CHAPTER 12

Developing an inventory of handshapes, locations, and movements in Hong Kong Sign Language

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In this chapter, we describe how we incorporate the Prosodic Model (Brentari 1998), especially the concept of a hierarchy of nodes with features, into a template for feature coding of sign entries in a lexical database, and how we make use of the features to organize learner's dictionaries of the respective signed languages. Besides coding prosodic features, other information recorded includes sign category (monomorphemic or polymorphemic), sign type (whether the sign is one-handed or two-handed), the country of origin, gloss and grammatical category. Beginning with Hong Kong Sign Language, Asia SignBank has archived signs from Indonesian Sign Languages, Sri Lanka Sign Languages, Japanese Sign Languages, Ho Chi Ming Sign Languages, and Myanmar Sign Languages. Data input and feature coding were done by Deaf signers trained in sign language analysis and dictionary compilation. Archiving phonological features of individual sign entries also facilitates identification and comparison of phonological and morphological features of signs.

Keywords: sign language documentation, lexical database, Deaf training, prosodic model, sign language phonetics, sign language phonology

1. Introduction

With printed language dictionaries gradually being replaced by online ones, we enter an era in which lexicography enjoys the benefits of easy updating, fast retrieval and queries, and flexible sorting and processing of language data. This technological transformation is particularly relevant to sign language documentation. As Zwitserlood (2010) comments, processing sign language data is challenging because sign languages do not come with an orthography and are under-researched. Traditional sign language dictionaries contain signs glossed in a spoken language,

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usually accompanied with line-drawings or still photos demonstrating how a sign is articulated. These static presentations of signs generally fail to fully capture dynamic information such as movement and nonmanuals. Online sign language platforms overcome these inadequacies since videos can be incorporated into the database. Therefore, recent years have seen a global development of sign language corpus projects – especially the development of lexical databases with principles of lemmatization based on sign language properties (Fenlon et al. 2015). Since both the lexical signs and their variants can be digitized and stored using ID glosses (Crasborn et al. 2016), this procedure supports comparisons for phonological and lexical variation in sign languages. Lexical databases with information about the phonetic features of signs also facilitate comparative research, such as lexical similarity across sign languages based on the Global SignBank (Börstell et al. 2020), regional lexical variation in Chinese Sign Language (Chen & Gong 2020), phonological generalizations on the formational units and features in Shanghai Sign Language (Zhang 2019), and variation in the use of 1-handshape and how the immediate phonological environments determine handshape assimilation (Fenlon et al. 2013).

Constructing lexical databases of sign languages is subject to how one conceptualizes sign formation. Stokoe's (1960/2005) original proposal of sign decomposition into sublexical units of handshape, movement and location was later supplemented by additional parameters of orientation (Battison 1978) and nonmanuals (Wilbur & Patschke 1998). Unearthing these fundamental building blocks of signs has led researchers to develop models to capture how they can be organized and represented, such as the Hold-Movement Model (Liddell & Johnson 1989), the Hand-Tier Model (Sandler 1989), the Head-Dependency Model (Van der Hulst 1993), and the Prosodic Model (Brentari 1998). Except for the Hold-Movement Model, feature geometry has been adopted to account for the hierarchical organization of the sub-lexical components, with class nodes at various levels specifying a set of features for sign representation.

In this paper, we report on a project which attempts to set up an inventory of handshapes, locations and movements in Hong Kong Sign Language (HKSL), based on the signs archived in the Asian SignBank (ASB, <http://www.cslds.org/asian-signbank/>. ASB is an online lexical database of signs of a number of Asian sign languages collected through the Asia Pacific Sign Linguistics Research and Training Programme project (APSL, <http://www.cslds.org/apsl/>). The machine-readable phonetic transcriptions (see Fung et al. 2008) archived in ASB have enabled not only searches of signs, but also analyses of distributional frequencies of the associated phonetic and phonological properties on which basis one may identify distinctive units. In this project, we made use of frequency distribution of various sublexical components to verify if units of handshape, location and movement

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follow a Zipfian distribution. We also argue that the patterns of frequency distribution of these units may shed light on the notion of markedness or lexicalization of iconic and morphological elements in sign languages.

2. Developing a HKSL Lexical Database System

Tang (2007) offers the first systematic documentation of lexical signs of HKSL in the form of a published dictionary containing sign linguistic information together with still images of 1982 one-handed and two-handed signs. The coding of the phonetic features of signs back then drew from the Prosodic Model (Brentari 1998). This written archive of HKSL signs laid the foundation for the construction of ASB in 2003.

2.1 The Asian SignBank project

The ASB project aims to develop an online lexical database of the sign language varieties in Asia, to support sign language research as well as the development of sign language dictionaries and teaching/learning materials. The construction of the ASB databases represents the collective efforts of teams of Deaf and hearing sign language researchers and a system engineer. Training of Deaf researchers in sign language research and documentation under the APSL Programme commenced in 2003. After the training, the Deaf researchers collected sign language data in their respective places of origin, including Hong Kong, Jakarta and Yogyakarta (Indonesia), Sri Lanka, Ho Chi Minh City, Yangon (Myanmar), Fiji and Japan. For the HKSL documentation project, four Deaf researchers were recruited. Three were born to Deaf parents. The fourth had hearing parents, but was exposed very early to HKSL. Initially, they scrutinized the entries in Tang (2007) and continued to add new signs for incorporation into ASB. The Deaf researchers collaborated with the hearing researchers in identifying and labeling the phonetic features of the lexical entries, and inputting them manually into ASB. To date, around 4,460 lexical signs of HKSL are archived in ASB, out of which around 2,000 are complete with transcriptions of phonetic features. ASB's web-based interface enable users to perform most search functions and data updates using ordinary internet browsers. Numerous theses and articles have arisen from the ASB data (see Lam 2003, Mak & Tang 2011, Mak 2012, Sze et al. 2012, Sze et al. 2018).

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2.2 Database schema

As noted above, the ASB schema drew reference from the Prosodic Model (Brentari 1998) and was designed to allow a high degree of flexibility in searching for sign by their phonetic features. Figure 1 shows the schema of the database and the annotation system.

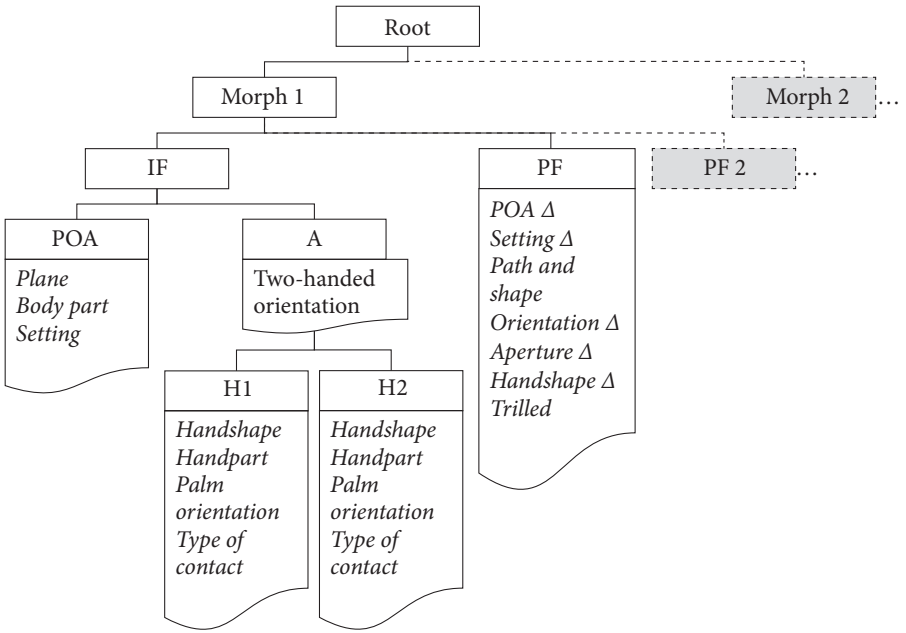


Figure 1. The schema of information structure

Each node of the structure contains a set of information about the signs:

ROOT:
- Sign_ID: a unique identifier for a sign entry;
- Sign category: whether the sign is simple or compound;
- Sign type: whether the sign is one-handed or two-handed;
- Country: country of origin of the sign;
- Gloss: Meaning of a sign glossed in English and a translation equivalent in the country's spoken language;
- Word class: lexical category of the sign;
- Source: source of sign collection, such as deaf schools, other dictionaries, etc.;
- Example: a sample sentence containing the sign entry;
- Related signs: list of variations of a sign.

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IF (Inherent Features):
- POA (Place of Articulation):
  - Plane of Articulation: the plane that a designated handpart faces if the sign is articulated in neutral signing space;
  - Body part and Setting: place of articulation when the sign involves the body plane, namely the body regions and their distinctive place features, e.g. "Head:Top".
- Manual:
  - Two-handed orientation: relative position and movement of the hands in two-handed signs.
- H1 / H2:
  - Handshape: the shape of the hand;
  - Handpart: orientation, plane of articulation and place of articulation when the non-dominant hand (H2) becomes the POA of the sign;
  - Palm orientation: relative orientation between the palm and POA;
  - Type of contact: contact between the POA and the hand or handpart, e.g., sustained contact, brushing contact.

PF (Prosodic Features):
- Path and shape: path movement and path shape;
- Setting change: change to a new setting within the POA;
- Orientation change: change of orientation induced by wrist rotation;
- Aperture change: change of finger position, open to closed or vice versa;
- Handshape change: change of handshape configuration in sign movement;
- POA change: change of place of articulation in sign movement;
- Trilled movements: uncountable, intense and rapid movements.

The design structure of ASB also supports the coding of signs that have sequences of movements. In the structure, the node 'Morph' (see Figure 1) and its sub-nodes can be duplicated. For instance, more commonly observed are those compound signs in which each of the morphemes contain one movement, either simple or complex. The phonetic features, inherent or prosodic, stored under each Morph node of the compound sign are expected to be articulated simultaneously. Additionally, the movement of Morph2 follows that of Morph1. The same coding principle applies to non-compound signs that have a sequence of movements. When the node 'PF' (Prosodic Features) is duplicated, it implies that movement of PF1 occurs before that of PF2, while the phonetic features stored under each PF are expected to be articulated simultaneously. The reason for storing movement information by duplicating the 'Morph' and/or 'PF' node is to facilitate the search function explained in the next section.

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2.3 Advanced search function

The ASB provides an advanced search function for registered users to support their research. For example, researchers can search for signs which are non-compound and use the Neck as a POA, as shown in Figure 2a.

In the advanced search interface, there are 5 columns of drop-down menus and a checkbox for user flexibility. The leftmost column is the AND/OR operator, which allows users to combine several criteria when searching for signs. In the second column, the user selects information and phonetic features such as *Country, Handshape, Body part*, etc. The third column allows the user to indicate whether the features selected are *Equal* or *Not equal* to their respective value. The fourth column displays the corresponding values for the selected features. The user may click *Any*, an option to any value in the query. This is useful when the user wants to find signs that have any kind of movement, regardless of how the hands move. The fifth column allows the user to narrow the search by limiting the fields and features selected, which can be H1, H2 or any hands. The checkboxes in the rightmost column allow the user to indicate whether they are looking for the initial feature of a sign (the default instruction) or not. For compound signs, or signs involving sequences of movements, checking these boxes means the search function will look for signs with the selected features appearing in any component of the coding system (i.e. Morph1, Morph2, etc.) or in any part of the movement sequence (i.e. PF, PF2, etc.).

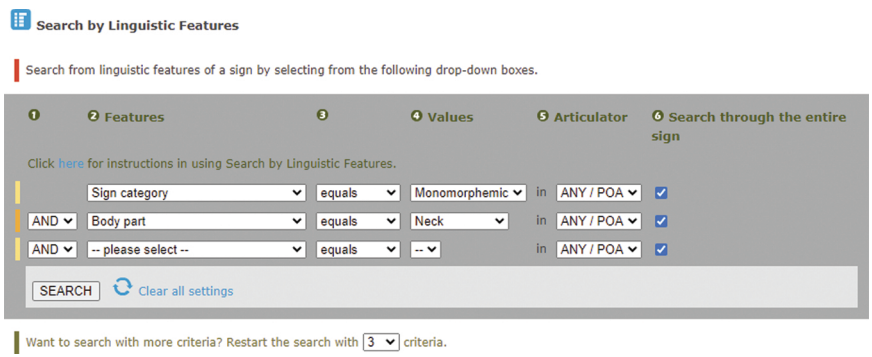


Figure 2a. Search interface

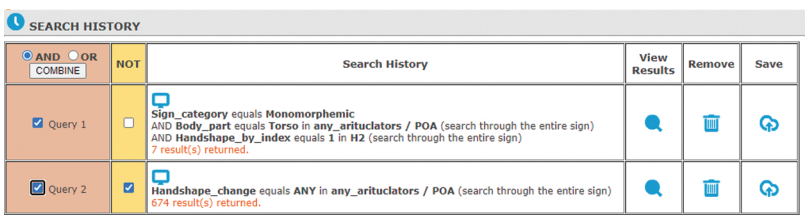


Figure 2b. Search history

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All queries performed in the Advanced Search interface are stored in the Search History as shown in Figure 2b. Users can refine their search results by using the AND/OR/NOT operators in combination with different search histories. For example, as shown in Figure 2b, users can search for non-compound signs with the Torso as POA and handshape index 1 ([]) as H2, but that do not involve any handshape changes in the movement.

