Acquisition of Handshape in Hong Kong Sign Language: A Case Study

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Abstract

The literature about handshape acquisition in signed language focuses mainly on American Sign Language (ASL) (McIntire 1977, Boyes Braem 1990, Marentette 1995, Siedlecki & Bonvillian 1997, Cheek, Cormier, Repp and Meier 2001). The current study aims to expand the literature with data contributed by Hong Kong Sign Language (HKSL).

In attempting to account for the acquisition of handshape of HKSL, I attempt to develop a Handshape Unit Model which represents a synthesis of the earlier models discussed in the literature (Brentari 1998, Eccarius 2002, Kooij 2002, Sandler 1989). In the current study, reference is drawn on Dependency Phonology (Anderson & Ewen 1987) which has been adopted in the analysis of handshape configuration in various models.

It has been found that deaf children acquiring a signed language display an order of acquisition of handshapes. In addition, when a deaf child is nontarget in his production, the patterns of substitutions are not random but systematic. The interaction between hand-internal movement (HIM) and handshape acquisition is also examined. It is found that the accuracy of handshape production tends to be lower when HIM is specified.

Lastly, the acquisition data obtained from the case study in HKSL is used to verify Ann (1993) physiology account on the degree of complexities of different handshapes. The acquisition data basically confirm Ann (1993) proposal of handshape scoring.

摘要

美國手語是手形習得文獻中的主要研究對象 (McIntire 1977, Boyes Braem 1990, Marentette 1995, Siedlecki & Bonvillian 1997, Adrianne, Kearsy, Ann and Meier 2001)。本論文所研究的是香港手語習得，盼藉此使手形習得的文獻更爲豐富。

爲了說明香港手語的手形習得特點，我嘗試做了一個綜合多份文獻中手形模形而成的「手形單位模形」。正如以前提出的手形模形，「手形單位模形」的建構亦有參照「依存關系語音學」(Dependency Phonology) 的原則。

本研究發現聾童於習得手形的過程中顯示一個特定次序。另外，當聾童未能正確做到某些手形時，錯誤的手形並非雜亂無章，而是與目標手形 (target handshape) 有一定的關連。本論文亦有查察手指的動作 (hand-internal movement) 與手形習得之關係。研究發現，當某手語需要手指有動作時，手形的準確性會下降。

本研究把所收集的香港手語手形習得語料，用來查證 Ann (1993) 用生理學說明的手形難易度評分系統，而本研究中的語料大體上證實了 Ann (1993) 從生理學提出的系統是正確的。

Acknowledgment

I first express my gratitude to my thesis supervisor Professor Gladys Tang for introducing me to the study of sign linguistics. When I was an undergraduate student, her enthusiasm and wonderful presentations in courses like Deaf Awareness, Sign Linguistics and Deaf Culture attracted me to knowing more about sign language and Deaf people. During the first year of my deferred postgraduate study, I went to teach at a deaf school and I was so occupied that I did not have enough time to continue with thesis writing. It was Gladys who strongly advised me to quit the teaching and focus on my thesis. I am certain I would not be able to finish this thesis if I continued to teach. I would like to thank Professor Virginia Yip for arousing my interests and providing me with background knowledge in language acquisition in my undergraduate years. I am also grateful to Professor Ping Jiang-King and Professor Thomas Lee for serving in my thesis committee and offering me with invaluable comments and support on my study, and Professor Yang Gu and Professor Foong Ha Yap for their teaching along the way.

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Last but most importantly, this thesis is dedicated to God who has been guiding me, supporting me through every step of the process, and providing me with all I need, including all the support mentioned above.

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Chapter 1 Sign phonology models

1.0 Introduction

The literature about handshape acquisition in signed language focuses mainly on American Sign Language (ASL) (McIntire 1977, Boyes Braem 1990, Marentette 1995, Siedlecki & Bonvillian 1997, Adrianne, Kearsy, Ann and Meier 2001). Karnopp (2002) is an excellent addition which focuses on Brazilian Sign Language. The current study aims to enrich the existing literature with data contributed by Hong Kong Sign Language (HKSL).

In order to account for the acquisition of handshape of HKSL in the current study, I attempt to develop a Handshape Unit Model which represents a synthesis of the earlier models discussed in the literature (Brentari 1998, Eccarius 2002, Kooij 2002, Sandler 1989). Some of these models assume typological markedness in analyzing the features of handshape configuration, resorting to their frequency of distribution among an array of sign languages. Also, these models also assume that features of handshape are hierarchically organized into class nodes with dependency relations. In the current study, reference is drawn on Dependency Phonology (Anderson & Ewen 1987) which has been adopted in the analysis of handshape configuration in various models. With respect to markedness, this approach also assumes that a structurally complex representation is relatively more marked than a simplex one. For instance, a representation with fewer dependent nodes implies that the structure is less complex, hence less marked than one with more dependent nodes (e.g. Kooij 2002).

In the current study, I also attempt to examine the interaction between hand-internal movement (HIM) as a dependent node in the Handshape Unit Model and handshape acquisition; in particular, how HIM influences the production of handshape. HIM has not been investigated in research on handshape acquisition before, to the best of my knowledge. It is found that the accuracy of handshape production tends to be lower when HIM as a dependent node is specified in the representation.

In sign language research, attempts have also been made to account for frequency of distribution by way of analyzing the physiology of handshape and ease of articulation (Ann 1993). In other words, what makes a handshape more complex in its phonological representation may have physiology of hand configuration as one of the determinants. In the current study, the acquisition data obtained from the case study in HKSL will be used to verify Ann's (1993) physiology account. The acquisition data basically confirm Ann's proposal of handshape scoring because the handshapes with lower scores (i.e. the "easy" handshapes) are generally acquired before those with higher scores (i.e. the "difficult" handshapes). However, the scoring as set up in Ann (1993) may need further refinement to achieve higher predictability of the order of acquisition of different handshapes.

In this chapter, sections 1.1 – 1.2 discuss the literature on sign language phonology, with a particular focus on how the models in sign language phonology have been influenced by theories of spoken language phonology. Specifically, I will discuss how Dependency Phonology as discussed in Andersen and Ewen (1987) finds its way into the sign language phonological theories developed by van de Hulst's group (Crasborn, Hulst, and Kooij 2000). Section 1.3 reviews three handshape models, including Sandler's (1989), Brentari's (1998), and Eccarius' (2002). Section 1.4 introduces the proposed Handshape Unit Model of the current study which is modified upon Eccarius' (2002). Section 1.5 presents the outline of the thesis and Section 1.6 the notation conventions.

1.1 Structuralism and Stokoe's pioneering work

Before proceeding to the acquisition of sign language phonology, we need to ask an important question, "What is phonology in sign language?" By the basic definition, phonology is "[t]he study of the ways in which speech sounds form systems and patterns" (Fromkin, Rodman and Hyams 2003:273). But apparently no "speech sounds" can be found in sign language, so the notion of 'sign phonology' must be justified before we embark on the study of sign phonology. Marentette and Mayberry (2000:71) give a brief introduction of spoken phonology acquisition and build up the notion of 'sign phonology' on top of it. They propose that

> [t]he study of phonology is concerned with the smallest parts of a language. These elements do not convey meaning on their own, however, particular combinations of these elements create signs (either spoken or signed) that do convey meaning (the bracketed words are added by me for emphasis).

In sign linguistics, Stokoe (1960) first proposes that individual signs are decomposable. Referring to ASL, he identifies three phonological parameters: handshape, location, and movement. Stokoe assumes that all the three parameters are structured simultaneously, contrary to the linearity in spoken language phonology (Sandler 2000).

Handshape, location, and movement on their own do not mean anything, it is only when they are put together to form a sign, then meaning is derived (Stokoe 1960).[1] This phenomenon is similar to that in spoken languages. In spoken languages, speech sounds are meaningless in isolation. However, when they are put together according to different phonological systems of the corresponding languages, different words, each with different meanings, are formed. For example, in English, the sounds [ɔ] and [t] on their own mean nothing. When they are combined to form [ɔt], the word 'ought' is formed and it is used to indicate 'obligation', 'advisability', 'desirability' or 'probability'.

This phenomenon is known as 'duality of patterning' in linguistics. Regarding 'duality of patterning', 'dual' refers to a two-level mechanism. Level one consists of a few meaningless sounds. At level two, these meaningless sounds combine under certain phonological rules of the corresponding languages to form many meaningful words, and this system pertains to the human communication system (Hockett, 1960).

Stokoe calls the parameters "cheremes", parallel to phonemes in spoken languages. As he wants to avoid terminology related to sounds, he uses "cheremes", a Greek word related to hands. A sign basically has three components, and Battison (1978) adds the fourth one, which is palm orientation. Each component is meaningless on its own but productive in different combinations.

[1]Stokoe referred to handshape as "designator" (DEZ), location as "tabula" (TAB) and movement as "signation" (SIG). For the sake of consistency, the terms handshape, location, and movement are used in this thesis, including direct quotes.

Table 1.1 gives a brief summary, based on Stokoe's proposal and Battison's addition.

Table 1.1 Components of a sign

	Component	Explanation	Example
1	Location	Where the hand is located relative to the body	[head, chin, nose, chest]
2	Movement	How the hand moves in space	[circle, arc, straight line, wiggle fingers]
3	Handshape	The form of the hand itself	All fingers extended and spread, , written as [5]; all fingers closed with Thumb to the side of the index finger, , written as [A]
4	Palm orientation	Where the palm orients towards	Towards the signer, away from the signer, pronated, supinated

Since Stokoe's ground-breaking proposal on the phonological structure of sign language, a lot of research have been done on different grammatical aspects of sign languages and it is now well-accepted that sign languages are natural languages and they enjoy the same linguistic status as other spoken languages.

1.2 Insights from Generative phonology

Sandler (2000) points out that as generative approaches emerge, phonologists begin to pay more attention to the existence of features, to rules which manipulate them, and to the rule system structure, for example, rule ordering. She cites Wilbur (1987), Padden & Perlmutter (1987) as two examples:

> Wilbur (1987) presents a generative treatment of the alternation between two phonetically similar handshapes, claiming that the two differ by one distinctive feature, and formulating a rule that derives the surface forms (Sandler 2000:352).[2]

Padden and Perlmutter (1987) show that there is an ordered interaction between morphological and phonological rules, such that there is a class of phonological rules that apply to the output of the lexicon (cf. Kiparsky 1982) (Sandler 2000:352) (see Appendix A for examples).

[2]Some signs involve two hand configurations, and in some cases, the second hand configuration is predictable. For example, in ASL, the sign TAKE involves an initial hand configuration [5] ( ) and a final hand configuration [S] ( ). These two differ in the joint position only. The fingers of the first hand configuration are extended but flexed at the base and nonbase joints in the second one. Therefore, only the first hand configuration [5] ( ) and the type of movement, [closing], need to be indicated because the second hand configuration, [S] ( ) can be derived. Note that handshape symbols are adopted from Tang (2007) in this thesis. Where no handshapes or symbols are provided, the symbols in the original paper are adopted.

1.2.1 Is handshape a segment or autosegment?

In spoken languages, a segment is "any discrete unit or phone, produced by the vocal apparatus, or a representation of such a unit".[3] A consonant or a vowel is commonly perceived as a segment in spoken language. However, in sign language phonology, there is no consensus about what is being classified as a segment. Sandler (2000) gives no explicit definition on segments, but basically she treats Movement and Location as segments, and Handshape as an autosegment. An autosegment has a set of properties which are independent of the segmental tier and it can scope over more than one segment. According to Sandler, as an autosegment, handshape may remain the same from one location to another. Kooij (2002) argues that Movement is only a transition and is not segmental. These different orientations result in differences in the hierarchical organization of handshapes. The phonological status of a handshape is a continuing and valuable debate, however, in this acquisition project, we hope to provide some preliminary results based on the most current analysis in the field.

[3](http://www.sil.org/linguistics/GlossaryOfLinguisticTerms/WhatIsASegment.htm, retrieved on 15 February, 2007).

1.2.2 CV phonology, the Movement Hold Model and the Hand-Tier model

CV phonology also adopts the concept of tiers. The originality of CV phonology lies in the postulation of a CV tier, a tier of C and V slots which are filled by segments (or the features represented by the segments). Segments can be mapped straightforwardly onto the CV slots (Clark &Yallop 1995). That sound segments are linearly organized into a CV-structure has a great impact on models of sign language phonology. It is against the background of CV phonology that Liddell & Johnson (1989) develop their Movement Hold (MH) Model. Conceptually, "Hold" in this model corresponds to a consonant in spoken language, whereas "movement" corresponds to a vowel. Nonhierarchical feature bundles are associated to the M and H slots. Handshape features are also represented in bundles. Their work is groundbreaking in pointing out the sequentiality of sign composition, contrary to Stokoe's (1960) proposal that handshape, location and movement are simultaneously organized. Second, the MH model claims that a syllable in ASL is sequentially organized because there is a sequentially organized static – dynamic alternation that can be compared to consonants (holds) and vowels (movements) (Sandler and Lillo-Martin, 2006). In other words, an HMH structure in ASL is analogous to a CVC syllabic structure in spoken language.

The CV approach is also adopted in the Hand Tier (HT) model (Sandler 1986, 1989, 1990, 1993b, c) but with some modifications. Sandler argues that the major categories should be location and movement instead of hold and movement. According to her, "hold" is defined as the absence of movement. However, hold deletion is very common in natural signing, resulting in a series of movements only. This is theoretically questionable. If a spoken language is articulated with a stream of vowels, with only very few consonants intervening it, it is both hard to produce and to perceive. Second, hold deletion predicted physiologically because it occurs when the signing is blocked by hand or body contact and emphatic stress. If hold can be deleted anywhere, it poses immense difficulty for acquisition. All these suggest that hold should not be an underlying property, as the MH model claims. Hence, Sandler (1989) proposes that the sequence of segment types is location and movement, instead of hold and movement (Sandler 1989).

The HT model is different from the MH model in two major ways. First, in the HT model, the segments are location and movement instead of hold and movement. Phonologically real holds are represented as geminate location, with two location slots associated to the same location feature bundle. Second, an independent autosegment, namely, the hand configuration is proposed. The representation of the hand configuration as a single, multiply associated autosegment is motivated by the fact that one sign typically assumes one handshape. Although there may be handshape 'changes' in signs, they are "handshape contours" in monomorphemic signs. In other words, typically, no more than one distinctive handshape is found in one monomorphemic sign[4] (Sandler & Lillo-Martin 2006).

Features in the hand configuration are hierarchically organized, and this hierarchical organization of features is absent from the MH model.

[4]A monomorphemic sign is a sign which consists of only one morpheme, in other words, it cannot be further decomposed into meaningful subunits. Such a definition excludes classifier constructions which are made up of several morphemes simultaneously stacked up together in one single sign.

1.2.3 Dependency Phonology

A rather different approach has been adopted by Hulst (1995) and Kooij (2002), who draw reference to Anderson and Ewen's (1987) DP. In this model, heads are at least as complex as their dependents (Dreshner & Hulst 1994).[5] Each dependent node adds complexity to the representation, and thus indicative of markedness.[6] Second, elements which enter into a dependency relationship are more marked than the 'single elements' in the set. For example, in spoken language phonology, it has been claimed that three 'basic' vowels /i/, /u/ and /a/ form a triangular system, and it is a system which contains the least marked vowels by virtue of the fact that they occur in high frequency cross-linguistically. They are represented as 'single elements' in DP. Compared to these 'single elements', some vowels require two elements to enter into a dependency relation, hence they are more marked. For example, the low back rounded vowel /ɔ/ is represented as {|a;u|}[7] (**a** over **u**), because the **a** component is more salient than the **u** and it determines that the vowel belongs to the set of low vowels.

That /ɔ/ is more marked than /i/, /u/ and /a/ is supported by the evidence that /ɔ/ is not as frequent as the other three "basic" vowels typologically.

[5]Kooij (2002:41) explains node complexity as follows: node A is more complex than node B if node A branches and node B does not; or node A has an immediate dependent and node B does not.

[6]Complexity here refers to representational complexity. In this thesis, markedness is a cover term for a number of observations listed in the table below:

Type of markedness	More marked	Less marked
Phonetic markedness	More difficult to articulate	Less difficult to articulate
Typological markedness	Less frequent across languages	More frequent across languages

[7]|i|, |a| and |u| indicate three vowel components, they are 'frontness', 'lowness' and 'roundness' respectively. The vertical lines represent that the component within is the only component in question, and the braces represent that the component is characterised phonologically (as far as the locational gesture is concerned).

Kooij (2002) adopts the DP framework in her sign phonology study of the Sign Language of the Netherlands. In DP, all the nodes branch into one head, and if necessary, one dependent. Following Andersen and Ewen (1987) and Hulst (1995), Kooij claims that heads are perceptually salient, for instance, the articulator node in her model is most salient in the representation because it carries more lexical distinctions than other components like location. Also, heads in a phonological structure are at least as complex as their dependents (Dreshner & Hulst 1994, cited in Kooij 2002), if not more complex. Therefore, in the handshape model, less complex heads (e.g. [one] and [all]) tend to allow further specifications; whereas more complex heads (e.g. the selection of three fingers or the selection for the ring finger) tend to reject further specification of finger position (Kooij 2002). The model advanced by Kooij also assumes that the phonological structure manifests in itself relative markedness based on structural complexity. The more elements a representation has, the more complex the structure is and hence relatively more marked. Technically, node A in the representation is more complex than node B if node A branches and node B does not, or node A has a dependent node and node B does not.

Kooij (2002) proposes other rules to represent handshapes. Therefore, some of the handshapes which are distinct in production share the same phonological specification, and the difference only lies in the specification of other rules. For example, [1] () and [D] () both are specified for [one], but there is an additional rule besides [one] for [D] () - it is specified for [one] + manual alphabet (Kooij 2002:156). There is a difference between [1] () and [D] (). The former is produced with the Thumb crossing over the Middle, Ring, and Pinky fingers; and the latter is produced with the Thumb contacting the Middle, Ring, and Pinky fingers. The "manual alphabet" rule is rather ad hoc.

The last model in this review is the prosodic model of sign language phonology proposed by Brentari (1998). It draws upon insights from autosegmental phonology and feature geometry, principles from constraint-based theories including OT, Harmonic Phonology (Goldsmith 1989, 1990, 1991, 1993), DP, and Phonetic Enhancement (Stevens, Keyser, and Kawasaki 1986; Stevens and Keyser 1989). The model is mainly composed of two parts, namely the inherent and prosodic features. Inherent features are the properties which are specified once per sign and do not change during the sign's production (e.g., finger selection, major body location); prosodic features are the properties of signs which can change during the sign's production (e.g. aperture, setting).

Inherent features are organized into a more complex hierarchical structure than prosodic features. Unifying the arguments over simultaneity and sequentiality of sign language, Brentari represents the static features under the node of inherent features; and the dynamic ones under the node of prosodic features.

1.2.4 Interim Summary

In this section, a general survey of sign language phonological models is presented. Most of these models are inspired by the generative approaches to phonological analysis, applying features and rule systems to the study of sign phonology. In the following section, I will focus on the handshape node as described in these models except for the Movement-Hold Model.[8]

1.3 The handshape node

As sign phonology develops, attention is drawn to handshape analysis. Different hierarchical organizations of handshape nodes and features have been proposed. The following section provides an introduction and evaluation of the handshape nodes and features proposed in the literature. In addition, with the insight from the previous proposals and data from HKSL signs, I propose a Handshape Unit Model at the end of this chapter.

1.3.1 Sandler's (1989) handshape node

Following the theory of Feature Geometry, the motivation for setting up feature classes includes the physical structure of the vocal tract and the behavior of features in rules, particularly assimilation rules (e.g., Clements 1985, Sagey 1986, Halle 1992, cited in Sandler and Lillo-Martin 2006). Grouping of the features comes from assimilation patterns. For example, features that tend to cluster together in rules – such as place features – form a class which shows the possibility of assimilation. In English, the

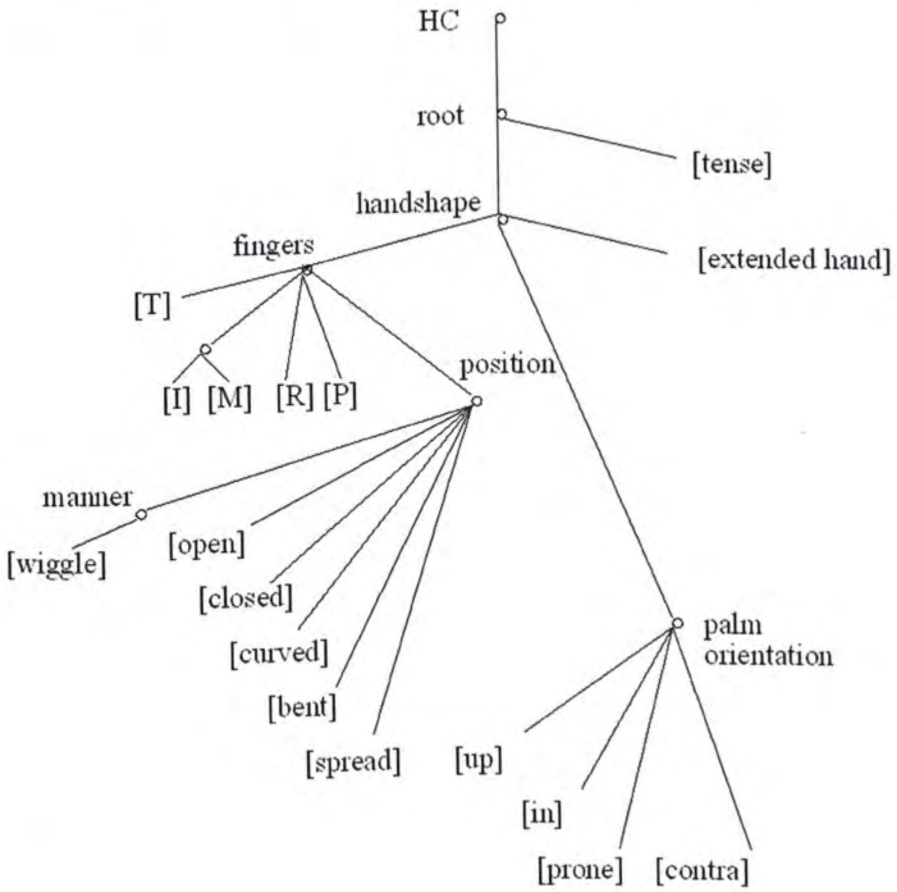
[8]The Movement-Hold model is not further discussed here because handshape is not hierarchically organized in the model.

prefixes observe the place assimilation rule. The nasal in the prefix *in-* has the same place of articulation as the following consonant. /ɪn/ becomes [ɪm] before bilabial consonants as in 'important'; /ɪn/ becomes [ɪŋ] before velar consonants as in 'incorrect', and /ɪn/ stays put as /ɪn/ elsewhere.

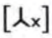
Sandler's (1989) feature geometry model follows the spirit of the spoken language phonological models in terms of grouping features by articulator (Sagey 1986). For example, the fingers and the palm of the hand are articulator nodes, and they all belong to the hand articulator (Sandler and Lillo-Martin 2006).

Figure 1.1 shows the hand configuration node by Sandler (1989). It is phonologically motivated, multi-tired and hierarchical in structure.

Figure 1.1 Hand configuration node by Sandler (1989:46)



In this model, the lower branching groups are more dynamic than the higher ones. For example, during the execution of a sign, the fingers basically do not change, i.e. which finger(s) is / or selected does not change, but the manner can change.

In the HT model, HC (hand configuration node) dominates the handshape fingers node, under which the selected fingers are represented, [T], [I], [M], [R], [P] refer to the selection of thumb, index finger, middle finger, ring finger and pinkie finger respectively, [I] and [M] are sub-grouped. The fingers node in turn dominates the position node. Position is a class which represents the shape of the selected fingers dominating the manner node. Nonselected[9] fingers are the fingers apart from the selected ones, and they can assume the feature [+extended hand] if the nonselected fingers are extended and [-extended hand] if they are not extended, as represented by the second branch on the right in Figure 1.1 above. In HKSL, it is observed that in handshapes with flexed selected fingers, the nonselected fingers are laxly extended but not fully extended. For example, in HKSL, the sign NOT-HAVE assumes the hand configuration [⅄ₓ] (), the three nonselected fingers (the Middle, Ring and Pinky) are laxly extended and abducted.

The feature [wiggle] is dominated by the manner[10] node which is in turn dominated by the position node. This represents that [wiggle] can cooccur with other finger positions.

The feature [+tense] specifies rapid repetition of the internal movement, similar to trills in spoken language. The feature [tense] is represented as directly associated to the root, and it also dominates the palm orientation node, hence it can capture a rapid repetition of orientation changes as well.

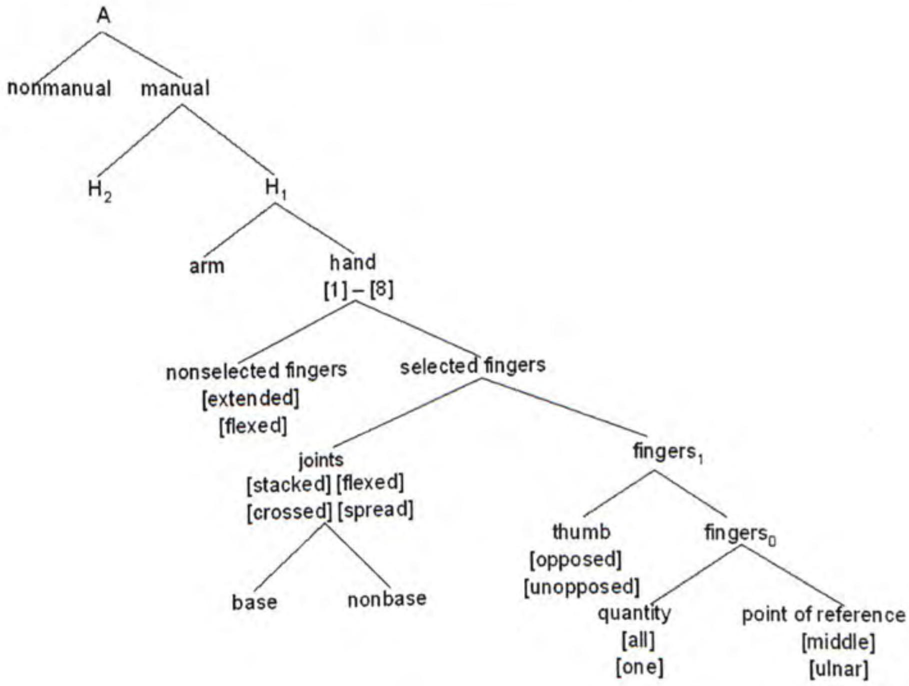
1.3.2 Brentari's (1998) handshape node

Figure 1.2 shows the structure of the articulator branch (Brentari 1998:100).

[9]In the handshape literature, 'unselected fingers' and 'nonselected fingers' are used interchangeably. For the sake of consistency, the term 'nonselected fingers' is used, including those in direct quotes.

[10]Sandler (1989) does not define "manner" in the model, but states that it "dominates [wiggle], which cooccurs with other position features" (Sandler 1989:116).

Figure 1.2 Structure of the articulator branch[Note]



[Note]Only the part under the hand node will be of relevance in this thesis. The "base" and "nonbase" are referred to as features in Brentari's (1998) text, but in the figure on p. 100 of her work, they are without square brackets. I follow her exposition here.

The "hand" node branches into "nonselected fingers" node and "selected fingers" node, with the latter being more complex. The selected fingers node branches into both "joints" and "fingers_1". The "joints" can be specified for [stacked] ("placing the fingers on top of one another with the pinky at the bottom – roughly speaking, in the position needed to grip a racket") (Brentari 1998:110); [crossed] (the palmar side of one selected finger touches the back side of the other selected finger, as in the handshape [R] ()); [spread] (the fingers are abducted from one another). The feature [stacked] is quite unclear in both definition and application. In the description of [stacked] ("placing the fingers on top of one another with the pinky at the bottom"), "on top of one another" and "pinky at the bottom" seem not to be about handshape only, but they also involve orientation. Brentari uses SALAD (see Clip 1-1 ) in ASL as an example of a stacked handshape. I postulate that this "stacked" configuration is physiologically driven. When the palms are supinated and the joints flexed, the degree of flexion tends to increase from the Index finger to the Pinky finger which gives a "stacked" configuration.

After the specification of the joint feature, what follows is the selection of [base] or [nonbase]. [Base] refers to the base joints, which are the metacarpophalangeal joints; and [nonbase] refers to the nonbase joints, which are the proximal interphalangeal joints and the distal interphalangeal joints. However, the position to specify for joint flexion is not in line with the practice of spoken language phonology: in order to represent base joint flexion, the representation should specify for [base] first, then the specification for [flex] since place of articulation ([base] in this case) is never represented as an end node in a spoken language model. In Brentari's (1998) model, if [base] and [nonbase] are not specified, it refers to the selection of both [base] and [nonbase], so the model treats the selection of both [base] and [nonbase] joints as unmarked.

The "fingers_1" node is further divided into "thumb" and "fingers_0". Thumb can be specified for [opposed] or [unopposed]. [Opposed] refers to the state of a flexed saddle joint, the palmar side of the thumb faces the palm. "fingers_0" is divided into "quantity" and "point of reference".

Under "quantity", there are features [one] and [all] and they can enter into dependency relations (c.f. Kooij, 2002). "Quantity" node denotes the number of selected finger:

[one] refers to one finger; [all] refers to all of the fingers selected, except for the Thumb[11]; [one;all] (read as "one over all") refers to two fingers selected; [all;one] (read as "all over one") refers to three fingers selected. [All] and [one] are two of the possible features under the Quantity node, they can either occur alone; or together in dependency relationship.

The "point of reference" (POR) node is responsible for specifying which fingers to be selected. If the Index finger is the only selected digit, the POR is assumed to be radial (ø). Since [radial] is the default value, hence underspecified, it will not appear in the tree. If only the Middle or the Pinky is selected in a handshape, the POR node overtly specifies for a feature, [mid] or [ulnar] respectively. If the Ring finger is the only selected digit in a handshape (for example, SEVEN in ASL), the [ulnar] and [mid] features are both overtly specified at the POR node and they enter into a dependency relationship with [ulnar] dominating [mid] because the ring finger has a closer relationship to [ulnar] than [mid] (Brentari 1998, cited in Eccarius 2002).

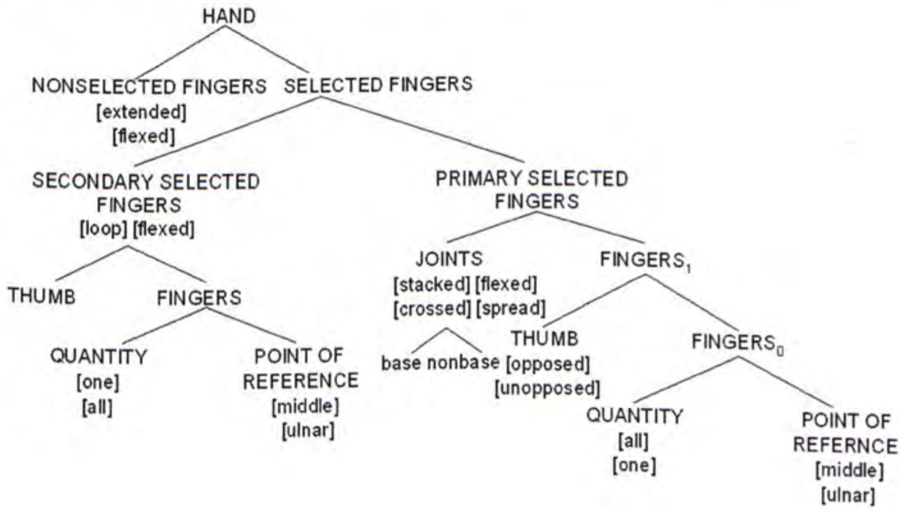
1.3.3 Eccarius' (2002) handshape node

Eccarius (2002) conducts a cross-linguistic analysis of 12 sign languages, including HKSL, and she finds that some handshapes (17 altogether) cannot be represented by Brentari's (1998) Prosodic model. She modifies Brentari's original model by adding a "secondary selected fingers" (SSF) node, as shown in Figure 1.3. The "primary selected fingers" (PSF) node is the same as Brentari's (1998) "selected fingers" node.

[11] The thumb is treated separately under the "thumb" node.

The newly added SSF node, according to Eccarius (2002:53), is "a limited version of PSF; in many ways this branch will be a midway point between "non-selected fingers" (NSF) and PSF". Given its "midway" status, Eccarius labels it as "secondary".

