zucchi (2009)).[65] Wilbur (1994) rejects the analogy between non-manuals and intonation, providing a 'dynamic' view of the

[62] Boyes-Braem (1999) deals with the use of rhythmic torso movements as prosodic devices typical of early but not late learners of Swiss-German Sign Language (German: *Deutschschweizer Gebärdensprache*, abbreviated DSGS).

[63] This was of course a novel idea, only from the view point of the generative paradigm. As detailed in Lahiri & Plank (2010), there is a rich, older tradition of acknowledging a prosodic organization in linguistic utterances, albeit it one that was more geared toward the prosodic organization of real utterances and stressing non-syntactic factors in determining this organization.

[64] Lack of isomorphy for the smallest units is self-evident to the extent that such units can occur within monomorphemic words. The alleged lack of isomorphy of larger units is dependent on the morpho-syntactic structure that are postulated; see Sandler (2010) for comparing the so-called 'direct reference approach' which takes syntactic constituents to be sufficient as domains for phrasal phonology and the indirect reference approach which derives a prosodic structure from syntactic structure, making phrasal phonology sensitive to the former.

[65] The perception of prosodic structure is studied in Fenlon (2010) and Gonzalez (2011).

interaction between syntax, semantics and prosody. The debate, as in the study of spoken languages, continues.

d. Iconicity. As mentioned in this chapter, early sign language literature traditionally de-emphasized the role of iconicity because this property had long led many to regard sign language as a form of spontaneous miming, which included the assumption that sign language is not far removed from spontaneous gesturing, much as hearing people do when they speak (or co-speech gesture) or when, for whatever reason, they are unable to use spoken language.

Soon, however, iconicity was argued to be a fundamental factor in the formation of signs and signing in general (see Mandel (1977), Friedman (1977a), DeMatteo (1977)), even though Frishberg (1975) and Klima & Bellugi (1979) established that signed languages become "less iconic" over time. While this is true, it has also been noted, among others in Tervoort (1953), that iconicity, while perhaps dormant and somewhat opaque in frozen signs, can always be reactivated. The issue of iconicity is closely connected to the idea that the units of signs (regarded by many as monomorphemic) can have meaning. The connection is that those phonological units are often iconic with respect to the meaning that they express, rather than being arbitrarily related to the meaning. Boyes-Braem (1981) and Brennan (1990) propose explicit models to account for 'meaningful, iconic phonological units' to enter into new formation of signs. Iconicity has been a serious topic of study in cognitive, semiotic, and functionalist linguistic perspectives as discussed in Wilcox (2004). An detailed study of the role of iconicity in the grammar of sign languages is Meir et al. (2013).[66] These various approaches share the idea that iconicity and phonology are not incompatible, and this view is gaining more support within the field.

e. Gesture. After having shown that sign language *is* not some kind of spontaneous gesture, a reconsideration of the role of gesture in signing can be seen during the 1990s; see Emmorey (1999), Liddell (1990a, 2003) and Dufour (1993), as well as the studies of Goldin-Meadow (2003, 2012).[67] A very comprehensive review of gesture in sign is Brentari & Goldin-Meadow (2017), which shows that there is 'co-sign gesture', just like there is co-speech gesture . These authors thus suggest that sign language should be compared not to speech alone but to speech plus gesture. Because in sign language, gesture and signs occur in the same modality, this makes it harder to differentiate between them.

*f. Sign phonology acquisition***.** When Klima and Bellugi started their work at the Salk Institute, they brought with them an interest in the study the acquisition of sign language. [68] I refer to Lillo-Martin (2009) for a review of work up to that date, as well as Kegl (2018). Attention to acquisition also followed logically from Chomsky's research program for linguistics which had made the question of how children acquire language a central issue of the field; see Newport & Meier (1985). A lot of work has focused on the acquisition of handshapes, which are the most salient lexical property of signs (as opposed to movement and location): Boyes-Braem (1973, 1994); McIntire (1977), van der Hulst (1996) and Hochgesang (2014). Kantor (1980) studies the acquisition of so-called classifier constructions; Akamatsu (1982) studies the acquisition of fingerspelling; Supalla

[66] This group of researchers has published various studies of sign morphology (see Aronoff, Meir & Sandler (2000, 2005)).

[67] Ferrara (2012) investigates the role of gesture in so-called 'depicting sign' in Auslan.

[68] Attention to acquisition followed from the fact that Roger Brown (1925-1997) had been Ursula Bellugi's advisor at MIT.