The results of the search function also generate descriptive statistics such as frequency of occurrence of signs based on a particular feature or a combination of features. Researchers can export the search outputs to an MS Excel file for further analysis. Another function of ASB is the automatic creation of sign language dictionaries and teaching materials. After customizing the basic page layout, the system automatically generates pages of a sign language dictionary or teaching materials in a PDF format. All these steps are done through an internet browser and no special software is required.

3. The current project

The current project used 1682 one-handed and two-handed, non-compound signs archived in ASB to establish an inventory of handshapes, locations and movements in HKSL. Initially we conducted frequency counts in terms of handshape, location and movement already annotated and stored in the system. As a preliminary study, we simplified the searches by including only initial handshapes, initial locations and initial movements of non-compound signs, although for some signs there may be handshape/aperture change, POA/setting change and movement sequence. For handshapes and locations, the analytical procedure was to establish minimal pairs for contrastive units based on a closer analysis of the associated phonetic features. Sometimes, minimal pairs were difficult to find, and near minimal pairs were set up instead, and further verified through applying phonological rules. For movement, analysis was only based on types of movement combination attested in all non-compound signs. We did not perform commutation tests on movements because of their huge variation, and because they are used sometimes either morphologically or non-contrastively in proximalization and distalization.

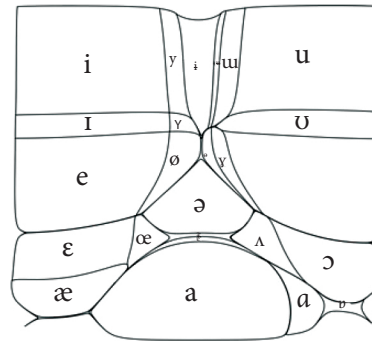
The frequencies of occurrence reported in this paper are all type frequencies, that is, frequencies based on signs in the ASB. In our analysis, we held two assumptions. First, the frequency distribution of different handshapes, locations, and movement combinations are uneven, similar as what has been reported in spoken languages. Figures 3a and 3b represent a regular and a transformed IPA vowel chart according to the frequency of occurrence of vowels in the spoken languages of the world. The larger the area a vowel occupies, the higher is its frequency of occurrence in the world's languages. This observation reveals that segmental inventories

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in spoken languages seldom distribute evenly, regardless of whether analysis is performed intra-linguistically or cross-linguistically. Second, we assumed that the uneven distribution, if observed, would be caused by properties intrinsic to sign language linguistic structure.

i	y	ɨ	ʉ	ɯ	u
ɪ	ʏ				ʊ
e	ø	ɘ	ɵ	ɤ	o
		ə			
ɛ	œ	ɜ	ɞ	ʌ	ɔ
æ		ɐ			
	Œ	a		ɑ	ɒ

a.



b.

Figure 3. IPA vowel charts (Mielke 2017: 133)

To account for the distribution, we argue that markedness is one contributing factor. The classical work of Jakobson (1968/1941) focuses on the featural and structural explanation of markedness. On the other hand, Greenberg's (1966) cross-linguistic study reveals a strong correlation of markedness and token frequency, that is, the more marked sounds occur in a more restricted environment and in a lower token frequency, and vice versa. Bybee (2001) further suggests that although frequency could be regarded as the outcome of structural relation of markedness, irregular forms such as 'feet' that occur frequently only shows that frequency of use, instead of structure, is the main determinant of markedness. Bybee (2010) discusses the theory of markedness in phonology, morphology and syntax, and makes two generalizations. First, frequency of use is correlated with unmarked status (that is, a more frequently distributed feature is less marked). Second, markedness is not just defined in terms of binary oppositions (absence/ presence of a feature), but can also be expressed in terms of degrees. In sign language research, markedness has been adopted to account for handshape contrasts. Sandler and Lillo-Martin (2006) report that less marked handshapes usually occur more frequently cross-linguistically (see also Henner et al. 2013 for a discussion on ASL handshape frequencies). They are also easier to produce, are acquired early by children, and are more resistant to loss in aphasia than marked handshapes. Within the framework of the Hand Configuration Model, they also argue that relative complexity of linguistic representations reflects the relative markedness of handshapes.

In the ensuing sections, we report on our search for contrastive handshapes and locations, and types of movement combination in HKSL, based on the available

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lexical signs archived in ASB. In our analysis, we measure markedness using distribution of type frequencies. When a certain phonological parameter is described as 'unmarked', it broadly means "usual" and "frequent". Although we understand that type frequency may deviate from token frequency or the actual frequency of use, at least this preliminary quantitative analysis provides us with a starting point to measure the degree of markedness of a set of phonetic inventories in HKSL. With these findings, we attempt to examine how structural complexity, lexicalization of iconic, gestural and morphologically complex elements and foreign vocabulary interact with frequency distribution of these units.

3.1 Handshapes

3.1.1 *Dominant hand (H1)*

The list of handshapes as archived in ASB for HKSL was drawn originally from Tang (2007). The frequency counts below are based on the handshapes of the dominant hand (H1).

Table 1. Number of signs based on different H1 handshapes (Tang 2007)

Handshapes #01–#15	No. of signs	Handshapes #16–#30	No. of signs	Handshapes #31–#45	No. of signs	Handshapes #46–#60	No. of signs
	84		40		16		2
	72		32		3		1
	19		2		5		37
	47		30		59		197
	53		12		2		32
	7		2		21		34
	182		10		1		21
	74		7		7		25
	24		47		1		27
	5		16		2		6
	3		19		9		2
	3		34		10		133
	5		58		2		26
	6		4		39		19
	5		11		14		16

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As shown in Table 1, the most frequently occurring handshapes are [], [], [], and [], each of which has over 80 signs. These handshapes are included in Battison's (1978) list of unmarked handshapes potentially occurring in many sign languages of the world, Boyes Braem's (1990) Stages I & II handshapes of ASL child acquirers, and Ortega and Morgan's (2010) early handshapes of BSL child acquirers. On the other hand, some handshapes, including [], [], [], [], [], [], [], [], [], and [], have a very low frequency of occurrence, occurring only in one or two signs.

Confirmation of contrastive handshapes in HKSL began with scrutinizing all 60 handshapes based on their underlying phonetic properties of selected/unselected fingers (index, middle, ring, pinky vs thumb) and their associated joint specifications (base/non-base; flexed/extended), from handshapes with no selected finger to those involving all fingers, and from flexed to extended finger position. Since these features were already annotated and stored in an electronic database, it was easy to define the search of signs with specific features and to confirm the minimal pairs with the Deaf researchers.

In spoken languages, commutation tests (Dresher 2011) help to judge whether phonetically similar sounds, such as the voiceless bilabial stops [p] and [p^h], are used contrastively in a language or not. For example, substituting [p^h] with [p] as in Example (1) results in a new word in Mandarin Chinese, but not in English. Therefore Mandarin Chinese uses [p] and [p^h] to show lexical contrasts, whereas English does not.

(1)	English:	[b æ n] "ban"	[p^hæ n] "pan"	*[p æ n] "pan"
			*[s p^hæ n] "span"	[s p æ n] "span"
			[n æ p] "nap"	[n æ p̚] "nap"
	Mandarin:	[p aː n˥] "class"	[p^haː n˥] "to climb"	

Minimal pairs of spoken languages indicate that substituting one sound with a different one in the same environment potentially results in a different word (that is, a different meaning). Additionally, some sound segments are not contrastive, but exist in complementary distribution or in free variation (Dresher 2011). In our analysis, we adopted a similar principle in developing commutation tests for handshapes (see Figure 4) and locations.

When applying this test for oppositions, we assumed that the handshape inventory might produce some phonetically similar pairs of handshapes differing in one feature only. These were treated as contrastive handshapes only if they constitute different signs of different meanings. Otherwise, we labeled non-contrastive handshapes showing phonetically similar features as either in complementary distribution or free variation. For instance, Figure 5 shows that [], [] and [] are phonetically similar, differing only in thumb position, namely [opposed],

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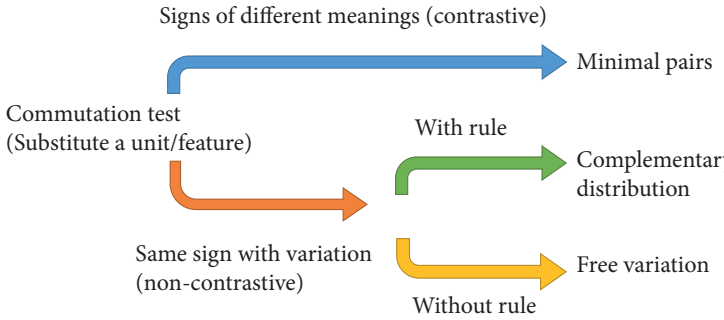


Figure 4. Procedures for identifying contrastive and non-contrastive handshapes

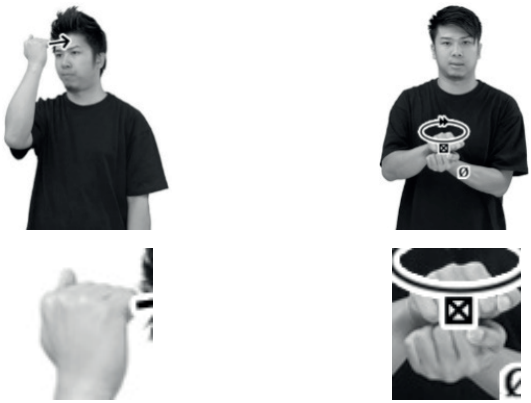
[unopposed] and [extended], respectively. Substituting [] in HIT with [] leads to a different sign, GOOD. Similarly, substituting [] in UPSET with [] results in a different sign, ENOUGH. The discovery of these minimal pairs confirmed the contrastiveness of the []–[] and []–[] pairs in HKSL. This test of opposition also led to the discovery of non-contrastive pairs, as shown in Figures 6a and b.

Although [] and [] differ in one feature only, they are not necessarily contrastive in HKSL. Substituting [] in STUPID and GRIND with [] does not result in a different sign. Further to our analysis was the identification of phonological environments in which these two handshapes occur. We found that [] occurs in signs in an environment that involves [contact] made to the back of fingers at the non-base joint (i.e., palm side of the hand plane). Following Uyechi's (1995) proposal that a hand cube has six articulatory planes, we found that signs with a contact feature involving the other five articulatory planes all adopt the [] handshape,



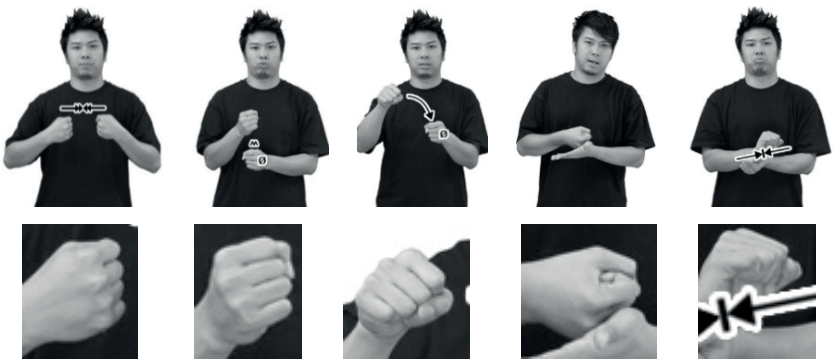
Figure 5. Contrastiveness of []–[] and []–[]

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STUPID GRIND

Figure 6a. Non-contrastiveness of [ ]–[ ]



WAR WORK ADD ALAS IMPRISON

Figure 6b. Non-contrastiveness of [ ]–[ ]

but never the [ ] handshape (see Figures 6a and 6b). In other words, [ ] and [ ] are non-contrastive since they do not form a minimal pair. Instead, they are in complementary distribution, and their occurrences are governed by the articulatory plane of the hand cube with which contact between the articulator and the place of articulation is made. In English, "p" is assumed to be the underlying sound because it is more basic, widely distributed and unmarked. Similarly, we treat to be the underlying handshape, since it occurs in more environments and has a higher frequency of occurrence than [ ]. In Table 1, [ ] occurs in 84 signs and [ ] in 19 signs. The phonological rule governing the occurrence of [ ] and [ ] is presented in (2) below:

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(2) → [ ] / ____ back of fingers at the non-base joint, e.g. "STUPID", "GRIND"
→ [ ] / elsewhere, e.g., "WAR", "WORK", "ADD", "ALAS", "IMPRISON"

In HKSL, [ ] is also used as a fingerspelling handshape "S" and [ ] as "A". However, these fingerspelling handshapes are not native to the HKSL lexicon; therefore, we do not include them in the core lexical handshape inventory of the language unless their contrastive uses are found in the core lexicon.