Figure 1.3 Eccarius' handshape model (Eccarius 2002:54)



Besides adding the SSF branch, Eccarius (2002) adds a feature called "looped" to apply to the SSF to describe a configuration where the thumb tip contacts with the tips of other fingers. She also predicts that NSF has the simplest feature possibilities (either flexed or extended), PSF the most complex (bent, flat, curved, open, and others) and SSF the medial (flexed, extended or looped).

Deviations from Brentari's model and the SSF node are described in details in the subsequent subsections.

1.3.3.1 The Joint feature *[Crossed]* of the PSF node

Brentari (1998) and Eccarius (2002) define the feature [crossed] differently. The definition by Brentari (1998) is more restricted because she claims that this feature applies to the Index and the Middle fingers only, as she specifies overtly, "[t]he position in which the middle finger crosses over the index finger, specified by the feature [crossed], occurs only with an 'H' handshape (e.g., CIGAR)" (Brentari 1998:110). Eccarius (2002:11) has chosen to define this feature as "fingers (the thumb is not included here) in a position where the palm side of one digit touches the back of another digit, usually at the tips". Overgeneralization occurs with the definition by Eccarius (2002) because [crossed] indeed only applies to the Index and the Middle fingers but not other combinations of fingers, as shown in her own cross-language study.

1.3.3.2 Branching of Selected Fingers into Primary and Secondary Selected Fingers

Unlike Mandel's (1981) claim, Eccarius (2002) finds that handshapes can at most be divided into three groups instead of two groups only. Therefore, in Eccarius' (2002) model, the Selected fingers node branches into two nodes. They are the Secondary selected fingers (SSF) node and the Primary selected fingers (PSF) node. A handshape consisting of three sets of configurations are noted as involving SSF. In a handshape with SSFs, all PSFs have one configuration, all SSFs have another configuration, and all NSFs have yet another configuration. Referring to the SSF node, the joint specifications for this "less selected" finger group will be more complicated than the two available (i.e. [extended] and [flexed]) in the NSF branch, but less complex than those in the PSF joint node. The SSF node is motivated by the fact that there are some handshapes which involve three sets of configuration, as observed in some sign languages.

Before describing the Secondary selected fingers node, a relevant question to ask is 'Which finger groups should be assigned to the PSF node and which should be assigned to SSF node?' Regarding this question, Eccarius (2002:54) suggests "to look at the handshapes in the context of handshape change and in lexical contexts with respect to contact points and places of articulation". The handshapes with SSFs found by Eccarius (2002) are shown in Table 1.2.

Table 1.2 Handshapes with secondary selected Fingers (Eccarius 2002:55)[Note]

HS#	HS	NSF	SSF		PSF	
		Fingers	Fingers	Quantity feature	Fingers	Quantity feature
1		M+R+P	T	/	I	[one]
2		/	T+I	[one]	M+R+P	[all;one]
3		M+R+P	T	/	I	[one]
4		/	T+I	[all]	M+R+P	[all;one]
5		M+R+P	I	[one]	T	/
6		M+R+P	T	/	I	[one]
7		M+R+P	T	/	I	[one]
8		R+P	T	/	I+M	[one;all]
9		/	T+I	[all]	M+R+P	[all;one]
10		M+R+P	T	/	I	[one]
11		R+P	I	[one]	T+M	[one]
12		P	T	/	I+M+R	[all;one]
13[a]		T+R+P	M	[one]	I	[one]
14		/	T+R+P	[all]	I+M	[one;all]
15		R+P	T	/	I+M	[one;all]
16		M+R+P	T	/	I	[one]
17		R+P	I	[one]	T+M	[one]

[Note]The SSF and PSF assignment is adopted from Eccarius (2002:55). She uses numbers to represent different fingers but I used T, I, M, R, P for consistency in this thesis. (T=Thumb; I=Index; M=Middle; R=Ring; P=Pinky).

[a]In HKSL, hs#13 has reverse assignment of PSF and SSF since the Middle finger is responsible for contacting the place of articulation, so M would be the PSF rather than SSF in HKSL.

1.3.3.3 The Secondary selected fingers node

There are two feature possibilities under the Secondary selected fingers node. They are [flexed] and [loop]. As mentioned above, [flexed] was not defined by Eccarius (2002), so the most general sense is adopted. She defines [loop] as the "thumb tip came in contact with the tips of other *selected* fingers" (Eccarius 2002:55. *Italics* are my own clarification).

The SSF node is divided into two nodes, Thumb and Fingers.

1.3.3.4 The Thumb node in the Secondary selected fingers branch

Eccarius (2002:56) says that

> [t]he Thumb node in the SSF branch is simpler than [the Thumb node] in the PSF branch because there is no contrastive opposition between [opposed] and [unopposed] in these handshapes; in all positions, the configuration of the saddle joint is predictable.

She mentioned in passing, without much illustration, that there is no contrastive opposition between [opposed] and [unopposed] in handshapes with SSFs. If my interpretation is correct, she probably means that there are no minimal pairs of handshapes with SSFs which take Thumb opposition as a distinctive feature. This is also in line with my observation of HKSL data. But the features I propose in the node are different and will be explained in the relevant subsection below.

The Fingers node of the SSF branch is divided into Quantity and Point of reference (POR).

1.3.3.5 Quantity in SSF vs. Quantity in PSF

Eccarius (2002:56) claims that

> Quantity [under SSF] looks the same [as that under PSF] in the tree since it has both [one] and [all], but because there appears to be no need for more than two fingers, there is no need for any kind of dependency relationship; if there are two fingers in the group, both features occur in tandem.

Contradictory to Eccarius' claim, however, I found a HKSL handshape with more than two SSFs. The handshape is [Wc] () with the Middle, Ring and Pinky fingers being the SSFs. I would propose modifications on this node to accommodate this example and it will be discussed later in the relevant section.

1.3.3.6 The Point of reference node in the Secondary selected fingers branch

Eccarius (2002:56) claims that "POR has both [mid] and [ulnar] features, but there is no need for the two to enter into any kind of complex structure". She also points out that Secondary selected finger groups only contain single or adjacent digits. I adopt this unless counter-example is found.

1.4 The proposed Handshape Unit Model

The proposed model is based on Eccarius' (2002). I choose to modify her model but not others because she puts forward this model after investigating data from 12 sign languages, including HKSL. Moreover, she adopts the framework of DP which I will use as a framework to analyze the handshape acquisition data in the current study.

The model follows the conventional representation of DP in that a vertical line denotes a head, whereas a dependent is represented by an angled line. Each node branches into one head and one dependent except for the terminal nodes.

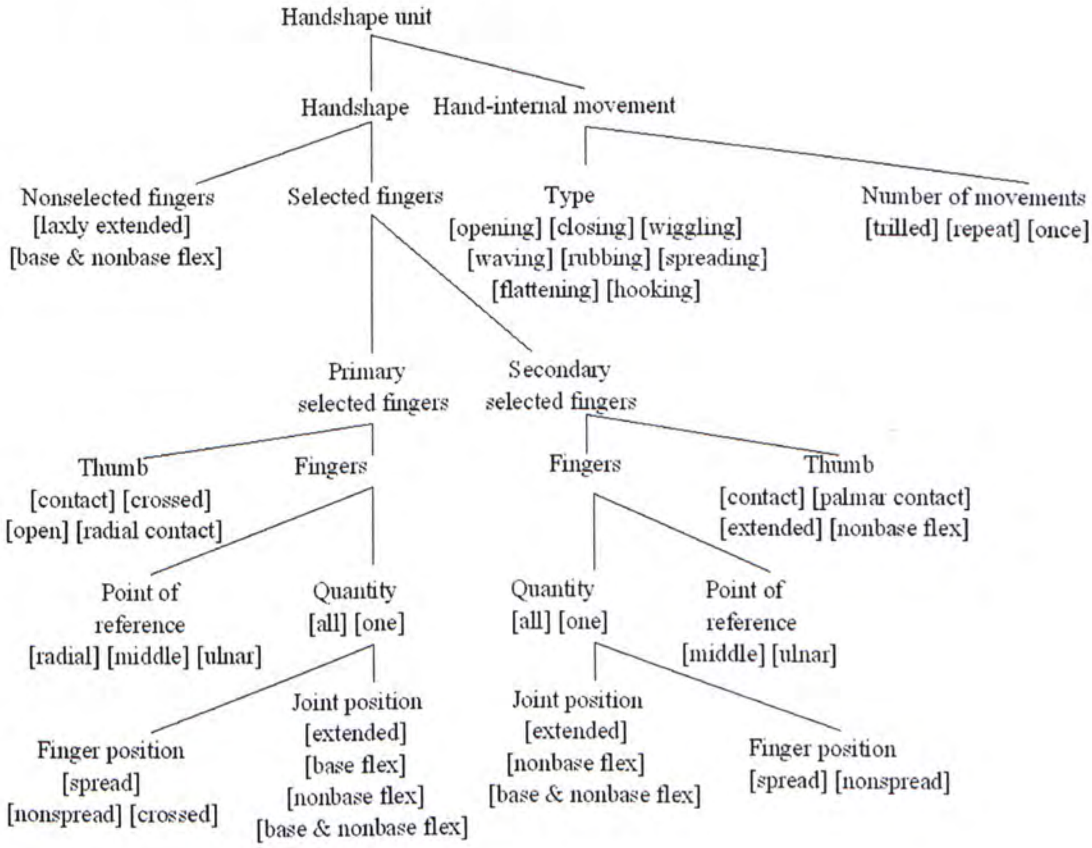
The structure aims at showing a hierarchical structure and the markedness of a handshape unit. Following Kooij (2002), each dependent node adds complexity to the representation, and different features or combinations of features contribute to different degrees of markedness. I draw upon findings from different researchers and rank markedness of features included in some nodes. In the current analysis, markedness has a typological or a physiological basis; with references drawn from Eccarius (2002) and Ann (1993), features are less marked if they are typologically frequent and physiologically easy. Typological and physiological bases are applicable to both signed and spoken languages. If the relevant data are unavailable from Eccarius' (2002) study, physiological factors are taken into consideration (Ann 1993). If no data are available from these two studies, the features are not ranked for markedness at this stage.

It should be noted that the idea of underspecification and "default feature" used in Eccarius (2002) is not adopted in the current study because claiming a feature as underspecified needs thorough research not only in one language, but also across languages, but the young age of sign linguistics does not allow such a concrete claim as the features are still at a stage of proposal, not to mention their interrelations or implications. For example, in English, all front vowels are unrounded, therefore, under the theory of Restricted Underspecification (Mester and Itô 1989), one can claim that in English, [-round] is underspecified when the vowels are specified for [-back] without exceptions. Radical Underspecification allows the specification of only one feature in a binary pair, and it is assumed that every segment which is not specified for that value has another one, for instance, only [+voice] needs to be specified, the segment without the specification of [+voice] takes the other default value [-voice].

Brentari (1998) claims that [radial] is the default feature of the POR node of the PSF node when the Index finger is the only selected digit, but this is not comparable to underspecification in general linguistics. A handshape with the Index finger being the only selected digit involves two features under the PSF node: [one] in the Quantity node and [radial] in the POR node. However, when [one] is specified, the POR feature can be [ulnar] to represent the Pinky finger being the only selected digit; or [middle] to represent the Middle finger being the only selected digit. In this example, [one] does not predict [radial] and rule out the other features, so it is not a case of underspecification. Second, the proposed Handshape Unit Model does not employ a system of binary features, but a system of unary features instead because DP employs unarism (Anderson & Ewen 1987), so Radical Underspecification is not applicable either. Since I aim at descriptive adequacy for the proposed Handshape Unit Model at this stage, I choose to spell out all the features involved in describing and analyzing and handshapes, but not applying the theory of Underspecification. In fact what Brentari (1998) suggests may be interpreted from the perception of markedness instead: [one] + [radial] is less marked than [one] + [ulnar] which in turn is less marked than [one] + [middle].

The proposed Handshape Unit Model is described node by node in the following subsections.

Figure 1.4 The proposed Handshape Unit Model



1.4.1 Handshape unit node

The mother node of the proposed model is the Handshape unit. It comprises Handshape and HIM. HIM is not the focus of Eccarius' (2002) study, so it is absent from her model. But since I would like to investigate the relationship between HIMs and handshape, it is necessary for me to add such a branch into the model. A dependent node is "optional", depending on whether the sign requires the relevant specification. Handshape is the head and HIM is the dependent because there is not a single sign without handshape but there are signs which do not have any HIMs. Moreover, whether the handshape can accept a specification of HIM, or the kind of HIM to be specified, depends on the handshape. For example, a relatively marked handshape like [R] () is unlikely to be specified for any HIMs; and a closed handshape like [S] () cannot be specified for [hooking]. In the literature (Sandler 1989, Brentari 1998, and Kooij 2002), HIM is represented as either branching of the aperture and / or finger position nodes. In the current analysis, I assume that HIM is dependent on handshape. Path movement and aperture changes (recognized as one of the HIMs in the current study) belong to the PF in Brentari (1998). Although both HIM and path movements are movements, it is observed that the path movement does not depend on the handshape but HIM does, so only HIM, but not path movement, is represented as a dependent here.[12] For example, a relatively marked handshape involving SSF [i'] () can allow a path movement as in the HKSL sign DEEP (see Clip 1-2 ). Besides, there seems to be no restriction on the cooccurrence of certain handshape and certain path movement, but it is different in the case of handshape and HIM. For instance, [spreading], the repeated abduction and adduction of the fingers, only applies to the handshape [V] () but not other handshapes. In addition, if I followed the traditional representation in the literature, such as Sandler (1989) and Kooij (2002), I would have to represent HIM with a binary branching without any dependency relationship. For example, branching of Finger position into [spread] and [nonspread], the two branches would not be in head-dependent relationship and they would be

[12]Phonologically, in spoken language, a sound segment is composed of features specified for place of articulation and manner of articulation. According to Brentari (1998), the "POA" node represents the place of articulation, which is similar to the place of articulation in spoken language because the same term across signed and spoken languages refers to the point of contact in production; and if a parallel needs to be drawn between spoken and signed languages, HIM may be considered similar to "the manner of articulation" in spoken language. At it stands, HIM is a dependent node of the head "handshape". There are signs which assume no path movement but HIM only, as in GREEN in HKSL. In this case, the HIM in the sign associates itself to the nucleus in the syllable structure, just as what Perlmutter (1992) claims: when there is no path movement, the Position node can be a syllable nucleus on its own.

realised sequentially. Both the non-head-dependent relationship and the sequential realization are inconsistent with the proposed Handshape Unit Model, hence is theoretically undesirable.

1.4.2 HIM node

The HIM node branches into the Type node as the head and Number of movements node as the dependent. The Type node indicates the type of the HIMs and the Number of movements node shows how many times the specified HIM should be produced. I suggest this branching due to two reasons. First, if the type and number of movements are grouped under the same node, the feature possibilities will be redundant, including [close once], [trilled close], [repeated close], [open once], [trilled open], [repeated open] etc. Second, if the head-dependent relation is swapped, the grammar does not hold because theoretically, a representation can have one head without a dependent, and if the number of movements becomes the head, the specification of the number of movements such as [trilled] without the specification for the type of movement is theoretically possible, but in fact it is impossible to realize [trilled] without the type of movement.

The motivation of the features [once] and [trilled] is supported by a near minimal pair found in HKSL. They are FLOWER (see Clip 1-3 ) and BLINKING-LIGHTS (see Clip 1-4 ). The former is signed with [once], whereas the latter is produced with [trilled]. Although no examples can be found on minimal pairs contrasting [repeat] with the other two features, certain HKSL signs must be signed with [repeat] according to the intuition of native signers, e.g. SUN. I suspect that the feature [repeat] is due to influence from Chinese since a considerable number of Chinese nouns are disyllabic.

No ranking of features can be proposed for the Type and Number of movements nodes since Eccarius (2002) and Ann (1993) do not investigate HIMs.

1.4.3 The Type node

I adapt Kooij's (2002) HIM types as the features of the Type node in my current model because her proposal is the most comprehensive list that I have come across in the literature. Her list of HIM types is shown in Table 1.3. In order to avoid confusion, if there are two names for the same type of HIM, only the name before the stroke is adopted.

Table 1.3 Types of HIMs (Kooij 2002:61)

HIM	*Description*
Opening / Releasing	The hand changes from a closed (in a fist or the thumb touching or restraining the fingers) to an open position
Closing	The hand changes from an open position to a closed one
Wiggling	Selected fingers flex and extend repeatedly in an alternating way
Waving	Selected fingers flex (close) and extend (open) one after the other
Rubbing	Thumb rubs one or more of the finger pads or sides of the selected fingers
Hooking / Clawing	The selected fingers flex at the non-base joints only and there is no opposition relation with the thumb
Flattening / Hinging	The selected fingers flex at the base joint only and there is no opposition relation with the thumb
Spreading	The selected fingers change from a spread to a non-spread position and/or vice versa

[Opening] in the current study means the hand changes from a closed (in a fist or the thumb touching or restraining the fingers) to an open position, *or the hand changes from a position with the thumb pad touching the pad(s) of the selected finger(s) to a position* *without thumb pad contact.* Kooij (2002) does not have the part in italics because she represents this change using Aperture branching. Brentari also places Aperture change under PF. However, since I consider Aperture change as a kind of HIM, I assign Aperture change to the HIM node.

[Closing] in the current study means the selected fingers change from a less flexed position to a more flexed position. It can apply to handshape contour like [B̈] ( ) closing to [B̂] ( ) or [5] ( ) closing to [S] ( ).[13]

I define [wiggling] as 'selected fingers flex and extend repeatedly *at the base joints*[14] in an alternating way', to be more specific.

[Waving] is defined as 'selected fingers flex (close) and extend (open) *at the base joints* one after the other'.

[13][B̈] ( ) closing to [B̂] ( ) is represented as [close] in the Aperture node in Kooij's (2002) model, but I include aperture change here because it is considered as a kind of HIMs in this study.

[14]Eccarius (2002) defines base joints as the metacarpophalangeal joints (B), and nonbase joints as the proximal interphalangeal joints (N). The definition of the nonbase joints is different from the traditional definition. In sign language phonology literature (Brentari 1998 and Kooij 2002), nonbase joints refer to the proximal interphalangeal joints and the distal interphalangeal joints because proximal interphalangeal joints and distal interphalangeal joints seldom assume different positions simultaneously in sign language. I follow the traditional definitions in the current study as I also observe that proximal interphalangeal joints and distal interphalangeal joints seldom assume different positions simultaneously in sign language.

[Waving] and [wiggling] imply the feature [trilled], so theoretically, the feature for the number of movements node needs not be overtly specified. Such representation would mean that these two HIMs are less marked than the others. However, there seems to be no typological or physiological evidence supporting these two features being less marked than the other HIMs. I am aware of this problem and I would like to leave this for future research.

1.4.4 The Number of movements node

The Number of movements node has three feature possibilities. They are [trilled], [repeated] and [once]. [Trilled] in the current thesis is defined as the same as [trilled movement] in Brentari (1998:50): "an uncountably, rapidly repeated movement". [Repeated] refers to producing the HIM twice. [Once] refers to producing the HIM once.

1.4.5 The handshape node

The handshape node is divided into two branches following Eccarius' (2002) model. They are the selected fingers node and the nonselected fingers node.

1.4.6 The Nonselected fingers node

In the handshape literature, there is a rule related to the nonselected fingers (NSFs), it is the Nonselected fingers redundancy rule (NSFRR). The rule states that "[i]f the selected fingers are closed (i.e. *involved any joint flexion*), nonselected fingers are open (i.e. *laxly extended*); otherwise nonselected fingers are closed (*i.e. flexed at both base and nonbase joints*)' (Corina 1993, cited in Kooij 2002:59, the italics are my own modifications). According to my observation on HKSL data, this rule is valid in a large proportion of handshapes, but a few exceptions are observed, with both the selected fingers and the nonselected fingers are closed: [Ĝ] ( ), [Ĝ̂] ( ). Since they are exceptions to the NSFRR, they may be considered more marked than the handshapes which observe the rule, such as the handshapes [F̂] ( ) and [F] ( ).

Following Brentari (1998), Eccarius (2002) states two possible features under the nonselected fingers (NSF) node, namely [extended] and [flexed]; and either one of the features must be specified if the handshape involves NSF(s). The merit of proposing these two features under the NSF node is that all handshapes can be represented (including the exceptions to the NSFRR). It should be noted that the NSFRR is valid in a large number of handshapes, and those which observe the rule are less marked than the ones which do not, regarding the NSF node. I follow Eccarius (2002) in the NSF node, but the features are changed into [laxly extended] and [base & nonbase flex] for clarity and consistency within the model because the extension of NSFs is lax, as in the handshapes [F̂] ( ) and [F] ( ), and the laxness is made explicit here to contrast with the fully extended selected fingers as in the handshape [5] ( ); when NSFs are flexed, they are flexed at the base and nonbase joints, so [base & nonbase flex] is used instead of [flexed].

As for the nonselected Thumb, I would like to add two Nonselected Thumb rules. In lexical signs of HKSL, when the Thumb is nonselected:

The Thumb is phonetically extended when the selected fingers flatten in trilled movements, e.g., in DIRTY (see Clip 1-5 ), ADMIRE (see Clip 1-6 ), LOVING-SOMEBODY-SECRETLY (see Clip 1-7 ), and CAN (see Clip

1-8 ).

- The Thumb is also phonetically extended when the selected fingers are specified for the Joint position feature [nonbase flex], as in the signs RELATIVES (see Clip 1-9 ), TRY-HARD (see Clip 1-10 ), LOST (see Clip 1-11 ) and FAINT (see Clip 1-12 ).

- There is a free variation of the nonselected Thumb between the handshapes [Ḃ] () and [B] ().

The last point to note about this NSF node is that the node is unnecessary when all fingers are selected, in other words, when there are no nonselected fingers. The representation without the overt specification of the NSF node captures the relative 'unmarkedness' of the handshape unit because all fingers act together. One-group handshapes, that is the handshapes in which all the fingers, including the Thumb, assume the same configuration are considered "easy" according to Ann (1993).

1.4.7 The Selected fingers node

The current study adopts the concept of selected fingers and nonselected fingers from Mandel (1981) but with two exceptions. As indicated by the cross-linguistic findings of Eccarius (2002), a handshape can be divided into at most three but not two groups of fingers. Second, Mandel (1981) states that selected fingers can be in any position except closed, Brentari (1998) also suggests that the handshape [S] () does not have any selected fingers, but I put forward two pieces of counter-evidence. Mandel (1981) points out that nonselected fingers cannot move, but the fingers in a "closed" handshape can actually move as in the HKSL sign DISCARD (see Clip 1-13 ). The initial handshape is a "closed" handshape [S] () and it opens to a [5] () at the end of the sign execution. Second, Mandel (1981) also claims that nonselected fingers cannot make contact, but fingers in a "closed" handshape can indeed make contact as in the HKSL sign OLD (see Clip 1-14 ). The handshape [A] () traces the cheek in a downward manner. Therefore, in the current study, the concept of selected fingers and nonselected fingers is similar to that proposed in Mandel (1981) except that a handshape can be divided into at most three groups, and selected fingers can be in any position: straight and extended, smoothly curved, angled, or hooked; touching the thumb, crossed with another finger, including "closed". In the "closed" handshapes, all the fingers are selected and they are specified for flexion at all the joints. The NSFs are those which do not participate in phonetic realizations like HIM or contact with place of articulation. NSFs are often flexed at both the base and nonbase joints, as opposed to the selected fingers which are often extended.

The selected fingers node branches into the Primary selected fingers (PSF) node and the Secondary selected fingers (SSF) node, following Eccarius' (2002) model. The PSF node always needs to realize since all signs have selected fingers, so this is theoretically represented as the head, showing its relative prominence.

1.4.8 The Primary selected fingers node

In Eccarius' (2002) model, she first divides the PSF node into Fingers_1 and Joints node. I do not follow her because my modification makes the structure more consistent in specifying the place of articulation from general to specific: the PSF node is first divided into Fingers and Thumb, followed by Quantity and Point of reference, i.e. the number of selected fingers and which fingers are selected; and at the terminal nodes finely representing the features associated with Joints flexion and the 'spreadness' of the selected fingers denoted by the Fingers positions node. This division is in line with the literature that the fingers (Index, Middle, Ring, and Pinky) constitute the head and the Thumb is the dependent since when assimilation occurs, the specifications for the other fingers spread to the Thumb from Fingers (Brentari 1998). Moreover, this also reflects the sister relationship between Thumb and Fingers.

1.4.9 The Thumb node

I do not follow the traditional use of [opposed] / [unopposed] because [opposed] refers to the physical flexion of the base joint, and whether the selected Thumb needs to be flexed at the base joints or not depends on the other selected finger(s). The Thumb is a dependent on the Fingers node. If the Thumb is selected along with other selected finger(s) which is / are flexed at the base (and nonbase) joints, the Thumb copies the Joint position feature of the other selected finger(s). If the selected finger(s) is / are flexed, the Thumb must be [opposed] since the flexion of the base (and nonbase) joints spreads from the selected fingers to the Thumb. Therefore, the specification of opposition is redundant.

The Thumb node has four feature possibilities. They are [contact], [crossed], [open] and [radial contact]. [Contact] refers to the state of the thumb contacting other selected fingers and the exact point of contact can be predicted by other configuration features. If the selected fingers are flexed at the base joints only, the thumb's pad is predicted to be contacting the pad(s) of other selected fingers, as in the handshape [B̊] (). If the selected fingers are flexed at both the base and non-base joints, [contact] is realized as the thumb's tip contacting the tip(s) of other selected fingers, e.g., in the handshape [O] (). Traditionally, [crossed] applies to selected fingers only, usually used to describe the state of the handshape [R] (), with one selected finger's palmar side crosses over the back side of the other selected finger. But in this model, following the practice of the Tang (2007), [crossed] can be applied to Thumb also since the mechanism is similar: the selected Thumb's palmar side crosses over the back of the other selected fingers, contrasting the handshapes: [S] () and [O] (). [Open] refers to the non-contact, non-crossed, but opposed state of the selected thumb, as in the handshapes [C] (), [Ḡ] () and [Ğ] () etc. The feature [radial contact] is only realized if the handshape involves SSF(s). This feature is specified when the thumb's palmar side is required to contact the radial side of another selected finger, like in the handshapes [P] () and [+] (). No ranking of feature is proposed for this node since no cross-linguistic data are available for reference.

Generally, the Thumb is treated as a dependent in the sign language phonology literature. I agree that in most cases the Thumb is a dependent if it is selected because it basically shares the same joint features of the other selected fingers. However, there are also instances in which the Thumb is the only selected digit under the PSF node or the SSF node, such as the sign THANK-YOU (see Clip 1-15 ) in HKSL. The handshape involves the Thumb as the only selected digit, and the Thumb has a HIM [trilled] [hooking]; this is similar to other selected fingers as they can be specified for HIMs also.

I argue that in cases like this, the Thumb becomes the head of the PSF node since it behaves like the Index, Middle, Ring, or Pinky fingers when they are selected, and a headless representation does not stand theoretically in DP.[15]

In general, a structure is more complex with an additional dependent, but this is not necessarily true for the Thumb. Although the specification of a Thumb is theoretically more marked than the same structure without the Thumb specification, it should be noted that if [all] is realized in the Quantity node, adding the realization of the Thumb is not more marked (if not less marked) than [all] without the Thumb. This is because the hand tends to act together according to Ann (1993).

1.4.10 The Fingers node

The Fingers node branches into the Quantity node as the head and Point of reference (POR) node as the dependent. POR is a dependent on Quantity because whether POR needs to realize or not depends on the Quantity of the selected fingers. For example, if Quantity specifies for the value [all], realization of POR is unnecessary.

[15]The dependent becomes the head in the sign THANK-YOU may be similar to the syllabification of a sonorant consonant when a vowel is absent in spoken language. In a syllable, the nucleus (the vowel) is the head whereas the consonants are the dependent. For example, in the word 'little', some people pronounce as ['lɪtl], with the final [l] syllabified, becoming the head of the second syllable.

1.4.11 The Quantity node

The Quantity node is the same as Eccarius' (2002). The markedness of features under the Quantity node is ranked as the following from the least marked (typologically most frequent) according to Eccarius' (2002) cross-linguistic findings:

[all] < [one] < [one;all] < [all;one]

This is also in line with the generalization of DP that "single features" are less marked than those which enter into a dependency relationship because [all] and [one] are less marked than [one;all] and [all;one]. It should also be noted that although [all] is ranked as less marked than [one], the markedness difference between them may not be very big because their typological frequencies are very similar (Eccarius 2002:25). In Eccarius' study, [all] was found in 201 handshapes in the 12 sign languages and [one] was found in 194 handshapes in the 12 sign languages (i.e. the same handshape appearing in different sign languages are added up, for example, if both [5] () and [C] () were found in all 12 sign languages, it would be counted as a frequency of 2 x 12 = 24 for [all]).

1.4.12 The Point of reference node

The POR node specifies which finger(s) is / are to be selected. The three possible features are [radial], [ulnar] and [middle].

Typological data show that [radial], the Index finger side of the hand, is the least marked POR feature. It is because Index finger being the only selected finger is found in all the 12 sign languages in Eccarius' study (Eccarius 2002). Also, the selection of two fingers, the Index + Middle, assuming the [radial] feature, is found again in all the 12 sign languages. As for the three fingers selection, the combination of Index + Middle + Ring which also assumes the [radial] feature, is found in 10 out of the 12 sign languages (Eccarius 2002). On the other hand, other selected finger combinations do not exhibit such a high frequency of distribution. They are found in less than 10 of the sign languages, if not unattested at all.

[Ulnar] refers to the Pinky side of the hand, and [middle] refers to the use of the Middle finger as the Point of reference.

[Middle] is more marked than [ulnar] because from the cross-linguistic findings of Eccarius (2002), the sole selection of the Middle finger is found in 11 sign languages; and the sole selection of the Pinky finger is found in all 12 sign languages under investigation. This markedness difference is supported by HKSL data. One of the generalizations of heads in DP phonology is: simple heads tend to allow further specifications; and vice versa for complex heads (Batistella 1990 cited in Kooij 2002). Comparing the selection of the Middle finger only and the selection of the Pinky finger only, in HKSL, there is no sign with the Middle finger as the only selected digit which specifies for HIMs. Where only the Middle finger is selected, this more complex head here rejects further specifications, HIM in this case. However, if the Pinky finger is the only selected digit, the Pinky finger can flex at the nonbase joints repeatedly to mean GINGER (see Clip 1-16 ), i.e. the less complex head allows further specification. Moreover, the extended Pinky finger [I] () is used in more different lexical items than the extended Middle finger [⅄] (). In this study, simple heads are heads which consist of less marked features, and / or the features are fewer in number; and complex heads are heads which consist of more marked features or a larger number of features.

Therefore, the markedness ranking of the features under the POR node are as follows:

[radial] < [ulnar] < [middle]

1.4.13 The Joint position node

The Quantity node branches into the Joint position node as the head and the Finger position node as the dependent.

I put Joint position as the head and Finger position as the dependent because some of the finger positions can be predicted by the joint positions. This is further illustrated in the following subsection. Joint position refers to flexion or nonflexion of the selected fingers. Joint position has the least marked feature [extended], because significantly higher numbers for handshapes with extended selected fingers are found in the 12 languages studied by Eccarius in 2002. And the other features are [base flex], [nonbase flex] and [base & nonbase flex] which refer to flexion at the base joints, flexion at the nonbase joints, and flexion at the base and nonbase joints respectively.

Ann (1993) suggests that a ranking of finger positions from the physiologically easiest to the hardest as follows:

closed (i.e. finger flexed at both the base and nonbase joints with the fingertips contacting the palm) < bent (i.e. finger flexed at the base joint) < extended < curved[16] (i.e. fingers flexed at the nonbase joints only).

[16]"Curved" in the handshape literature usually refers to flexion at both the base and nonbase joints without Thumb contact, but Ann (1993) uses "curved" to refer to fingers flexed at the nonbase joints only.

Incorporating findings from Eccarius (2002) and suggestions by Ann (1993), I propose that [extended] is the least marked feature in the Joint position node due to its high frequency in finger selection and [nonbase flex] as the most marked due to its highest physiological difficulty. This leaves [base flex] and [base & nonbase flex] in the middle unranked because [base & nonbase flex] is not the same as "closed" in Ann (1993) since "closed" in her study implies fingertips contacting the palm which is not a must in the current study for [base & nonbase flex]. The [base & nonbase flex] in the current study is not discussed in Ann (1993). Therefore, the tentative markedness ranking of the features in this node is as follows:

[extended] < [base & nonbase flex], [base flex] < [nonbase flex]

My proposed Joint position node is different from Eccarius' (2002) because she puts "base" and "nonbase" as the terminals of the Joints node. This is uncommon in the practice of spoken language phonology studies because terminals should be features instead of nodes for places of articulation. In addition, I do not divide "base" and "nonbase" into two branches because no dependency relationship[17] can be found: flexion can be independently realized at the base joints only, at the nonbase joints only, or at both the base and nonbase joints.