(1982) and Meier (1982) are important dissertations that study the acquisition of verb agreement. A series of studies by Siedlecki & Bonvillian (1993a, b, 1997) investigates the order of acquisition of the major units of signs; see also Siedlecki (1991), Bonvillian & Siedlecki (1996), Bonvillian, Orlansky & Folven (1990). Conlin et al. (2000) also report on the acquisition of first signs in terms of place, handshape, and movement. Another such study is Marentette & Mayberry (2000). For acquisition of prosody see Wolford (2012) and Brentari, Falk & Wolford (2015). A study that attracted considerable interest, probably due to its unexpected finding, is Petitto & Marentette (1991), which reported that deaf children go through a phase of manual babbling.

g. *Emergence of phonology*. An interesting question is how and why phonological structure emerges in new or young sign languages. While internal concepts must be linked to some external and observable signal, it seems that an internal analysis in terms of meaningless units of this signal arises over time under the pressure of conventionalization and lexical retrieval with an increasing lexicon. The details of this development are not yet clear for sign languages (let alone for spoken languages) which is why newly emerging sign languages, in which the development of phonology can be 'observed', play an important role. Much has been written on the emergence of grammatical structure, including phonology, in Nicaraguan Sign Language; see Kegl, Senghas & Coppola (1999) and also Fusellier-Souza (2006). In their studies of Al-Sayyid Bedouin sign language, Sandler et al. (2011a) conclude that this language may be at a stage where there is 'no phonology', meaning no conventional, discrete submorphemic organization in signs. This is suggested by the fact that signs in this language show considerable variability within and across signers, although the authors note that 'a kernel of phonology' can be observed in young signers. (Brentari et al. 2012) and Brentari et al. (2016) link the emergence of phonological compositionality to an emerging linkage between phonological complexity and type of classifier.[69] With an increasing interest in questions of language evolution[70], it has been noted that the study of grammar emergence in sign languages is relevant here because it can provide a model for the evolutionary development of language, especially if one adheres to a theory that attributes a primary role to gesture.

h. Cross-linguistic work. Most of the work that has been discussed is based on the study of ASL, but there are of course accounts of the phonology of languages other than ASL: Australian sign language (Johnston & Schembri 2007), Israeli Sign Language (Aronoff et al. 2008), Sign Language of the Netherlands (van der Kooij 2002); see Oxford Bibliographies Online (OBO) (Börstell, Sandler & Aronoff 2015) for more examples.[71] It has always been a central theme in sign linguistics to compare the grammatical structure of sign languages to those of spoken languages; see Bellugi & Fischer (1972), Friedman (1974); Fischer (2000). Influenced by the generative paradigm, linguists sought universals that hold for any language modality (e.g., Sandler & Lillo-Martin (2006)). By now, significant progress has been made in the area of sign language typology with the availability of studies of many different sign languages, which allows for language comparison at all levels of grammar and language use. However, extensive comparative

[69] Sandler et al. (2014) discuss the emergence of complexity in prosodic organization.
[70] In part due to Stokoe's interest in this issue; see Stokoe (1972).
[71] I here refer to typological work by Ulrike Zeshan; see, for example, Zeshan (2013). See also Bakken Jepsen et al. (2015).

work on sign phonology remains to be done.[72] Perhaps a lack of interest in such work is an overwhelming perception that the phonologies of sign languages differ from each other much less than spoken languages do. Nevertheless, differences have been noted (as early as in Klima and Bellugi 1979), not only in the choice of handshapes, locations and movements, but also at a more phonetic level of analysis.

13. Conclusions: relevance of and directions in sign phonology

In this chapter, I have shown that, in effect, the history of sign phonology (and sign linguistics in general) goes back centuries. It unfolded within the context of educational systems for the deaf and, especially, in the development of notational systems. In modern times, the onset of such studies are traced back to the important work on William Stokoe, although it is clear that the work of La Mont West also deserves to be mentioned. I have drawn attention in several places that his work proposes notions and theoretical ideas that predate later developments in sign linguistics, that followed the lead of Stokoe (1960). During the 60s and 70s it seemed important to draw attention to parallels between signed and spoken languages in order to validate the notion that sign languages are 'real languages'. This came with downplaying the iconic forces that are at play in sign formation and signing. At the same time, many researchers emphasized that sign languages have to be studied in their own right and not through the prism of what is known about spoken language, although some of that is virtually inevitable, and, if taken heuristically, can be quite productive.