Sometimes the commutation test did not result in a different sign but two signs of the same meaning. We treated these handshape pairs as showing free variation. Native HKSL signers reported that the handshapes [ ] and [ ] in the signs FAR and DEEP are interchangeable. Another pair is [ ] and [ ] occurring in signs HAVE_MEAL and FEED (see Figure 7).

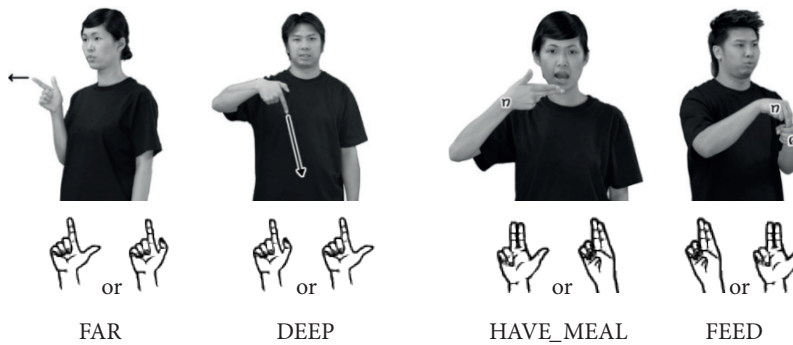


Figure 7. Free variations [ ]–[ ] and [ ]–[ ]

The interchangeability of handshapes in these signs shows that [ ] and [ ] are non-contrastive, so are [ ] and [ ]. In the handshape chart (Table 1), [ ] occurs in 74 signs and [ ] only in 3; [ ] in 30 and [ ] in 12. Therefore, based on frequency of occurrence, we tagged [ ] as the underlying handshape of the [ ] – [ ] pair, and [ ] the underlying handshape of [ ] and [ ]:

(3)

[ ]	/ \ [ ] [ ]	/ \ [ ] [ ]	/ \ [ ] [ ]
(see Figure 5)	(see Figure 6)	(see Figure 7)	

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To summarize, we adopted commutation tests in order to determine whether similar handshapes were contrastive or non-contrastive, and frequency of occurrence as a criterion to identify the underlying handshapes and their phonetically similar but non-contrastive variants, taking into account the phonological environments in which they occur (see Table 2).

Table 2. Underlying contrastive and non-contrastive handshapes

Underlying	Non-contrastive	Underlying	Non-contrastive
			
			
			
			
			
			
			
			
			
			
			
			
			

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To date, we have verified 30 out of 60 handshapes documented in Tang (2007) as underlying and contrastive, together with their 22 non-contrastive counterparts. There are still eight handshapes to account for (namely [], [], [], [], [], [], and []), all of which show a very low frequency of occurrence.

In spoken languages, the lexicon may be comprised of a core and peripheral stratum (Ito & Mester 1995; Bauer 2006). Similarly, Brentari and Padden (2001) categorize ASL signs into: (i) a set of core lexical stems, (ii) productive polymorphemic classifier predicates, and (iii) foreign or non-native vocabulary (e.g., manual alphabets). For the non-native signs, the more peripheral they are, the fewer the phonological constraints that hold in the core component they obey. In HKSL, those eight handshapes with a low frequency of occurrence are found to be peripheral to the core lexicon, hence observing less phonological constraints. The origin of these handshapes may involve either borrowing from other sign languages, or from iconic gesture and the number system (see Table 3).

Table 3. Handshapes motivated by factors external to the core lexicon

(i) Alphabet	
(ii) Chinese character	
(iii) Number	
(iv) Classifier	
(v) Gesture	
(vi) Morpheme Incorporation	

Table 3 includes handshapes that are motivated by factors external to the core lexicon. They reveal (i) an alphabetic origin [][], that is, to represent English alphabets or words (e.g., EMAIL and WC), (ii) a character origin [], that is, to graphically represent radicals of Chinese characters, (iii) a number origin [][] [][], (iv) a sign language classifier origin [][][][][], (v) iconic gesture origin [], and (vi) morpheme incorporation origin []. These motivated handshapes may also show up in signs of the core lexicon, as shown in Figure 8.

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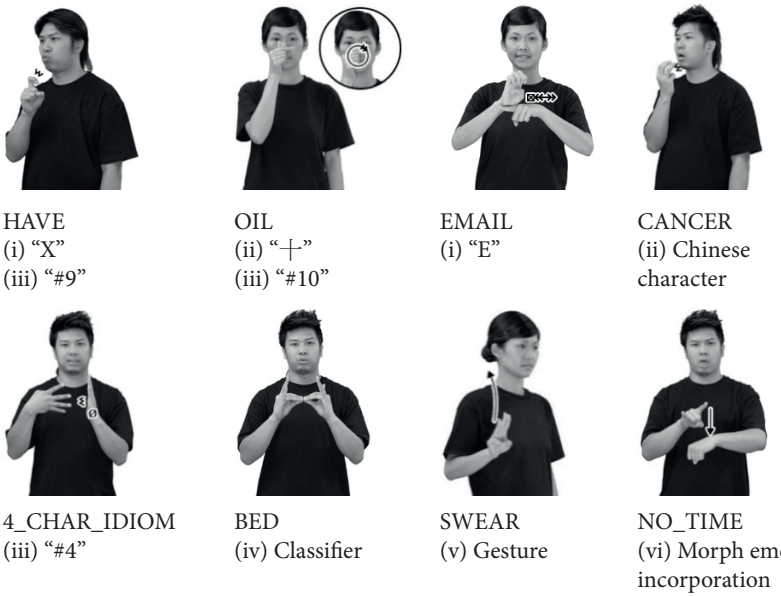


Figure 8. Motivated handshapes for signs in the lexicon

Following Brentari and Padden (2001), we divided the native HKSL lexicon into the core lexicon and the non-core lexicon. The core lexicon consists of all lexicalized signs. It overlaps partially with the polymorphemic/iconic components, such as classifier signs, which are native to HKSL. The core lexicon also partially intersects with the non-native lexicon comprised of foreign elements such as fingerspelled signs. Therefore, some HKSL handshapes may be observed in the core as well as the non-core lexicon, because they are adopted for use in multiple domains. On the other hand, some handshapes can only be found in specific domains of use lying outside the core lexicon, coming either from the polymorphemic/iconic components, or from the foreign components. For instance, [] appears in HAVE, which is a core lexical sign, but is also found in other domains of use, such as "#9" (a numeral sign) and "X" (a manual alphabet). [] appears in OIL, a core lexical sign, but is also adopted for the number sign "#10", which resembles the Chinese character "十". Therefore, [] and [] appear in multiple domains of use in both the core and the non-core lexicon.

On the other hand, some handshapes appear only as manual alphabets, character signs, number signs, classifier signs or gestural signs; hence they belong to the non-core lexicon. For example, the alphabet sign [] only appears in EMAIL; [] in WC; [] in fingerspelling signs like CD; [] is the handshape of the character sign CANCER, resembling the lower radical of the Chinese character "癌"; [] denoting

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number "#4" in FOUR_CHARACTER_IDIOM; [] in classifier signs meaning FOX or BED if symmetrically two-handed; and [] in a gestural sign, SWEAR. The status of [] remains unclear as it only appears in a few of what we called 'polymorphemic signs' where the pinky finger is analyzed as a negative particle, for example, NO_TIME, NOT_SUITABLE. Alternatively, it represents a number sign "#11" as used by the younger Deaf generation, or an output of numeral incorporation meaning "one-and-a-half-" with a time counting stem as in ONE_AND_A_HALF-HOUR or ONE_AND_A_HALF-MONTH. We analyzed this handshape as having a polymorphemic origin. All these forms belong to the non-core lexicon of HKSL. Figure 9 demonstrates how the handshapes are used in the core and the non-core lexicon of HKSL.

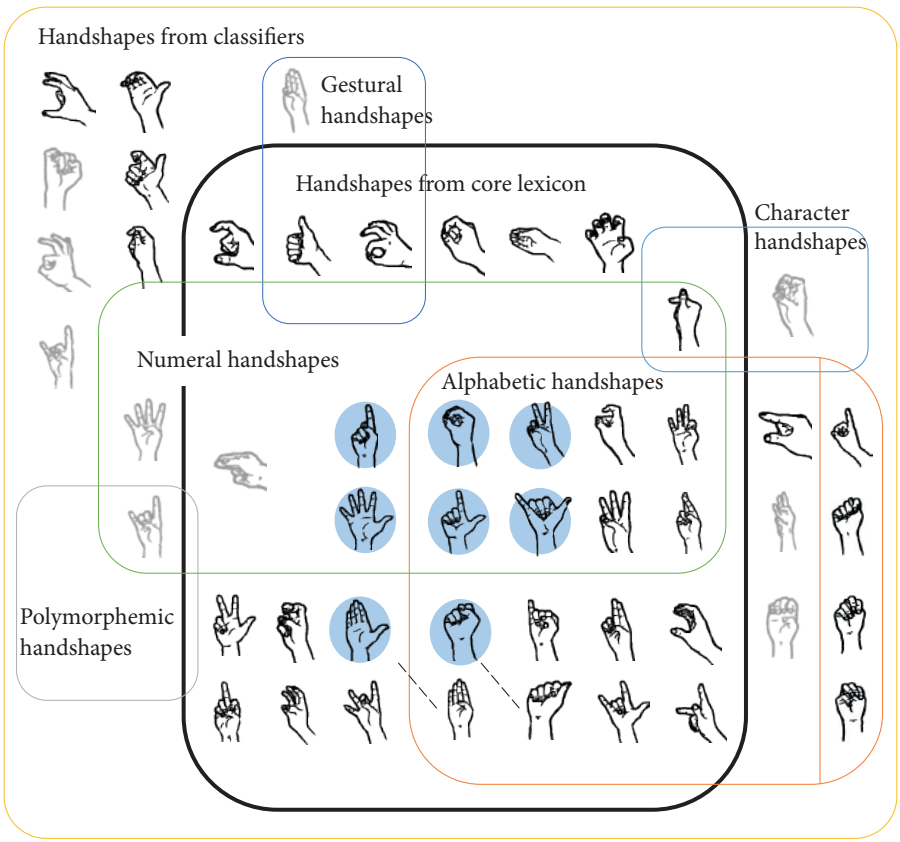


Figure 9. Examples of H1 handshapes in the core and non-core lexicon of HKSL

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The rectangle in the middle includes 30 underlying handshapes observed in the core lexical signs. As shown in Table 2, these 30 underlying handshapes include 22 non-contrastive counterparts, such as [] and []. The reason to put these two handshapes in Figure 9 with the dotted lines connecting [] and [] is to illustrate that despite being non-contrastive, they occur in core lexical signs. If we consider other domains of use in the non-core lexicon, such as adopting them for alphabetic signs, they become slightly contrastive only in that domain of use, such as [], [], and [] to represent alphabets "A", "B", and "S" respectively. Although classifier predicates belong to the native lexicon, only a subset of these classifier handshapes are used in the core lexicon. We have also identified eight most frequently occurring handshapes (presented with shaded circles) and ten least frequently occurring handshapes (presented in grey). For the latter group, it seems that the limited domains of use with these handshapes lead to their low type frequencies of occurrence. To conclude, the inventory of HKSL handshapes includes 30 underlying handshapes, 22 non-contrastive handshapes, eight handshapes ([], [], [], [], [], [], [], and []) motivated by factors external to the core lexicon, and four handshapes (i.e., "D", "M", "N", "T") that appear only in the non-native, non-core use of fingerspelling, and never occur in the core lexical signs. Figure 10 shows the frequencies of occurrences of the 60 handshapes (Table 1) in the form of a bar chart.

As mentioned, [], [], [], and [] top the ranks in terms of type frequencies. In Figure 9, these handshapes fall within the central range of the group of core lexical handshapes, whereas the usage of [] and [] overlaps with those of the number handshapes. The most frequently occurring [] handshape constitutes 11.7% of all signs in the HKSL database. Additionally, the eight most frequently occurring handshapes ([], [], [], [], [], [], [], and []) constitute 51.1% of all signs, whereas the ten least frequently occurring handshapes ([], [], [], [], [], [], [], [], [], and []) only constitute 1.01% of all signs. These results reflect a highly uneven distribution in terms of type frequencies.