[17]In the DP framework, a phonological structure involves constructions, each of the constructions has a determinate head, and the head is characteristic of the construction For example, in the representation of the high-mid vowel [e] in spoken language, the **i** component is more salient than the **a**, therefore [e] belongs to the set of high vowels and is represented as {i;a} (i.e., i over a) (Anderson 2002).

1.4.14 The Finger position node

The Finger position node refers to the relationship of the adjacent selected fingers. The Quantity node governs the Finger position node because whether the Finger position node can be realized depends on the Quantity of the selected fingers. Finger position node only realizes when there is more than one selected finger. The node has three feature possibilities. They are [spread], [nonspread] and [crossed].

[Spread] means abduction of fingers, [nonspread] refers to adduction of fingers, and [crossed] means the palmar side of one finger touches the back of the other selected finger.

Finger position is dependent on the Joint position because physiological relationship can be found between the two. When the selected fingers are extended, it is more effortful to make them nonspread because they naturally spread (Ann 1993); and when the selected fingers are [extended], [spread] is predicted in the Finger position node, whereas [extended] and [nonspread] is a more marked configuration. On the other hand, when the selected fingers are nonextended, the predicted feature is [nonspread], if the handshape has nonextended and spread selected fingers, [spread] needs to be overtly specified. [Crossed] has been argued in the literature that it is some kind of hyper-[nonspread] which is even more effortful than [nonspread]. Some Finger positions can be predicted physiologically as the following table shows. The handshape is less marked when it realizes with the predicted Finger position feature.

Table 1.4 The predicted finger positions in different joint positions

Joint position	Predicted Finger position physiologically and thus less marked	Can be specified if required, but more marked than the predicted counterpart
[extended]	[spread]	[nonspread] < [crossed]
[base flex]	[nonspread]	[spread]
[base & nonbase flex]	[nonspread]	[spread]
[nonbase flex]	[spread]	[nonspread]

1.4.15 The Secondary selected fingers node

Similar to Eccarius (2002), the SSF node is structurally a copy of the PSF node but simplified. The SSF structure is less complicated than PSF but more complicated than NSF.

1.4.15.1 Primary vs. Secondary selected fingers

In order to determine which finger groups should be assigned to PSF and which should be assigned to SSF, Eccarius (2002) proposes the following method: "to look at the handshapes in the context of handshape change and in lexical contexts with respect to contact points and places of articulation" (Eccarius 2002:54). In other words, the fingers which involve HIM or lexically specified contact are the PSFs, and the other foregrounded fingers are the SSFs. I would adapt this method of PSF or SSF assignment because HIM and contact clearly indicate which fingers are selected, and they are useful indicators to show which fingers are more prominently selected to be assigned to the PSF node.

1.4.15.2 Comparing the SSF node with the PSF node

From the HKSL data and the handshapes listed in Eccarius (2002:53), for SSF, neither [base flex] nor [crossed] is observed , so under the SSF node, the Joint position node and the Finger position node do not bear these two features.

Eccarius (2002) proposes [loop] and [flexed] to represent the positions of the SSFs but [loop] looks identical to [base & nonbase flex] of the selected Thumb and other selected finger(s) with Thumb [contact], so I keep the use of [base & nonbase flex] under SSF instead of using [loop] for consistency.

The least marked feature of the Joint position node under SSF is [extended] like PSF since [extended] is the most frequent position of the SSF node, according to Eccarius (2002:55). The other features are [contact], [nonbase flex] and [palmar contact]. [Contact] is the same as the one in the Thumb node, and [nonbase flex] is specified when the Thumb interphalangeal joint is required to flex.

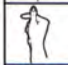
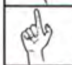
[Palmar contact] refers to the specification of the Thumb tip contacting the palmar side of the other selected finger. For example, in the handshape [Â] (), the Index finger is flexed at the nonbase joints and the Thumb tip contacts the palmar side of the Index at the second nonbase joint.

1.4.15.3 The Quantity node of the Secondary selected fingers node

Eccarius (2002:56) states that "there appears to be no need for more than two fingers". However, the handshape [Wc] () in HKSL has three SSFs, the Middle, the Ring and the

Pinky fingers. The PSFs are the Thumb and the Index finger because there is a sign variety using this handshape with [trilled] [closing] (but without final finger tip contact) of the Thumb and the Index. Eccarius (2002:56) also claims that "there is no need for any kind of dependency relationship; if there are two fingers in the group, both features occur in tandem". In my observation of the HKSL data and the handshapes listed in Eccarius (2002:53), the Quantity node only needs to specify for [all] or [one], but since the SSF node is the dependent of the PSF node, the interpretation of the Quantity of the SSF node depends on the Quantity of the PSF node. In the Quantity node of the SSF node, [all] is interpreted as 'all the rest of the fingers besides the PSFs (not including the Thumb)'. Second, Eccarius (2002) argues that [all] and [one] need to occur in tandem but it is not the case according to my observation of the HKSL data and the handshapes listed in Eccarius (2002). It is adequate for the SSF Quantity to specify for [one] or [all] only, and the two features need not occur in tandem at all. This again supports that the SSF node is less complex since it allows fewer feature combinations. [All] and [one] in the SSF Quantity do not need to enter into dependency and the evidence is given in Tables 1.2 and 1.5. Table 1.5 shows handshapes involving Secondary selected fingers in HKSL, and the criteria to differentiate between PSFs and SSFs follow those suggested in Section 1.4.15.1.

Table 1.5 Handshapes involving Secondary selected fingers in HKSL

HS#	NSF	SSF		PSF	
	Fingers	Fingers	Quantity feature	Fingers	Quantity feature
 Â	M+R+P	I	[one]	T	/
 Â^{x}	M+R+P	I	[one]	T	/
 i	M+R+P	T	/	I	[one]
 i^{F}	M+R+P	I	/	T	[one]
 Ux	T+R+P	I	[one]	M	[one]
 K	R+P	M	[one]	T+I	[one]
 ♀	/	I+P	[all]	T+M+R	[one;all]
 Wc	/	M+R+P	[all]	T+I	[one]

1.4.15.4 The Point of reference node of the Secondary selected fingers node

Eccarius points out that "POR has both [mid] and [ulnar] features, but there is no need for the two to enter into any kind of complex structure (Eccarius 2002:56)". This is in line with my observation so I would adopt Eccarius' (2002) POR node of the SSF node in my proposed model.

No ranking of feature markedness is proposed for this node as no cross-linguistic data are available.

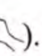
1.4.15.5 Joint position node of the Secondary selected fingers node

The Secondary selected fingers only realize with three joint positions. They are [extended], [base and nonbase flex] and [base flex]. Since no cross-linguistic frequency is available, so currently no ranking of feature markedness can be proposed for this node.

1.4.15.6 Finger position node of the Secondary selected fingers node

The Finger position node of the SSF node is similar to that of the PSF node. The only difference is that the Finger position node of the SSF node does not have the feature possibility [crossed] since no [crossed] SSFs have ever been observed. Therefore, only two feature possibilities remain, they are [spread] and [nonspread]. And no ranking of feature markedness can be proposed due to the absence of such cross-linguistic frequency data.

1.4.15.7 Conclusion

This chapter introduces and evaluates three handshape nodes. They are Sandler's (1989), Brentari's (1998) and Eccarius' (2002). Eccarius' (2002) handshape node is chosen because hers is the only model that includes HKSL in her data. I modify Eccarius' model in a number of ways due to some theoretical concerns. Theoretically, the terminals should be features instead of nodes for place of articulation, so unlike Eccarius (2002), I do not put [base] and [nonbase] as two of the terminals in my model. Moreover, in order to represent the NSFRR, I modify the features postulated for the nonselected fingers node. Eccarius (2002) proposes [extended] and [flexed], but I propose that [base and nonbase] flex is the only feature which needs specification. This is because the positions of the NSFs are predicted by the NSFRR except in handshapes like [Ĝ̈] (). In this case, [base and nonbase flex] of the NSF node needs to be overtly specified. I add the HIM node because it is not within the scope of Eccarius' (2002) study, and I adapt Kooij's (2002) classification of HIMs since hers is by far the most comprehensive in the literature. And HIM is represented as the dependent of the handshape as justified in Section 1.4.1 but not end-branching features in the handshape node as in Sandler (1989).

Structurally, each nonterminal node in my proposed Handshape Unit Model clearly branches into one head and one dependent which is in line with the philosophy of DP: "a node has exactly one head (not zero and not more than one) and one dependent node" (Hulst, personal communication). The relationships of the heads and the relative dependents are all justified.

To conclude, the advantage of the proposed Handshape Unit Model over previous models are as follows:

1. Physiological account is included in the development of the model while determining the markedness of the features;
2. A detailed account is provided for the dependency relation between the class nodes of different phonological categories of signs;
3. Theoretical consistency is embodied in the model, the whole model composes of unary features and all the features are realized simultaneously. Hulst (1989) argues that the advantage of unary features is that they "restrict the set of entities that phonological rules can refer to" (Kooij 2002:43);
4. The structure of the model is systematic and consistent: place of articulation is specified from general to specific; and
5. Redundant thumb opposition is deleted.

The Handshape Unit Model I propose is tested against the acquisition data collected in this study. The findings are presented in Chapter 4.

1.5 Outline of the thesis

In Chapter 2, a literature review on acquisition of phonology is presented. In Chapter 3, an introduction to the deaf subject is given, followed by the methodology of data collection and hypotheses formulated in the current study. Chapter 4 reports that the data generally support the proposed Handshape Unit Model; moreover, it investigates into whether and how HIM affects the handshape production. Chapter 5 aims at testing the data collected in this study against the classification of 'easy' and 'difficult' handshapes proposed by Ann (1993). It shows that her classification is generally supported by the current acquisition data but may need more refined scoring in order to be more predictive on the order of acquisition. Chapter 6 is the concluding chapter.

1.6 Notation conventions

In this thesis, signs are glossed into English capital letters, which provide the closest meaning equivalents of the sign. When more than one English word is needed to gloss a sign, the words are hyphenated, for example, THANK-YOU. Following the practice of the Hong Kong Sign Language Dictionary (Tang 2007), each handshape is assigned a corresponding handshape symbol. The symbols are mainly adapted from Stokoe *et al.* (1976) and Brien (1992). The small marks on some of the symbols represent some specific values of handshape configuration. For example, the difference between "V" () and "V̇" () is that the latter has an extended thumb and it is represented by the dot on top of "V̇". "1" () with three dots horizontally on top "1⃛" () refers to flexion of the selected index finger at the nonbase joints. The handshape symbol is in slashes when the phonemic form is referred to, and in square brackets when the phonetic form is referred to. In different pieces of literature, the same handshape is referred to using different symbols. For instance, handshape () is sometimes called [G] and sometimes [1]. Therefore, in the current study, a handshape in brackets is always provided to facilitate the readers and to avoid confusions. For the sake of consistency, all the phonetic symbols are presented according to those in Tang (2007) unless otherwise specified. The handshape fonts and handshape symbols are adapted from Tang (2007). Please refer to Appendix B for the handshape-symbol pairs.

Chapter 2 Literature review and introduction to the current study

2.0 Introduction

Before proceeding to the acquisition of phonology in sign language, it is useful to offer some background of research on the acquisition of phonology in spoken language. The phenomena of acquisition of phonology are described in Section 2.1. Section 2.2 presents the phenomena of sign phonology acquisition, with the last subsection presenting a detailed description of handshape acquisition. Section 2.3 provides an interim summary and Section 2.4 discusses the implications of the previous findings in the literature on the current study and my hypotheses on the acquisition of handshape.

2.1 Generalizations of phonology acquisition phenomena

Some of the phonology acquisition phenomena are presented here to serve as a basis for a later comparison with the findings from research on handshape acquisition in the signed language literature.

2.1.1 Early child speech as prephonemic

According to Menn (1983), early child speech is often called pre-phonemic (Nakazima 1972, Menyuk 1977). Menn (1983) gives three reasons on the basis of children's production to support this. First, phonemic contrast and phonetic control do not develop in synchrony. This is manifested by the common observation that a child can produce certain voiced phones, like the voiced [b, d, g] correctly, but may fail to produce the voiceless counterparts, i.e. [p, t, k]. Hence, one can only claim that the child has acquired the phones [b, d, g] but not the phonemes /b, d, g/ since the child's speech production does not exhibit any contrast with /p, t, k/. Second, minimal pairs are rare in children's speech, so it is difficult to state the presence or absence of phonemic contrast. Third, there is arbitrary variation in phonetic targeting between one lexical item and the next one. For example, the subject Jacob in Menn's (1976 a, b) study had more different renditions of the vowel in the word 'down' than 'round', while the vowel in both words should be the same phoneme. In the example of 'down' and 'round' above, even though both words are monosyllabic and the vowels are interconsonantal, the subject produced the vowel in 'down' with more various vowels than in the word 'round'.

Note that Menn's arguments (1976) are mainly based on production data only. Counter evidence, however, can be found in perception studies which reveal that infants are actually sensitive to phonemic contrast. For example, preferential sucking experiments show that an infant may be able to perceive 'bead' and 'beat' as different long before it can produce the final consonant [d] and [t]. Hence, early child 'speech' may be prephonemic, but not necessarily so for child 'language' when perception is referred to. In language acquisition research, being able to perceive difference is already a good indication of competence. Furthermore, the scarcity of minimal pairs in child speech does not necessarily mean that phonemic contrast is absent from children's mental representation, as shown by in children's performance in perception studies. Menn's argument about the vowel production in word like 'down' and 'round' cannot be established, either. Strictly speaking, the onsets and the codas of the two words are different, and the difference may contribute to the variation in phonetic targeting between one lexical item and the next one, and it may not be as "arbitrary" as Menn (1983) claims. Hence, the examples from Menn (1983) can at most show that early child speech may be prephonemic, but not necessarily so for child language, especially when perception is referred to.

2.1.2 Commonly acquired sound segments at the end of the babbling stage

There are 24 consonants in American English. For 12-month-olds who are acquiring American English, only 11 different consonants, /h/, /w/, /j/, /p/, /b/, /m/, /t/, /d/, /n/, /k/, and /g/ make up about 90% of their consonants productions. These 11 different consonants also account for a large proportion of consonant productions in children exposed to other languages as well (Locke and Pearson 1992). Children acquiring English seldom form consonant clusters like /kl/ or /pl/ until well after the age of two. As for vowels, some are more frequent than the others, like /ə/, and /æ/ are more frequent than /i/ or /u/ (Vihman 1988).

2.1.3 Characteristics of early words – Loss of phonological contrasts

Children's words carry less phonological contrasts than the corresponding adult targets and thus they have a lot of homonyms; in addition, they cannot maintain all the adult phonetic contrasts and so they cannot produce their words accurately (Menn and Stoel-Gammon 1995). For example, in Cantonese, 'elder brother' should be pronounced as [kɔ] [kɔ], and a brand of drinks, 'Yakult' should be pronounced as [jek] [lik] [tɔ], and children usually call it [tɔ] [tɔ]. But children at earlier stage may produce [tɔ] [tɔ] to mean both 'elder brother' and 'Yakult'.[1]

[1]Since only the segmental information is important here, the tones are not represented.

2.1.4 Systematic mappings

When children's productions do not meet the corresponding adult targets, they usually show systematic substitutions, and rules are derived from the observation of their productions to account for their substitutions. For instance, final devoicing (i.e. no continuation of vocal cord vibration during the production of a consonant like /b/, /d/, /g/, /v/, and /z/ at the end of a word) is a 'natural process' because this appears not only in child speech, but also in adult speech crosslinguistically, like in German and Russian.[2]

2.1.5 Context-dependent rules / processes

When children cannot produce the adult target sounds, some rules / processes of substitution or omission are at work, and they are context-dependent. For example, a child acquiring English may substitute word-initial velars by alveolars while velars not in word-initial positions are produced correctly, thus yielding productions like [tUki] for "cookie" . Although the two velars are the onsets of the two syllables, the vowel which follows each of them is different, and the first syllable is stressed while the second is not. All these may yield to the different productions of the same target sound.

[2]Substitution of stops for fricatives ([ti] for 'see'); reduction of consonant clusters to a singleton consonant ([pat] for 'spot'); and deletion of initial [h] etc. There are also other partial assimilation rules which project whole-word consonant harmonies, especially place assimilation ([gak] for 'sock') (also known as "consonant harmony" in this case) and nasal assimilation ([minz] for 'beans'). Some of the rules can be explained from the perspective of motor development, according to Smith (1973), for example, an unstressed syllable in a word may be replaced by a "dummy syllable" (either a typical near-consonant shape or a copy of the stressed syllable such as [rita:] for 'guitar'). Consonant cluster simplification, usually achieved through preservation of the most obstruent segment, may instead be done by combining features from the several segments, for example, /s+nasal/ became voiceless nasal, /sk/ became the velar fricative [x], even when the adult language does not possess the resulting feature combination (Menn and Stoel-Gammon 1995).

Another example of context-dependent rules / processes is omitting the liquids only in stop-liquid clusters like the /r/ in "truck". Lastly, a child may be able to produce all the sounds individually but not in a certain sequence (Menn and Stoel-Gammon 1995).

2.1.6 Strategies and metalinguistic awareness in the early period

Children like to look for sounds which lie within their production repertoire, and this is called "favorite sounds" or "exploitation" strategy. Other strategies that reflect a degree of awareness of the child learner in circumventing perceived difficulties are avoidance, lexical selection and self-correction. Avoidance is a common strategy for children who are at the stage of producing less than about 25 – 75 words.

These phenomena show that children possess metalinguistic awareness as they recognize that they do not produce the adult forms correctly and thus they get around them with different strategies.

2.1.7 Stages of the phonological development

Children go through different stages when they are learning new sounds. At first, they may be ignorant of their own production and the target sounds; later, they become aware that they do not reach the adult targets in their output but still unable to produce them correctly; after that, they go through a stage of target productions in imitated tokens but not in spontaneous ones; still later; they are in a stage of free variation between the correct form and the earlier from; and finally, they produced the adult targets correctly.

The paces of these progresses are different across individuals. Moreover, a child may be able to produce some sounds correctly while continues to articulate deviant forms for other sounds without recognizing the discrepancy. (Menn and Stoel-Gammon 1995).

2.2 Acquisition of phonology in sign language

With respect to sign language, "the acquisition of phonology could best be described as a process of mastering the articulation of phones (manual[3] or oral) in the language" (McCarthy 1954, cited in Yeni-Komshian, Kavanagh, and Ferguson 1980:211). Studies of acquisition of sign language phonology usually focus on the three parameters: handshape, location and movement.

A lot of the studies on the acquisition of phonology in sign language focused on ASL. All of their production data show that children get highest accuracy for location, followed by movement, and lowest for handshape (Siedlecki 1991, Conlin *et al.* 2000, Marentette, Mayberry & Rachel 2000). The phenomena of acquisition of the three parameters will be presented in the order from the highest production accuracy to the lowest.

[3]Manual phones are equivalent to sign language phonological components

2.2.1 Acquisition of location

Location (also known as place of articulation) is the parameter which children produce most accurately (Bonvillian and Siedlecki 1996, Meier *et al.* 1998, Conlin *et al.* 2000, Karnopp 2002, Marentette and Mayberry 2000).

Location errors tend to be consistent across tokens but the errors disappear as age progresses. For example, one child was nontarget consistently in producing the ASL sign DOLL (see Clip 2-1 ); in seven attempts she produced DOLL at the lower lip instead of at the nose (Conlin *et al.* 2000). Siedlecki & Bonvillian (1993) find that the accuracy rate of locations sustains at a comparatively high level without much variations throughout the age period included in their study. In other words, location is the earliest acquired parameter in sign phonology acquisition.

Bonvillian and Siedlecki (1996), and Karnopp (2002) find that the order of acquisition of location is as follows: [neutral space] → [trunk] → [chin] → [forehead]. This suggests a trend of acquiring locations in neutral space and on the body first, then finer distinctive locations on the body, and Karnopp (2002) adds the acquisition of non-dominant hand to the last stage of location acquisition. The stages of location acquisition are represented as follows:

Neutral space → on the body → finer distinctive locations on the body → nondominant hand

Children make relatively more errors on the torso as the place of articulation. The majority of this class of errors involve medial or *contralateral*[4] location being substituted by an *ipsilateral*[5] location (Conlin *et al.* 2000). Karnopp (2002) also observes that the production of locations at the contralateral side took place in *neutral space*[6]. Bonvillian and Siedlecki (1997) also note a similar phenomenon in their parental report data. Therefore, it can be generalized that if a child is nontarget in producing the contralateral location, the ipsilateral location or the neutral space is likely to be the substitute. Neutral space being the substitute supports the stages proposed by Karnopp (2002) because neutral space is the first stage of acquisition. The relative unmarkedness of neutral space is supported by the fact that it is acquired early and it is used as a substitute.

Conlin *et al.* (2000) also notice that the frequency of signs made with the nondominant hand as the place of articulation (6.7%) and those on the body other than the nondominant hand (7.8%) are much lower than those found in the Dictionary of ASL (25% and 37% respectively) (Stokoe *et al.* 1965). This indicates that they have not acquired these two locations. However, the data still support the stages proposed in Karnopp (2002) because nondominant hand is in the last stage of acquisition, and children use the nondominant hand (6.7%) as the place of articulation less frequently than the body (7.8%), the second stage of acquisition.

[4]Opposite side of the body from the dominant signing hand (Brentari, 1998).

[5]Same side of the body of the dominant signing hand (Brentari, 1998).

[6]'[T]he area directly in front of the signer at the level of the torso' (Brentari, 1998:5)

2.2.2 Acquisition of movement

Movement here includes path movement, executed by the elbow joint; and internal movement[7], executed by the wrist and the finger joints. Movement is the parameter which children produce second most accurately (Bonvillian and Siedlecki 1996, Meier et al. 1998, Conlin et al. 2000, Karnopp 2002, Marentette and Mayberry 2000). In terms of frequency, the most frequently produced movements by the children include [in], [out], [pronate], [supinate] and [down] (Bonvillian et al. 1985).[8] Karnopp (2002) discusses the order of acquisition using the movement types as the units: the child first produced straight and wide movements; then circular ones; and finally hand-internal ones, leading to changes in palm / finger orientation and handshape. Focusing on internal movements, the most frequent ones were bending of the base joints and rotation of the lower arm (Marentette and Mayberry 2000). "Bending of the base joints" is known as [flattening]; "rotation of the lower arm" yields palm orientation change and is not considered as HIM (this will be further discussed in Chapter 4). Marentette and Mayberry (2000) state that the movement substitutions are not as systematic as those of location and handshape, but they have not elaborated on this claim or cited any examples.

A commonly reported phenomenon of movement acquisition is proximalization. Children tend to proximalize the movements in their early signing (Meier *et al.* 1998, Conlin et al. 2000, Marentette and Mayberry 2000). For example, the colour signs of

[7]In the current study, hand-internal movement is restricted to that executed by the finger joints and this is further discussed in the later relevant section.

[8][In] and [out] refer to moving the signing hand(s) towards and away from the signer respectively. [Pronate] and [supinate] refer to a movement to a prone position and to a supine position of the palm respectively. [Down] literally refers to the downward movement of the signing hand(s).

ASL are formed with repeated twisting movement of the forearm (e.g. YELLOW, GREEN, BLUE, and PURPLE, see Clip 2-2 , Clip 2-3 , Clip 2-4 , and Clip 2-5 ), but one of the participants in the study by Conlin et al. (2000) adds a repeated up-and-down movement of the arm at the shoulder. Some children also replace a wrist movement with an elbow one (Meier *et al.* 1998).

2.2.3 Acquisition of handshape

Handshape is the parameter which children produce least accurately (Bonvillian and Siedlecki 1996, Meier *et al.* 1998, Conlin *et al.* 2000, Karnopp 2002, Marentette and Mayberry 2000). Since the current study focuses on the acquisition of handshape, a detailed review of the relevant studies is provided here. Different methods are used in collecting data for handshape acquisition studies, such as videotaping of children's natural signing and parental diaries. Hearing and deaf subjects are analyzed as long as sign language is reported as the dominant language in the family. In what follows, general findings will be presented first, followed by longitudinal studies with feature analysis.

2.2.3.1 Acquisition of spoken and signed language phonology: Common observations

Parallel phenomena between spoken and signed language acquisition are observed, implying that both deaf and hearing children go through a similar acquisition process.

Handshape can be accurate when it is produced in isolation

Findings in spoken language acquisition suggest that a child may be able to produce all the sounds individually but not when they are embedded in a certain sequence (Menn and Stoel-Gammon 1995). A parallel phenomenon can be found in the acquisition of handshape in sign language. The performance contrast between fingerspelling and other lexical signs is a case in point. Sometimes a child may be able to produce all the letters of the manual alphabets in ASL in isolation but fail to do so in spontaneous signing when these handshapes are combined with location and movement (Bonvillian *et al.* 1988, cited in Siedlecki 1991). Such a contrast indicates that the nontarget handshapes in spontaneous production in deaf children may be attributable to processing factors.

Children only produce a subset of the inventory

Locke and Pearson (1992) report that the production of sound segments by children exposed to English mainly consist of a subset of the English sound inventory, as mentioned in Section 2.1.2. In handshape acquisition, it is also similar because children only produce a subset of the ASL handshape inventory, as reported in Bonvillian, Orlansky, Novack, Folven & Holley-Wilcox (1985), and Orlansky & Bonvillian (1988). In the study by Marentette and Mayberry (2000), the most frequently produced handshapes by the subject are [] (5), [] (1), and [] (A). The majority of the handshapes produced by children in the acquisition process only constitute a subset of the whole ASL handshape inventory.

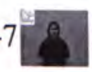
2.2.3.2 Acquisition phenomena specific to handshape acquisition

Besides the aforementioned phenomena in spoken and handshape acquisition, there are some other interesting phenomena which are specific to handshape acquisition. They are described in the subsequent subsections.

Preference for fingertip contact

Boyes Braem (1990) observes that children prefer fingertip contact over contact with other parts of the hand. For instance, the citation form of SHOE (see Clip 2-6 ) in ASL requires the two hands assuming a handshape [A] ( )[9] which make contact at the (radial) side of the hands. A deaf child in her study substitutes it with two [Ĝ] ( )[10] handshapes, bringing the two hands together into contact at the fingertips (with palms facing each other) (Boyes Braem 1990:116, words inside brackets added for clarification).

Complex movement leads to omission of HIM

Another observation Boyes Braem raises is the tendency for HIM to be omitted if the sign involves a complex movement. In ASL, the sign PRETTY (see Clip 2-7 ) requires a handshape [5] ( ) held in front of the face, with the fingers closing successively, while the hand simultaneously twists inwards. Theoretically, it involves HIM and wrist movement. Pola, the deaf child in her study, "simplifies" all these by

[9]Handshape symbols are adopted from the Hong Kong Sign Language Dictionary (Tang 2007) in this thesis. Where no handshapes or symbols are provided, the symbols in the original paper are adopted.

[10]This handshape is usually called the [bO] handshape in the literature. I follow all the phonetic symbols from Tang (2007) for the sake of consistency. The same applies to other handshapes when the phonetic symbols in the literature are different from those in Tang (2007).

maintaining a handshape [Ḃ] () throughout the sign and only twisting the wrist. Boyes Braem (1990:117) uses this example to suggest that a complex movement may result in selecting a handshape that is phonologically less complex than the target. Boyes Braem's study sheds light on the complexity involved when HIM is specified for the sign, hence affecting the production of handshape configuration. She assigns handshapes to different stages with reference to physiology and perception. [5] () is categorized as Stage 1 handshape whereas [Ḃ] () is a Stage II handshape according to her. In this substitution, however, the handshape [Ḃ] () is not simpler (articulatorily easier) than [5] handshape (), because extended fingers tend to spread from one another physiologically (Ann 1993), and the substitute is also not simpler according to her classification of stages. Yet, this example reveals that the requirement of a complicated HIM together with a palm orientation change in child signing leads to omission of the HIM or production of a non-target handshape, but not necessarily "simplifying" a handshape.

Anticipation and retention

Boyes Braem (1990) also observes that handshapes may be substituted due to anticipation and retention in natural signing. For example, in one instance, the deaf child in her study signs URSIE (a name sign produced with the handshape [U] () and EAT (requires a [B̂] () (see Clip 2-8 )), but she extended the handshape [U] () to EAT as well. Substitutions of this kind never use handshapes other than the immediately preceding or following handshapes (Boyes Braem 1990). In the current study, this is considered as assimilation[11] instead of substitution.

[11] Assimilation here refers to a handshape change process by which one handshape becomes identical to the one in the neibouring sign in the sign stream.

Sympathetic thumb extension

The last observation Boyes Braem (1990 makes is that when the sign requires the index finger alone to be extended, the other radial digit, the thumb, is often also extended by the child in several signs (Boyes Braem 1990).

2.2.3.3 Substitution

When children are nontarget in handshape production, they replace the target handshapes with other handshapes, which is known as substitution in the literature. It is found that handshape substitutions are not random, similar to substitutional patterns observed in spoken language phonology. Similarities in substitution patterns are observed across different studies. Referring to Tables 2.1 and 2.2 below, one or more than one target handshapes is / are substituted by one handshape; [Ḃ] ( ) and [C] ( ) are reported to be substituted by [5] ( ); [5] ( ) and [1] ( ) are observed to be used as common substitutes; and the targets and the substitutes 'look similar'. The relationship between the targets and their corresponding substitutes by the subject of the current study will be analyzed using a feature analysis in Chapter 4.

Table 2.1 Generalization of substitution pattern (Marentette and Mayberry 2000)

Target(s)	Substitute
[Ḃ] ( ) [5̈] ( ) [C] ( ) [B̂] ( )	[5] ( )
[1b] ( ) [a] [Ṫ] ( ) [Y] ( )	[1] ( )
[S] ( ) [Ĝ] ( )	[A] ( )
[3] ( )	[Ĝ] ( )

[a]No phonetic symbol is given for the handshape ( ) in the HKSL Dictionary, so I follow Marentette and Mayberry (2000) in labeling it as [1b] here.

Table 2.2 Generalization of substitution pattern (Orlansky and Bonvillian 1988)

Target(s)	Substitute
[Ḃ]	[5]
[5]	[Ḃ]
[C] [A] [1]	[5]
[5] [U] [V] [W] [A]	[1]

2.2.3.4 Applying a linguistic phonology model in handshape acquisition study

Handshape acquisition data are not only reported using handshapes as holistic units, they are also analyzed in features. Karnopp (2002) uses a sign phonology model to describe and analyze the acquisition of handshapes in Brazilian Sign Language. The model is the One over All and All over One model (also known as the 'One-all model') advanced by Brentari, Hulst, Kooij and Sandler in 1996. Note that this model has its basis on DP as well. The subject of the study is a deaf girl called Ana. The period of observation is between 8 to 30 months old. For signs involving HIMs, only the initial handshapes are analyzed; and only spontaneous data are included in the analysis. The One-all model is described below.

Karnopp (2002) divides Ana's acquisition of handshapes into five phases. The five phases are classified according to the acquisition of new features. It is shown in Table 2.3. "Acquisition" in her study is defined as accuracy of production, order of position and production frequency.

Table 2.3 Five phases in acquisition of handshapes (Karnopp 2000: 43)

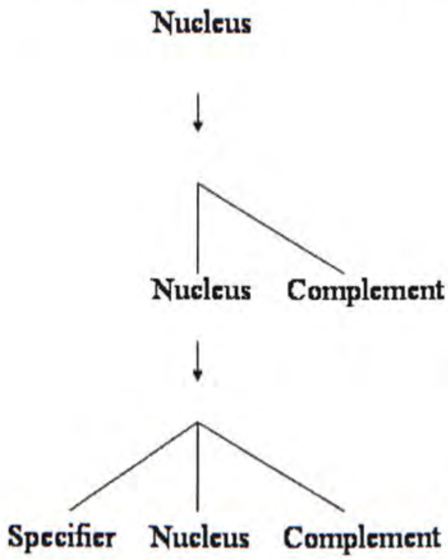
Phase	Years;month	Handshape type	Features Acquired
1	0;11	[1] [5]	[SF: One/(All)]
2	1;1	[B] [Ḃ] [5̄]	[Adduction: adducted] [Thumb: selected]
3	1;5	[A] [Ȧ] [S]	[Aperture: closed] in [All]
4	1;7	[C] [O] [3] [a] [Ĝ] [T̄] [b] [Â] [B̊]	[Aperture: open] in [All] [Aperture: closed] in [All]
5	2;0	[G̿] [c] [B̊] [Y]	[Flexion: flex; base] in [One] [Flexion: flex; base] in [All] [SF: I^u] (side: ulnar)

[a]In Brazilian Sign Language and ASL, this handshape has the thumb and the index finger selected; but in HKSL, it is the middle, ring and pinky fingers which are selected.
[b]This handshape and the one which follows are not discussed but only put in the table.
[c]This handshape is unavailable in the Hong Kong Sign Language Dictionary, therefore, no handkey can be provided.