Over time, sign linguists have learned to strike a balance between seeing true analogies and true differences in the comparison between signed and spoken languages. The analogies could testify to properties that are determined by a human language capacity that is neutral with respect to modality, while the differences would result from the fact that signed and spoken languages are expressed by different production and perception systems. This, however, does not mean that the differences are merely 'in the phonetics'. Several researchers have argued that the role of recruiting visual space reaches deep into the morpho-syntactic and semantic mechanisms that are available for the expression of grammatical relations, as clearly exemplified in so-called classifier constructions and pronominal reference (see Lillo-Martin and Sandler 1986; also see Bouchard 2013). In the domain of phonological structure, differences between auditory and visual perception, as well as differences on the side of articulation have far-reaching consequences for phonological structure. The long-noted overwhelming simultaneity of phonological features in sign language, as opposed to the prevailing sequentiality in spoken language, is clearly due to the fact that visual perception is better at overall perception of a scene, while audition is well-equipped to rapidly process information that is presented sequentially (as the speech signal necessarily is); see Meier (1993). Simultaneity is also fostered by the availability of articulators that can operate with great independence such as the face and body vis-à-vis the hands, and within the former various parts of the face and body. At the level of 'segments', the pervasive sequentiality of the speech signal as such results from an overall smaller array of phonetic distinctions in comparison to sign. It has been argued in Meier (1982) and van der Hulst (1995) that the differences in the

[72] Rachel Channon and Harry van der Hulst have collected a database (signtyp) with hundreds of signs from 15 different sign languages. All signs have been encoded for phonological and phonetic properties. This database will be mined for comparative phonological studies; see https://signtyp.uconn.edu/.

articulatory repertoire between both language modalities is significant.[73] With fewer resources to construct segments, spoken language must resort to segment sequencing, and sequencing of whole syllables[74], to accommodate the number of morphemes that is required.

The investigation of language in different modalities[75], as well as of different communication systems within modalities, is a combined effort that will lead to insights in the human capacity to create and use grammatical systems. This is especially so if phonology taken to be not just an 'externalization system', as assumed in Chomsky (2007), that is external to the human narrow language capacity. That said, it has become less clear that there is convincing justification for postulating an innate for language to begin with. Rather, properties of phonological systems (and grammar in general) are now more frequently seen as emerging from cognitive and physical systems that exist independent from languages, yet are recruited by them. A clear example of this concerns phonological features. Given that spoken languages and signed languages need different sets of features, with their own phonetic correlates, the field of sign phonology has undermined the idea that phonological features are innate.[76] That this is the right perspective has become abundantly clear since most of what was once held to be due to innate principles is either modality-specific or indeed can be explained as being emergent from other systems; see Sandler (2018).

The investigation of the phonology of signs has made considerable progress in less than 60 years. Stokoe's work kicked off not only the investigation of phonology, but also the entire field of sign linguistics, which has expanded into many different areas. West's work would have had a similar effect, had it been known outside a small circle. The book by Klima and Bellugi (1979) played a significant role and Wilbur (1979), while less cited, provided an early full-fledged review of the field in its early stages. Today it is fair to say that every area of research that looks at spoken language has an equivalent in the study of sign languages. This is undoubtedly a reflection of the fact that signed languages are indeed on a par with spoken languages in every respect conceivable.

What strikes me as the most important development in the field of sign phonology is the fact that the initial importance of analyzing sign languages at the submorphemic level was that this analysis reveals a level of structure that combined meaningless, pure formal units, which had long been taken as the hallmark of phonological analysis as applied to spoken languages because it implies duality of patterning. However, it is now increasingly recognized, although it has been explicitly acknowledged from early on (in the work by West, Friedman, Boyes-Braem and others, as well as in Stokoe's Semantic Phonology), that the formal buildings blocks of morphemes may not be so meaningless. The consequences of this recognition remains unclear. In one view, such meaning-bearing building blocks are in fact morphemes. Another view is that it is perhaps not correct to maintain that phonological building blocks cannot be associated with meaning (see van der Hulst, to appear). This issue is not only be the case for signed languages, however. There is a fast growing literature on meaning-bearing phonological units in spoken languages (see Perniss, Thompson and Vigliocco 2010).

This chapter has focused more extensively on early developments in sign phonology. Reviews of later developments and some specific research areas are mostly limited to references

[73] See Meier, Cormier & Quinto-Pozos (2002) for a volume with studies on the effects of modality.

[74] The need for sequencing might be less pronounced in languages that have a rich tonal inventory, like Asian languages, which tend to be monosyllabic.

[75] See Collins (2004) for an analysis of tactile ASL as used by deaf and blind people; see OBO for additional references.

[76] This idea has also been criticized from within the field of spoken language phonology; see Mielke (2008).

to relevant publications. While new results are constantly obtained, it is to be hoped that 'old' discoveries are not forgotten. Various important areas in which the study of sign languages has made significant progress include the areas of language acquisition, language change and evolution (in particular with respect to the question of the evolution of phonology), the relationship between sign language and gesture.

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