In what follows, we attempt to confirm the distribution of the HKSL handshapes with reference to Zipf's law (1949), originally developed to verify the distribution of word frequencies in natural language corpora. It models statistical distributions in terms of frequency and rank, with the assumption that they are in a power law relation. Zipf's law is usually observed by plotting a log-log graph, where the x-axis represents the log of rank order and the y-axis the log of frequency. Zipf's law stipulates that the data comply to a power law of $(\text{frequency count})_{\text{rank}} = \text{constant} / (\text{rank})^{\alpha}$, where power α can be any value. If the data comply to Zipf's law, the plot is linear. Empirical tests of distribution in spoken languages reveal that in natural language corpora, not only word frequencies, but also sound frequencies, follow some variants of a power law (Macklin-Cordes & Rounds 2020; Martindale et al. 1996; Tambovtsev & Martindale 2007). In sign language research, Weber et al.

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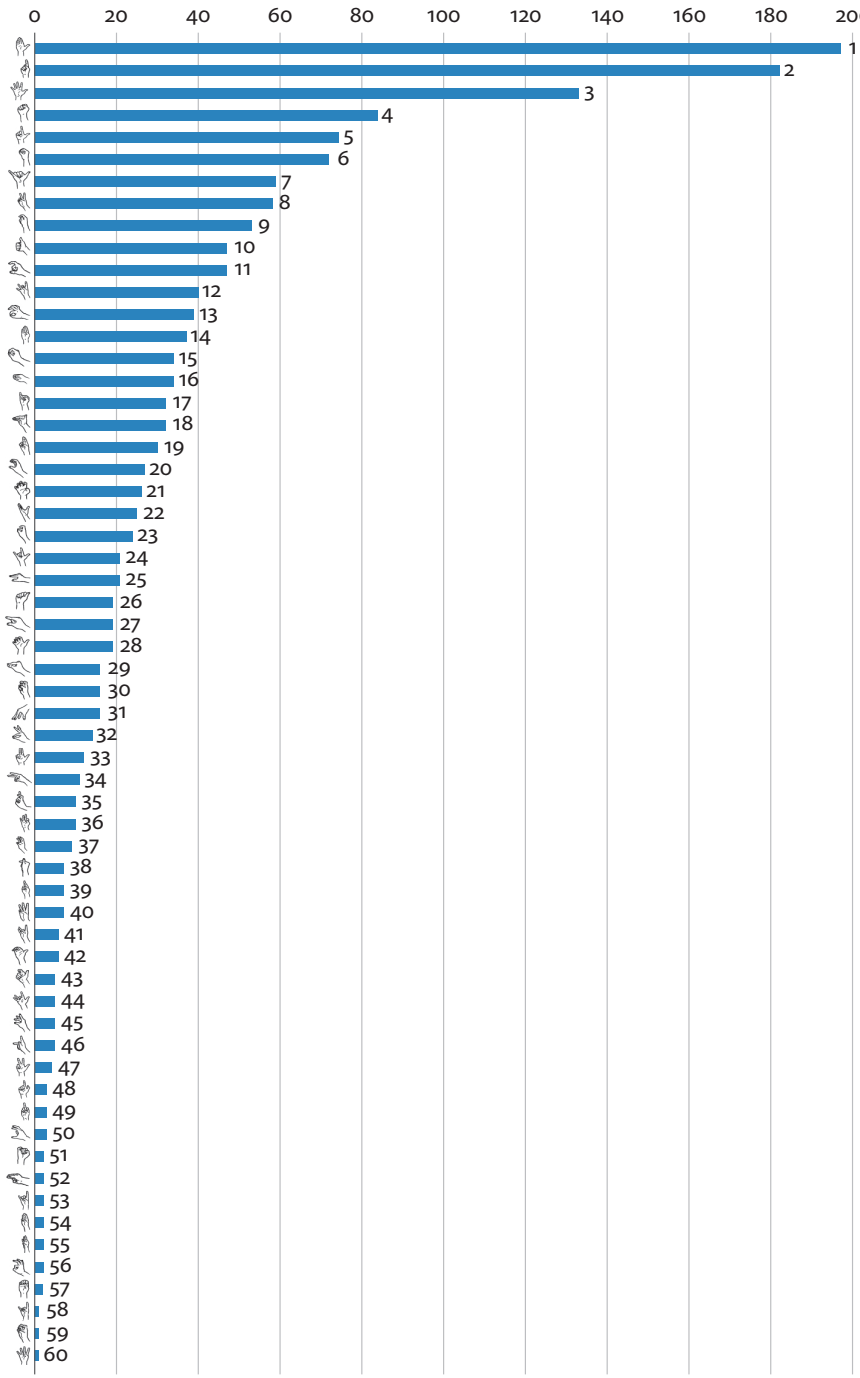


Figure 10. Frequency distribution of H1 handshapes

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(2015) examined the lexical frequency of signs in ASL. Specifically, they were interested in examining the relations between ASL sign frequency, iconicity and sign length. They observed a Zipfian distribution whereby more frequent signs tend to take less time to articulate, similar to spoken words. In our analysis, we ask whether the distribution of the 60 handshapes complies with Zipf's law.

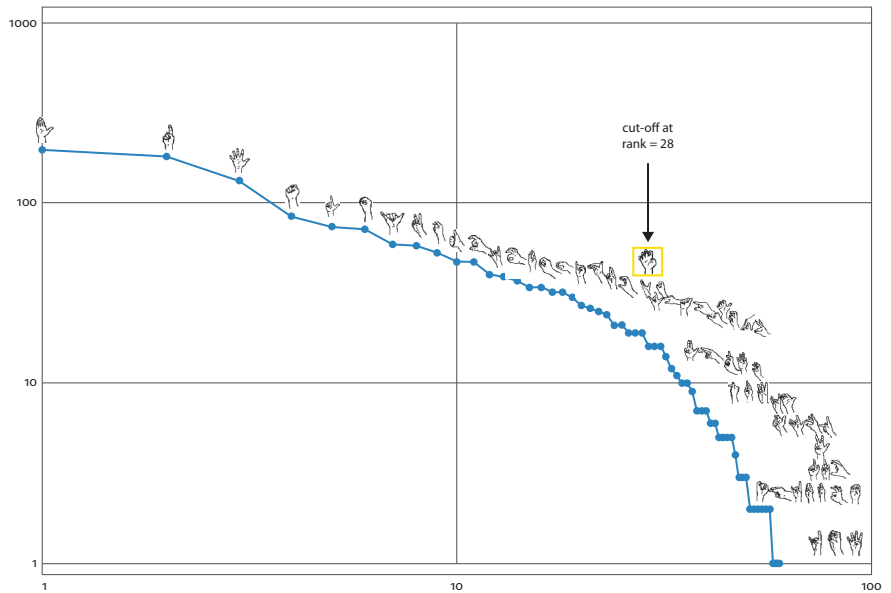


Figure 11. Log-log plot of the distribution of H1 handshapes

In Figure 11, the x-axis represents the rank order (from the lowest to the highest) and the y-axis the type frequencies of each handshape. This log-log plot indicates a distribution that complies to a variant of Zipf's law – a broken power law relation such that the plot shows a linear relation covering a range of handshapes until the frequency of occurrence of a certain handshape, at which the relation "breaks" (i.e., forms a sharp dip). To identify the handshape at which the dip occurred, we performed two linear regressions: one with the data points before the purported cut-off handshape, and the other with the data points after the purported cut-off handshape. By iterating the same set of regressions on different purported cut-off handshapes, the handshape showing the best-fit (i.e., producing the least summation of two standard errors for the data points before and after the purported cut-off handshape) was identified. At the end, the cut-off was determined at the 28th handshape (std. error = 0.0430 + 0.0761, $p < 0.001$), which was [].

There may be factors influencing the frequency distribution of the 60 handshapes in different degrees, resulting in a broken power law relation. First, our

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data confirm Battison's (1978) purported unmarked handshapes, as they are all above the 28th handshape, with a higher frequency of occurrence than those below. Second, ease of articulation affects the handshapes' type and token frequencies, as suggested by Ann (2006), although some exceptions are found. For example, handshapes like [] and [] that are reported to be relatively difficult to articulate rank quite high among the top eight handshapes. On the other hand, [] which is judged to be easy to articulate ranks quite low, among the bottom ten handshapes. Third, the rank order of handshapes in Figure 11 corroborates largely with Boyes Braem's (1990) stages of L1 handshape acquisition. Those handshapes that are reported in Boyes Braem's Stages I and II did show a higher frequency of occurrence and ranked above the 28th handshape in the current analysis. Nevertheless, there are exceptions. For instance, [], which ranks above the 28th handshape, is reported to be acquired late by children, usually at Stage IV of Boyes Braem's developmental timetable. Fourth, Eccarius (2008) claims that markedness constraints interact with contrastiveness in shaping the handshape inventory of a sign language. In the literature, the following handshapes are proposed to be structurally marked: they are either handshapes with three selected fingers (3FHS) (e.g., [], [], [], [], []), a [stacked] feature (e.g., []), secondary selected fingers (SSF) (e.g.[], []), or complex in structure (e.g.[], []) (Brentari & Eccarius 2010; Eccarius 2008, 2011). In Figure 11, all these handshapes rank well below the 28th handshape, occupying the tail of the log-log plot. Fifth, as Brentari and Padden (2001) suggest, there is bound to be a periphery that is external to the core stratum of a sign language lexicon. In this study, the handshapes that are motivated by factors external to the core lexicon (see Table 3) are well below the 28th handshape, and are among the handshapes with a very low frequency of occurrence, suggesting that their distribution in the language is highly restrictive. According to Brentari and Padden (2001), classifiers and foreign vocabulary are in the periphery of the lexicon, and the rare handshapes with such limited domains of use confirm that. Hence, we expect that they observe less phonological constraints.

To conclude, the distribution of the 60 handshapes reflects a broken power law relation between rank order and frequency of occurrence. Although less complex structure, ease of articulation and ease of acquisition may contribute to a high frequency of occurrence of simple and easy handshapes, the dip at the tail suggests that those handshapes below the 28th cut-off occur less frequently than expected. Indeed, they are found in the non-core lexicon in Figure 9. They observe fewer phonological constraints and occur in a more restricted set of domains of use. On the other hand, handshapes belonging to the core lexicon may or may not be motivated by these external factors, and are adopted more widely. Despite the occurrence of some language-specific handshapes, we postulate that the more domains in which a handshape generally occurs, the more frequency of use it enjoys. Nevertheless,

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we point out that some handshapes observed in HKSL are not yet analyzed, although we suspect that their frequency of occurrence is low. For instance, one of our Deaf researchers commented that the bent V-handshape may vary either between a spread or a non-spread feature of the index and middle finger with the thumb specified for either "extension" or "opposed". Future research is needed to explore these handshapes, using the commutation test for their status in the handshape inventory.

3.1.2 *Non-dominant hand (H2)*

According to Battison (1978), there are three types of two-handed signs. In Type-1 signs, both hands are active and perform identical movements. In Type-2 signs, one hand is active and the other passive, and both are specified for the same handshape. In Type-3 signs, one hand is active and the other is passive, but they are specified for different handshapes. In the current analysis, we singled out Type-2 and Type-3 signs in which the non-dominant (H2) handshapes serve as POA. There are 393 such signs in the dataset. The distributional frequency of these H2 handshapes is summarized in Figure 12.

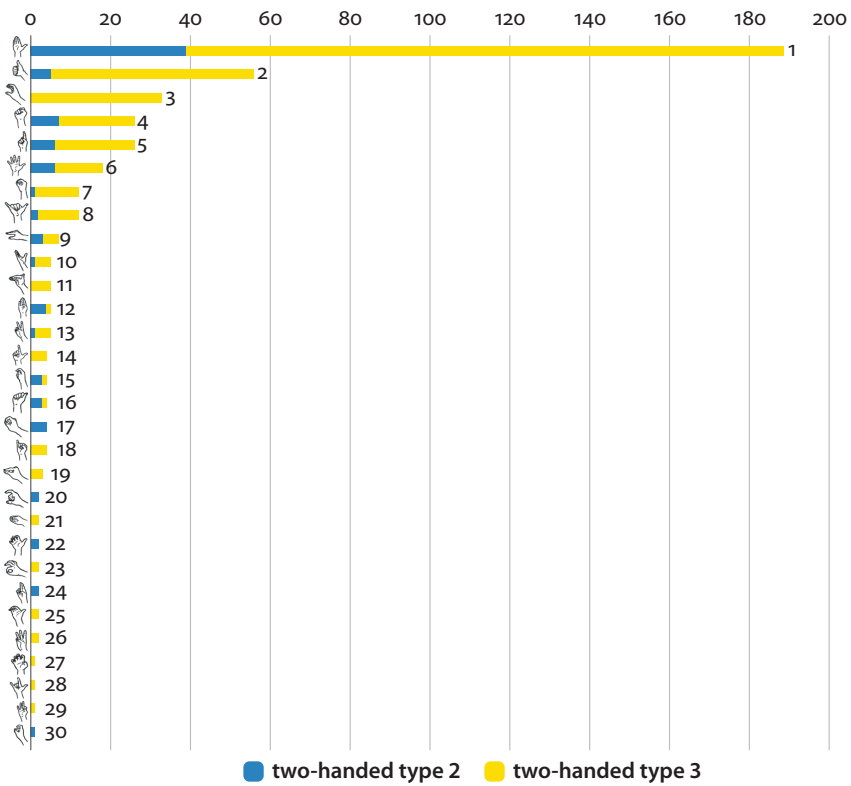


Figure 12. Frequency distribution of H2 handshapes

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Figure 12 combines Type-2 and Type-3 two-handed signs in the frequency distribution. The eight most frequently adopted H2 handshapes are [], [], [], [], [], [], [], and [], which overlap mostly with the most frequent handshapes on the dominant hand ([], [], [], [], [], [], []). Except for [], the H2 handshapes are the same as the limited set of unmarked handshapes, "B", "A", "S", "C", "O", "5", and "1" proposed by Battison's (1978) Dominance Condition for two-handed signs.