Adopting the One-All model advanced by Brentari *et al.* (1996), Karnopp (2002) concludes that the acquisition starts with acquiring the Nucleus, followed by Nucleus+Complement, and finally the fully fledged phonological representation, with Specifier+[Nucleus+Complement].[12] This acquisition path is graphically represented in Figure 2.1.

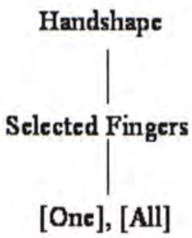
[12]In the model, the vertical nodes are the Nucleus, the ones flipped to the right Complement and those to the left Specifier.

Figure 2.1 Acquisition path suggested by Karnopp (2000)



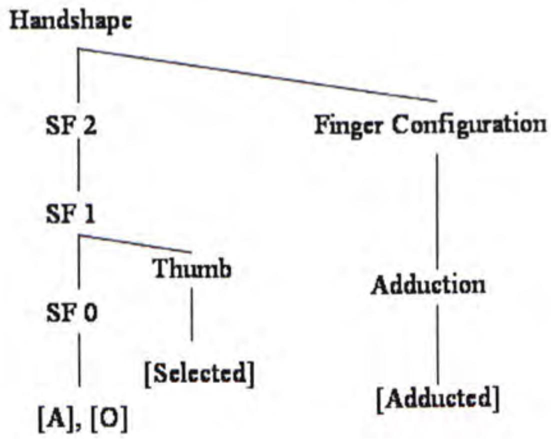
The five phases are discussed below adopting the One-All model (Brentari et al., 1996).

Figure 2.2 Phase 1 [1] () and [5] ()



At Phase 1, only the nucleus, i.e. the Selected Fingers node is acquired. The handshapes [1] () and [5] () are specified for [one] and [all] respectively.

Figure 2.3[Note] **Phase 2** [B] ( ), [Ḃ] ( ) and [5̄] ( )

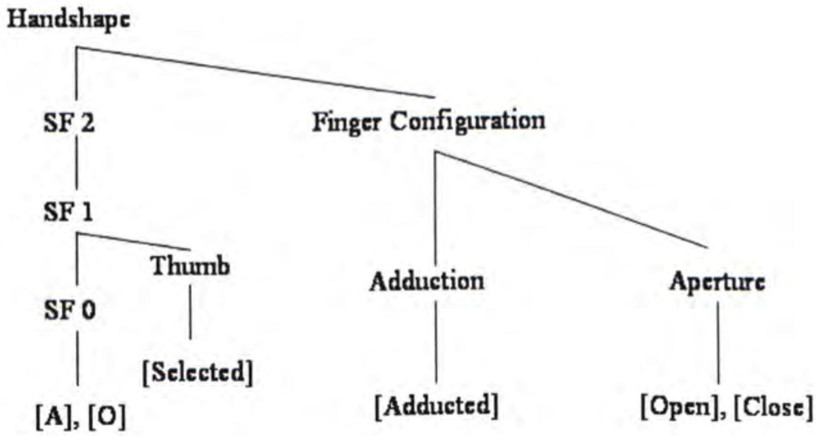


[Note]SF0, SF1 and SF2 all represent the node selected fingers. The selected fingers node is divided this way in order to accommodate the branching of "Thumb" and "Side" ("Side" appears in Figure 2.5).

Karnopp (2002) claims that at Phase 2, Complement is acquired in addition to the Nucleus, as shown by the acquisition of Finger Configuration under the Handshape node and the Thumb under the SF 1 node. Comparing between [Ḃ] ( ) of Phase 2 and [5] ( ) of Phase 1, the difference lies in adduction. The fingers are adducted in Phase 2.

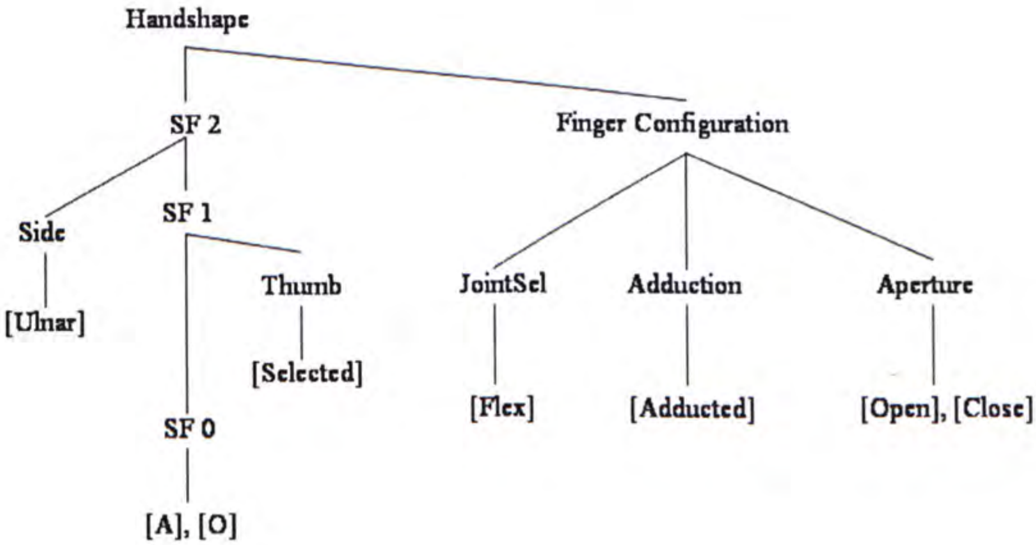
However, referring to Thumb selection, it already happens at Phase 1 in the handshape [5] ( ). It is not known why Karnopp (2002) places it at Phase 2 instead. If Thumb selection happens at Phase 1, then Karnopp's (2002) conclusion needs modification. The initial stage may be Nucleus + Complement, rather than Nucleus only.

Figure 2.4 Phases 3 and 4 [A] ( ), [Ȧ] ( ), [S] ( ), [C] ( ), [O] ( ), [3] ( ), [Ĝ] ( ), [T̄] ( ), [Â] ( ) and [B̂] ( )



At Phases 3 and 4, the 'complement of a complement', the Aperture node, is acquired in addition to the already acquired nodes. When aperture is specified, the selected finger(s) is / are opposed to the selected Thumb. [Open] refers to the state of opposition without finger tip contact and [close] refers to the state of opposition with finger tip contact. Karnopp (2002) claims that opposition is not observed from Phases 1 to 2, thus Aperture is a newly acquired node at Phase 3. However, the Aperture node should already be invoked in Phase 2 as shown by the handshape [5̿] ( ): the Thumb is opposed to other selected fingers, and feature specified should be [open] as no finger tip contact is involved. Besides, Karnopp (2002)'s data suggest that adduction is acquired before aperture. However, according to the Stages proposed by Boyes Braem (1990) and the data observed in the current study, aperture is acquired before adduction. This acquisition path difference may be language specific.

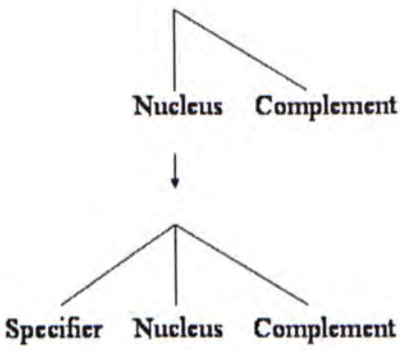
Figure 2.5 Phase 5 [G̅] (), [B̂] (), () and [Y] ()



At Phase 5, the fully fledged handshape model emerges. The model adds a Specifier to the [Nucleus + Complement] structure. The acquisition advances with adding two specifiers, the Side and the JointSel node. The feature [ulnar] under the Side node emerges in Phase 5 because of the acquisition of [Y] (), the Pinky finger selected without other fingers besides the Thumb. The feature [flex] under the Joint Selection node is also realized at Phase 5 with the acquisition of [G̅] (). However, the feature [flex] already happens at Phase 4 with the handshape [T̅] (), although [flex] at base joints is observed to be acquired at Phase 2 wit the handshape [5̿] (). Therefore, the JointSel node should not emerge at Phase 5 but Phase 2.

Karnopp (2002) is the first attempt that uses a linguistic model to account for acquisition of handshape. The model she uses represents the phases of handshape acquisition with adding of new nodes. Karnopp's (2002) model is based on an earlier version of Brentari (1998). Therefore, revisions of representation are necessary. Yet, why the Thumb node is not acquired at Phase 1; and the Aperture node, and the JointSel are not acquired at Phase 2 warrant further clarification. Lastly, whether the acquisition path suggested by Karnopp (2002) reflects the reality is doubtful because [5] () is a handshape commonly reported as acquired early, but this early acquired handshape already invokes a complement, the Thumb node, unlike Karnopp's (2002) suggestion that the first phase of acquisition invokes the head of the representation only. This suggests that the acquisition path may not be the same as what Karnopp (2002) concludes; it may rather look like Figure 2.6 instead.

Figure 2.6 Revised acquisition path



2.2.3.5 Group data: a reanalysis

No feature analysis has been conducted on group data on handshape acquisition. In this section, I will attempt to reanalyze the data generated from Siedlecki (1991), Siedlecki & Bonvillian (1993), Siedlecki, Theodore, and Bonvillian (1997). The findings of these three studies are based on nine subjects. The data are valuable because they are videotaped natural signing of the subjects. Similar to Boyes Braem's methodology, this group of researchers put forward five levels of development based on "difficulty". The level of difficulty of a handshape is determined by its frequency, accuracy, and mean ordinal position for first production relative to other handshapes. Table 2.4 provides a reanalysis of the group data in terms of features. This reanalysis is crucial for it serves as a reference against which the acquisition data of the current study can be compared. In that table, the common features of each level are presented in the rightmost column.

Table 2.4-p.1 Five levels of difficulty suggested by Siedlecki (1991), Siedlecki & Bonvillian (1993), Siedlecki, Theodore, and Bonvillian (1997)

Levels	Handshapes	Common features of each level
Level One	[5], [1]	One or all five fingers selected. When five fingers are selected, they spread away from one another. No flexion for the selected fingers.
Level Two	[Ḃ], [A]/[S]	All four fingers selected. All of them are nonspread. Selected fingers can be flexed at both the base and the nonbase joints. Thumb can be crossed over other selected fingers.
Level Three	[O], [I], [Ĝ], [C]	When all the five fingers are selected, both the base and nonbase joints are flexed, the Thumb can be positioned to be contacting other selected fingers at the finger tips [O] or not [C]. When only the Thumb and the Index are selected, either both are extended [I] or both are flexed at the base and nonbase joints, and they contact each other at the finger tips if they are flexed [Ĝ].

Table 2.4-p.2 Five levels of difficulty suggested by Siedlecki (1991), Siedlecki & Bonvillian (1993), Siedlecki, Theodore, and Bonvillian (1997)

Level Four	[V̇] ( ), [E] ( ), [H][a] ( ), [K] ( ), [Â] ( ), [V] ( ), [Ť] ( )	This level consists of handshapes with various configurations. If all the fingers are selected, they are flexed at the nonbase joints without thumb contact [E] ( ). When the Index and the Middle fingers are selected, they are extended, and they spread away from each other [V] ( ) or not [H] ( ). If they spread from each other, the Thumb can be selected [V̇], yielding ( ); or not selected, yielding [V] ( ). If only one finger is selected, it is the Index, and it is flexed at the nonbase joints only [Ť] ( ). Secondary selected finger appears at this stage. For example, in the handshape [K] ( ). In another handshape with secondary selected finger: [Â] ( ), the index finger is selected with flexion at the nonbase joints only, and the thumb is selected with base joint flexion only, and its finger tip contacts the palmar side of the index finger.

[a]The Dictionary of Hong Kong Sign Language (Tang, 2007) did not suggest a phonetic symbol for the handshape ( ), so I followed Siedlecki (1991), Siedlecki & Bonvillian (1993), Siedlecki, Theodore, and Bonvillian (1997) in labeling it as [H].

Table 2.4-p.3 Five levels of difficulty suggested by Siedlecki (1991), Siedlecki & Bonvillian (1993), Siedlecki, Theodore, and Bonvillian (1997)

Level Five	[3] (), [I] (), [bent-L][a], [R] (), [W] () / [M] ()[b], [Y] (), [ʊ] ()	Three-finger selection appears at this stage. In the handshape [3] (), the middle, ring and pinky are selected without flexion. In the other two handshapes, [M] () and [W] (), both select the Index, middle and ring, one with base and nonbase joints flexion and the other without. Selection of extended pinky finger alone appears at this stage [I] (). The thumb can be selected together as in [Y] (). The feature [crossed] applies to the selected fingers (not to the thumb) at this stage. When the index and the middle are selected, they are [crossed] [R] (). The sole selection of the Middle finger appears at this stage. When the middle alone is selected, it is flexed at the base joint and the nonselected fingers are lax [ʊ] ().

[a]Since only handshape labels are provided in the original study, it is not clear what it actually refers to.

[b]The Dictionary of Hong Kong Sign Language (Tang, 2007) did not suggest a phonetic symbol for the handshape (), so I followed Siedlecki (1991), Siedlecki & Bonvillian (1993), Siedlecki, Theodore, and Bonvillian (1997) in labeling it as [M].

The first three levels proposed by Siedlecki et al. are composed of handshapes from the first two stages of Boyes Braem's proposal. The only difference is that Boyes Braem puts [3] () in stage II but Siedlecki et al. put it on the last level. Siedlecki et al. describe the developmental stage of handshape with finer distinctions as they divide the handshapes into five levels of difficulty, but Boyes Braem (1990) only categorizes the handshapes into four stages to predict the order of acquisition. Perhaps the younger ages and the larger number of subjects studied by Siedlecki et al. facilitate them to do so.

Siedlecki et al. point out that handshape production significantly improves in accuracy over the ages included in the study. They conclude that handshapes are acquired late by children compared to location and movement due to the following observations: first, children make a number of handshape production errors which led to the lowest accuracy percentage among the three parameters; second, children as a group produce a relatively small proportion of the different handshapes described by Stokoe; third, handshape is rarely the first parameter to be used correctly by a child when forming a sign. Moreover, with signs specifying for the handshapes [5] ( ), [A] ( ), [C] ( ), or [O] ( ), and if the sign requires a fingertip or thumb tip as the point of contact, the substitute will likely be a [1] ( ) handshape. If the heel of the palm is involved at the point of contact, a [5] ( ) handshape is sometimes substituted for an [A] ( ) handshape, for example, BATH (see Clip 2-9 ) in ASL.

Referring to the rightmost column of Table 2.4, similar to Karnopp's (2002) conclusion, the degree of difficulty in handshape acquisition progresses with more elements added to a higher level, and Level 5 shows the most difficult handshapes being acquired by the subjects. In terms of quantity of finger selection, selecting one or all fingers is predominant from Level One to Level Three; selecting two fingers (excluding the Thumb)[13] belongs to Level Four; selecting three fingers (excluding the Thumb) belongs to Level Five. Joint flexion and adduction are absent from Level One; they are present at Level Two. Thumb crossed over other selected fingers belongs to Level Two. Thumb opposed to the

[13]The Thumb is treated independently in handshape studies. This will be discussed in detail in the later relevant sections.

selected finger(s) either with or without contact is classified as Level Three. Handshapes with secondary selected fingers are categorized as Level Four. Selection of the Pinky only (with or without the Thumb), selection of the Middle finger only, crossing of selected fingers, and nonselected fingers which are not flexed at all the joints are classified as Level Five.

2.3 Interim summary

Both longitudinal and group studies reveal similar findings on handshape acquisition. Children only produce a subset of handshapes of the adult inventory, and this subset is used for their target productions as well as substitutions. In addition, substitutions are not random. The order of handshape acquisition is from unmarked handshapes to the marked ones as more features are acquired at later phases.

2.4 Implications on the current study

Findings from both spoken and signed languages suggest that language acquisition process is largely modality independent and children acquire the phonology of the target language systematically, demonstrating an increase in complexity along the way. In spoken language acquisition research, an accumulation of research findings allow the researchers to posit an order of acquisition in many individual languages under study so far. Also, cross-linguistic comparison shows that this order may be universal. Do deaf children acquiring a signed language also display an order of acquisition, in this case, of handshapes? Although not many, the results of the previous studies suggest that a similar order may be observed. Do deaf children acquire the structurally less complex handshapes before the more complex ones?

Moreover, in the literature on spoken phonology acquisition, it is observed that when children are nontarget in their production, the patterns of substitutions are not random but systematic. Assuming a similar process of language acquisition, it is justified to hypothesize that deaf children behave just as hearing children do in substituting more marked segments with less marked segments, i.e. replacing more marked with less marked handshapes. In the literature on the acquisition of signed language phonology, some researchers resort to markedness constraints in attempting to explain the acquisition phenomenon. However, the notion of markedness is not clearly defined in most studies. It is understandable since theories of sign language phonology are still developing, and typological findings of signed languages are not many. Therefore, it is hard to set up hypothesis based on limited data. In the following chapter, I will attempt to offer an account of markedness which will be adopted to account for the acquisition process that the deaf child of HKSL displays.

Chapter 3 Hypotheses and Methodology

3.0 Introduction

This chapter presents the hypotheses and methodology of the current study. Section 3.1 discusses the notion of markedness, and the acquisition hypotheses of the current study. Section 3.2 provides the background information of the current study, including an introduction to the subject of this study, data collection, types of signs included in the present study, coding methodology, and criteria for acquisition. Chapter 3.3 concludes the chapter.

3.1 Markedness and acquisition hypotheses of the current study

'Markedness' has been used to account for linguistic theories and acquisition of spoken and signed languages. The current study uses it to account for handshape acquisition. The notion of 'markedness' was first proposed by Nicholas Trubetzkoy and Roman Jakobson in the 1930s. The idea behind this notion is that binary oppositions of some linguistic values (e.g. open and closed syllables, nasalized and oral vowels, voiced and voiceless obstruents) are not only polar opposites but there is a difference of markedness in each pair. The difference of markedness is related to difference in typological frequency: the more frequent member of the pairs is designated as the unmarked one. The status of being 'unmarked' implies that it is simpler, more basic and more frequent than the other member of the opposition, which is the marked member. In the examples mentioned above, open syllables, oral vowels and voiceless obstruents are unmarked compared to closed syllables, nasalized vowels and voiced obstruents respectively. Haspelmath (2006) offers an excellent review of the notion of markedness and comes up with twelve senses grouped into four larger categories: markedness as complexity, as difficulty, as abnormality, and as a multidimensional correlation. Table 3.1 is adopted from Haspelmath (2006:26).

Table 3.1 Twelve senses of 'markedness ' and their typical uses

Markedness as complexity	**Example**
1.Trubetzkoyan markedness: Markedness as specification for a phonological distinction	'In German, the phonological opposition *t:d* is neutralized syllable-finally in favor of *t*, which shows that *d* is the mark-bearing member of the opposition.'
2.Semantic markedness: Markedness as specification for a semantic distinction	'In the English opposition *dog/bitch*, *dog* is the unmarked member because it can refer to male dogs or to dogs in general.'
3.Formal markedness: Markedness as overt coding	'In English, the past tense is marked (by *-ed*) and the present tense is unmarked.
Markedness as difficulty	**Example**
4. Phonetic markedness: Markedness as phonetic difficulty	'On the scale *b* > *d* > *g* > *G*, the consonants to the right are increasingly more marked.'
5.Markedness as morphological difficulty / unnaturalness	'A singular / plural pair like *book/books* is less marked than *sheep/sheep* because the latter is not iconic.'
6.Cognitive markedness: Markedness as conceptual difficulty	'The plural category is marked because it requires more mental effort and processing time than the singular.'
Markedness as abnormality	**Example**
7.Textual markedness: Markedness as rarity in texts	'For direct objects, coreference with the subject is marked and disjoint reference is unmarked.'
8.Situational markedness: Markedness as rarity in the world	'For marked situations, languages typically use complex expressions.'
9.Typological markedness: Markedness as typological implication or cross-linguistic rarity	'The syllable coda position is marked in contrast to the onset position.'
10.Distributional markedness: Markedness as restricted distribution	'Object-verb word order is the marked case: it occurs only with negation.'
11.Markedness as deviation from default parameter setting	'Absence of noun incorporation is the unmarked case, and the presence of productive noun incorporation has to be triggered by a specific parametric property.'
Markedness as multidimensional correlation	**Example**
12.Markedness as a multidimensional correlation	The singular is more marked than the plural, and the plural is more marked than the dual.'

Phonetic Markedness (Sense 4) and Typological Markedness (Sense 9) are adopted in the current study to formulate acquisition hypotheses because, so far as handshape is concerned, there has been some discussion about the relationship between hand physiology and typological markedness. Physiology has direct relevance to phonetic difficulty, which in turn has a bearing on their frequency of distribution. This issue is also discussed in Haspelmath (2006), namely that phonetic difficulty is closely related to rarity. Articulatory complexity can cause rarity since speakers unconsciously prefer expressions with simple segments for items and thus articulatorily simple segments are produced more frequently in discourse.

Markedness has been used in acquisition studies, which show that children prefer less marked structures. For example, Gnanadesikan (1996) demonstrates that in the acquisition of syllables, children first take the unmarked form of core syllables, or CV, showing a preference for the least marked onsets (i.e. segments which are least sonorant). Pater (1997) also showed that when children truncate early words with an initial unstressed syllable, they tend to preserve the consonant that is least marked (least sonorant) in the onset. Therefore, although some children truncate the word *banana* into ['nænə], others pronounce the word as ['bænə] (examples taken from Stites, Demuth, & Kirk 2004:566).

Markedness has a basis on cross-language distribution. Most of the time, structures that are frequent across languages are also frequent within a specific language, and these less marked structures are usually acquired early by children. However, whether the cross-language 'unmarkedness' or language-specific 'unmarkedness' contributes to the early acquisition of such structures is hard to claim. Zamuner *et al.* (2005) investigate into this issue by studying the coda acquisition of English-speaking children. They make two hypotheses, the first one is called the Universal Grammar Hypothesis (UGH), which "predicts that children should initially produce those sound patterns that are unmarked or frequent across languages before those patterns that are marked or infrequent" (Zamuner *et al.* 2005:1406); the second one is the Specific Language Grammar Hypothesis (SLGH), which "predicts that children should initially produce the more frequently occurring sound patterns in their ambient language before producing the less frequent ones". It has been found that coronal and sonorant codas are more frequent across languages; however, results show that children do not favor these codas; rather, it is reported that there are significant correlations between children's coda productions and the frequency of English codas. This suggests that in some aspects of acquisition, the input frequency of the ambient language (SLGH) outranks the typological frequency (UGH).

Jakobson (1941, 1968) also observes that the marked members of the oppositions are acquired later by children and are typologically less frequent, suggesting that "they are not only more complex in their abstract structure, but also more difficult for language users" (Haspelmath 2006:30). Recall from Chapter 1 that DP represents the less marked structures by specification for fewer features, or the features specified are less marked. Besides, features are less marked if they involve no dependency relationship, as in the spoken vowels /i/, /u/ and /a/).[1]

[1]Also in terms of generative approaches to language acquisition, according to Chomsky (1981:8), the theory of markedness "imposes a preference structure on the parameters of UG [Universal Grammar]... In the absence of evidence to the contrary, unmarked options are selected" (cited in Haspelmath 2006:12).

In light of Chomsky's theory and Jakobson's observation, the current study also hypothesizes that the early acquired handshapes are relatively unmarked; and handshapes which are more marked are acquired later (H1). Referring to the Handshape Unit Model, less marked handshapes invoke fewer number of nodes and the features specified are less marked, and vice versa for the more marked handshapes. Therefore, handshapes like [5] () and [1] () are predicted to be acquired early because both handshapes involve the activation of the PSF node only. The handshape [5] () is specified for [all], the least marked feature in the Quantity node, [extended], the least marked feature in the Joint position node, and [spread] of the Finger position node is predicted as shown in Table 1.4. The handshape [1] () is specified for [one], the second least marked in the Quantity node; it is also specified with the least marked POR feature [radial] and the least marked Joint position feature [extended]. Applying the Handshape Unit Model, the handshapes [5] () and [1] () are represented in Figures 3.1 and 3.2 respectively.

Figure 3.1 [5] ()

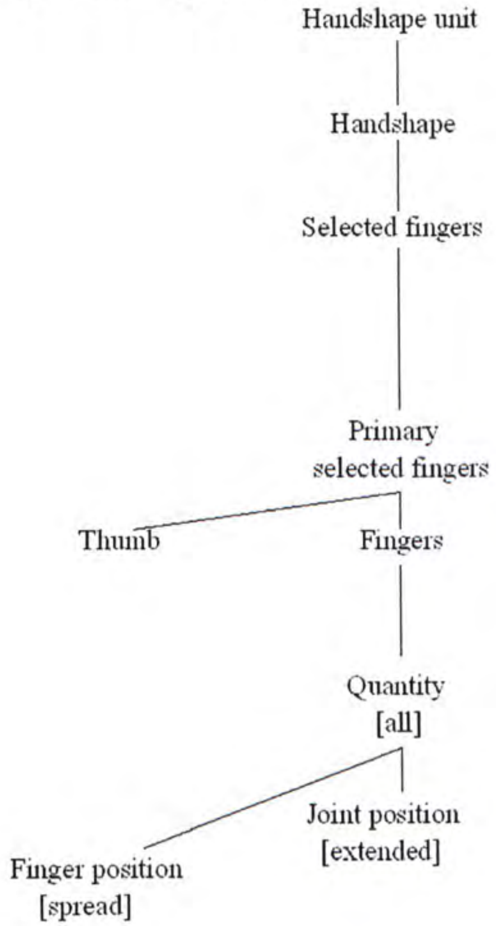
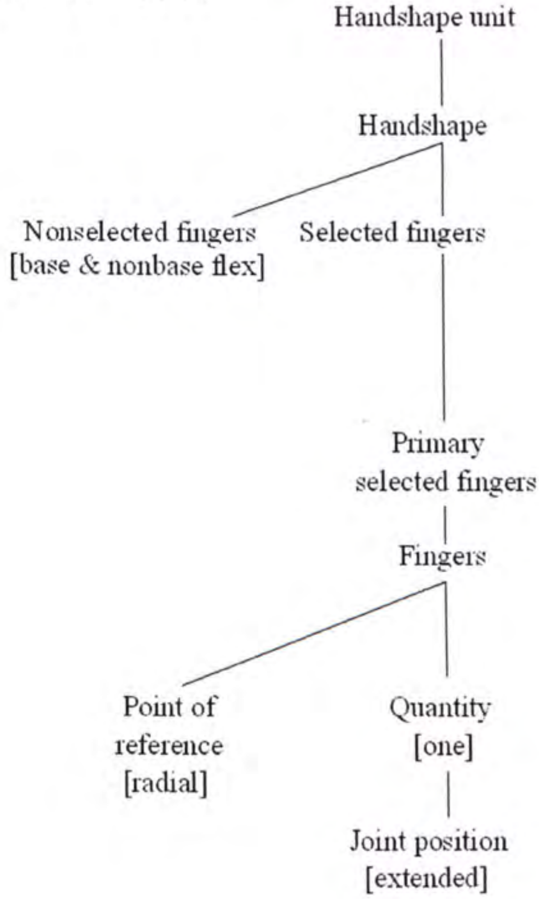


Figure 3.2 [1] ()



In contrast, handshapes such as [I] () and [Wc] () are more marked because they involve the activation of more nodes and / or the specification of more marked features. Although the handshape [I] () does not invoke the SSF node and it is specified for [one], the second least marked feature in the Quantity node, it is not specified for the least marked POR feature [radial], but the medially ranked feature [ulnar]; it is also specified for the most marked Joint position feature [nonbase flex]. This combination makes a relatively marked handshape and it is predicted that such a handshape would be acquired late. The handshape [Wc] () invokes the SSF node which adds to a large degree of structural complexity, and indeed all handshapes involving SSFs are predicted to be acquired late. Applying the Handshape Unit Model, the handshapes [Ï] ( ) and [Wc] ( ) are represented in Figures 3.3 and 3.4 respectively.

Figure 3.3 [Ï] ( )

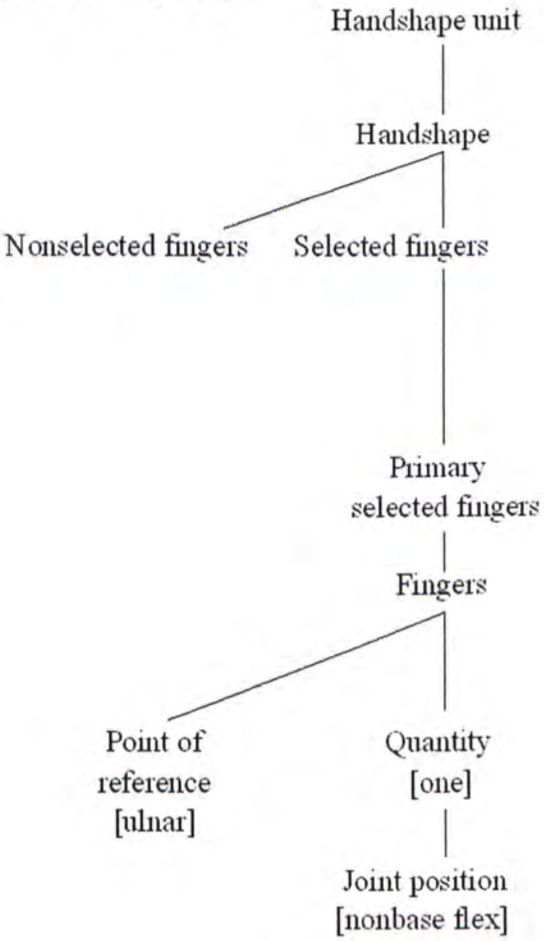
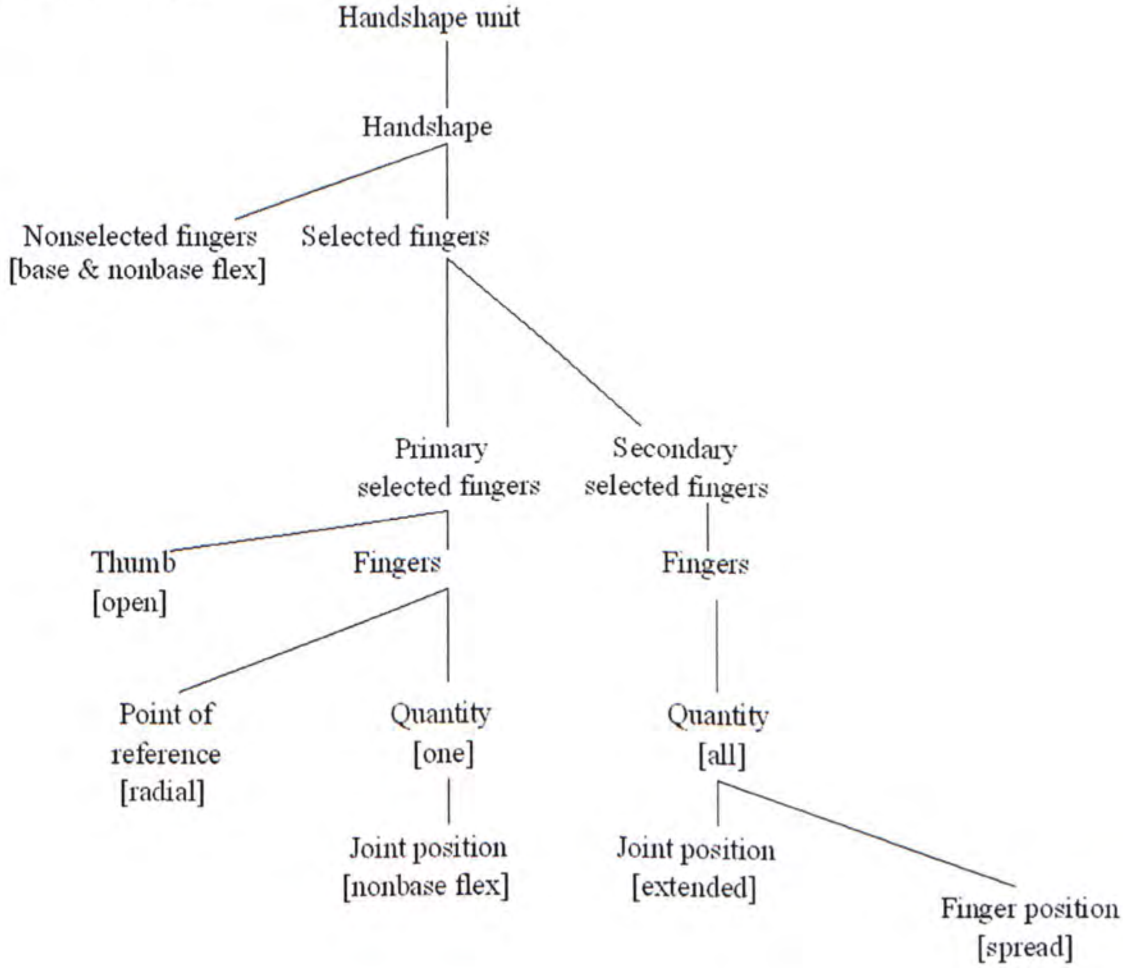


Figure 3.4 [Wc] ()



The second hypothesis (H2) is proposed following the claims in the handshape acquisition literature. It has been claimed that when children are nontarget in their productions of handshape, they substitute the target handshapes with other less marked handshapes and their substitutions are not random. The current study tests against this hypothesis too.

According to Kooij (2002), the more elements a DP presentation consists of, the more complex the structure is. Hence, the third hypothesis (H3) goes like this: the overt specification of the HIM branch as a dependent branch makes a structure more complex. Consequences are that children will acquire this marked representation late. Therefore, the accuracy rates of finger selection and finger configuration tend to drop with the requirement of HIM in the configuration. Finger selection refers to the combination of the Quantity and the POR nodes, and finger configuration refers to the combination of the Joint position and the Finger position nodes proposed in Chapter 1.

To conclude, the Handshape Unit Model shows two levels of markedness. At one level, typological markedness forms the basis of feature markedness ranking according to frequency of distribution. When the literature is available, the findings generally offer support to the physiology account proposed by Ann (1993). At another level, structural complexity of the phonological representation of the handshape unit also entails a degree of markedness, namely that a more complex representation is structurally more marked, hence acquired late. In this section, three acquisition hypotheses are derived from these two assumptions. In the next chapter, the Handshape Unit Model will be used as a tool to test against the three hypotheses with respect to the HKSL data collected in the current study.

3.2 Background information for the current study

3.2.1 Subject of the present study

The participant, known as CC here, is a male child of deaf parents and he has prelingual moderate/severe hearing loss. He did not have much exposure to HKSL because his parents at first resisted the idea of interacting with him through signing. They mainly communicated with him through speech or sign-supported speech. They only changed their attitudes after meeting with the research team. Therefore CC was first exposed to HKSL when he was 1;9.6, so this can be considered a case of late acquisition. At the same time, a female research assistant went to his home to teach him sign language around 5 days a week. Each session was around one hour. After one summer, as CC showed stable acquisition of HKSL, she reduced the frequency of home visits and teaching to around two days a week, again, around one hour per visit. CC got most of the HKSL exposure through interacting with the two native Deaf research assistants during the home visits and videotaping sessions, with his parents in his daily life and through observing the sign interaction of the Deaf adults.

3.2.2 Data collection

The data are videotaped natural interactions with basically two Deaf research assistants, one male and one female, who are native HKSL signers. The videotaping was conducted at CC's home on a weekly basis, with one hour per session. During the videotaping session, the participants played with different toys and household objects (for example, toothbrush, cup, toy car etc.), picture cards and story books were used also. One video camera was used when the child was from 1;9.6 to 2;3.4. From 2;4.16 onwards, two video cameras were used. One was used to videotape the signing of the child and his interlocutors, while the other was directed at the child alone. The videotaping started when the child was around 1;9 and at that time he was already at the one word stage with only a little babbling, and so only the 'words', i.e. the signs, are analysed but not the 'babbles'. Table 3.2 shows the age and duration of the videotaped data which are analyzed in this study.

Table 3.2 Age and duration of the videotaped data

Age	Duration (hour:minute:second)
1;9.6	01:09:29
1;10.10	01:24:09
1;11.8	01:30:17
2;0.12	01:06:32
2;1.9	01:00:47
2;2.14	01:00:07
2;3.4	01:00:35
2;4.16	01:01:26
2;5.6	01:00:06
2;6.3	00:55:54
2;7.3	01:02:24
2;8.6	01:02:19
2;9.11	01:01:29
2;10.9	01:00:04
2;11.13	00:59:56
3;0.13	01:00:14
3;1.8	01:00:16
3;2.3	00:59:42
	Total: 19:15:46

3.2.3 Types of signs included in the present study

In the current study, I trace the acquisition of handshapes of CC for one and a half year on a monthly basis. A sign by the child in this study is defined as a manual action with an interpretable meaning in an interactional context, and only spontaneous signs are included. Only one-handed noncompound[2] lexical items are included as data for analysis. A list of the lexical units in which the handshape units occur is given in Appendix C, and the corresponding specified HIMs are also shown. Two-handed lexical or classifier

[2]Compound will be discussed more thoroughly in Section 3.2.3.1.

predicate[3] signs are excluded from the current study because the presence of the nondominant hand increases the complexity of the phonological configuration of the sign. For example, if both hands are engaged in motor acts, the issue of symmetrical and identical orientation needs to be introduced. For two-handed signs in which only one hand moves, two hands may assume different handshapes, and at this stage, it is not known how the differences in orientation and in handshape combinations may affect the acquisition of handshapes. These issues are definitely worthy of investigation, but in this study I would like to set up a modest goal and focus on only one-handed signs.

As for compounds, they usually involve a handshape change rather than a predictable handshape contour[4]. A handshape change in the production of compounds is theoretically less comparable to the majority one-handed lexical items. The occurrence of compounds and classifier predicates only contribute to a very small proportion to the entire data set since CC was still at the initial stage of language development. Therefore, excluding them from the current analysis would not obscure the general developmental pattern.

[3]Classifier predicate will be exemplified in Section 3.2.3.1.

[4]The concept of handshape contour will be illustrated in Section 3.2.3.1

Signed numbers are also excluded from the current study because the number system in sign languages in general tends to make use of only one hand (i. e. 5 digits) to represent 1 to 10, and it is not uncommon to see signed numbers with handshapes which are relatively less productive or infrequent in the lexicon. For example, in HKSL, SEVEN assumes the handshape [Û](), and this is absent from one-handed signs according to Tang (2007). Owing to this reason, attempts of signed numbers are discarded from the current analysis.

Name signs are also excluded from this study. As I observe, some of the name signs used by HKSL signers involve handshape clusters, or they are produced in locations which are rarely used in the native lexicon. As such, I decided to exclude all name signs from the current study.

Altogether 1252 sign tokens were coded and analyzed. Among the 60[5] handshapes listed in Tang (2007), only 32 were attempted by CC (53.3%) if only one-handed lexical items are counted.[6]

[5]The handshapes listed in Tang (2007) are phonetic rather than phonemic. As such, within the set of attempted handshapes, some of them may be allophonic variations.

[6]This figure does not include signed numbers.

3.2.3.1 Identification of handshape for analysis: signs with more than one handshape

There are signs which involve more than one handshape. "Handshape sequence may arise from a variety of sources" (Corina 1993), and they are shown in Table 3.3.

Table 3.3 Handshape sequences arising from different sources

	Source	Sign Example in HKSL	Surface Handshape Sequence
1	Compounding	PARENTS (see Clip 3-1)	[Ȧ] () → [1] ()
2	Fingerspelled loans	CD (see Clip 3-2)	[C] () → [D] ()
3	Classifier predicates	A plane flew down, one of its wingspans crashed onto the mountain, and it broke. (see Clip 3-3)	[ẏ] () → [i] ()
4	Monosyllabic signs	DISCARD (see Clip 3-4)	[S] () → [5] ()

According to Corina (1993), handshape sequences arising from sources 1 – 3 (called handshape clusters) behave qualitatively differently from 4 (known as handshape contours). The differences can be summarized in Table 3.4.

Table 3.4 Differences between handshape cluster and handshape contour

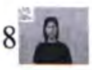
Handshape cluster	Handshape contour
Less restricted in inventory and composition: -two or more distinct handshapes within a single sign allowed -the handshapes can use the same or different selected finger(s)	More restricted in inventory and composition: -a single sequence of two distinct handshapes -the handshapes must use the same selected finger(s)
Duration of path movements significantly longer than monosyllabic signs without handshape change	Duration of path movements similar to monosyllabic signs without handshape change

With respect to the findings above, Sandler (1989) points out that in monosyllabic signs with handshape contour, the two distinct surface handshapes actually belong to the same underlying handshape. Corina (1993) suggests that the underlying handshape is the one which preserves in phenomena such as allophonic variation or historical change.[7]

In the current study, only signs without handshape changes and those which involve handshape contour are included. The movement which derives the handshape contour is called hand-internal movements (HIMs) here. If a sign involves handshape contour, the handshape which can be used independently to form a lexical sign is taken as the 'underlying' one to be analyzed, and the other one is derived by the HIM. For example, in HKSL, in the sign SHEEP (see Clip 3-5 ), the initial handshape is [B̈] (), with four fingers and the thumb on each side of the cheek, and it is signed with a downward movement and the fingers simultaneously close to [B̂] () at the end of the sign. [B̂] () can be used independently to form a sign as in FOOD (see Clip 3-6 ), but it is not the case for [B̈] (): whenever it appears, it involves opening or closing, as in MORNING

[7]For a detailed discussion of allophonic variation and historical change, readers can refer to Corina (1993).

(see Clip 3-7 ) and NIGHT (see Clip 3-8 ) respectively. The only instance in which the handshape [B̈] ( ) does not involve any hand-internal movement is the classifier handshape depicting a prism. It is two-handed, with the finger tips of one hand touching those of the other hand (see Clip 3-9 ). Another similar example is a sign involving the handshapes [5] ( ) and [O] ( ). The former is taken as the underlying handshape because very often when the handshape [O] ( ) appears, it involves opening as in FIRE (see Clip 3-10 ), WHITE (see Clip 3-11 ), SUN (see Clip 3-12 ) , FORGET (see Clip 3-13 ), MUSTARD (see Clip 3-14 ), SPEAK (see Clip 3-15 ) and SUGGEST (see Clip 3-16 ) etc.

According to the Hong Kong Sign Language Dictionary (Tang 2007), only two one-handed lexical signs make use of the handshape [O] ( ) without opening. They are PERCENTAGE (see Clip 3-17 ) and SHOOTING-STAR (see Clip 3-18 ). If a sign involves the handshapes [5] ( ) and [S] ( ), the latter is taken as the underlying one because in signs involving these two handshapes, the handshape [5] ( ) is not necessarily fully extended but the handshape [S] ( ) must be fully flexed as in the sign TAKE (see Clip 3-19 ).

So it is evident that [B̈] ( ) is an allophonic variation of [B̂] ( ). As such, SHEEP assumes the underlying handshape [B̂] ( ), and it is specified for the HIM [close].

3.2.4 Coding of the data

Each sign is coded with two categories of information: general information and linguistic information. General information includes a meaning gloss, the age of production, and the time of the video when the sign is produced. Linguistic information refers to the features based on my proposed Handshape Unit Model. Each handshape is specified for certain features, and CC's production is coded as target or nontarget to each of the feature. All the signs are input into separate excel sheets according to the nature of the production, including spontaneous, imitation with explicit instructions[8], imitation without explicit instructions, and miscellaneous[9]. Afterwards, all the imitation data with explicit instructions were discarded because they were not the child's natural production, especially for the signs which were physically manipulated by an adult. Imitation data without explicit instructions were also discarded from the analysis because they were not much different from the spontaneous productions in terms of the handshapes, and in order to minimize the possible adult influence, these data were discarded from the analysis. Miscellaneous[9] data were also discarded, and thus finally, only the spontaneous data were left for analysis.

When CC's hand was occupied with an object, the manual action was not coded. Some nonlinguistic gestures were also excluded from analysis, for example, reaching for objects, touching body parts showing uneasiness like hurts, summoning others, and hitting others. These manual activities were nonlinguistic and should not be included as data in the analysis of sign language acquisition. Another type of production discarded from the analysis was pointing signs, which involve the extended index finger being

[8]Explicit instruction refers to forming the handshape once again in front of the child at the cost of a wrong location, adding orientation change to help the child see the different parts of the fingers, or manipulating the child's hand(s) physically.

[9]This includes cases where the child is the only one on the screen, and it cannot be judged whether the production is spontaneous or not.

directed towards a person, object, or location (Marentette 1995). Pointing signs have anaphoric and deictic functions in sign language and thus could be considered lexical in HKSL. However, it is difficult to differentiate between a "common pointing" and a "linguistic pointing" which carries demonstrative or locative information in sign language, because 'any criteria chosen to make this distinction are arbitrary" (Pizzuto 1990, cited in Marentette 1995). Neither is it clear that at what age pointing begins to serve the linguistic functions (Marentette 1995). Owing to these reasons, pointings are not considered lexical in the present study and excluded from analysis.

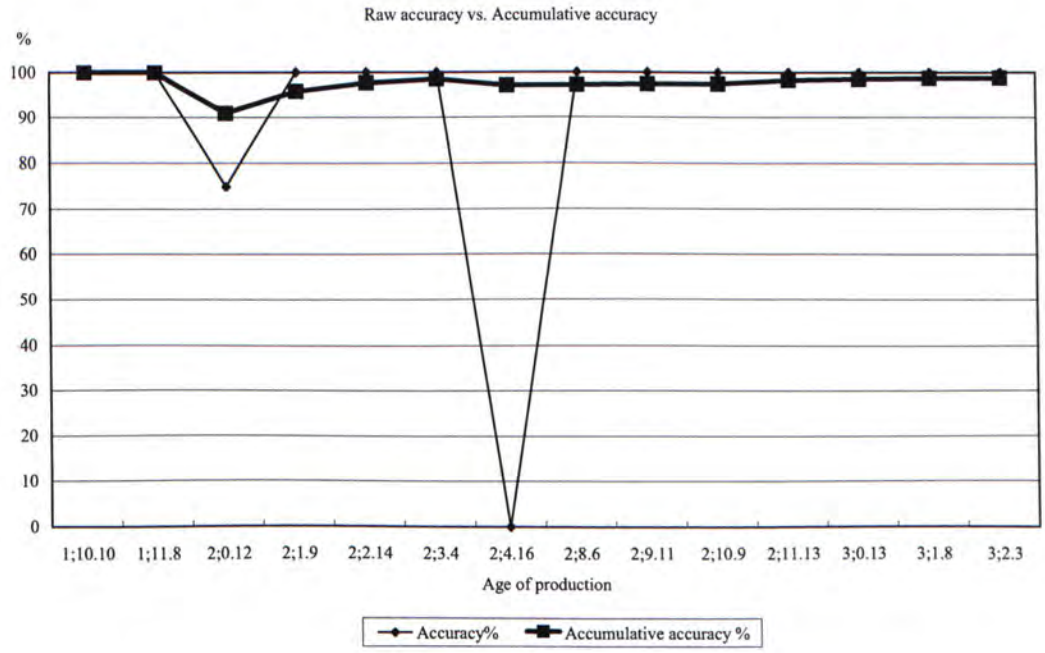
3.2.5 Criteria for acquisition

Whether a handshape has been acquired or not is determined by its accumulative accuracy and its accumulative frequency of attempts. A handshape is considered as 'acquired' if the following two criteria are met: 80% accumulative accuracy is reached and the accumulative frequency of attempts is at least 5. Accumulative accuracy is used because it can show the developmental progression of each single handshape without any confusion or misleading representation. Accumulative accuracy shows the number of attempts and accuracy proportionally. The following table and figure are made up for illustration:

Table 3.5 Made-up table for illustrating the use of accumulative accuracy

Age	No. of target productions	Total no. of production:	Accuracy%	Accumulate target	Accumulate production	Accumulative accuracy %
1;10.10	4	4	100	4	4	100
1;11.8	3	3	100	7	7	100
2;0.12	3	4	75	10	11	90.90909091
2;1.9	13	13	100	23	24	95.83333333
2;2.14	19	19	100	42	43	97.6744186
2;3.4	26	26	100	68	69	98.55072464
2;4.16	0	1	0	68	70	97.14285714
2;8.6	2	2	100	70	72	97.22222222
2;9.11	5	5	100	75	77	97.4025974
2;10.9	1	1	100	76	78	97.43589744
2;11.13	40	40	100	116	118	98.30508475
3;0.13	18	18	100	134	136	98.52941176
3;1.8	21	21	100	155	157	98.72611465
3;2.3	3	3	100	158	160	98.75

Figure 3.5 Made-up figure for illustrating the use of accumulative accuracy



Referring to the age of production 2;4.16, if raw accuracy is used, it drastically drops to 0% (the thinner line with dots). It should be noted that raw accuracy can be misleading and confusing because it does not represent the data proportionally. For example, in this case, in the session 2;4.16, the subject actually only attempted the handshape once and produced it wrongly; if accumulative frequency is used, it shows a drop of accuracy, but it is only a slight drop because the proportion of sample size is taken into consideration in such representation (the thicker line with squares).

Accumulative frequency of attempts should at least be 5 in order to avoid too small a sample size. The results attained from a small sample size are relatively insignificant.

3.3 Chapter summary

This chapter discusses how markedness has been used to describe, explain, and predict different phenomena in linguistics. 'Markedness' in the current study is represented by structural complexity as suggested by DP and some features are ranked according to typological and physiological data. Three hypotheses are formulated. In light of Chomsky's theory and Jakobson's observation, the current study hypothesizes that the acquired handshapes are relatively unmarked and handshapes which are more marked are acquired later (H1). The second hypothesis (H2) is proposed following the claims in the handshape acquisition literature: when children are nontarget in their productions of handshape, they substitute the target handshapes by other less marked handshapes and their substitutions are not random. According to Kooij (2002), a more complex structure involves the specification of more features. Hence, a structure is more complex with the overt specification of the HIM branch. Since children acquire marked structures later, my third hypothesis (H3) is that the accuracy rates of finger selection and finger configuration tend to drop with the requirement of HIMs. The second part of this chapter provides the background information of the current study, including an introduction to the subject of this study, data collection, types of signs included in the present study, coding methodology, and criteria for acquisition.

Chapter 4 Results

4.0 Introduction

The three hypotheses proposed in Chapter 3 will be verified in this chapter. To recapitulate, they are as follows:

Hypothesis One (H1):

There is an order of acquisition of handshapes and the order is in an increasing degree of markedness;

Hypothesis Two (H2):

When children are nontarget in their production of handshapes, they substitute the target handshapes with other less marked handshapes and these substitutions are not random;

Hypothesis Three (H3):

The accuracies of finger selection and finger configuration tend to drop with the requirement of HIMs due to the requirement of a more marked structure, involving HIM as a dependent structure of the Handshape unit.

Section 4.1 will focus on the verification of H1 using CC's production data and some acquisition findings from several other studies. Section 4.2 discusses the handshapes that were not attempted by CC during the period of observation. Section 4.3 focuses on verifying H2 and the substitution errors he produced. Section 4.4 focuses on H3, namely the relationship between HIM and handshape acquisition.

4.1 Order of Acquisition of HKSL handshapes

4.1.1 Analysis of CC's data

H1 hypothesizes that there is an order of acquisition of handshapes and the order is in an increasing degree of markedness. Table 4.1 shows the order of acquired handshapes. The age of acquisition refers to the earliest videotaping session in which the data fulfill the two criteria of acquisition defined in this study, i.e. an accumulated accuracy of 80% and accumulative attempts of 5 or more. The rightmost column shows the accumulative accuracy reached at the corresponding videotaping session. The order of acquisition is presented in the table, and since CC is a case of late acquisition, the chronological age presented may not be relevant for comparison with deaf children in other acquisition studies who are exposed to an accessible first language immediately after birth.

Table 4.1 Order of acquired handshapes[Note]

Age of acquisition	Acquired handshapes	Accumulative. accuracy (%)
1;9.6		
1;10.10	[1] ( )	85.7
1;11.8	[5] ( )	100
2;0.12	[Ĝ] ( )	100
2;1.9		
2;2.14	[Ȧ] ( )	100
2;3.4		
2;4.16		
2;5.6		
2;6.3	[S] ( )	100
2;7.3		
2;8.6		
2;9.11		
2;10.9	[B̂] ( ) with [once] [closing]	100
	[O] ( ) with [once] [opening]	100
2;11.13	[A] ( )	100
	[ɪ] ( )	100
3;0.13	[S] ( ) with [once] [closing]	87.5
	[I] ( )	80.8
3;1.8		
3;2.3	[⅄] ( )	82.9

[Note]The handshapes are without HIMs unless otherwise specified.

Similar to findings in the previous studies, [1] ( ), [5] ( ) and [Ĝ] ( ) were acquired very early. [Ȧ] ( ) was also acquired early in HKSL but this handshape has not been widely discussed in the literature. This is also a relatively unmarked handshape because only the Thumb is selected without any other specifications such as HIM or SSF. The handshapes [1] ( ), [5] ( ), [Ĝ] ( ) and [Ȧ] ( ) are represented in Figures 4.1 to 4.4 respectively, using the proposed Handshape Unit Model.

Figure 4.1 [1] (☝)

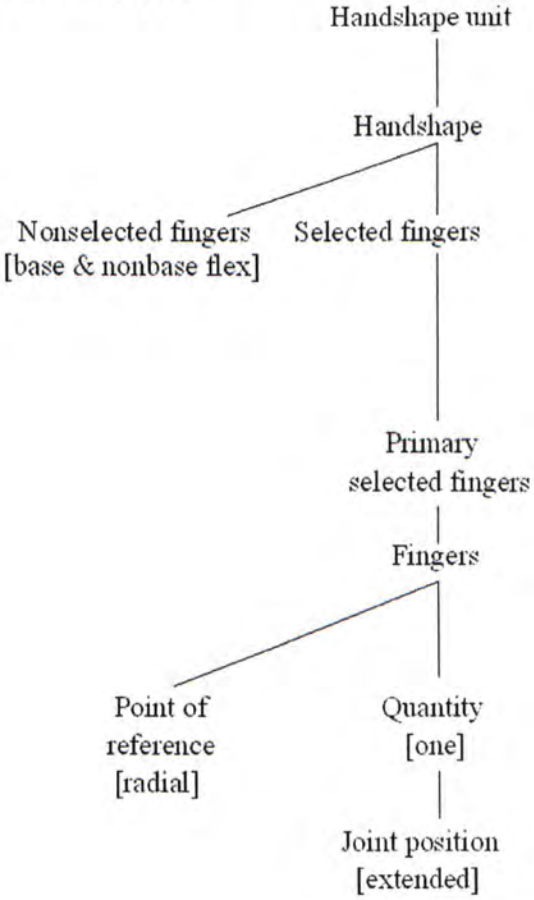


Figure 4.2 [5] (✋)

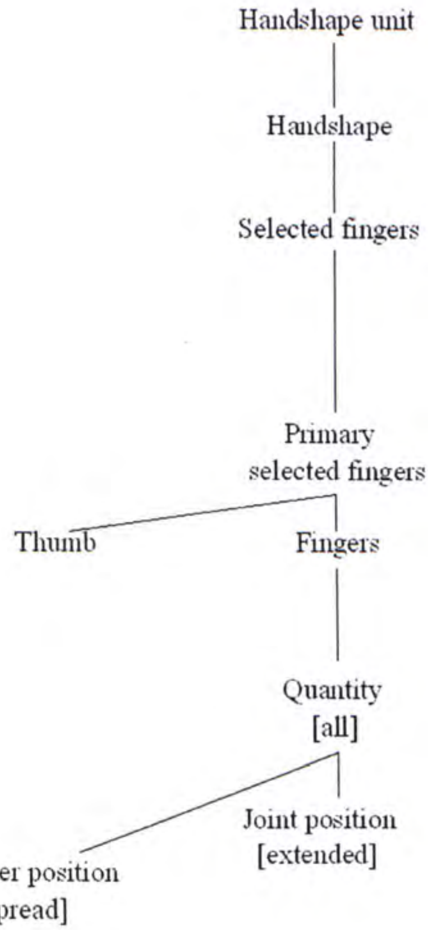


Figure 4.3 [Ĝ] ( )

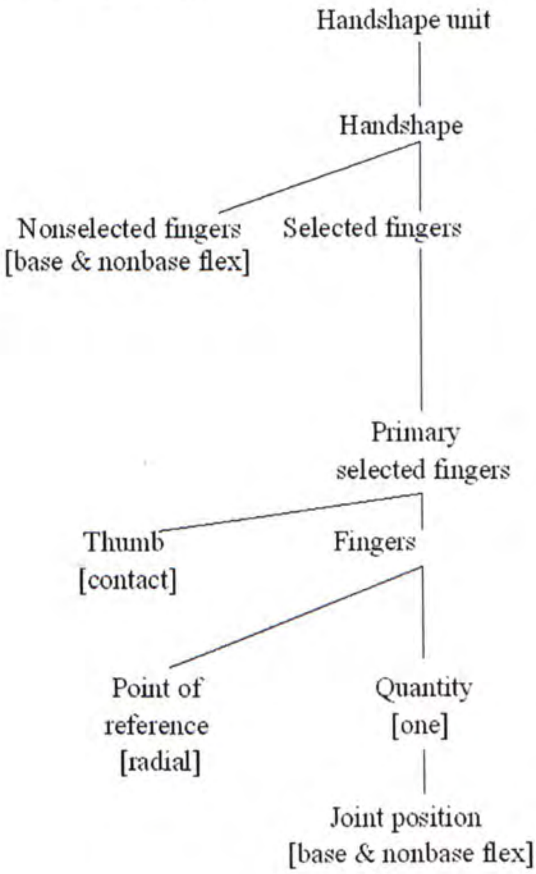
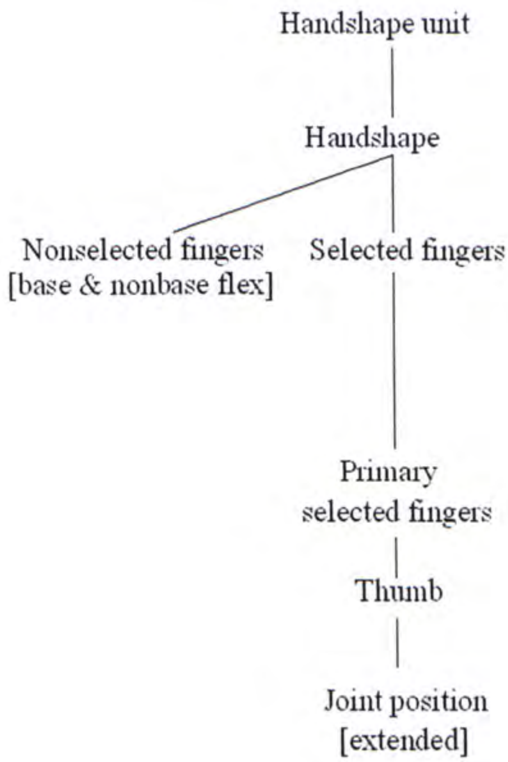


Figure 4.4 [Ȧ] ( )



As shown in Figures 4.1 to 4.4, the handshapes are not very complex structurally, for example, the HIM and SSF nodes are not yet acquired. Moreover, features involved are the least marked or relatively unmarked, and some of the features are predicted. All handshapes observe the NSFRR except for the handshape [Ĝ] ( ) because the non-selected fingers are closed (flexed at both the base and nonbase joints) rather than open (extended) as it is usually predicted by the NSFRR. The NSF node even does not need to be specified for the handshape [5] ( ). The two least marked PSF Quantity features are acquired, they are [all] and [one]. Only the least marked POR feature [radial] is acquired. Three of the handshapes are specified for the least marked PSF Joint position feature [extended], with the other one specifying for a relatively unmarked feature [base & nonbase flex]. The Finger position feature [spread] in the handshape [5] () is predicted from the Joint position feature [extended] as mentioned in Table 1.4.

Unlike findings from other studies, [S] () was not acquired as early as usually expected in the literature. For example, in Boyes Braem's study (1990), [S] () was predicted to be acquired at the first stage. In my study, however, [S] () was acquired relatively later than the earliest acquired handshapes like [1] (), [5] () and [Ĝ] (), which clearly form a cluster. Although [S] () is acquired later when compared to the literature, this may be due to nonlinguistic reasons. [S] () was used only in the sign ICE-CREAM (see Clip 4-1 ) by CC. The sign first emerged when he was 2;6.3 within the scope of the data studied, and he produced it six times and all were target in that session. Therefore, this later acquisition is not a challenge to the findings generally reported in the literature. Neither does it falsify my postulated Handshape Unit Model.

The handshapes which were acquired towards the end of the observed period involved a wider range of features (or feature combinations), thus more marked, for instance, [base flex] with Thumb [contact] as in [B̂] (), [base & nonbase flex] with Thumb [contact] as in [O] (). [Ulnar] in [I] () and [Middle] in [⅄] () are relatively more marked in the POR node (c.f. Section 1.4.12), and they were also acquired towards the end of the observed period. This supports the proposed markedness of the features in the POR node because [middle] ([⅄] (), aged 3;2.3) is postulated to be the most marked POR feature and it is acquired later than [ulnar] ([I] (), aged 3;0.13), which in turn is acquired much later than the least marked feature [radial] ([1] (), aged 1;10.10). At a later stage, one of the handshapes which had been already acquired, i.e. [S] (), were produced accurately even when HIM was specified. The fact that the handshape [S] () without HIM is acquired earlier than [S] () specified for [closing] supports the prediction of my proposed Handshape Unit Model because the HIM adds a dependent to the structure and yields a relatively more marked structure. Two handshapes acquired towards the end of the observed period observed are represented in Figures 4.5 to 4.6.

Figure 4.5 [B̂] () **with [once] [closing]**

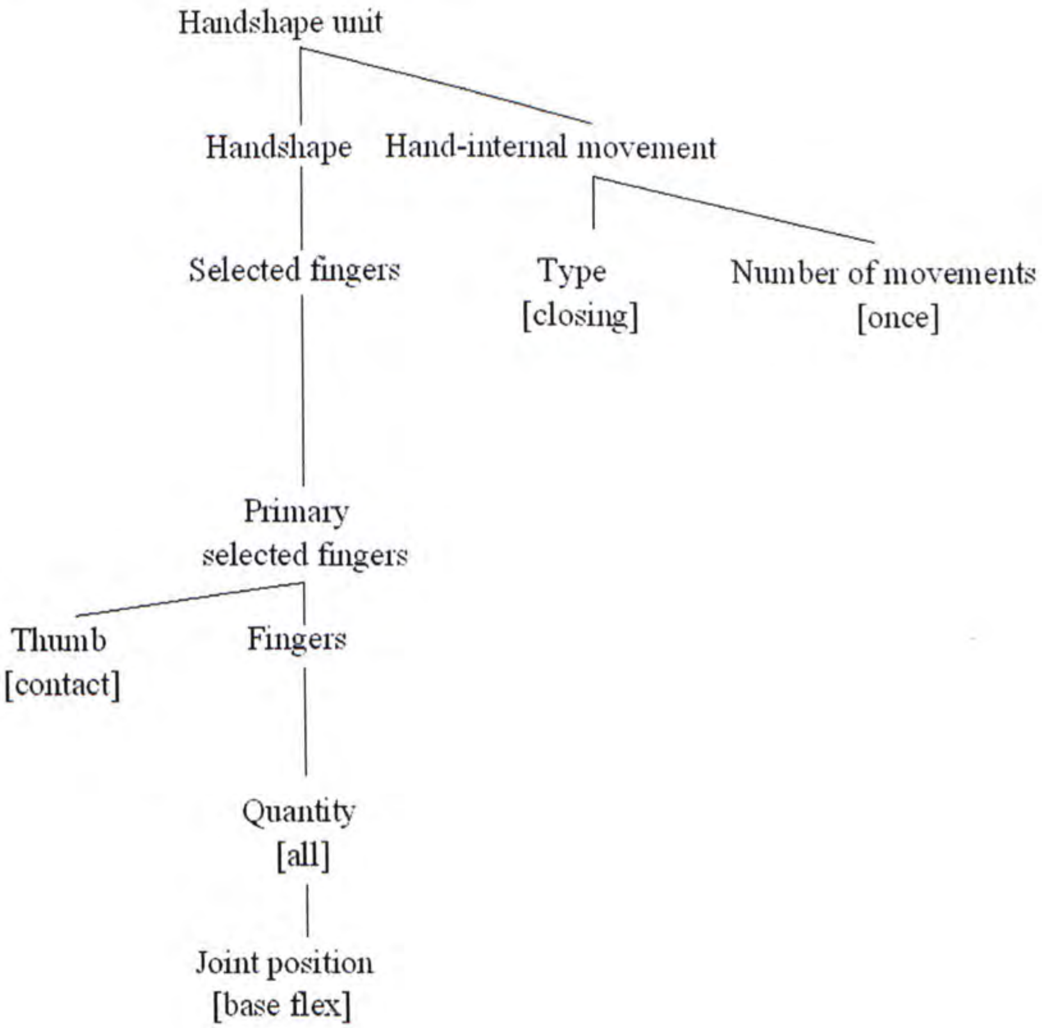
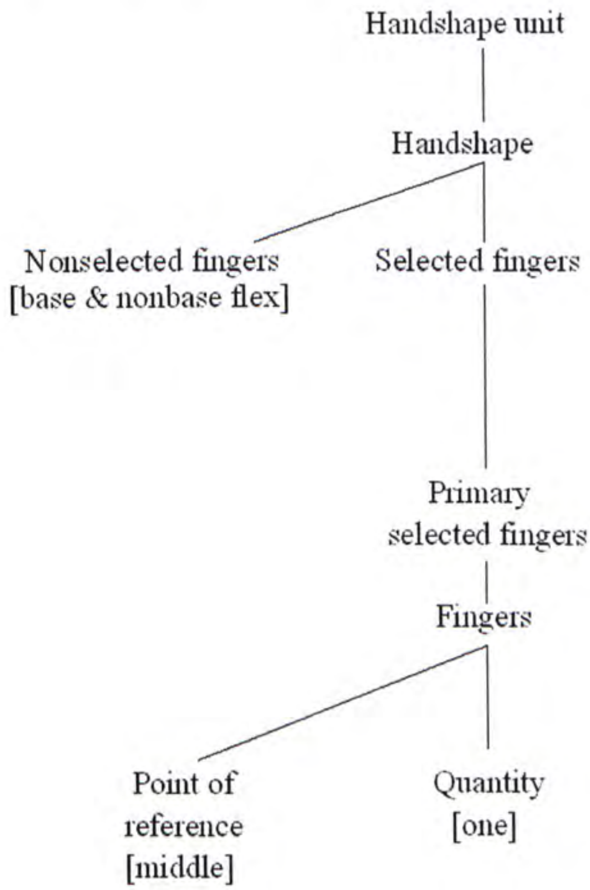


Figure 4.6 [人]



The HIM node does not appear during this early stage of development, but does so towards the end of the observed period, as shown by the acquisition of [once] [closing] of [B̂]. The most marked POR feature of the PSF node, [middle], is acquired at the last videotaping session, which confirms H1: the more marked handshapes are acquired later.