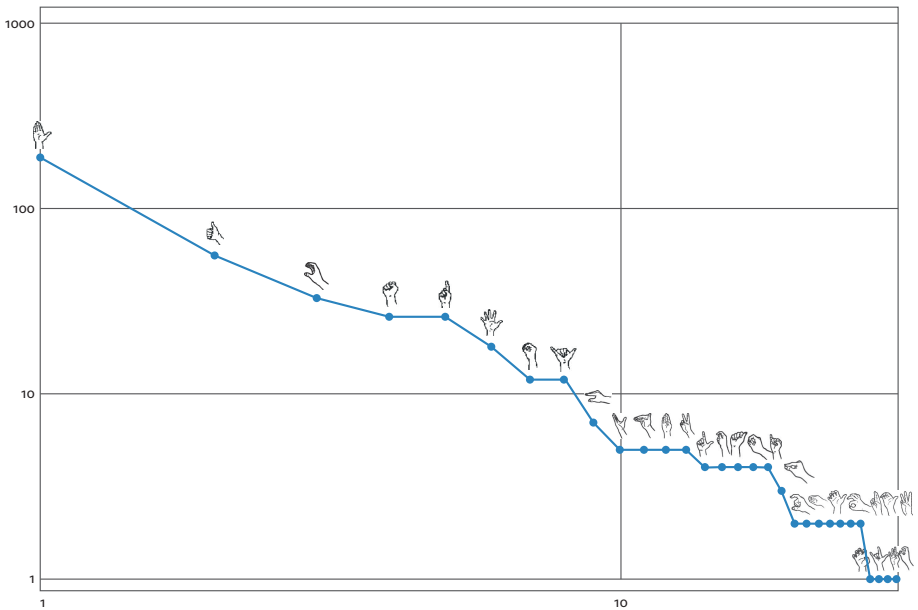


Figure 13. Log-log plot of the distribution of H2 Handshapes

The log-log plot of H2 handshapes as shown in Figure 13 suggests a Zipfian distribution without an observable dip (a linear regression, std. error = 0.0630, $p < 0.001$). Further analysis shows that the most frequent H2 handshape [], which occurs in 189 (i.e., 48.1%) signs, correlates with [H2:Palm] (see Section 3.2), the most frequent place distinction on H2 as POA (occurring in 172 of the 393 signs, i.e., 43.8%). The high frequency of co-occurrence of the [] handshape as H2 and the palm of this handshape as a specific POA may be explained by HKSL using this place distinction to denote a flat surface in many signs with a classifier origin, such as SIT, STAND, and ENTER. This combination occurs in 126 out of the 393 signs (i.e., 32.1%) in HKSL. The second most frequently observed H2 handshape is [], which occurs in 56 out of 393 signs (i.e., 14.2%). In HKSL, this H2 handshape has a classifier origin referring to a human entity serving as grammatical object, as in HELP, SUPPORT, LOOK_AFTER, and SCOLD.

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To conclude, the distribution of the 30 H2 handshapes serving as POA in two-handed signs complies with Zipf's law, and reflects an interaction between frequency of use and iconicity, namely H2 with classifier origins.

3.2 Locations

According to the Prosodic Model (Brentari 1998: 119), the signing space has distinct specifications for plane and place of articulation. All signs in ASB are tagged with plane of articulation, or a combined use of two planes as observed in a small number of signs. If a sign is articulated in neutral space, there is no additional specification on body part. If a sign is annotated with a body plane, there are further specifications on one of the four major body locations, namely head, body, arm, and H2 (Brentari 1998: 121). Note that our annotations do not follow the proposal of the Prosodic Model that each location must have eight place distinctions. Discussing the H2 handshapes in Section 3.1.2, we observed that [H2:Palm] as a place distinction of the [] handshape attracts many signs. In this section, we report on the frequency of occurrence of [H2:Handpart] and [H2:Fingerpart] as place distinctions on the non-dominant hand.

Initially, we conducted a frequency count of signs in terms of five main locations – Neutral Space, Head, Body, Arm, and H2. In Figure 14, out of the 1682 signs, 592 signs (i.e., 35.2%) involve the Neutral Space, 474 (i.e., 28.2%) are signed on the Head, 393 (i.e., 23.4%) on various H2 locations, 172 (i.e., 10.2%) on the Torso, and 51 (i.e., 3.03%) on the Arm. The frequency of occurrence based on the main body locations are summarized in Table 4.

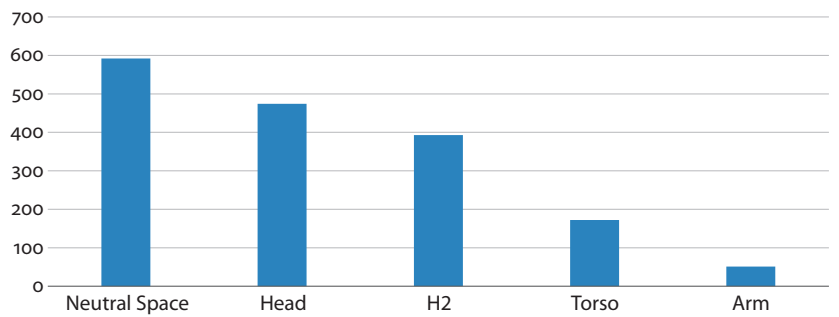


Figure 14. Frequency distribution of five major locations

Some locations attract more signs, such as [Z-Plane], [X-Plane], and [Y-Plane], [Head:Mouth], [H2:Palm] and [H2:Fingerpart], and [Torso:Whole]. Each of these place distinctions occurs in over 100 signs (see Table 4). On the other hand, locations that have a very low frequency of occurrence (less than four signs) are [Y-X Plane], [Z-Y Plane], [Z-X Plane], [Clavicle], [Tongue], [Hip], [Arm:Whole], and [Forearm].

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Table 4. Frequency distribution of signs articulated on the major locations and their sub-divisions

Neutral Space		Head		H2		Torso		Arm	
X Plane	200	Whole	53	Handpart	87	Neck	11	UpperArm	17
Y Plane	166	Forehead/ Temple	76	Palm	172	Clavicle	3	Elbow	5
Z Plane	205	Face	12	Fingerpart	134	Shoulder	22	Whole	1
X-Y Plane	14	Cheek	42			Whole	114	Forearm	2
Y-X Plane	3	Ear	32			Waist	16	Wrist	26
Z-Y Plane	3	Eye	34			Hip	1		
Z-X Plane	1	Nose	42			UpperLeg	5		
		Mouth	120						
		Tongue	1						
		Chin	41						
		Chin: Und	21						
Subtotal	592	Subtotal	474	Subtotal	393	Subtotal	172	Subtotal	51
Total									1682

In spoken languages, different locations on the upper jaw are employed to produce an inventory of contrastive sounds. Likewise, sign language(s) make use of sets of locations to mark contrasts in signs. Figure 15 shows the minimal pairs of locations.

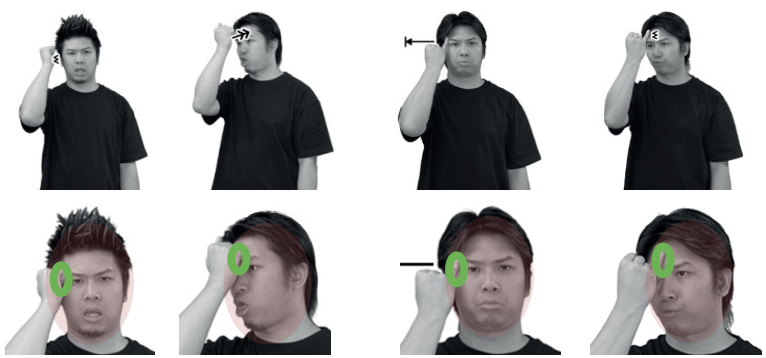


Figure 15. Temple versus forehead

The minimal pair "temple versus forehead" shows that these two specific locations are contrastive in HKSL. In what follows, we present the contrastive locations categorized under Neutral Space, Head, Torso, Arm, and H2.

3.2.1 *Neutral space and body plane*

The first major location is Neutral Space. Following the Prosodic Model (Brentari 1998), we assume HKSL makes use of the three planes in Neutral Space as POA:

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is the frontal plane [X-Plane]; the transverse plane [Y-Plane]; and the midsagittal plane [Z-Plane]. Signs that are articulated in Neutral Space do not induce a contact feature to any body part, as shown by the examples in Figure 16.

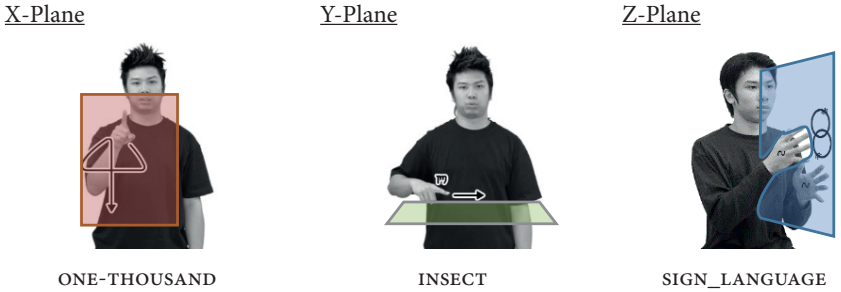


Figure 16. Planes of articulation

According to Brentari (1998: 120), in ASL, [X-Plane] in neutral space is often used as a "calendar plane" in signs such as EVERY_MONDAY. The [Y-Plane] is most commonly used in one-handed signs, and the [Z-Plane] in two-handed symmetrical signs. In HKSL, the [Z-Plane] is the most commonly used plane for two-handed symmetrical signs, similar to ASL; however, it is [X-Plane], and not [Y-Plane], that attracts more one-handed signs in neutral space. Signs that are not articulated in neutral space, but on the body plane, may or may not carry a contact feature.

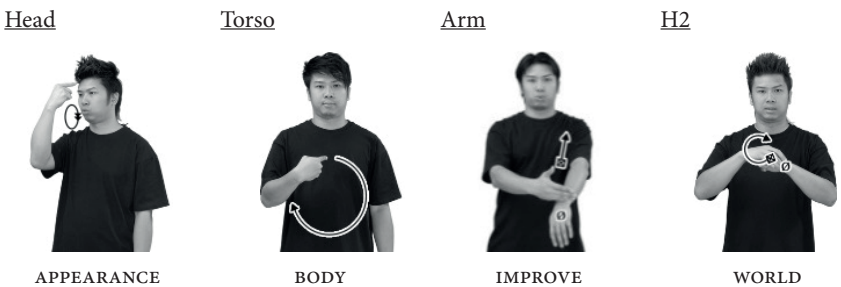


Figure 17. Entire body regions as POA

3.2.2 *Head*

We may consider the whole head as a head prism (see Figure 18), as inspired by the hand prism of the Visual Phonology Model of Uyechi (1995). Being the most productive POA, the Head is further divided into four contrastive locations: Head-top, Head-ipsi, Head-front (Face) and Head-back. Head-front (Face) as POA finds further contrastive locations: Forehead, Temple, Eye, Ear, Nose, Cheek, Mouth, Chin, and Chin-under (Figures 19a and 19b).