To conclude, the data in this section confirm H1: there is an order of acquisition of handshapes and the order is in an increasing degree of markedness.

4.1.2 Data from other handshape acquisition studies

In this section I would like to compare the findings of the current study with the findings reported in several other studies. Since the age of the subjects varies across different studies, the reported accuracies are used as a reference to suggest the order of acquisition; a higher accuracy implies that the involved handshape is acquired earlier. The rates are divided into four groups with an interval of 5% in order to show the general order of acquisition. As different studies employ different criteria to determine whether a handshape is acquired or not, for the sake of consistency, I use the criteria defined in the current study to identify which handshapes are acquired in other studies and present them in Table 4.2. Some handshapes with an acquired HIM node are shown in Table 4.1, but they are omitted in Table 4.2 because other acquisition studies typically exclude handshapes with HIMs. Even if they are included in those analyses, they are represented separately as independent units, like 'initial handshape' and 'final handshape' (Siedlecki 1991). This makes a direct comparison with other studies difficult, if not entirely impossible.

Table 4.2 Order of acquisition across studies based on production accuracy

%	Current study[a]	McIntire (1977)	Boyes Braem (1990)	Siedlecki (1991)	Marentette (1995)
96-100	[5]	[5]			
	[Ĝ]		[Ĝ]		
	[Ȧ]				
	[S]				
	[A]		[A]		
	[i]				
			[C]		
			[D]		
			[V̇]		
91 -95					[A]
			[5]		
			[1]		
			[Ḃ]		
86-90	[1]				
			[i]		
80-85	[I]				
	[⅄]				
		[1]		[1]	
		[Ĝ]			

[a]Accumulative accuracy shown in Table 4.1 is adopted here.

Referring to Table 4.2, H1 is generally confirmed regarding data from the current study because the handshapes with the highest accuracies are relatively unmarked and those with lowest accuracies are more marked, as demonstrated in Section 4.1.1 above.

H1 is strongly confirmed regarding data from McIntire (1977). The handshape [5] attains the highest accuracy and it is very unmarked because it is specified for the least marked feature of the PSF Quantity node, [all], together with the selection of the Thumb; and it is also specified for [extended], the least marked feature of the PSF Joint position (see also Figure 4.2 for the phonological representation). The handshapes [1] and [Ĝ] fall into the group of lowest accuracies and they are more marked than [5]. [1]

() is more marked than [5] () because [1] () needs to activate the NSF node. It is specified for [one] in the Quantity node, which is more marked than [all]. The POR node is also specified, but not so in the handshape [5] (). [Ĝ] () is even more marked because besides selecting [one] and specifying the Thumb for [contact], the handshape specifies for [radial] in the POR node. The Joint position is not specified for the least marked feature, which is [extended], but rather [base & nonbase flex]. (see Figure 4.1 & 4.3)

H1 is generally confirmed with the data from Boyes Braem (1990). The handshapes [Ĝ] () and [A] () attain a high accuracy and they are relatively unmarked. [i] () is lower in accuracy compared to [1] () and this confirms H1 because [i] () is structurally more marked than [1] ().

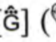
If adopting the criteria of acquisition used in the current study, only one handshape was acquired in Siedlecki (1991) and Marentette (1995) because the accuracy of the handshapes produced by their subjects are relatively low. In order to get a more comprehensive view of the acquired inventory, the handshapes which reached 60% of accuracy or above and with five attempts are also singled out, so handshapes [A] () (71.9%), [5] () (70.8%) and [Ḃ] () (64.6%) are included in Siedlecki (1991); handshape [1] () is added to the acquired data in Marentette (1995). H1 is confirmed in a pair of data in Siedlecki (1997): the accuracy of [Ḃ] () is lower than [5] () because [extended] with [nonspread] is more marked than the physiologically predicted [extended] and [spread] (c.f. Table 1.4).

The handshape [1] () is relatively unmarked according to the proposed Handshape Unit Model because it is specified for [one], the second least marked feature of the Quantity node under the PSF node, and it is also specified for the least marked POR and Joint position features, [radial] and [extended] respectively. However, its production accuracy is below 90% in four of the studies reported above, which is quite unpredicted.

Some handshapes are acquired in one study but not the others. The handshapes [C] (), [D] (), and [V̇] () were acquired in Boyes Braem (1990) but not in other studies. The first two handshapes are used in fingerspelled alphabets 'C' and 'D' respectively. Since fingerspelling is quite common in America, this may contribute to the successful acquisition of these handshapes. The handshape [V̇] () is a number sign '3' in ASL and is also the classifier for vehicle, hence it should be highly frequent in the sign language input to deaf children. If this is correct, frequency of input is also an important factor in the acquisition of handshapes in sign languages. The acquisition of the three relatively more marked handshapes at an early stage may also due to the age of the subject. In Boyes Braem (1990), the child was aged 2:7 when the data were collected. Presumably the child had reached an advanced stage of phonological development because the child started to acquire sign language since birth. It explains why she could produce these more marked handshapes with a high accuracy.

Similarly, two relatively marked handshapes [I] () and [人] () were only acquired by the subject of the current study, but it should be noted that they were acquired towards the end of the observed period, when the subject was 3;0.13 and 3;2.3. The handshape [I] () was used in YOUNGER-SISTER, BAD and WRONG; whereas the handshape [人] ()

was used in ELDER-BROTHER. This may be due to a language specific reason because HKSL makes use of these two handshapes to generate signs mentioned above and they become quite frequent in child input because teaching children kinship terms or what is right or wrong occurs frequently in daily interactions between the mother and the child. Moreover, the subject, being the 'elder brother' in the family, has a 'younger sister'. This is similar to the finding of coda acquisition mentioned in Chapter 3, the SLGH outranks the UGH in this case. Moreover, in the videotaped sessions, it is observed that both the subject and the Deaf researcher always talked about this younger sister and sometimes the Deaf researcher even gave him explicit instruction on the formation of these two handshapes. Therefore, language specific reasons, frequency of input and output, and even explicit instruction may all lead to CC's acquisition of the two handshapes.

Despite the differences mentioned above, the data in the current study generally show a set of common handshapes acquired during this stage of development. They are [5] (), [ĉ] (), [A] (), [ı] (), and [1] (). This is similar to the phenomena reported in the spoken language phonology acquisition. Referring to Section 2.1.2, 11 different consonants, /h/, /w/, /j/, /p/, /b/, /m/, /t/, /d/, /n/, /k/, and /g/, account for a large proportion of consonant productions in children exposed to different languages (Locke and Pearson 1992). This shows that there is an inventory of acquired or produced phonological units commonly acquired by children. Moreover, the inventory usually contains relatively less marked members of the set. It supports H1 that children acquire the less marked handshapes first, and the general order of acquisition is from less marked handshapes to more marked ones.

4.2 Not-attempted handshapes

Some handshapes appear in the HKSL inventory but were not attempted by CC over the period of study, and they are shown in Table 4.3. The handshapes are first arranged according to the number of finger selection in descending order, and if the handshapes share the same number of finger selection, they are further arranged from fully extended to fully flexed, followed by those with secondary selected fingers.

Table 4.3 Not attempted handshapes[Note]

Handshapes
[E]
[5̈]
[B̈]
[4]
[3]
[W_{NS}], [Ẅ]
[V̇], [V̇̈], [V̈]
[Û]
[Ḡ]
[F], [F_o]
[W_{TP}]
[Ï]
[8̂], [8̂], [8̄],
[8]
[W_C]
[Ŷ], [Y]
[K]
[Ä]
[İ], [İ]
[U_X]

[Note] The data are in reference to the Dictionary of Hong Kong Sign Language (Tang 2007). Although CC did not attempt the handshapes listed in this table, some of the handshapes were used as substitutes, as in the substitutions of [B̈] by [E], [B] by [4] and [V] by [V̇].

The handshapes which were not attempted during the period studied have the following properties:

a) They involve secondary selected fingers, as in [ŷ] (), [Wc] (), [K] (), [Ä̈] (), [ɪ'] (), [ṫ] () and [Ux] () (c.f. Table 1.5);

b) They specify for a more marked feature of the POR node under the PSF node, such as [ulnar] or [middle] (with Thumb [contact]), e.g. [WTP] (), [8̂] (), [8̂] (), and [ȣ] (). They also specify for the most marked feature [nonbase flex], under the Joint position node of the PSF node, e.g., [Ẅ] (), [V̈] (), and [Ï] ();

c) They are used in a few lexical items only, which may yield a low input frequency, for instance, [E] () in EAST, [4] () in OBEY; [3] () in SUBTITLE and TRENDY; [WNS] () in SWEAR and BOY-SCOUT; [F°] () in POLICE, PEEP, SPIT and BUTTON, [Ḡ] () in INCH, EDGE, EQUAL, TROUBLESOME, INTERESTING, and AIR-TIGHT; [5̈] () in RELATIVES, LOSE, PORNOGRAPHIC, LEWD, INDECENT- ASSUALT, LUST, and LECHER;

d) They appear in two-handed signs only, like [V̈] (), [Ü] (), and [ʏ] ();

e) They are used in lexical items which are seldom used in child conversation. For example, [V̇] () is only used in lexical items like GOVERNOR, PRIME-MINISTER, CHAIRMAN, PERSON-IN-CHARGE, SUPERVISOR, INJECTION, and INJECT; and

f) They must involve HIMs in signs but they are not the underlying handshapes according to the criteria of the current study (c.f. Section 3.2.3.1), e.g., [B̈] (), and [8̄] ().

The handshape [F] () is used in the sign NOT-HAVE in HKSL, so it should be quite frequent. However, CC did not attempt it but consistently produced a gesture for it instead: he used both hands, located in the neutral space, assuming a lax handshape [5] () with palms facing upward. This may be because he employed the strategy of avoidance, which is also found in acquisition of spoken phonology (c.f. Section 2.1.6). Two handshapes, [Ĝ] () and [V̈] (), have not yet appeared in the data description or Table 4.2 because whenever they appear, they must be specified for HIMs, so they will be introduced later in sections analyzing handshape units specified for HIMs.

4.3 Errors of Substitution

This section tests against H2 using CC's production data. H2 hypothesizes that when children are nontarget in their productions of handshape, they substitute the target handshapes with other less marked handshapes and their substitutions are not random. The figures are given in Table 4.4.

Table 4.4 – p. 1 Feature substitution figures[Note]

Quantity substitution						
Target feature	# of attempts	Total # of substitution	Overall nontarget (%)	Substitute feature	# of substitutions/total substitutions (%)	# of substitutions/total attempts (%)
[all;one]	4	3	75	**[all]**	2/3 (66.7%)	2/4 (50%)
				[one]	1/3 (33.3%)	1/4 (25%)
[all]	214	60	28.0	**[one]**	56/60 (93.9%)	56/214 (26.1%)
				[one;all]	4/60 (6.7%)	4/214 (1.9%)
[one;all]	18	4	22.2	**[one]**	3/4 (75%)	3/18 (16.7%)
				[all]	1/4 (25%)	1/18 (5.6%)
[one]	163	15	9.2	**[all]**	13/15 (86.7%)	13/163 (8.0%)
				[one;all]	2/15 (13.3%)	2/163 (1.2%)
Point of reference substitution						
Target feature	# of attempts	Total # of substitution	Overall nontarget (%)	Substitute feature	# of substitutions/total substitutions (%)	# of substitutions/total attempts (%)
[radial;ulnar]	4	2	50	**[ulnar]**	2/2 (100%)	2/4 (50%)
[ulnar]	47	2	4.3	**[radial]**	2/2 (100%)	2/47 (4.3%)

[Note]In this table, [b flex] = [base flex]; [nb flex] = [nonbase flex]; [b & nb flex] = [base & nonbase flex]; [ext] = [ext]

Table 4.4 – p. 2 Feature substitution figures

Joint position substitution						
Target feature	# of attempts	Total # of substitution	Overall nontarget (%)	Substitute feature	# of substitutions/total substitutions (%)	# of substitutions/total attempts (%)
[nb flex]	102	95	93.1	**[b & nb flex]**	55/95 (57.9%)	55/102 (53.9%)
				[b flex]	29/95 (30.5%)	29/102 (28.4%)
				[ext]	11/95 (11.6%)	11/102 (10.8%)
[b flex]	93	61	65.6	**[b & nb flex]**	46/61 (75.4%)	46/93 (49.5%)
				[ext]	11/61 (18.0%)	11/93 (11.8%)
				[nb flex]	4/61 (6.6%)	4/93 (4.3%)
[b & nb flex]	18	6	33.3	**[ext]**	6/6 (100%)	6/18 (33.3%)
[ext]	142	9	6.3	**[b & nb flex]**	5/9 (55.6%)	5/142 (3.5%)
				[nb flex]	4/9 (44.4%)	4/142 (2.8%)
Finger position substitution						
Target feature	# of attempts	Total # of substitution	Overall nontarget (%)	Substitute feature	# of substitutions/total substitutions (%)	# of substitutions/total attempts (%)
[nonspread]	128	77	60.2	**[spread]**	77/77 (100%)	77/128 (60.2%)
[spread]	14	1	7.1	**[nonspread]**	1/1 (100%)	1/14 (7.1%)
[crossed]	3	3	100	I crossed over M	1/3 (33.3%)	1/3 (33.3%)
				I crossed over M, R [ext], T & P lax	1/3 (33.3%)	1/3 (33.3%)
				I crossed over M; T, R & P very lax	1/3 (33.3%)	1/3 (33.3%)

Table 4.4 – p. 3 Feature substitution figures

Secondary selected fingers substitution						
Target feature	# of attempts	Total # of substitution	Overall nontarget (%)	Substitute feature	# of substitutions/total substitutions (%)	# of substitutions/total attempts (%)
[palmar contact]	16	10	62.5	**contacted at the tips of T & I**	8/10 (80%)	8/16 (50%)
				T [crossed]	1/10 (10%)	1/16 (6.3%)
				palmar side of T contacted the back of I	1/10 (10%)	1/16 (6.3%)
Thumb feature substitution						
Target feature	# of attempts	Total # of substitution	Overall nontarget (%)	Substitute feature	# of substitutions/total substitutions (%)	# of substitutions/total attempts (%)
nonselected T [ext]	85	7	8.2	**nonselected T [b & nb flex]**	5/7 (71.4%)	5/85 (5.9%)
				nonselected T [b flex]	2/7 (28.6%)	2/85 (2.4%)
nonselected T [b & nb flex]	86	4	4.7	**nonselected T [ext]**	4/4 (100%)	4/86 (4.7%)
T [contact]	79	8	10.1	**no T [contact]**	8/8 (100%)	8/79 (10.1%)
no T [contact] (T nonselected)	171	6	3.5	**added T selection & added T [contact]**	6/6 (100%)	6/171 (3.5%)
no T [crossed] (T nonselected)	171	2	1.2	**added T selection & added T [crossed]**	2/2 (100%)	2/171 (1.2%)
no T [contact] (T selected but no contact)	133	3	2.3	**T [contact]**	3/3 (100%)	3/133 (2.3%)
no T [crossed] (T selected but no crossed)	119	8	6.7	**T [crossed]**	8/8 (100%)	8/119 (6.7%)
nonselected	171	19	11.1	**selected**	19/19 (100%)	19/171 (11.1%)
selected	228	11	4.8	**nonselected**	11/11 (100%)	11/228 (4.8%)

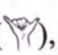
Table 4.4 – p. 4 Feature substitution figures

Thumb selection substitution						
Target feature	# of attempts	Total # of substitution	Overall nontarget (%)	Substitute feature	# of substitutions/total substitutions (%)	# of substitutions/total attempts (%)
nonselected	171	19	11.1	**selected**	19/19 (100%)	19/171 (11.1%)
selected	228	11	4.8	**nonselected**	11/11 (100%)	11/228 (4.8%)

Table 4.4 reports the substitutions observed in the current study. The data are arranged according to the organization of the following subsections. Some of the feature substitutes are in bold, meaning that they represent more than 50% in proportion to the overall substitutions of the respective target features. In other words, they are the frequent substitutes of the corresponding target features. Only the bolded data will be described here as they account for a larger proportion of the substitutions of different target features. Section 4.3.1 presents the data which confirm H2. Section 4.3.2 discusses the data which do not confirm or reject H2 because the relevant features could not be ranked in Chapter 1 due to the lack of typological or physiological information or due to other reasons which will be discussed in details. Section 4.3.3 analyzes the data which reject H2.

4.3.1 Data which confirm H2

4.3.1.1 Quantity substitution

In Section 1.4.11, the proposed feature markedness ranking of the Quantity node under the PSF node is: [all] < [one] < [one;all] < [all;one]. Table 4.4 shows that features [one] and [all] were mutual substitutes of each other as the markedness difference between them is not great (c.f. Section 1.4.11). For example, [all] was substituted by [one], demonstrated by the sign CUP in which [C] () was substituted by [G̈] (); and [one] by [all], as demonstrated by the sign HAVE in which [T̄] () was substituted by [S] (). The Quantity features were also substituted by the dominant one when they entered into a dependency relationship. For example, [one;all] was substituted by [one], demonstrated by the sign AIRPLANE in which [Ẏ] () was substituted by [Y] (), and [all;one] was substituted by [all], demonstrated by the sign FORK, as in the substitution of [W] () by [5] (). [All] and [one] are the least marked in the node, and they were the frequent substitutes. These observations confirm H2.

4.3.1.2 Point of reference substitution

Referring to Point of reference, [ulnar] was substituted by [radial], as demonstrated by the sign SOFT-DRINKS in which [Y] () was substituted by [i] (). Moreover, [radial;ulnar] was substituted by [ulnar] as in the substitution of [ṫ] () by [Y] (). These two substitutions again confirm H2 because the substitute features are less marked than the target features: [ulnar] is less marked than [radial] (c.f. Section 1.4.12), and [ulnar] is less marked than [radial;ulnar] because the later exhibits a dependency relationship.

4.3.1.3 Joint position substitution

As predicted by the postulated Handshape Unit Model, the most marked feature [nonbase flex] was frequently nontarget and the least marked feature [extended] had the highest accuracy. [Nonbase flex] was mostly substituted by a less marked feature, [base and nonbase]. In the model, since the markedness status between [base flex] and [base and nonbase flex] is uncertain, a bidirectional substitution is expected. However, in the data, [base flex] was often substituted by [base and nonbase flex], whereas [base and nonbase flex] was never substituted by [base flex]. Therefore, findings of acquisition research can provide clues for the rank of feature markedness; in this case, the acquisition data suggest that [base and nonbase flex] is less marked than [base flex]. This may be because [base and nonbase flex] is similar to the 'closed' configuration discussed in Ann (1993), which is physiologically easiest. [Base and nonbase flex] was also substituted by a less marked feature [extended]. [Extended] is the least marked feature. So whenever it was nontarget, the substitute feature must be more marked than it, but such substitution occurred infrequently as predicted. All these confirm H2.

4.3.1.4 Finger position substitution

Finger position is proposed to be the dependent of Joint position because Finger position features can be predicted in cases such as: [extended] and [nonbase flex] predict [spread]; whereas [base flex] and [base and nonbase flex] predict [nonspread] (c.f. Table 1.4). The unpredicted Finger position features can be specified, but they will be more marked than the predicted combination, for example, with selected fingers specified for [extended], they can be specified for [nonspread], but this combination will be more marked than the predicted one: [extended] + [spread]. H2 states that substitute structures are less marked than the target ones. The target features, [nonspread] and [spread] in Table 4.4 are the unpredicted but specified instances which are substituted by the predicted structures which are less marked than the target ones, hence both substitutions here confirm H2.

4.3.2 Data which do not confirm or reject H2

This section discusses the data which do not confirm or reject H2. Sections 4.3.2.1 to 4.3.2.3 discuss the data with which the relevant features involved are not ranked in Chapter 1 due to the lack of typological or physiological information, so H2 cannot be confirmed or rejected. Although data in Sections 4.3.2.1 and 4.3.2.2 do not confirm or reject H2, they confirm H1.

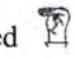
4.3.2.1 [Crossed] in the Finger position node

The target form of [crossed] requires the Middle finger to cross over the Index finger, but CC produced it the other way round, i.e. the Index crossed over the Middle (see Clip 4-2). Since no feature ranking is proposed for the Finger position node, H2 cannot be confirmed or rejected here. However, the fact that the relatively marked feature [crossed] was never produced correctly confirms H1 as it states that handshapes which are more marked are acquired later.

4.3.2.2 Secondary selected fingers substitution

For handshapes which involve secondary selected fingers, for example, in the sign KEY assuming the handshape [Â] ( ), Thumb [palmar contact] was nontarget as CC's tips of the Thumb and Index ( ) contacted instead of Thumb tip contacting the palmar side of the middle phalange of the Index ( ). Similar to [crossed] in the Joint position node, since the features are not ranked in the Thumb node under the SSF node, H2 cannot be confirmed or rejected here. In fact, handshapes involving secondary selected fingers are predicted to be produced less accurately due to its higher structural complexity, as represented by the specification of an additional dependent: the SSF branch. The low accuracy rate of the SSF feature [palmar contact] therefore confirms H1: handshapes which are more marked are acquired later. CC did not acquire any handshapes involving SSF over the studied period.

4.3.2.3 Thumb feature substitution

The nontarget percentage of the nonselected thumb specifying for [extended] was higher than that of the nonselected thumb specifying for [base & nonbase flex]. And they were mutual substitutes to each other. For example, when producing signs like SEE, assuming the handshape [V] (), CC produced [V̇] () instead. On the other hand, in attempting the sign BLUE which assumes the handshape [B̊] (), he produced  instead, realizing Thumb [base & nonbase flex] instead.

As for Thumb [contact], there were instances in which it was omitted while it was required, for example, in the sign FOOD, the target handshape is [B̊] (), but CC produced [] (G̿). On the other hand, Thumb [contact] was also added when it was not required, for example, in the sign CUP, the target handshape is [C] (), but CC produced [Ĝ] (). However, omission of Thumb [contact] was a little more frequent than the adding of it. Besides, there were other cases in which Thumb [crossed] was added while the target did not require it. However, since the features in the Thumb node are not ranked, the data here cannot confirm or reject H2.

4.3.3 Data which reject H2

4.3.3.1 Thumb selection substitution

Adding the Thumb as a selected digit is more frequent[1] than deleting the Thumb when the target requires it. This 'Thumb adding' phenomenon rejects H2 because the structure becomes more complex with the realization of the Thumb. However, the Thumb was

[1]Frequency in this part refers to data from the sixth column of Table 4.4.

added usually when [all] was realized in the Quantity node, which makes the Thumb behaves in a similar fashion to the other selected fingers in the configuration. This may be physiologically driven as Ann (1993) suggests that the fingers of the hand tend to act together.

4.3.4 Summary of data testing against H2

As seen from Sections 4.3.1, H2 is largely confirmed. Section 4.3.1 confirms H2 with data from four nodes. The data which do not confirm or reject H2 are discussed in Section 4.3.2. However, it should be noted that some of the data in Section 4.3.2, while failing to confirm or reject H2, actually confirm H1. The data which reject H2 is the 'Thumb adding' phenomenon, suggesting that the Thumb may have a special status that its realization or nonrealization may not contribute to a big difference in the markedness of the handshape unit structure. Alternatively, it may be hypothesized that the child has not yet separated the Thumb as a dependent, but treated it as the same as the other selected fingers. It is observed that the Thumb was added when the required POR feature is [radial], for example, [V] () was produced as [V̇] () and [1] () was produced as [i] (), but the Thumb was never added when the required POR feature is [ulnar]: [I] () was never substituted by [Y] (). The fact that the Thumb is also on the 'radial' side of the hand may lead to a difficulty for the child to treat the Thumb separately.

4.4 HIM and handshape acquisition

In this section, I am going to investigate how HIM[2] interacts with finger selection and finger configuration, an aspect which has not been investigated in the literature to the best of my knowledge. Finger selection refers to the combination of the Quantity and the POR nodes, and finger configuration refers to the combination of the Joint position and the Finger position nodes proposed in Chapter 1. Section 4.4.1 offers a definition of HIM.

Previous handshape acquisition research usually did not include data which involve HIM or did not state whether they include handshapes with HIM or not. For example, Siedlecki (1991) studied them separately as ‘initial handshapes’ and ‘final handshapes’; Cheek *et al.* (2001) studied HIM separately and did not state how they tackled the handshapes which involve HIMs; and Karnopp (2002) only studied “initial handshapes” while ignoring HIMs. The issue of whether HIM interacts with handshape acquisition is worth investigating because in my preliminary observation, given the same handshape, the requirement of HIM somehow lowers the accuracy of the handshape production. Besides, a sign is composed of handshape, location & movement. It has been reported in the literature that location and path movement are acquired early as they involve bigger joints which are developed earlier than the finer joints. Therefore, they should not be critical in affecting the performance of finger selection and finger configuration. However, HIMs, such as finger wiggling, opening, closing, and rubbing, all involve finer

[2]For the sake of a more-detailed exposition, throughout this chapter, HIM is further subcategorized if the target sign was specified for repetition. For instance, [once] [closing] and [repeated] [closing] are analyzed as two categories.

joints, and presumably they interact directly with finger selection and finger configuration.

According to Kooij (2002), the more elements a representation consists of, the more complex the structure is. To recap, H3 states that the accuracy of finger selection and finger configuration tend to drop with the requirement of HIMs due to the requirement of a more marked structure, involving HIM as a dependent structure of the Handshape unit. Sections 4.4.2 to 4.4.3 test against H3. It has been found that CC's production data generally support H3. Section 4.4.4 suggests a HIM complexity hierarchy by examining CC's production data.

4.4.1 Defining HIM

There are different definitions of 'HIM' in the literature. For example, Sandler (1989:23) defines internal movement as:

> movement that is not path movement; i.e., rather than moving the hand from one location to another, internal movement involves movement within the hand, by changing the position either of the fingers or of the wrist.

HIMs (also known as nonpath movements) in Kooij (2002) refer to local movements and secondary movements. Local movements mean lexical changes in finger position or changes in the orientation of the hand. Secondary movements refer to rapidly repeated local movements (including finger wiggling) or path movements (including circling and zigzagging). Local movements and secondary movements are called HIMs in Cheek *et al.* (2001). Cheek *et al.* (2001:300) offer another definition: "HIM is limited to articulations of the finger and knuckle joints", meaning that orientation is not considered as HIM.

According to Sandler (1989), orientation change is also considered as a kind of HIMs because orientation change is the movement of the wrist joint, and the wrist is a part of the hand. In contrast, Kooij suggested that orientation change is articulated by the forearm joint instead of the wrist joint (personal communication). Due to its unclear status, orientation change is not taken into consideration in this study. In the current study, I would adopt the definition of HIM by Cheek et al. (2001) because I suspect that movements of the finger and knuckle joints (i.e. the distal interphalangeal joints, the proximal interphalangeal joints and the metacarpophalangeal joints) would affect the production of handshape more directly.

4.4.2 H3: Accuracy of Finger selection and finger configuration is lower when HIM is specified

I hypothesize that in children's handshape production, the accuracy of finger selection and finger configuration is lower if HIM is specified. Given the same handshape, if one does not require HIM and the other one does, the latter is structurally more complex because it invokes a dependent, namely the HIM branch. This leads to a more complex structure and may lead to a higher degree of articulatory difficulty. This requirement appears to interact closely with finger configuration.

In order to test my hypothesis, only the handshapes which appeared both with and without HIMs are singled out for analysis. The handshapes involved are [S] (), [Ḃ] (), [Ȧ] (), [B̂] () and [V] (). A quantitative data analysis is followed by a qualitative one.

4.4.2.1 HIM and finger selection

In Table 4.5, FS_T refers to target production of finger selection and FS_N refers to nontarget production of finger selection.

Table 4.5 The relationship between HIM and finger selection

		# of tokens without HIM	% of distribution	# of tokens with HIM	% of distribution
[S] ()	FS_T	13	100%	37	100%
	FS_N	0	0%	0	0%
[Ḃ] ()	FS_T	74	**100%**	11	**92%**
	FS_N	0	0%	1	8%
[Ȧ] ()	FS_T	66	**100%**	22	**92%**
	FS_N	0	0%	2	8%
[B̂] ()	FS_T	21	27%	42	88%
	FS_N	58	73%	6	13%
[V] ()	FS_T	21	**91%**	10	**67%**
	FS_N	2	9%	5	33%
	Total attempts	255		136	
	Total FS_T	195	76%	122	90%
	Total FS_N	60	24%	14	10%

Quantitatively, it can be seen from Table 4.5 that the accuracy of finger selection in general drops with the requirement of HIM (see percentages in **bold**), this confirms H3. However, there are also two exceptions. They are the handshapes [S] () and [B̂] (). The handshape [S] () does not verify nor falsify H3 because the accuracy of finger selection are identical with and without the requirement of HIM. The handshape [B̂] ()

seems to falsify H3. However, this unpredicted higher accuracy rate may be attributable to a gestural explanation: when handshape [B̊] is specified for [closing], it is very similar to a human hand picking up a flat object. This gestural origin may explain why CC could attain a better performance of finger configuration even in the requirement of HIM.

4.4.2.2 Analysis of the relationship between HIM and finger configuration

Table 4.6 shows the relationship between HIM and finger configuration. FC_T refers to target production of finger configuration and FC_N refers to nontarget production of finger configuration.

Table 4.6 The relationship between HIM and finger configuration

		# of tokens without HIM	% of distribution	# of tokens with HIM	% of distribution
[S]	FC_T	12	**92%**	26	**70%**
	FC_N	1	8%	11	30%
[Ḃ]	FC_T	38	**51%**	0	**0%**
	FC_N	36	49%	12	100%
[Ȧ]	FC_T	66	**100%**	22	**92%**
	FC_N	0	0%	2	8%
[B̊]	FC_T	24	30%	30	63%
	FC_N	55	70%	18	38%
[V]	FC_T	23	100%	15	100%
	FC_N	0	0%	0	0%
	Total attempts	255		136	
	Total FC_T	163	64%	93	68%
	Total FC_N	92	36%	43	32%

Quantitatively, findings from Table 4.6 are similar to those from Table 4.5, in that the accuracy of finger configuration tends to drop with the requirement of HIM, and this supports H3. However, there are two exceptions, namely the handshapes [B̊] () and [V] (). [V] () does not verify nor falsify H3 because the accuracy rates of the finger configuration with and without HIM are identical. The handshape [B̊] () again seems to falsify my hypothesis, but, as stated previously, the gestural origin of the Handshape unit may be the cause of such an exception.

4.4.2.3 Generalizations

Four generalizations are arrived at in the analysis of signs specified for HIMs. First, the handshape [5] () was often used as the substitute handshape for signs involving HIMs. The handshape [5] () was used as the substitute handshape in signs specifying for [Ḃ] () with [trilled] [flattening], [V] () with [trilled] [spreading], and [B̊] () with [trilled] [closing]. There are two possible reasons why the handshape [5] () was used as a substitute handshape. First, it is the least marked handshape: it specifies for [all], so no NSFs, and no POR features are needed. It also specifies for the least marked Joint position feature [extended], and it predicts [spread] so no Finger position feature needs to be specified. Second, the handshape [5] () is similar to the target handshapes mentioned above, their differences are listed in Table 4.7.

Table 4.7 The handshape [5] ( ) compared with handshapes with HIMs

Target handshape	Substitute handshape	Feature difference(s)	Affected node(s)
[Ḃ] ( )	[5] ( )	[nonspread] vs. [spread]	PSF: Finger position
[V] ( )	[5] ( )	[one;all] vs. [all]	PSF: Quantity
[B̂] ( )	[5] ( )	[base flex] + Thumb [contact] vs. [extended]	PSF: Joint position + Thumb

The second generalization is that regarding the three handshapes mentioned in Table 4.7, when they were not specified for HIMs, the handshape [5] ( ) was also used as a substitute.

Third, there are instances in which the same target feature gets erred no matter HIM is specified or not. The follow cases illustrate it is the Thumb feature which is erred. CC attempts [S] ( ) with two HIMs only: [once] [opening] and [once] [closing]. [O] ( ) is used as an initial handshape substitute in signs specified for [once] [opening]; and it is also used as the final handshape substitute in signs specified for [once] [closing].[3] The substitution goes in the opposite direction as well because there are cases in which [O] ( ) is substituted by [S] ( ). When the handshape [S] ( ) is not specified for HIM, CC produced it as a lax [C] ( ), thus substituting Thumb [crossed] by Thumb [open], again an error on the Thumb feature.

[3]Signs specified for [S] ( ) with [opening] may actually be articulated phonetically as an opening of the handshape [O] ( ). However, in the course of data coding, since I did not want to overestimate CC's performance, I treated all forms which deviated from the citation forms as nontarget.

The fourth generalization is that [closing] was often used as an HIM substitute. [Closing] at base and nonbase joints substituted for [trilled] [hooking] and [trilled] [spreading]. [Closing] at base joints substituted for [trilled] [flattening].

4.4.3 Detailed analysis of signs involving HIMs

This section aims at offering a qualitative analysis of signs involving HIM. This section is divided into four subsections: data which confirm H3, data which partially confirm H3, data which do not confirm nor reject H3, and data which reject H3.

4.4.3.1 Data which confirm H3

Accuracy rates of finger selection and finger configuration dropped when the following handshapes were specified for HIMs: [Ḃ] () and [Ȧ] (). Both of them confirm H3.

CC attempted [Ḃ] () with one type of HIM exclusively, namely [trilled] [flattening] in the sign FISH (see Clip 4-3 ). He attempted 12 tokens of FISH, and was wrong in finger selection once. In that token he perspicuously added the Thumb as a selected digit because he first assumed the handshape [5] () and then closed it to [B̂] (). The adding of the Thumb is evident because the Thumb is involved in the HIM [base flex] Besides, CC was nontarget in finger configuration in all of the 12 attempts of FISH.

For the handshape [Ȧ] (), it was specified for [trilled] [hooking] as in the sign THANK-YOU (see Clip 4-4 ). CC attempted 24 such tokens, two were wrong in finger selection (he selected all four fingers with or without the Thumb). In one token, CC first assumed the handshape [5] ( ), then he closed to [O] ( ). In this case, he selected all 5 fingers instead of the target Thumb only. Moreover, when he closed from [5] ( ) to [O] ( ), he actually produced a HIM with flexion at both the base and nonbase joints instead of the target flexion at the nonbase joint only. With the other token, he first assumed the handshape [5] ( ), then the Index, Middle, Ring and Pinky flexed at the base joint once. By doing so, CC swapped the selected finger with the nonselected fingers because the target required CC to flex the Thumb but not other fingers - what he did was just the opposite. Moreover, he substituted the target HIM [hooking] (at the nonbase joints) by [flattening] (at the base joints). This is similar to the Joint position node, with [nonbase flex] more marked than [base flex]. In the 24 attempts of THANK-YOU, two were wrong in finger configuration. In one token, CC assumed the handshape [A] ( ), which reflects that he erred in the configuration of the Thumb because he flexed it at the base joint instead of extending it. The initial handshape which CC produced was [A] ( ), with this handshape he produced an HIM of flexing his Thumb at both the base and nonbase joints, assuming the handshape [Ȧ] ( ) and flexes at the nonbase joints only in a trilled manner. With the other token, CC assumed the handshape [S] ( ), and again he flexed his Thumb at both the base and nonbase joints, instead of the target flexing of the nonbase joints only. It was again the Thumb configuration which CC erred. This time he produced Thumb [crossed] instead of the target Thumb [extended].

4.4.3.2 Data which partially confirm H3

'Data which partially confirm H3' refers to the data supporting the prediction with respect to finger selection or finger configuration, but not both. In the discussion, I will focus on the handshapes [V] () and [S] ().

The only HIM CC attempted with the handshape [V] () was [trilled] [spreading] as in the sign SCISSORS (see Clip 4-5 ). The accuracy of finger selection was much lower when HIM was specified. Altogether he attempted 15 such tokens, five of which were nontarget in finger selection. With these tokens, CC assumed the handshape [5] () and flexed different fingers randomly at both the base and nonbase joints instead of the target [spreading]. As the handshape [V] () is specified for a Quantity feature with a dependency relation: [one;all], it may also lead to the error in finger selection. The requirement of HIM does not lower the accuracy of the finger configuration for SCISSORS and this is probably because [extended] is the least marked feature in the Joint position node and [nonspread] can be predicted by [extended]. Across the data, the handshape [V] (), regardless of whether HIM is specified, has a finger configuration accuracy rate of 100%.

When the signs involved handshape [S] () and HIMs, they were always [once] [opening] as in the sign DISCARD (see Clip 4-6 ) or [once] [closing] as in the sign GRAB (see Clip 4-7 ). CC erred not in finger selection, but finger configuration. CC attempted [S] () with [once] [closing] for 11 tokens, he was only wrong in one token, in which he first assumed a lax handshape [5] (), and closed it to [O] ()

instead of closing it to the target [S] (). In this case, he produced thumb [contact] instead of the target thumb [crossed] in the finger configuration. On the other hand, he attempted [S] () with [once] [opening] for 26 tokens, he was wrong in 10 tokens and the errors were concerned with finger configuration. Out of the 10 erroneous tokens, CC did not produce [once] [opening] in four of them. In two of these four tokens, CC produced a lax handshape [5] (), so he produced the final handshape only. In one of these four tokens, he only produced a lax handshape [V̈] (), an 'intermediate' between the initial and final handshape, with flexion at the nonbase joints only. In the last one of these four tokens, CC produced [O] () instead, which means he again substituted Thumb [crossed] by Thumb [contact]. When CC did not omit the HIM and did produce [once] [opening], [O] () still surfaced as the initial handshape contour in two tokens, lax handshape [V̈] () in two tokens. [B̂] () was also used as the initial handshape to replace the sign specifying for [S] () and [once] [opening]. For the substitute handshape [B̂] (), CC produced Thumb [contact] instead of the target feature Thumb [crossed]; and [base flex] instead of [base and nonbase flex] in the Joint position node. Whether CC produced the target HIM [once] [opening] or not, [O] () and [V̈] () were used as some of the substitute handshapes. The specification of HIMs in this handshape [S] () only lowers the accuracy of the finger configuration but not finger selection, thus partially confirming H3.

4.4.3.3 Data which reject H3

The findings concerning the handshape [B̂] () is exceptional compared to other handshapes mentioned above because the accuracy rates of both finger selection and finger configuration did not drop, but raised, with the specification for HIM. This seems to reject H3. CC attempted the handshape [B̊] ( ) with [trilled] [closing], [once] [closing] and [rubbing] in signs. The distribution is shown in Table 4.8.

Table 4.8 Distribution of the handshape [B̊] ( ) with HIMs

Type of HIM	Meaning of the sign	#of attempts	Proportion of the attempts
[trilled] [closing]	DUCK	9	19.6%
	BREAD	12	26.1%
	WET	3	23.9%
	DIRTY[a]	8	17.4%
[once] [closing]	SHEEP	7	15.2%
[rubbing]	MONEY	7	15.2%

[a]The Deaf researcher teaches CC the sign DIRTY in a child-directed form. Its phonological configuration is identical with that specified for WET. CC attempted to produce this form of DIRTY in the tokens noted here.

The phonological configuration of the sign SHEEP (c.f. 3.2.3.1) may actually facilitate the production, yielding the high accuracy rates of both finger selection and finger configuration. Concepts of BREAD, WET, DIRTY and DUCK were frequently discussed in interactions with children, this may also lead to the higher accuracy rates of both finger selection and finger configuration in these signs. Moreover, [B̊] ( ) specifying with [closing] looks very similar to a human hand picking up a flat object. This gestural origin may tentatively explain why CC could attain a better performance of finger configuration even in the requirement of HIM. This piece of data suggests that other factors including configurations of other phonological parameters, lexical frequency, and similarity to gesture interact and may even override the tendency of lower accuracies in signs with higher complexities.

4.4.3.4 Interim summary

In general, the accuracy rates of finger selection and / or finger configuration drop with the requirement of HIM which fully or partially confirm H3. The handshape [B̂] () was an exception. It apparently rejects H3 but it may be explained in reference to the interaction of other factors, namely the configurations of other phonological parameters, lexical frequency, and its gestural characterization. Therefore, sometimes, though not very often, the interaction of the factors mentioned above may override the tendency of lower accuracy rates of finger selection and finger configuration in Handshape units with higher structural complexities (i.e. with the specification of HIM in this case).

4.4.4 HIM complexity

There are not any studies analyzing the complexity of different types of HIM. If assuming that language acquisition proceeds from less complex structures to more complex structures, a more complex HIM will imply a higher level of difficulty, hence lower accuracy. Therefore, a hierarchy of different HIMs may be set up through examining CC's acquisition data.

Table 4.9 shows the accuracies of different HIMs, and they are ranked in a descending order. In that table, Columns A and D represent HIM types, the T and N after the underscores mean 'target' and 'nontarget' respectively. Columns B and E refer to number of target and nontarget tokens respectively. Columns C and F refer to target and nontarget accuracy rate respectively. For example, regarding the HIM [trilled] [rubbing], CC attempted seven tokens (Columns B + E). Six were target, as shown in Column B; and one was nontarget, as shown in Column E. Column C shows that the accuracy is 86% (6/7*100), and Column F shows the nontarget rate is 14% (1/7*100).

Table 4.9 The accuracy rates of different HIMs

A	B	C	D	E	F
HIM type_T	# of target tokens	Rate	HIM type_N	# of nontarget tokens	Rate
Trilled closing_T	33	100%	Trilled closing_N	0	0%
Once closing_T	21	100%	Once closing_N	0	0%
Trilled rubbing_T	6	86%	Trilled rubbing_N	1	14%
Once opening_T	35	80%	Once opening_N	9	20%
Trilled spreading_T	4	27%	Trilled spreading_N	11	73%
Trilled flattening_T	1	8%	Trilled flattening_N	12	92%
Trilled hooking_T	1	4%	Trilled hooking_N	25	96%

As shown from Table 4.9, the 'HIM complexity hierarchy' would be as follows (in ascending order):

[once] [closing] = [trilled] [closing] < [trilled] [rubbing] < [once] [opening] < [trilled] [spreading] < [trilled] [flattening] < [trilled] [hooking]

The ranking here is also consistent with the suggestions in Section 1.4.13. [Closing] and [opening] are relatively unmarked and they involve the articulation of base and nonbase joints or the base joints only, similar to the Joint position features [base & nonbase flex] and [base flex]. [Spreading] is relatively marked because the fingers need to alter repeatedly between [extended] + [spread] and [extended] + [nonspread], with [extended] + [nonspread] being a more marked feature combination than [extended] + [spread]. [Flattening] involves the base joints only, also similar to [base flex] in the Joint position node. The most marked [hooking] involves the nonbase joints only, similar to [nonbase flex] in the Joint position node, which is also ranked as the most marked feature.

In sum, the results from the 'HIM complexity hierarchy' reflects the markedness production on language acquisition, with less marked features that underlie the HIM type occupy a higher position in the accuracy. And it also shows that it is crucial for the child to identify the target joints in order to produce the target configuration, no matter in respect to Joint position or in HIM.

4.5 Conclusion

The three hypotheses set up at the beginning of this chapter are generally confirmed by the HKSL data. The acquisition data concerning the Thumb calls for a further modification on the proposed Handshape Unit Model because when the signs were realized with [all] in the Quantity node, the Thumb tends to be 'added' even it is not specified (c.f. Section 4.3.3.1). The 'exceptional [B̂] ()' in the discussion of HIM suggests that other factors including configurations of other phonological parameters, lexical frequency, and gestural characterization interact and may sometimes override the tendency that accuracy rates of finger selection and finger configuration in Handshape units drop with higher structural complexities (i.e. with the specification of HIM in this case). Lastly, a HIM complexity hierarchy is proposed through examining CC's production data.

Chapter 5 Physiology and Handshape Acquisition

5.0 Introduction

This chapter aims at testing Ann's (1993) model using the acquisition data collected in this study.

In the handshape acquisition literature, different explanations are employed to account for handshape acquisition, such as motor development of children, cognitive demand and perceptual salience of the handshapes, etc. In the literature, it is commonly acknowledged that ease of articulation also plays a role in the acquisition of handshape. As such, this chapter examines this alternative account. In this context, Ann's account (1993) provides a tool for researchers to probe into the relationship between the ease of articulation and the patterns of handshape acquisition.

Section 5.1 summarizes the motoric accounts for handshape acquisition in the literature. Section 5.2 gives an introduction to Ann's (1993) model, including the criteria and the formula which generate the scores of the handshapes. Section 5.3 uses the acquisition data to test against the model and finds that the data generally support the classification of the handshapes by Ann (1993). Section 5.4 concludes the chapter with a summary of the strengths of Ann's (1993) model and suggests some directions for modifications.

5.1 Motoric account for handshape acquisition

Motor factors have been used as one of the accounts for handshape acquisition in production. This section presents a summary of the previous motor accounts.

Meier, Mirus and Conlin (1998) suggest that two general properties of motor development may affect early sign acquisition. First, gross motor control over large muscle groups (e.g., those in the shoulder or arm) matures earlier than fine motor control over small muscle groups (e.g., those in the hands); and second, development of motor control generally starts from proximal joints (e.g., the shoulder) to distal ones (e.g., the wrist and fingers). The accuracy in location is higher than that in handshape in production because location is articulated by manipulating the gross joints such as the shoulder joint; whereas handshape is formed by configuring the fine joints such as the finger joints. Therefore, the lower accuracy rate for handshape production can be readily accounted for because distal articulators mature later.

Boyes Braem (1990) suggests that the order of handshape acquisition has its basis from hand anatomy. According to her, the thumb is the most independent comparing to the other four fingers since it has a highly mobile and independently articulated saddle joint; but other fingers have carpometacarpal joints which only allow a limited degree of freedom. This unique joint makes possible the opposition of the thumb. Moreover, the muscles to the thumb are all completely independent of the muscles branching to the other digits. Therefore, the thumb is given a special status in all the sign phonology analyses in the literature. The index finger and the little finger each have an additional separate extensor, making it more independent than other fingers. In contrast, the middle and ring fingers are the least independent and they have fairly immobile joints and no separate extensors or flexors.

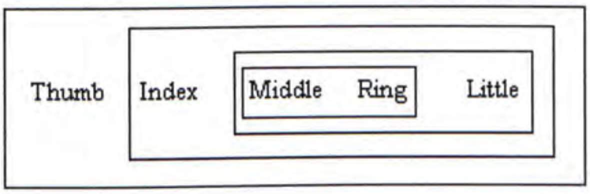
The thumb and the index finger are the most independently articulated. They are treated as a group and called the "radial group" because they are on the same side of the arm as the radius bone. The more interdependent middle, ring, and little fingers are referred to as the 'ulnar group' because they are on the ulnar bone side of the arm.

According to Swan (1936, cited in Boyes Braem 1990:109) "developmental studies have shown that the first fingers to be moved and controlled independently by the infant are also those which are anatomically most independent". In this case, they are the Thumb and the Index finger.

Based on hand anatomy, Boyes Braem (1990) proposes that the child first acquire handshapes which require the manipulation of the hand as a whole (like having the fingers all extended or all closed); then the independent manipulation of the Index and Thumb, with the other three ulnar fingers acting together as a group; the Pinky is then liberated from the ulnar group; and finally, the independent manipulation of the Middle and Ring fingers.

Boyes Braem uses a figure to represent the anatomical interdependency of the fingers. The most anatomically interdependent digits are within the inner-most rectangle, whereas the most independent digit is in the outer rectangle, reproduced as Figure 5.1 below:

Figure 5.1 Anatomical interdependency of the digits



Apart from the sequence of finger manipulation proposed above, in order to produce all the handshapes in the adult inventory, a child not only needs to extend the specific digits, but also to inhibit the fingers connected to the ones he or she wishes not to extend. It is not difficult with the anatomically independent digits but the difficulty increases towards the inner rectangles (Figure 5.1). Handshapes which need to extend and inhibit only the anatomical interdependent digit(s), like the handshape [ʁ] (), are predicted to be acquired later.

The accounts above state that physiology plays a role in affecting handshape acquisition. Ann's (1993) attempts to quantify ease of articulation by giving a score of physiological 'easiness' in the production of each handshape. Her model is described in the subsequent section.

5.2 Physiology Account

Based on the physiology of the hand, Ann (1993) proposes a metric for determining which handshapes are "easy", which are "difficult", and which are "impossible". She uses physiology to determine the cutoff point between "impossible" handshapes and the others. For example, extended Middle finger scores 4 following her calculation, and she points out that extended Middle finger is impossible physiologically[1], so any handshapes score 4 or above are considered as "impossible" in the category of handshapes with nonselected fingers closed (i.e. nonselected fingers are flexed at the base and nonbase joints, and if the Thumb is also nonselected, it crosses over other nonselected fingers). "Easy" handshapes are those which are calculated as a score of 0 or "in effect, those which have nothing difficult about them" (Ann 1993:173). The "difficult" handshapes are those which fall between "easy" and "impossible", and they score above 0.

The classification of "easy", "hard" and "impossible" handshapes depends on the handshape type. Different handshape types yield different scores according to the formula Ann (1993) proposes, which will be discussed in the following subsections. For example, it is not an absolute relationship that a score of 2 equals to a "hard" handshape in all cases, although all "easy" handshapes score 0 in her study. The scoring and the classification are presented in Table 5.1 adopted from Ann (1993:207).

Table 5.1 Scoring of handshapes per different type

HS Type / Category	Nonselected fingers closed	Nonselected fingers open	Opposed	Unspread
Easy	0	0	0	0
Hard	1 – 3	1	1 – 2	3 – 4
Impossible	4 – 6	2 – 4	3 – 4	5 – 7

[1]The sign ELDER-BROTHER in HKSL is specified for the handshape extended Middle finger. It is phonetically impossible to fully extend the Middle finger. In other words, the greatest degree of extension of the Middle finger is not as great as that of the Index finger, but ELDER-BROTHER is phonologically specified as assuming the handshape with an extended Middle finger since the finger is not fully flexed at the base joint either.

Three criteria are used to determine the ease of articulation of different handshapes: (a) muscle opposition in configuration, (b) independent extensor / sufficient support, and (c) profundus / juncturae tendinum.

5.2.1 Criterion (a): Muscle Opposition in Configuration

For criterion (a), the more muscle opposition, the more difficult it is in terms of articulation. Table 5.2 shows whether extensors, flexors, and / or intrinsics are necessary in producing the finger configurations. The muscles which are 'not necessary' are those which are relaxing, i.e. not contributing to any opposition. Muscles related to Table 5.2 are shown in Appendix D for reference.

Table 5.2 Muscles for producing the four finger configurations (Ann 1993:152)

	Extensors	**Flexors**	**Intrinsics**
Closed	Not necessary	Necessary	Not necessary
Bent	Not necessary	Not necessary	**Necessary**
Extended	**Necessary**	Not necessary	**Necessary**
Nonbase joints flexed[a]	**Necessary**	**Necessary**	Not necessary

[a]In Ann (1993), she names the four distinctive configurations as 'closed', 'bent', 'extended' and curved'. 'Closed' means flexion at both the base and nonbase joints; 'bent' refers to a configuration with flexion of base joints only; what Ann (1993) calls 'curved' is actually the finger configuration which involves flexion at the nonbase joints. In order to avoid confusions, I rename it as 'nonbase joint flexed'.

In Table 5.2, some configurations involve one group of "necessary" muscles, including closed and bent; and some involve two groups of "necessary" muscles, including "extended" and "nonbase joint flexed". Configurations which use only one set of muscles do not induce opposition. Configurations which use two muscle groups oppose each other to different degrees. Physiologically, the extensors and flexors maximally oppose each other, so any configuration which uses both extensors and flexors has maximal opposition. The intrinsics do not maximally oppose either the flexors or the extensors. Therefore, less opposition is present in configurations which use either the extensors or the flexors and the intrinsics (Ann 1993).

As a result, amongst the four configurations, "nonbase joint flexed" is the most difficult in terms of articulation as it has maximum opposition with the necessary participation of extensors and flexors. The second difficult configuration is "extended" because it involves two muscle sets, the extensors and intrinsics which do not maximally oppose each other. "Bent" and "closed" each requires one muscle set only, namely the intrinsics and the flexors respectively. So far, it cannot be distinguished whether "bent" or "closed" is articulatorily easier. However, other observations suggest that "closed" is articulatorily easier than "bent". For example, full flexion is involved in palmar grasp reflex in infants.

It has also been pointed out that "infants are born with their muscles flexed and only later develop the ability to extend them" (Boyes Braem 1990:111, Halverson 1937, cited in Ann 1993:154). Therefore, the articulatory complexity hierarchy is as follows (ranked from the hardest), and each of them is assigned a score by Ann (1993):

Nonbase joint flexed (3) > extended (2) > bent (1) > closed (0)

Comparing Ann's (1993) ranking and the Joint position feature ranking in Chapter 1, the flexion at the nonbase joints is the most difficult physiologically, and this is reflected in the Joint position feature ranking, with [nonbase flex] being the most marked. However, note that "extended", being the second most difficult, is the most frequent features for selected fingers typologically. This may be due to a perceptual reason: extended selected fingers contrast most with the nonselected fingers which are flexed at the base and nonbase joints. "Closed" in Ann (1993) is similar to [base & nonbase flex] in the Joint position node, and it is also ranked less marked than "bent" ([base flex] in the Joint position node). The similarities and differences between Ann's ranking and the feature markedness ranking based on typological frequency suggest that physiology affects the frequency of distribution of the features, but not fully determine the distribution.

All in all, the muscle opposition criterion is used to rank all four configurations of the fingers as bent, curved, extended and closed, from easiest to most difficult.

5.2.2 Criterion (b): Independent extensor / sufficient support

This criterion states that a (group of) finger(s) can extend if they have independent extensors. This applies to the Thumb, Index and Pinky. For the Middle and Ring fingers, they can extend if they have sufficient support, meaning that they can extend if they are (i) with a finger that has an independent extensor and is immediately adjacent; or (ii) with a group of extended fingers in which each member is immediately adjacent to at least one other member of the group and one of the members has an independent extensor (Ann 1993: 156).

To sum up, the independent extensor / sufficient support criterion is used to determine whether the least flexed fingers in a "two-group handshape"[2] have the ability to extend fully.

5.2.3 Criterion(c): Profundus / juncturae tendinum

The profundus / juncturae tendinum criterion suggests that it is articulatorily easier for the Middle, Ring and Pinky to act as a group because the flexor digitorum profundus connects the Middle, Ring and Pinky. The other two muscles act equally on all four fingers (Index, Middle, Ring and Pinky), and hence does not suggest any particular grouping. Therefore, the flexors digitorum profundus facts indicate that the Middle, Ring and Pinky are a group separated from the rest of the fingers (Ann 1993).[3]

5.2.4 Other factors affecting the ease and difficulty of a handshape

Ann (1993) claims that all one-group handshapes, i.e. handshapes with all fingers, including the Thumb, selected, are considered as "easy" because "whatever the hand does when all of the fingers act together seems to be easy" (Ann 1993:175).

[2]"Two-group handshape" refers to handshape with one set of selected finger(s) and one set of nonselected finger(s); that is, one without secondary selected fingers. Handshapes with secondary selected fingers are not studied in Ann (1993).

[3]I am reserved here about whether the anatomical fact here is strong enough to claim that the Middle, Ring and Pinky fingers act as a whole. Perhaps it may only suggest that they act together in terms of flexion, but not necessarily for the other configurations. However, I would follow Ann (1993) since I have no counterevidence at this juncture.

When the fingers are extended or when they are only flexed at the nonbase joints, they automatically spread. In order for the fingers to "nonspread"[4] (i.e., to adduct), the adductor pollicis and three dorsal interossei must be activated. Therefore, given the same handshape (with fingers extended or flexed at the nonbase joints only), the nonspread version is considered to be more difficult than the spread versions because extra muscles must be activated (Ann 1993).The formula of calculating the handshape scores and the justification for the algorithm are shown in Appendix E.

5.3 Accounting for CC's acquisition data

Since each handshape gets a score from Ann's (1993) proposed scoring system and algorithm, the acquisition data of the current study are presented together with the scores calculated. It is intended to check against any relevance between the 'easiness' of the handshapes and the order of acquisition.

The handshapes acquired by CC are presented in Section 5.3.1, followed by those attempted but not yet acquired over the period of study in Section 5.3.2, and lastly those not attempted at all in section 5.3.3.

5.3.1 Acquired handshapes

Table 5.3 lists the handshapes acquired by CC and the respective ages of acquisition. The scores besides the handshapes are proposed by Ann (1993). The capital letters refer

[4]Ann (1993) uses "unspread", but for the sake of consistence, I use "nonspread" throughout the current study.

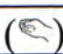
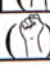
to the different degrees of difficulty. 'E' represents 'easy' handshapes, 'D' represents 'difficult' handshapes and 'I' represents 'impossible' handshapes. Of the 12 acquired handshapes (those with and without hand-internal movement are listed separately), seven of them score zero, and they are classified as 'easy' handshapes; only two of them are more difficult handshapes, scoring one and two each. Ann (1993) claims that a handshape with extended Middle finger alone scores four, which means it is physically impossible to produce. However, there is such a handshape in HKSL, [⅄] (). Using Ann's account, this handshape obtain a score of 4 due to its extreme articulatory difficulty. The score of [Ĝ] () is marked with a question mark because this handshape is not scored by Ann (1993). Utilizing the formula[5] proposed by Ann (1993), the handshape [Ĝ] () also scores 0.

The acquisition data here support Ann's (1993) proposal because the majority of the acquired handshapes are easy, only a few of them are difficult, and the difficult ones are acquired later. In addition, the handshapes acquired with the specification for hand-internal movements score from zero to one, revealing that only handshapes of relative ease of articulation are acquired especially if they require hand-internal movements. The handshape [⅄] () is acquired in spite of articulatory difficulty, contrary to Ann's (1993) predictions.

[5]The formula is (IE/SS + P/JT) X $\text{MOC}_{\text{of selected fingers}}$, IE/SS is irrelevant because this handshape does not involve finger extension, P/JT is 0 in this handshape because the Middle, Ring and Pinky fingers act together: they are all flexed at the base and nonbase joints. $\text{MOC}_{\text{of selected fingers}}$ is also 0 because no muscle opposition is present in this handshape, only flexors are at work. 0 X 0 equals 0. Hence, the handshape [Ĝ] () scores 0. IE/SS is again irrelevant because no fingers extend in the handshape [A] (). P/JT is also 0 because the Middle, the Ring and the Pinky fingers are all flexed at the base and nonbase joints. $\text{MOC}_{\text{of selected fingers}}$ is 1 because the Thumb is "bent" (i.e. flexed at the base joint). 0 X 1 equals 0, thus the handshape [A] () scores 0.

In fact, the scores of Ann's (1993) model may be too broad in the sense that many handshapes fall into the category of "easy handshapes" without finer distinctions, weakening the predictability of her scoring system. Therefore, in order to be more predictive about the acquisition patterns, a more refined system needs to be developed.

Table 5.3 Acquired handshapes of CC with Ann's (1993) proposed scores[Note]

		Acquired handshapes			
	1;9.6				
	1;10.10	[1] () (Score 0)	E		
	1;11.8	[5] () (Score 0)	E		
	2;0.12	[Ĝ] () (Score 0?)	E?		
	2;1.9				
	2;2.14	[Å] () (Score 0)	E		
	2;3.4				
Age of acquisition	2;4.16				
	2;5.6				
	2;6.3	[S] () (Score 0)	E		
	2;7.3				
	2;8.6				
	2;9.11				
	2;10.9	[B̂] () (Score 1) with [once] [closing]	E	[O] () (Score 1) with [once] [opening]	E
	2;11.13	[A] () (Score *)	#	[i] () (Score 0)	E
	3;0.13	[S] () (Score 0) with [once] [closing]	E	[I] () (Score 2)	D
	3;1.8				
	3;2.3	[人] () (Score 4)	I		

[Note]It should be noted that the scores proposed by Ann (1993) only refer to static handshapes without HIM, and handshapes without scores are not further discussed.
*The asterisk indicates that the exact handshape is not discussed by Ann (1993) so no score is available
#Since no score is available, the handshape is not categorized as "easy" "difficult" or "impossible".

5.3.2 Attempted but not yet acquired handshapes

Table 5.4 shows the attempted but not yet acquired handshapes of CC with Ann's (1993) proposed scores. The handshapes are attempted but not yet acquired because they did not reach the threshold of 5 attempts accumulated over time and / or did not reach an accumulative accuracy of 80%.

Table 5.4 Attempted but not yet acquired handshapes of CC with Ann's (1993) proposed scores[Note]

HS #		Handshapes and Scores
1	E	[G̈] () (Score 0)
2	E	[Ï] () (Score 0)
3	E	[5̈] () (Score 0)
4	E	[B̈] () (Score 0)
5	E	[Ċ] () (Score 0)
6	#	[F̂] () (Score *)
7	#	[B] () (Score *)
8	#	[Ḃ] () (Score *)
9	E	[B̿] () (Score 1)
10	E	[C] () (Score 1)
11	E	[B̂] () (Score 1)
12	#	[5̿] () (Score *)
13	D	[V] () (Score 2)
14	D	[Y] () (Score 2)
15	D	[Ẏ] () (Score 2)
16	D	[W] () (Score 2)
17	D	[U] () (Score 3)
18	#	[U̇] () (Score *)
19	#	[R] () (Score *)
20	#	[Â] () (Score *)

[Note]Handshapes without scores are not further discussed. (This also applies to Tables 5.5 and 5.6.)

*The asterisk indicates that the exact handshape is not discussed by Ann (1993) so no score is available (This also applies to Tables 5.5 and 5.6.)

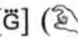
#Since no score is available, the handshape is not categorized as "easy" "difficult" or "impossible". (This also applies to Tables 5.5 and 5.6.)

"Easy" handshapes made up around one-third of CC's attempted varieties. A larger number of difficult handshapes were found in the attempted inventory than in the acquired inventory. More handshapes were attempted with HIMs and more handshape types were attempted when compared to the acquired inventory.

Some data in Table 5.4 were unpredictable because "easy" handshapes were predicted to be acquired early, but some of them were only attempted but not acquired. This may be due to two reasons. First, the working criteria of 'acquired' in the current study may be 'too stringent'. Second, the results were only derived upon investigating one subject for one and a half year. The limited data size may obscure the actual acquisition pattern.

5.3.2.1 Ann's (1993) scoring system: An evaluation

Ann's (1993) scoring system can account for quite a large proportion of CC's data. First, the acquired handshapes belong to her category of "easy" handshapes, for example, [Ȧ] (), [1] () and [i̇] (), although one 'difficult' and one 'impossible' handshapes, [I] () and [⅄] () respectively, are included (see reasons discussed in Section 4.1.2). Second, some "easy" handshapes such as [Ȧ] (), [T̄] () and [G̈] () as identified by her system were only attempted but not yet acquired by CC. For some like [Ȧ] () in the sign THANK-YOU, it may be due to the specification for HIMs, Lastly, "impossible" handshapes as described in Ann (1993) are unattested in the Dictionary.