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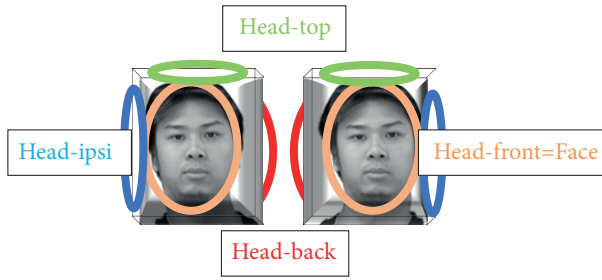


Figure 18. The head prism

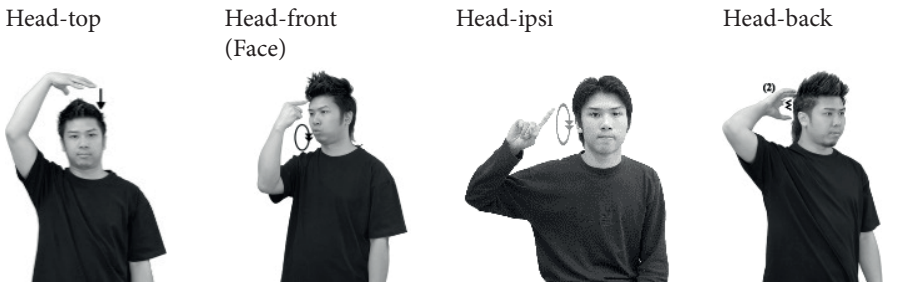


Figure 19a. Head as POA

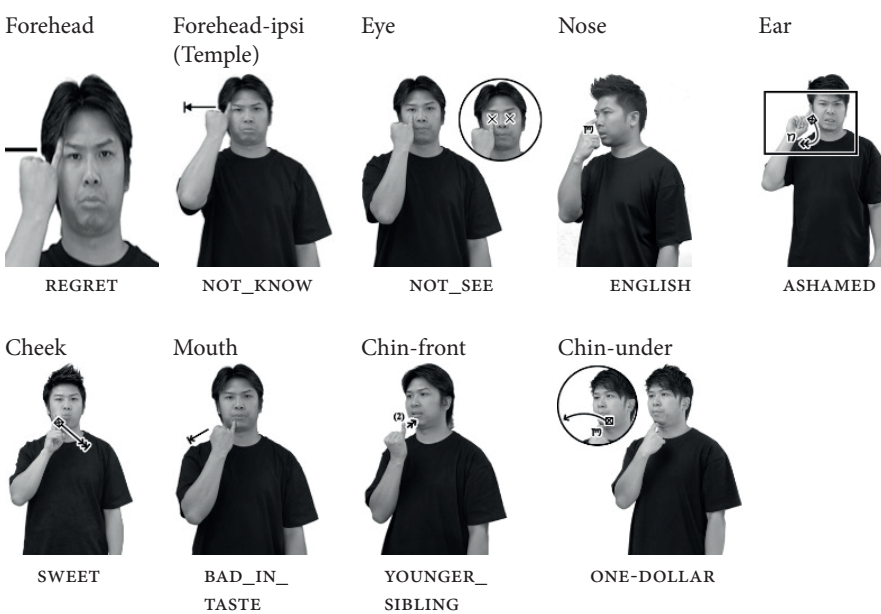


Figure 19b. Head-front (Face) as POA

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3.2.3 *Torso*

Figure 20 shows the contrastive locations on the torso: Neck, Neck-ipsi, Shoulder, Torso-top, Torso-bottom, Waist, Hip, and Upper Leg.

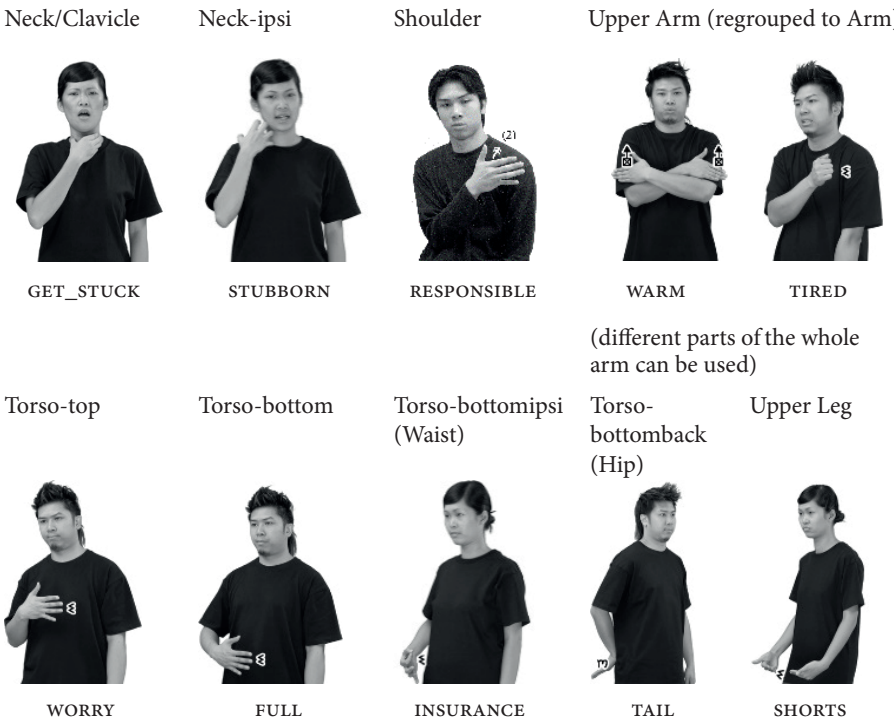


Figure 20. Torso as POA

Also shown in Figure 20, signs with place distinctions such as [Neck], [Clavicle], [Shoulder] and [Upper Arm] are re-categorized into contrastive locations of Neck, Neck-ipsi, Shoulder (under Torso), and Upper Arm (under Arm), based on the patterns observed in free variation.

As expected, the frequency distribution of the five major locations is uneven, and they rank in the order of Neutral Space > Head > H2 > Torso > Arm. There are 592/1682 (i.e., 35.2%) signs articulated in Neutral Space, but only 51/1682 (i.e., 3.03%) on the Arm. Figure 21 displays a bar chart of frequencies of occurrence (Table 4) of all phonetic locations.

The bar chart in Figure 21 shows the frequency distribution of 33 phonetic locations. The most frequent location – [Z-Plane] – constitutes 12.2% of all signs in the database. As a whole, [Z-Plane], [X-Plane] and [Y-Plane] in Neutral Space, [H2:Palm] and [H2:Fingerpart] constitute 52.0% of all the signs archived so far.

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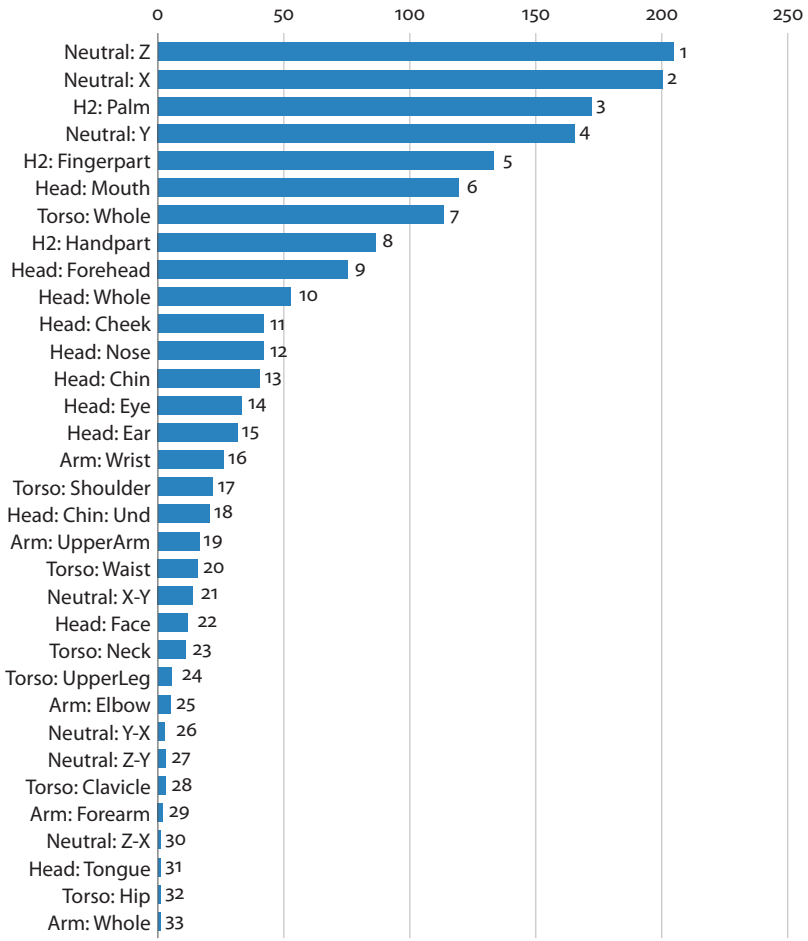


Figure 21. Frequency distribution of the major locations and their sub-divisions

[H2:Handpart], which combines various parts of the hand (such as heel, back and ulnar) as a single category, attracts just 87 signs, thus ranking much lower than [H2:Palm] with 172 signs and [H2:Fingerpart] with 134 signs. Among the different place distinctions of Head, [Mouth] is the most frequently selected place distinction with 120 signs. Locations that attract very few signs include [Upper Leg], [Elbow], [Y-X Plane], [Z-Y Plane], [Clavicle], [Forearm], [Z-X Plane], [Tongue], [Hip], and [Arm:Whole]. These locations only constitute 1.19% of all the signs in the database. The log-log plot in Figure 22 explores whether the distribution complies with Zipf's law.

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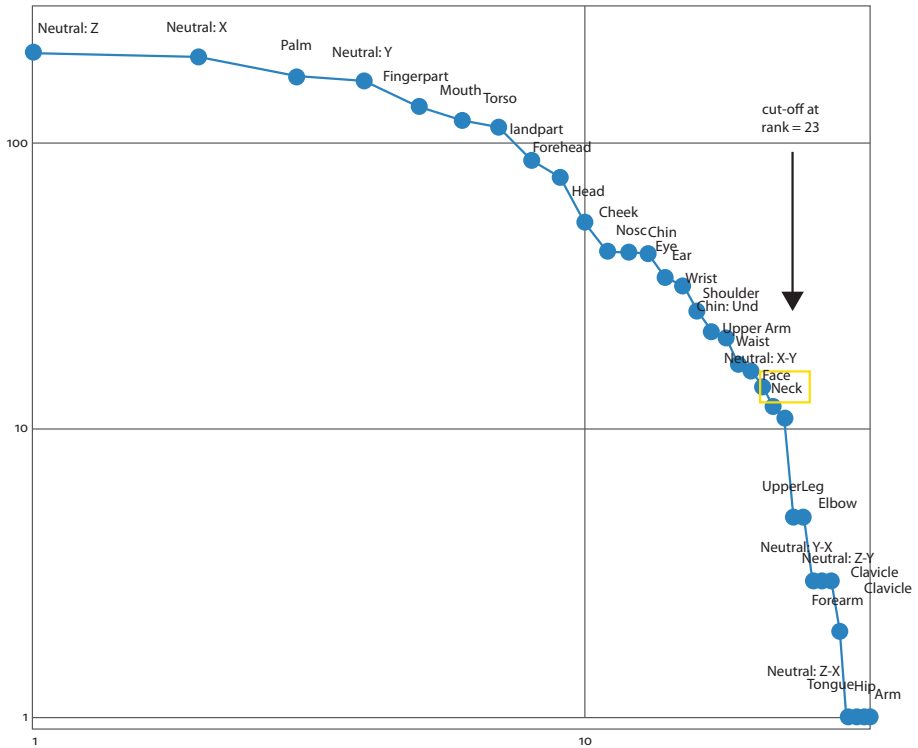


Figure 22. Log-log plot of locations

Figure 22 reveals a broken power law relation between the rank order of locations and their associated frequency of occurrence, with a dip occurring towards the tail of the plot. Using the same regression analysis discussed above to estimate a cut-off location, we found the best-fit to be at the 23rd location (std. error = 0.1628 + 0.1017, $p < 0.001$), which is [Torso:Neck]. All basic planes in Neutral Space, H2 and all place distinctions on Head (except [Tongue]) demonstrating a high frequency of occurrence are found above the 23rd cut-off location. Further analysis reveals that these locations are generally perceptually salient. On the other hand, iconicity-motivated signs on locations like [Tongue], [Hip], [Upper Leg] such as TONGUE, TAIL, and SHORTS are found to be below the 23rd location, with very low frequencies of occurrence.

Following Bybee's (2010) assumption of markedness, we assume that a linguistic element characterized as "unmarked" tends to show a high frequency of use in different domains, and is mostly regarded as "natural" and "expected". Based on our data, unmarked places of articulation are Neutral Space, H2, and Head as a single category since they obtain the highest frequencies of occurrence. Stokoe

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(1965) uses Ø for Neutral Space in his notation system, and Van der Kooij (2002) analyzes Neutral Space as being without phonological specifications. Both scholars, therefore imply that Neutral Space as POA is unmarked relative to the body. Second, Head and all its associated place distinctions except [Tongue] are found above the 23rd location. In other sign languages, the Head and its associated place distinctions also attract more signs than places on the trunk and arm (see Battison 1978; Fenlon et al. 2014; Fenlon et al. 2017). That signers always fix their gaze on the lower part of the signer's face, which causes the highest acuity in this region, has already been suggested by Siple (1978). In other words, the visual modality of sign languages identifies locations in space in front of the signer and locations on the head as perceptually salient, thus attracting more signs to be articulated in these locations. As for H2, we saw that [H2:Palm] and [H2:Fingerpart] rank high among the H2-locations. This finding echoes our earlier observation that there is a close connection between the unmarked [] handshape and [H2:Palm] on the non-dominant hand. However, we did not discover any corresponding relation between the H2 handshapes and specific fingerparts as POAs. We suspect that [H2:Fingerpart] may be selected by many different H2 handshapes with different sets of selected fingers, and further research is necessary to verify this phenomenon.

To conclude, the distribution of the 33 locations complies with a broken power law relation and Figures 16 to 20 list some examples of 28 contrastive locations. It seems that naturalness and perceptual salience (that is, ease of perception) of the neutral space in front of the signer attract many signs to be articulated in those locations, including the x-, y- and z-planes. Other perceptually salient locations occur on the Head, especially the [Mouth], and H2, especially the [H2:Palm]. On the other hand, less perceptually salient locations and more difficulty in articulation may lead to a low frequency of occurrence, such as those iconicity-motivated signs which are articulated in some restrictive locations [Tongue], [Hip] and [Upper Leg]. Future research can focus on some arm locations such as forearm, elbow, wrist, and the complex use of x-y, y-x, z-y, and z-x planes. For the Arm and some finer H2 place distinctions, it is more difficult to identify minimal pairs, which was why we grouped all fingerparts and handparts of H2 as a single category in the analysis.

3.3 Movements

Mak and Tang (2011) developed a framework for analyzing movement in HKSL. They propose that degree of movement complexity is a function of combining different types of movement with types of repetition, leading to a division between simplex and complex signs in the language. In their framework, class nodes Path (P), Orientation (O), Aperture (A) and Setting (S) are adopted to account for

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the basic movement types: path movement, orientation change, aperture change, and setting change. Repetitions are divided into no repetition (NoRep), full repetition (Rep, full cycles of repeated movements) and trilled movements (TM). Additionally, movement may be absent in signs (NoMvt). No-repetition (NoRep) is observed in signs with a simple movement (i.e., P-only, O-only, A-only), or in signs that show a combination of two, or at most three, movements (i.e., P|O, P|A, O|A, P|O|A) (see Figure 23).

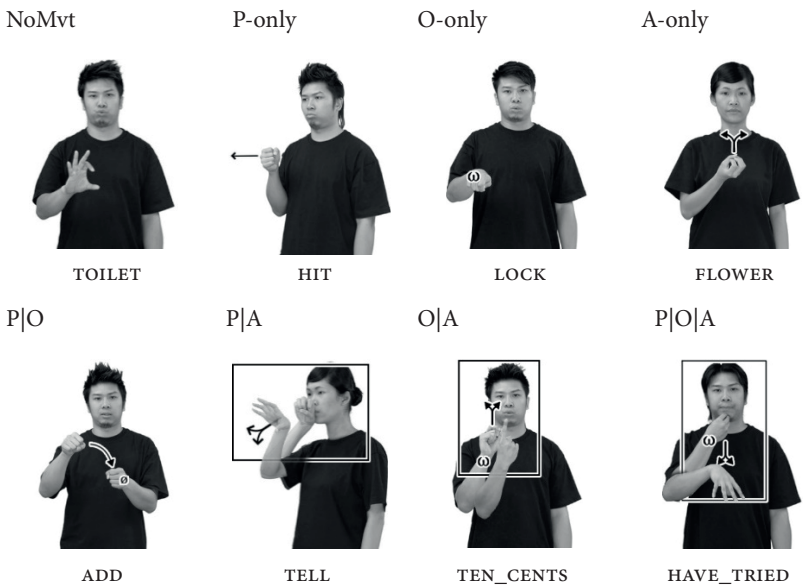


Figure 23. Movement types and changes

Figure 24 shows examples of signs with no repetition (NoRep), full repetition (Rep) and trilled movement (TM). Figure 25 shows two types of setting change. The first type does not involve any repetition (NoRep). The sign DOCTOR in HKSL involves two points of contact between the contra and ipsi settings on the Torso as POA. The second type involves repetitions (Rep). As shown by the sign BUTTON, repetitions lead to a setting change with more than two points of contact from top to bottom on the torso as POA.

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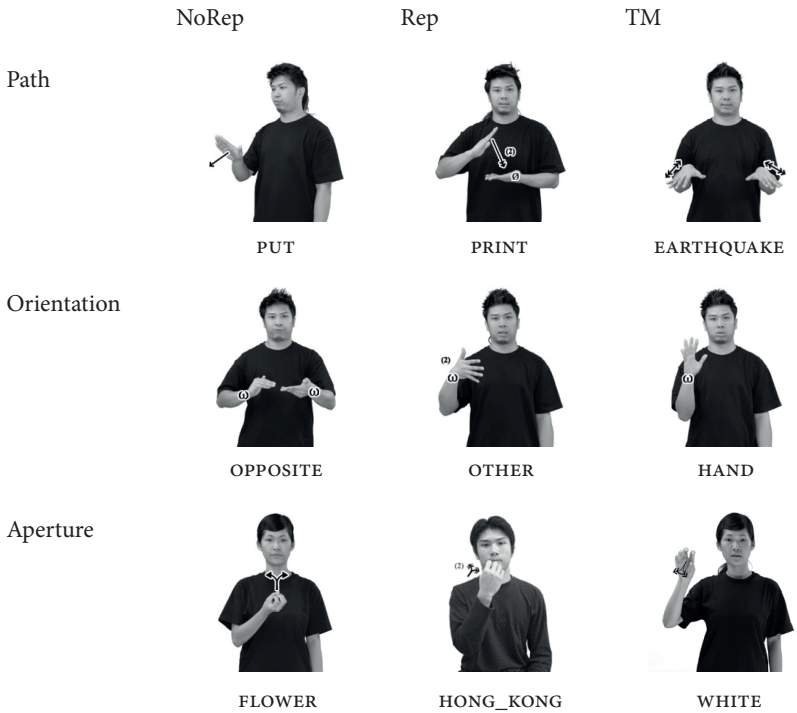


Figure 24. Types of repetition

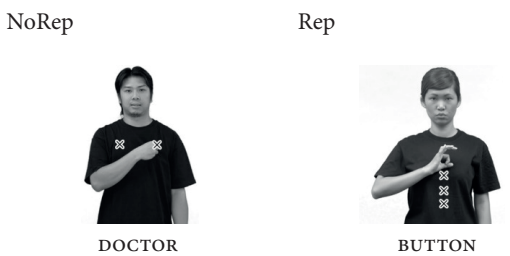


Figure 25. Setting change

Among the 1,682 non-compound HKSL signs archived in ASB, the frequency of occurrence of signs with different movements and repetition types are summarized in Table 5. HKSL's lexical signs show a heavy use of layers of movement hence adding complexity to sign formation. Besides simple movements, different patterns of combinations of movements, such as P|A, P|O, O|A, P|O|A (see Figure 23), and repetition types (NoRep, Rep, TM) (see Figure 24) lead to the formation of complex signs and different natural classes.

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Table 5. Frequency distribution of movement and repetition types

Rep. Types / Mov. Types	NoMvt	NoRep	Rep	TM	NoRep Primary Mvt	Rep Primary Mvt
NoMvt (118)	118					
Setting (13)		11	2			
P only (855)		393	207	255		
O only (154)		44	15	95		
A only (145)		32	8	105		
P|O (139)		104	35			
P|A (187)		151	34	2		
O|A (6)		6	0			
P|O|A (18)		16	2			
P|P:TM (7)					7	
P|O:TM (15)					12	3
P|A:TM (23)					16	7
(P|O):NoRep | P:TM (1)					1	
P:Rep| P:TM| A:TM (1)						1
Total: 1682	118	757	303	457	36	11

In Table 5, only 118 out of 1,682 (0.07%) signs are without movement. For signs involving movement, +/− repetition and trilled movement form the major categories. There are 757 signs (45%) without any repetition, and they are distributed over simple movements (P-only, A-only, and O-only) as well as complex movements (P|O, P|A, O|A and P|O|A) combining two to a maximum of three movement types. Relatively less signs, just 303 (18%), are marked with repetition, and their distribution is similar to signs without repetition, namely, more signs with P-only, P|O and P|A than other movements. Trilled movement is observed among 457 out of 1,682 signs (27%) and most of them involve simple P-only, O-only and A-only. Besides simple trilled movements, 47 (2.79%) lexical signs involve a path movement with a trilled movement (e.g. P|P:TM, P|O:TM, P|A:TM), and a path movement with two other movement types with or without repetition (i.e., (P|O):NoRep|P:TM and P:Rep|P:TM|A:TM in Table 5). The last two types only occur in two signs, respectively VARIOUS and PIANO. Taken together, path movement usually serves as primary movement, and it may or may not be repeated (see "No Rep/Primary Mvt" and "Rep/Primary Mvt" in Table 5), whereas trilled movements usually serve as secondary movement. Figure 26 presents the distribution of the types of movement identified in this study.

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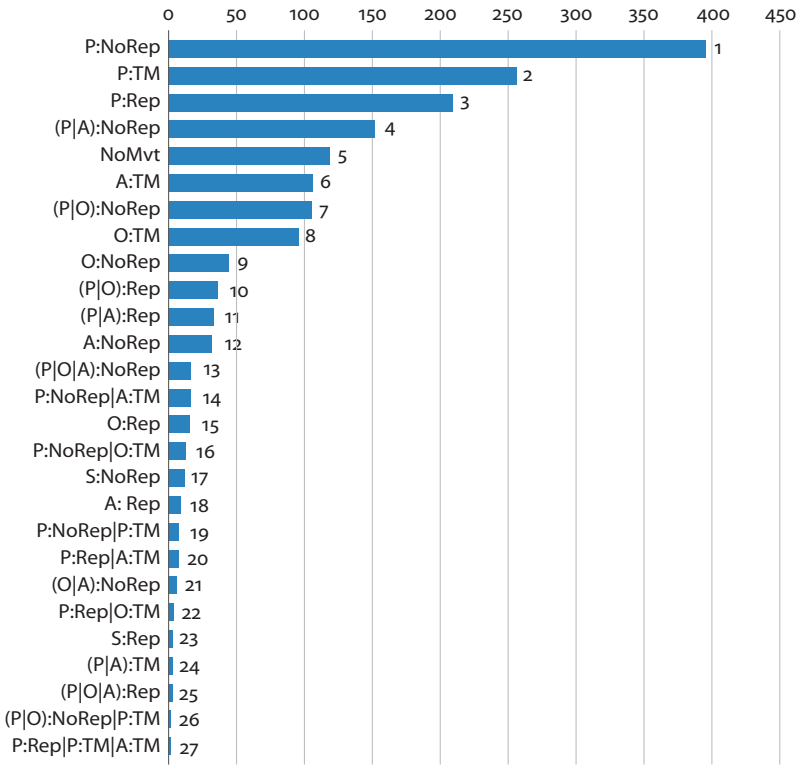


Figure 26. Frequency distribution of movement types

Figure 26 shows the frequency of occurrence of the 27 types of movement combination identified in this study. P:NoRep is the most frequently occurring movement, occurring in 23.4% of the signs in ASB. The three most frequently occurring movement types are P:NoRep, P:TM, and P:Rep, together comprising 50.8% of the signs in the HKSL lexicon. On the other hand, the seven least frequent movement types are (O|A):NoRep, P:Rep|P:TM, S:Rep, (P|A):TM, (P|O|A):Rep, (P|O):NoRep|P:TM, and P:Rep|P:TM|A:TM; altogether, they are found in just 1.01% of all the signs in ASB.

Similar to handshape and location, Figure 27 displays a broken power law distribution. Regression analysis shows that the best-fit with the least summation of standard errors was determined at the 8th movement type (std. error = 0.0301 + 0.1402, $p < 0.001$), which is O:TM. All simple path movements (P:NoRep, P:TM, and P:Rep), and all simple trilled movements (P:TM, A:TM, and O:TM), are above the 8th movement type, and they all show a higher frequency of occurrence. On the other hand, combinations of two movement types such as a non-repeated path movement as primary movement embedded with a trilled movement (i.e.,

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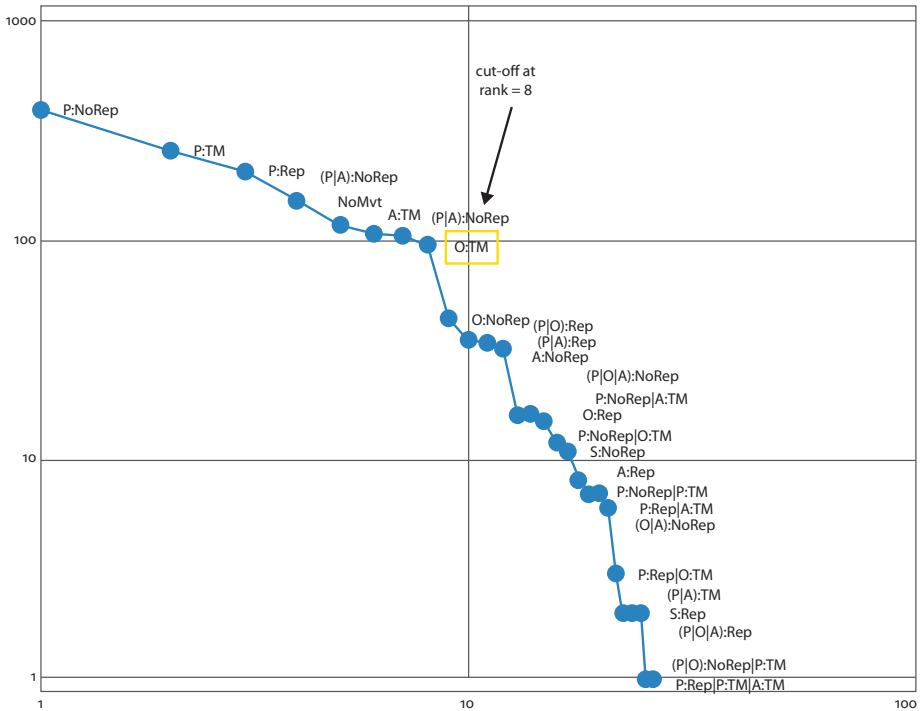


Figure 27. Log-log plot of movement types

P:NoRep|A:TM, P:NoRep|O:TM, P:NoRep|P:TM) are found below the 8th movement type, showing a lower frequency of occurrence. Last, combinations of three movement types (i.e., (P|O|A):Rep, (P|O):NoRep|P:TM, P:Rep|P:TM|P:TM) trail at the tail of the plot, suggesting a highly restrictive distribution of movement types in the language.

Focusing on the relation between simple path and simple local movements, we observe that all simple path movements receive the highest frequencies of occurrence among all movement types in the order of P:NoRep > P:TM > P:Rep, where path movement without any repetition ranks first. However, a similar order involving either simple orientation or aperture change is not found. The orders instead are O:TM > O:NoRep > O:Rep, and A:TM > A:NoRep > A:Rep, suggesting it is simple local movement with [TM] (e.g., O:TM and A:TM) that occur most frequently, followed by local movement without repetition, and the least frequent is local movement with repetition. This pattern of frequency distribution suggests that a distinction in terms of nature of movement and repetition might exist between path and local movement in HKSL. This finding is also reported in other

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sign languages (Brentari 1998; Liddell & Johnson 1989; Mak & Tang 2011; Sandler 1989; Van de Hulst 1993).

Brentari (1998) cites Battistella's (1990) markedness criteria, namely, simple phonological structures are unmarked and complex structures are marked. Moreover, unmarked structures have the widest distribution across the lexicon. In our study, we hypothesize that structural complexity may account for the distributional frequency of movement types, in the sense that the fewer the movement components combined to form a sign, the less complex it is in terms of structure and thus higher in frequency of occurrence. To verify this hypothesize, we controlled for repetition and singled out all movements without repetitions to obtain an order for analysis: P:NoRep > (P|A):NoRep > (P|O):NoRep > O:NoRep > A:NoRep > (P|O|A):NoRep > (O|A):NoRep. This order does not bear out our hypothesis entirely. As observed, the frequency of occurrence of signs with two movements (i.e., (P|A):NoRep and (P|O):NoRep) is higher than that with signs consisting of a single local movement (i.e., O:NoRep and A:NoRep). In addition, signs with three movements (i.e., (P|O|A):NoRep) have a higher frequency of occurrence than signs with two movements (i.e., (O|A):NoRep). However, a closer analysis reveals that path movement seems to be a factor interacting with the distribution of the frequencies of occurrence of movement types. First, path movement, on its own or combined with other local movements, occurs in more signs than local movements (i.e., orientation or aperture change) alone, or when they combine with each other. For instance, signs with two local movements (O|A):NoRep have the lowest frequency of occurrence in the HKSL database. Seen in this light, we posit that the wide distribution of path movements with a higher frequency of occurrence can be explained by perceptual salience, owing to the use of more proximal joints (i.e., shoulder and elbow joints) in articulation (Brentari 1998: 133).

To recapitulate, Bybee (2010) ascribes an unmarked status to a linguistic element based on high frequency of use, iconicity and economy, in those cases where structural complexity cannot address all marked-unmarked distinction satisfactorily. She further argues that markedness is not just defined in terms of binary oppositions, but may be expressed in terms of degrees. In our movement analysis, we observe a relation between structural complexity and frequency of use. Simple path movements with or without repetition, and simple path in trills as shown by the order P:NoRep > P:TM > P:Rep, show a higher frequency of occurrence, which may be categorized as unmarked. Signs that combine a path movement with a trilled movement (i.e., P:NoRep|A:TM, P:NoRep|O:TM, P:NoRep|P:TM) are relatively more complex than simple path movements, therefore occur less frequently. Last, signs consisting of three movement types are most complex, most marked and restrictive in their distribution in the lexicon (see Figure 28).

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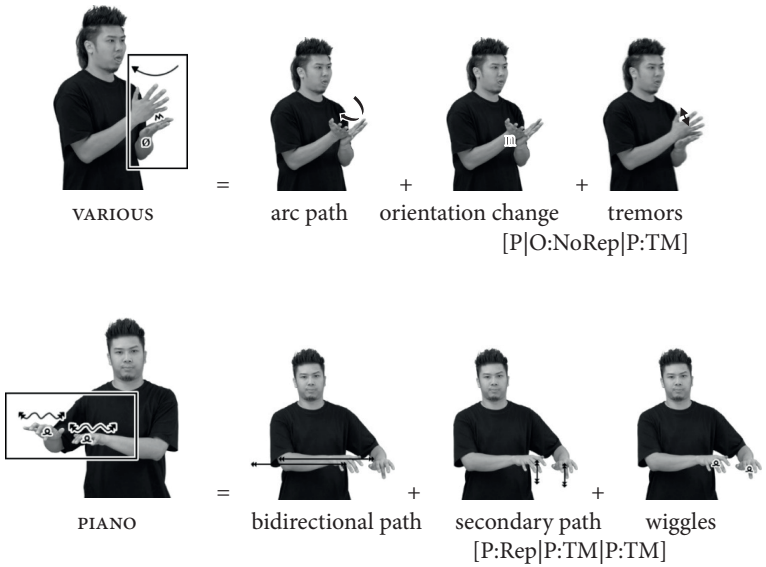


Figure 28. Highly complex movements

The two signs VARIOUS and PIANO presented in Figure 28 show the most complex movements in the HKSL lexicon, layered with three movement components. Similar to our analysis of motivated handshapes and locations, we argue that the movement components of these two signs are either iconically or morphologically motivated. PIANO is motivated by iconicity. The sign mimics the movement of the arms and the fingers. Lexicalization then acquires a bidirectional path movement, with a secondary (up and down) path movement, and TM: wiggle. PIANO falls on the periphery of the lexicon, which observes less phonological constraints and is therefore highly marked (Brentari & Padden 2001). VARIOUS is lexicalized as the morphological stem DIFFERENT inflected with an arc path, yielding an "exhaustive" meaning (Klima & Bellugi 1979). When lexicalized, the sign requires that the repeated path movement becomes phonologically compressed into TM: tremor, layered onto an arc path and orientation change, as shown in Figure 26.

To conclude, the distribution of 27 types of movement combination complies with a broken power law relation. Based on the analysis, movements involving a path feature – either alone or in combination with local movement – occur more frequently. We argue for perceptual salience as a potential factor interacting with frequency of occurrence. On the other hand, some iconicity-motivated signs such as PIANO may invoke a mimetic movement of a complex nature. Their highly restrictive distribution confirms their status as being structurally marked in the movement inventory. Yet, there are also iconicity-motivated signs such as FLOWER

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that requires a simple aperture change from closed to open only, and they are not as restrictive in terms of frequency of occurrence as other iconically motivated signs.

In fact, the current analysis does not exhaust all movement features in the search for contrastiveness, partly because movements may also encode morphological or syntactic properties in HKSL, and partly because proximalization and distalization of movement also leads to non-contrastiveness. Therefore, it is difficult to perform commutation tests on movement. Other than simple, complex, repetition, and trilled movements (see Figures 23 to 25), which we argue to be distinctive in nature, future research may be extended to other movement features which are left unexplored in this study, for example, shapes of path (e.g., straight, arc, circle) and directionality, wrist position, and finger joints and position.

4. Conclusion

In this study, we used 1,682 non-compound signs archived in ASB to set up an inventory of handshape, location and movement in HKSL. We identified 30 underlying handshapes, 28 locations and 27 types of movement combination. Using type frequencies, we identified some properties that are relatively unmarked: (1) a set of handshapes on H1 and H2 in HKSL that are also reported in other sign languages as "unmarked", (2) Neutral Space, H2, and Head for locations, and (3) movements including a path feature, either on its own or in combination with other local movements. Less complex structure, and ease of articulation and acquisition are the possible factors influencing handshape distribution; perceptual salience and ease of articulation for location distribution; and perceptual salience and structural simplicity for movements with a path feature.

We also confirmed the distribution of each of these phonological components by way of Zipf's law. We observed a broken power law relation for H1 handshapes, locations and movements, but a power law relation for H2 handshapes. We observed that, in addition to structural complexity, there may be other factors causing some H1 handshapes, locations and movements to occur less frequently in signs than expected, resulting in the dip towards the tail of the log-log plots, implicating a broken power law relation. These factors are: (1) domain-specificity in the use of some rare handshapes, such as [] to refer to an English alphabet, [] a Chinese radical, [] a number, [] a classifier, and [] an iconic gesture; (2) reference to specific body parts that indicate rare locations, such as [Tongue], [Hip], [Upper Leg]; (3) lexicalization of morphological elements, such as the incorporation of a negative particle in [] via the pinky finger, and movement modulation for exhaustive aspect such as VARIOUS; (4) iconicity in handshapes (e.g., BED) and locations (e.g., TAIL), and

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mimetic movements (e.g., PIANO). (5) There are also language-specific or culturally oriented characteristics leading to structurally complex but frequently occurring handshapes (e.g., [] for humans and [] for human legs or long and cylindrical objects), and structurally simple but infrequent handshapes (e.g., [] for number), as well as structurally complex but frequently occurring movements (e.g. (P|O):NoRep and (P|A):NoRep), and structurally simple but infrequent movements (e.g., O:NoRep and A:NoRep) in HKSL. Our findings invite future research on the relationship between these factors and the frequency distribution of handshapes, locations and movements in HKSL, the findings of which will contribute to revealing whether structural complexity, frequency of use or other factors mentioned above account for markedness.

Finally, the HKSL handshape inventory as archived in the ASB is not exhaustive, and future documentation might uncover more handshape variants. There are also locations with a very low frequency of occurrence, such as those on the arm and the complex planes, which pose difficulty in developing minimal pairs for contrastive analysis. Another area for future research is the distinctive handparts and fingerparts on H2. The current analysis only focuses on the frequency of occurrence of the palm as a distinctive location on H2, while other handparts and fingerparts are grouped as a single category in the analysis, owing to their relatively low frequencies of occurrence. As for movement, other features such as shape and directionality as path features engender interesting investigation in the future. We also expect that, as the size of the database enlarges, some observations reported in the current study may need modifying in order to account for language internal properties and typological comparison.

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Appendix. Notation conventions

GLOSS	– HKSL signs glossed in English
[]	– a contrastive handshape
[Clavicle]	– a phonetic location in brackets
[p^h]	– a phonetic sound in brackets
p	– a contrastive sound
[]	– a phonetic handshape in brackets
Torso	– a contrastive place of articulation with the first letter capitalized
Neck	– a contrastive location with the first letter capitalized
Neck-ipsi	– a contrastive location with setting in small letters
NoMvt	– an absence of any movement
P:NoRep|A:TM	– a combination of movement types articulated simultaenously
P	– a simple movement type in capital letter
P|A	– a complex movement combination separated by a vertical bar
NoRep	– a non-repeat movement type
Rep	– a repetition type (i.e., full repetition)
TM	– a repetition type (i.e., trilled movement)

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