Although Ann proposes a ranking based on phonetic difficulty, namely, nonbase joint flexed (3) > extended (2) > bent (1) > closed (0) (in descending degree of phonetic difficulty), the scoring thus derived fails to support the researcher in accounting for finer distinctions in the inventory. For example, given the same selected finger, the extended Index [1] (), and its nonbase flexed counterpart [T̄] (), both scored 0. Note that in the typology literature, [nonbase flex] is the most marked and [extended] the least marked. The same happens to [i] () and [G̈] (). Therefore, further modification is needed in her proposed formula in order to reflect the phonetic difficulty ranking she suggests.

5.3.2.3 Substitutions and Ann's (1993) scoring system

In the literature, it is usually suggested that 'less marked' handshapes substitute for 'more marked' handshapes. Ann's (1993) scoring system and the data collected in this study offers an opportunity to verify this notion because she divides the handshapes into three classes according to their 'markedness' phonetically defined.

Tables 5.5 and 5.6 list the scores and classes of the target handshapes and those of the substitutes. Table 5.5 shows the target handshapes which are easy, and Table 5.6 shows the target handshapes which are difficult. Categorically, many of the handshapes were substituted by other handshapes which were easier, or at least, no more difficult than the targets.

Table 5.5 Scores and classes of target handshapes and substitutes (Easy targets)

HS #	Target handshape	Score	Class	Handshape substitute	Score	Class
1		0	E		0	E
2		0	E		*	#
3		0	E		0	E
			E		0	E
			E		0	E
			E		0	E
4		0	E		0	E
					*	#
					1	E
5		0	E		0	E
					0	E
					0	E
					*	#
6		0	E		0	E
					0	E
					*	#
7		0	E		0	E
					0	E
					No score by Ann (1993) because this is unattested in TSL.	
					No score by Ann (1993) because this is unattested in TSL.	
					0	E
					0	E
8		0	E		0	E
					0	E
					0	E
					0	E
					*	#
9		*	#		0	E
10		*	#		0	E
11		1	E		0	E
					0	E
					0	E
					0	E
					1	E
					0	E
					0	E
					0	E
					*	#
					1	E
					0	E
12		*	#		0	E
					0	E
					1	E

The first three handshapes were all substituted by other easy handshapes which score 0 except for [A] ( ) since no score is available in Ann (1993).

Although [5̈] ( ) was substituted by [B̿] ( ) which scored 1, the substitute was easy according to Ann's (1993) classification and it only substituted for [5̈] ( ) once compared to the other scored-0-substitute [5] ( ) which occurred four times. [5̈] ( ) was also substituted by [5̿] ( ) once, and it did not have a score because Ann (1993) claimed that there are no handshapes which have the fingers spread when they are flexed at the base joints. However, such a handshape is actually attested in HKSL, for example, HAT.

[B] ( ) was substituted by . It only substituted for [B] ( ) three times, whereas the other score-0 handshape, [5] ( ), substituted for [B] ( ) for 30 times.

[Ṫ] ( ) and [G̈] ( ) were substituted by other easy handshapes which scored 0 or by handshapes unattested in Taiwan Sign Language which were not scored by Ann (1993). might be an exceptionally difficult substitute (Ann gave a score of 4 to a handshape with unspread curved TIM + RP flexed at base and nonbase joints), but it only substituted for [G̈] ( ) once only, compared to [G̿] ( ) which served as the substitute for 25 times.

[B̂] ( ) was substituted by handshapes which had the same score or those which scored lower.

To sum up, categorically, many of the handshapes are substituted by other handshapes which are easier, or at least, no more difficult than the targets. And this is in line with the claim in the literature that handshapes are substituted by less marked handshapes. Though sometimes the substitutes score higher than the targets but these 'harder' substitutes only made up occasional tokens, contributing to a very small proportion of relevant substitutions.

Table 5.6 lists the scores and classes of the difficult target handshapes and those of the substitutes. Similar to findings from Table 5.5, it is also observed in Table 5.6 that, categorically, all the handshapes are substituted by other handshapes which are easier, or at least, no more difficult than the targets.

Table 5.6 Scores and classes of target handshapes and substitutes (Difficult targets)

HS #	Target handshape	Score	Class	Handshape substitute	Score	Class
1		2	D		0	E
					0	E
2		2	D		0	E
					2	D
3		2	D		2	D
					No score by Ann (1993) because this is unattested in TSL.	
4		2	D		0	E
					0	E
					*	#
					0	E
					0	E
					0	E
					0	E
					0	E
					2	D
5		3	D		2	D
6		3	D		0	E
7		*	#		2	D
8		No score by Ann (1993) because she did not study [crossed].			No score by Ann (1993) because this is unattested in TSL.	
					No score by Ann (1993) because this is unattested in TSL.	
9		No score by Ann (1993) because she did not study handshapes with secondary selected fingers.			*	#
					0	E
					No score by Ann (1993) because this is unattested in TSL.	

Table 5.6 shows that all the difficult target handshapes were substituted by handshapes which are easy, or by handshapes which are difficult but score lower than the targets, or by handshapes which score the same as the targets.

[ϔ] ( ) was substituted by . The substitute was not scored by Ann (1993) because it is unattested in Taiwan Sign Language. substituted for [ϔ] ( ) once only, whereas [Y] ( ) substituted for [ϔ] ( ) twice.

Two sets of data were excluded from Tables 5.5 and 5.6 because the target handshapes were not scored by Ann (1993), so no further analysis can be conducted. The two target handshapes were [R] () and [Â] (). [R] () and [Â] () receive no scores because Ann (1993) did not study handshapes with Index and Middle fingers crossing each other and those that involve SSFs.

5.3.3 Unattempted handshapes

Presumably, most of the unattempted handshapes should be difficult. The handshapes which were identified by Tang (2007) and not attempted by CC are listed in Table 5.7 along with the scores and classes.

Table 5.7 Scores and classes of unattempted handshapes

HS #	Unattempted handshape	Score	Class
1	[E]	0	E
2	[5̈]	0	E
3	[4]	0	E
4	[3]	0	E
5	[G̿]	0	E
6	[B̈]	1	E
7	[Û]	1	E
8	[ȣ̂]	1	D
9	[ȣ̄]	1	D
10	[ȣ]	1	D
11	[ϙ̂]	1	D
12	[Y]	2	D
13	[V̇]	2	D
14	[W_{NS}]	3	D
15	[W⃛]	3	D
16	[V⃛]	3	D
17	[I⃛]	3	D
18	[V̈]	Unscored	
19	[F]	Unscored	
20	[F_o]	Unscored	
21	[W_{TP}]	Unscored	
22	[8̂]	Unscored	
23	[W_C]	Unscored	
24	[K]	Unscored	
25	[$Â^X$]	Unscored	
26	[i^F]	Unscored	
27	[i†]	Unscored	
28	[U_x]	Unscored	

There were 28 unattempted handshapes. Seven of which were classified as easy, 10 of which were difficult, and 11 of which were unscored. The 18th to the 22nd handshapes were not scored because they involve a set of fingers which are flexed at both the base and nonbase joints, but Ann only scored those with extended, curved (i.e. fingers flexed at the nonbase joints) and bent (i.e. fingers flexed at the base joints) handshapes. The 23rd to the 28th handshapes were not scored because they involve secondary selected fingers and they were not investigated in Ann's (1993) study. They cannot be scored at this stage because Ann (1993) does not provide any suggestions on scoring handshapes with secondary selected fingers.

Although it seems that easy and difficult handshapes made up similar proportions of unattempted handshapes, difficult handshapes actually made up a larger proportion of the unattempted handshapes because handshapes with secondary selected fingers are presumably difficult. Therefore, 16 difficult handshapes (six of which are unscored but involve SSFs, thus can be classified as "difficult") contributed to the unattempted inventory which consists of 28 handshapes. In other words, more than half of the unattempted handshapes were difficult. Ease of articulation may not be the only reason why CC did not attempt certain handshapes as some of them were easy. CC did not attempt certain handshapes can also be explained by the fact that some of the handshapes are used in a few lexical items only, and there might not be a need for CC to use these lexical items. The properties of the unattempted handshapes and the proposed reasons for why CC did not attempt some of the handshapes are discussed in Section 4.2.

5.4 Conclusion

This chapter introduces Ann's (1993) model and uses the acquisition data collected in this study to test against it. In general, the data lends support to Ann's (1993) physiology account, although mechanisms for arriving at finer distinctions modifications is necessary in order for the account to achieve a higher degree of predictability in the acquisition of sign language phonology.

The acquired inventory supports the classification of the handshapes by Ann (1993) because the majority of the acquired handshapes are 'easy', only a few of them are more 'difficult', and the more 'difficult' ones were acquired later by CC.

The substitution data also support the classification of handshapes by Ann (1993). Categorically, many of the handshapes were substituted by CC with other handshapes which were easier, or at least, no more difficult than the targets. This is in line with the claim in the literature that handshapes are substituted by less marked handshapes. Although the substitutes score higher than the targets sometimes, these 'harder' substitutes in fact come from occasional errors.

The unattempted handshapes reflect their intrinsic articulatory difficulties, which have been confirmed by the physiology account.

In addition, 'impossible' handshapes were unattested in the Dictionary which also supported the validity of Ann's (1993) classification.

Ann's (1993) physiology account is not without flaws. As it stands, the categorization of handshapes using the proposed formulae does not provide enough empirical evidence to support the researchers to set up an order of acquisition of handshapes. As seen from the above discussion, quite a number of handshapes are classified as "easy" which in fact show finer featural distinctions. Therefore, Ann's (1993) proposed criteria and formula need further modifications in order to be more reflective about the ranking of ease of articulation. This is suggested in data such as [1] () vs. [T̄] () and [i] () vs. [G̈] (). Given the same selected finger, Index, as in the former pair of data, both scored 0, but Ann (1993) actually proposes a ranking of ease of articulation: nonbase joint flexed (3) > extended (2) > bent (1) > closed (0) (in descending degree of phonetic difficulty). This ranking is however not confirmed in the scores of [1] () and [T̄] () because [T̄] () should be more difficult than [1] () and should score higher.

Moreover, Ann's (1993) model would be more comprehensive if [crossed] handshapes and handshapes with Secondary selected fingers were included in the investigation. Also, inclusion of "possible" handshapes is necessary. Ann (1993) claimed that there were no handshapes with fingers flexed at the base joints and spread; however, this was attested in the HKSL inventory, as in the handshape [5̿] ().

To conclude, Ann's (1993) model can account for the acquisition of CC, but finer modifications are necessary. In addition, her model lacks predictive power in terms of the relations between handshape substitutions, whereas my proposed Handshape unit model predicts that handshape substitutes are less marked than the handshape targets in terms of feature markedness of the relevant nodes. For example, [T̄] () is predicted to be substituted by [1] () because [extended] is less marked than [nonbase flex] in the Joint position node. Lastly, reasons other than ease of articulation should not be neglected in explaining the acquisition pattern because sometimes difficult handshapes could nevertheless be acquired quite early as discussed in Section 4.1.2; and easy handshapes could be unattempted as discussed in Section 4.2.

Chapter 6 Conclusion

6.1 Summary of the study

The current study adopts a DP approach in the analysis of the acquisition of handshapes in HKSL. The approach assumes that there is a hierarchical organization of class nodes, each embodying a set of unary features which show degree of markedness defined typologically and physiologically. As such, this featural system has advantages in analyzing handshape acquisition because using an entire handshape as a description unit may obscure the generalizations across different handshapes. The proposed Handshape Unit Model is adapted from Eccarius (2002) to capture the structural formation of a handshape unit. Moreover, the relationship between HIM and handshape, which has not yet been studied in earlier research, falls within the area of investigation in this study. Three hypotheses are made and tested against in this thesis. H1 hypothesizes that there is an order of acquisition, and children acquired handshapes from less marked to more marked ones. H2 hypothesizes that when children are nontarget in their productions of handshape, they substitute the target handshapes by other less marked handshapes and their substitutions are not random. H3 hypothesizes that the accuracy rates of finger selection and finger configuration tend to drop with the requirement of HIMs. The three hypotheses are generally confirmed in the current study.

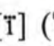
6.2 Physiology and handshape acquisition

6.2.1 'Ease of articulation' in phonetics and phonology

One of the central notions of markedness in this thesis is articulatory difficulty, with the hypothesis that handshape units which are easier to produce are acquired before those that require greater manual complexity. This may arouse concerns that such an approach may not be 'linguistic' enough because to view phonological development simply as gradual increase in the accuracy of phonetic production may seem to go against the spirit of mentalistic linguistics. However, it should be noted that, first, articulatory difficulty is not the only factor that determines the hierarchical structure of the Handshape Unit Model; data on typological frequency are also taken into consideration. Second, 'ease of articulation' is also used to explain some linguistic phenomena in spoken languages, such as "inventory of linguistic sounds", "distribution facts about the phonetic makeup of different sized consonant inventories", "order of acquisition of phonemes by children" and "rarity of some sounds across languages" (see Ann 1993 for more extended discussion). Moreover, in spoken languages, articulatory phonetics helps categorise similar sounds according to the way they are produced. For instance, /b/ /d/ and /g/ are classified as 'voiced' because these sounds are produced with vibration of the vocal folds. They behave as a group in some phonological processes, such as 'devoicing' in child language. The Handshape Unit Model proposed in this thesis may help classify handshapes into groups similarly. For example, from the data discussed in the current thesis, the handshapes which are specified for [nonbase flex] may all behave similarly phonologically because children tend not acquire this feature initially, resulting in to produce them without flexion at the early stage of acquisition and this can be viewed as 'deflexing' in child sign language.

6.2.2 Review of Ann's model

The current study also tests against the scoring of handshapes developed by Ann (1993). It has been found that the handshape scores generally predict the acquisition patterns in the sense that "easy'" handshapes were acquired before "difficult" ones, and the substitute handshapes are generally members of the set of "easy" handshape. The unattempted handshapes also echo the prediction that most of the unattempted handshapes are categorized as difficult. In addition, 'impossible' handshapes are unattested in Tang (2007), which also supports the validity of Ann's (1993) classification.

Inasmuch as many of the acquired handshapes are classified as easy and scored 0 by Ann (1993), a more refined scoring system is necessary so as to predict the order of acquisition. Ann's (1993) model also lacks predictive power in terms of the relations between handshape substitutions, whereas the Handshape Unit Model proposed in this study predicts that handshape substitutes are less marked than the handshape targets. For example, [Ť] () is predicted to be substituted by [1] () because [extended] is less marked than [nonbase flex] in the Joint position node of the PSF node. Moreover, Ann's (1993) model does not take into account handshapes involving the [crossed] feature (i.e. the handshape [R] ()) and those involving Secondary selected fingers. Therefore, her model fails to make predictions on handshapes involving these characteristics.

6.3 Bases of markedness in the current thesis

It is generally assumed that "in spoken languages, phonetics and phonology ideally inform each other about, and provide independent motivation for, their respective claims" (Pierrehumbert 1990, Rischel 1990, Lindblom 1990:139 and many others, cited in Ann 1993:35). As such, in order to study the phonology of sign language (handshape in the current case), phonetics of sign language needs to be taken into consideration, and presumably, physiology plays an important role in the phonetics of sign language. That is why physiology of the hand is referred to in developing the Handshape Unit Model. Apart from physiology, some linguists also believe that typological markedness offers an account of language acquisition path because frequency of distribution does not come about arbitrarily. Rather, factors such as ease of articulation, perceptual salience, and cognitive demand may yield the typological distributions we now observe. In fact, most models of sign language phonology resort to typological findings one way or another in making claims about feature distribution. Eccarius (2002) is a typical example whose proposal is based on a crosslinguistic comparison of 12 sign languages.

6.4 Handshape acquisition affected by factors other than markedness

The data collected in the present study to a large extent support the proposed Handshape Unit Model and confirm the three hypotheses. However, other factors such as the phonological features of the whole sign, frequency, and even gestural similarity are observed to play a role in affecting the acquisition of handshapes. As such, any single account would be insufficient in accounting for the acquisition findings as all the aforementioned factors interact with one another. 'Exceptional data' are almost unavoidable if only one single account is used in explaining acquisition. Nevertheless, the Handshape Unit Model proposed in this study is able to predict and account for a large proportion of handshape acquisition data collected in the present study.

6.5 Unresolved issues and limitations

As a first attempt in developing a sign language phonology model to account for the acquisition of handshape in HKSL, the current study suffers from some limitations.

6.5.1 The dependents of the Handshape Unit Model

The proposed Handshape Unit Model attempts to account for the order of handshape acquisition. It is confirmed in this study that a handshape unit which requires activation of a dependent node would be more difficult than one which does not. Nevertheless the kinds of the head-dependent relation and its effect on handshape acquisition are yet to be further explored.

The head-dependent relation for various nodes seems to reflect different kinds of articulatory difficulty. Some dependents (e.g. nonselected fingers) seem to be merely by-products of the choice of the head (e.g. selected fingers), while other dependents (e.g. hand internal movement) encode manual articulations made on top of the head (i.e. the handshape). Though the dependents are of heterogeneous nature, it remains a valid claim that adding of either kind of dependent nodes evokes a more complex hand configuration, suggesting a higher level of difficulty.

The 'by-product' kind of dependent may arouse concerns because it does not involve specification of additional features, compared to other kinds of head-dependent relations. However, even when referring to this 'by-product' kind of dependent, a handshape with fingers splitting as selected and nonselected is more marked than a handshape with all fingers selected, which is one that does not evoke the nonselected fingers dependent node. This claim is again supported with the findings in (Ann 1993) that one-group handshapes are always easy because the hand tends to act together. I admit that the various (kinds of) dependents may evoke different levels of difficulty and this calls for further investigation.

6.5.2 The Thumb

The acquisition data concerning the Thumb call for a further modification on the proposed Handshape Unit Model because when the signs were realized with [all] in the Quantity node, the Thumb tends to be 'added' even it is not specified (c.f. Section 4.3.3.1). The Thumb was also added when it was not required in some handshapes, especially when the POR specified was [radial], for example, [V] ( ) was produced as [V̇] ( ) and [1] ( ) was produced as [i] ( ). However, according to the proposed Handshape Unit Model, adding the Thumb would make the structure more complex. The acquisition data and the physiological tendency may clue researchers in on restructuring the Thumb node. It may be the case that the thumb should not be a dependent. Or, the Thumb remains as a dependent but the realization of the Thumb node does not make a structure more or less marked. If the Thumb is not a dependent, how the fingers are represented needs modification. If the Thumb remains as a dependent but the realization of the Thumb node does not make a structure more or less marked, it would lead to theory-internal inconsistency because DP states that a structure which is structurally more complex is more marked (Kooij 2002). Among these two 'solutions', perhaps not treating the thumb as a dependent may be a better choice because it does not ruin the theory-internal consistency. I leave this for future research.

6.5.3 Underspecification

Underspecification is not meant to be dismissed completely in the proposed Handshape Unit Model. At first, I wanted the Model to represent the NSFRR. However, the rules do not predict all the features of the NSFs because exceptions are observed, e.g. both the selected and nonselected fingers are flexed as in the handshape [Ĝ] (). Fully predicted redundancies await further research in order to improve the representation of the model.

6.5.4 Feature markedness ranking

In the Model, the ranking of feature markedness of individual nodes needs data from physiology and typology; however, such data are not sufficient at this stage. Some node features, for example, features in the Thumb node of the PSF node and the whole SSF node, lack markedness ranking at this stage, so the cross-linguistic frequencies of these features are needed in order to suggest the ranking of feature markedness in all the corresponding nodes.

6.5.5 Possible idiosyncrasy

As the current thesis is a case study, the fact that only one child is investigated in this study implies the possibility that some of the data may be idiosyncratic, which may lead to the low applicability of the Model because it is developed to account for the data of a single child. However, this possible idiosyncrasy is reduced by testing the Model against data from other studies, and the data from other studies largely confirm the validity of the Model.

Appendix A: Rule ordering postulated by Padden and Perlmutter (1987)

Padden and Perlmutter (1987) introduce a morphological rule, the "characteristic adjective rule" and a phonological rule, the "weak drop", and show that morphological rule should precede that of phonological rule.

Characteristic Adjective Rule

'Characteristic adjectives have the meaning 'characteristically (adjective)' (Padden and Perlmutter 1987:344). They can only be derived from adjectives denoting temporary or incidental states, not from those referring to an inherent state.

Almost all characteristic adjectives are two-handed and produced with circular movement. All of them are reduplicated. They can be arranged into two classes according to the manner of the movement: whether the two hands move in an identical or alternating manner. Actually the manner of movement of the characteristic adjectives is predictable: if the input, the basic adjective form, is one-handed, the output, the characteristic adjective form, is alternating; in contrast, if the input is two-handed, the output is also two-handed but nonalternating.

Weak Drop

Battison (1974, 1978) points out that some two-handed signs can be produced with only the strong hand under certain circumstances. This dropping of the weak hand is optional. It is more frequently observed in rapid or relaxed signing. Padden and Perlmutter (1987) name this phenomenon Weak Drop. Battison also mentions that Weak Drop is not allowed in alternating signs. In other words, Weak Drop is only applicable to nonalternating two-handed signs.

Evidence for a post-lexical phonological component

Applying the Characteristic Adjective Rule to the basic adjective forms, the outputs are alternating if the inputs are one-handed and non-alternating if they are two-handed. Take the two-handed adjective QUIET ((13) of the original paper, see Clip A-1 ). The Characteristic Adjective Rule correctly outputs the nonalternating characteristic adjective ((14) of the original paper, see Clip A-2 ) from the two-handed basic form. Weak Drop outputs the one-handed form ((54) of the original paper from the two-handed basic form. If derivational and phonological rules are all in the lexicon and therefore apply to each other's outputs, the Characteristic Adjective Rule can apply to the weak dropped form, then output the alternating characteristic adjective ((55) of the original paper, see Clip A-3 ).

However, it is ungrammatical. The correct form is the circular reduplicated nonalternating form ((14) of the original paper, Clip A-4 ) above.

This suggests that the Characteristic Adjective Rule, being a morphological rule, is in the lexicon, and Weak Drop is a phonological rule which is in the postlexical phonological component, so the Characteristic Adjective Rule in the lexicon cannot apply to outputs of Weak Drop. It is evident the interaction between morphological and phonological rules is orderly: phonological rules should follow the morphological rules.

Appendix B: Handshapes, handparts, features, and other terminology

Handshapes

Table A.1 lists the handshapes identified in HKSL, the table was adopted from the Dictionary (in press). The handshapes are arranged from fully closed to fully open row by row. The columns are arranged according to the finger positions which will be introduced in the subsequent section. The symbols are adapted from the Stokoe's notation system (Stokoe et.al. 1976), with minor modifications. Some descriptive labels are used for clarity of linguistic description. Table A.2 illustrates the use of such labels.

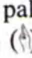
Table B.1 Handshapes and symbols

S								
O								
A	Ȧ				Â			Â^{x}
1	1̇		1⃛	1̇̇				1^{F}
⅄								
ȣ					ȣ̂	ȣ̿	ȣ̂̇	
I			I⃛					
U	U̇				Û			U$_{x}$
R								
			G⃛		Ĝ	G̿	Ĝ̇	
V	V̇	V̈	V⃛					V̄̇
K								
Y								
ʮ	ʮ̇				ʮ̂			
W			W⃛					W$_{NS}$
W$_{TP}$								
3								W$_{C}$
F					F̂			F$_{o}$
4								
B	Ḃ	B̂̇			B̂	B̿		B̄̈
C	Ċ							
E								
5			5⃛	5̈̇		5̿		

Table B.2 Use of descriptive labels

Label	Denotation	Example
Single dot	Presence of a nonclosed[a] Thumb	 1 vs.  i
Two dots	Flexed base joints	 V vs.  V̈
Three dots	Flexed nonbase joints	 1 vs.  1⃛
Four dots (Single dot + three dots)	Presence of an extended Thumb + Flexed nonbase joints	 1 vs.  1⃜
Arrow	Thumb contact	 B vs.  B⃗
Arrow + three dots	Thumb contact + Flexed nonbase joints	 ɤ vs.  8
Two lines	Flexed base joints and the selected finger(s) is/are parallel with the Thumb without contact	 B vs.  B̿
X	Crossed[b]	 U vs.  U_x
F	Thumb flexed at the nonbase joint	 i vs.  i^F
Inverted T	Opposition of Thumb without Thumb contact	 V̇ vs.  V̈
NS	Nonspread	 W vs.  W_{NS}
TP	Thumb and Pinky selected	 W vs.  W_{TP}
C	Configuration which looks like the alphabet C	 W vs.  W_C
O	Configuration which looks like the alphabet O	 F vs.  F_O

[a]'Nonclosed' refers to not flexed at both the base and nonbase joints.

[b]This is different from the feature [crossed] defined in the content of the thesis. [Crossed] as a Thumb feature or a Finger Position feature is defined as the palmar part of a selected finger crosses over the back of the other selected finger(s), as in [S] () and [R] (). Crossed here means any two fingers look crossed, without specifying which part of a finger crosses over which part of the other selected finger.

Appendix C: List of the lexical units in which the handshape units occur

Table C.1 shows the list of the lexical units in which the handshape units occur in the data analysed. Column A represents the handshape, Column B shows an English gloss of the sign, and Column C indicates the hand-internal movement. Column A is organised according to the order of appearance of the handshapes in the sign language dictionary entitled Hong Kong sign language: A trilingual dictionary with linguistic descriptions (Tang 2007).

Table C.1 – p. 1 List of the lexical units in which the handshape units occur in the data analysed

A Handshape	B Gloss	C HIM
 (S)	GRAB	[once] [closing]
	DISCARD	[once] [opening]
	ICE-CREAM	none
 (O)	BITE	[once] [closing]
	FLOWER	[once] [opening]
	FIRE	
	ASK	
	SAY	
	VEGETABLE	
	WHTIE	[trilled] [opening]
	SUN	[repeat] [opening]
 (A)	STUPID	none
	GRANDMOTHER	
	UNCLE	
	OLD-WOMAN	
	OLD-MAN	
	OLD	
 (Ȧ)	THANK-YOU	[trilled] [hooking]
	FATHER	none
	CORRECT / GOOD	

Table C.1 – p. 2 List of the lexical units in which the handshape units occur in the data analysed

A	B	C
Handshape	**Gloss**	**HIM**
 (Â)	SOUP	none
	KEY	
	COMB	
	FEMALE	
	TOOTHBRUSH	
	MIDAUTUMN-FESTIVAL	
 (1)	NOSE	none
	ONE-DOLLAR	
	FAN	
	BLACK	
	KNOW	
	WH-marker	
	SWEET	
	TOOTHBRUSH	
	ASHAMED	
	RED	
	MOTHER	
	WORM	[trilled] [hooking]
 (i)	SHOOT	none
	GUN	
	MANY	
	FARE-BETTER-THAN	[once] [opening]
 (Ï)	HAVE	none
	PINK	
	REMEMBER	
 (⅄)	ELDER-SISTER	none
	ELDER-BROTHER	
 (I)	YOUNGER-SISTER	none
	WRONG / BAD	
	DON'T-KNOW	
 (U)	NOODLES	none
 (U̇)	HAVE-A-MEAL	none
	VIDEOTAPE	
 (R)	SECRET	none
 (G̈)	NURSE	none
	SMILE	
	BISCUIT	

Table C.1 – p. 3 List of the lexical units in which the handshape units occur in the data analysed

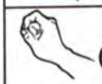
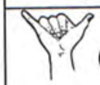
A Handshape	B Gloss	C HIM
 (Ĝ)	CHICKEN	[trilled] [closing]
	HAIR-CLIP	[once] [closing]
 (G⃛)	MELON-SEEDS	none
	LIKE	
	PEN	
	CLOTHES	
 (V)	CUT-HAIR	[trilled] [spreading]
	SCISSORS	[trilled] [spreading]
	CHANGE	none
	LOOK-AT	
	SEARCH	
	CRY	
 (V̈)	GREEN	[wiggling]
 (Y)	SOFT-DRINKS	none
	TELEPHONE	
	LEAVE	
 (Ṫ)	AEROPLANE	none
 (W)	MC-DONALD'S	[trilled] [flattening]
	FAECES	[trilled] [hooking]
	FORK	none
	WATER	
 (F̂)	PURPLE	none
 (B)	WAIT	none
	SORRY	
	PLEASE	
	POLICE	
	KNIFE	
	STINK	

Table C.1 – p. 4 List of the lexical units in which the handshape units occur in the data analysed

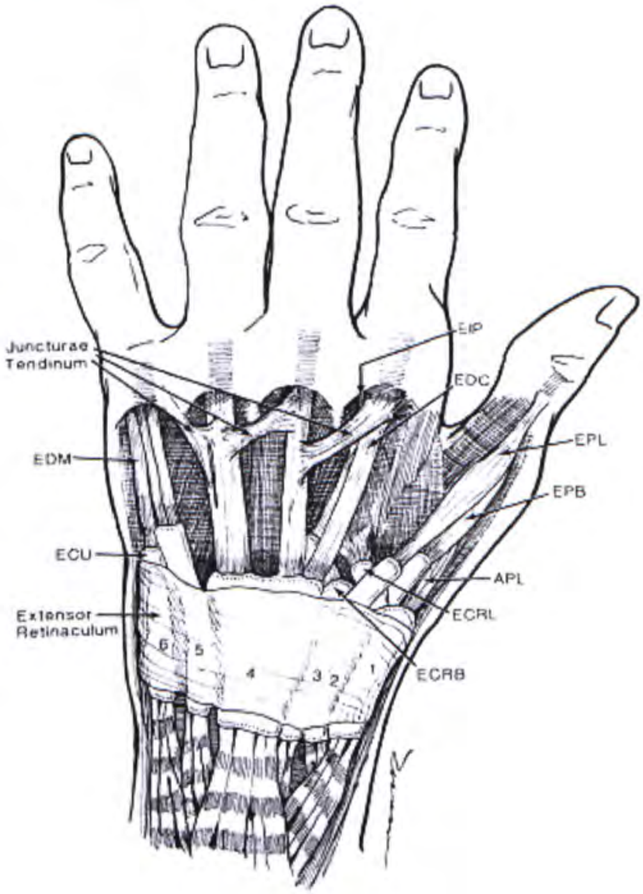
A	B	C
Handshape	**Gloss**	**HIM**
	IGNORE	none
	SMELL-WELL	
	SHORT	
	TALL	
	WIPE	
	ORANGE	
	MIRROR	
	TV	
	PUT	
	AFRAID	
	CUT	
	CHOP	
	FISH	[trilled] [flattening]
	BLUE	none
	DUCK	[trilled] [closing]
	BREAD	
	WET	
	DIRTY (home sign)	
	SHEEP	[once] [closing]
	FOOD / EAT	none
	DOCTOR	
	GIVE	
	MONEY	[trilled] [rubbing]
	ELEPHANT	none
	CUP / DRINK	none
	WALKIE-TALKIE	none
	FULL-STOMACH	none
	NO / NOT-GOOD	
	MY	
	MALE	
	BATH	

Table C.1 – p. 5 List of the lexical units in which the handshape units occur in the data analysed

A	B	C
Handshape	**Gloss**	**HIM**
 ($\overset{\dots}{5}$)	APPLE	none
	ANGRY	
	YELLOW	
	PIG	
 ($\overset{\equiv}{5}$)	HAT	none

Appendix D

Figure D.1 Extensors[Note]



[Note]Source: http://www.rcsed.ac.uk/fellows/bcpaterson/images/mallet2.jpg

The extensors discussed in Ann (1993) include the common extensors: EDC (extensor digitorum communis of the Index, Middle, Ring and Pinky), EPB (extensor pollicis brevis of the Thumb), and the independent extensors: EPL (extensor pollicis longus for the Thumb), EIP (extensor indicis proprius for the Index), and EDM (extensor digiti minimi for the Pinky).

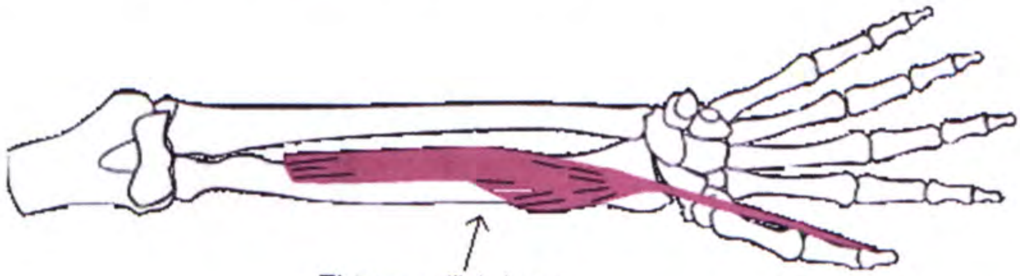
Figure D.2 Flexor digitorum profundus (the crossed part)[Note]

[Note]Source: http://www.eatonhand.com/mus/mus078.htm

Figure D.3 Flexor digitorum superficialis (the crossed part)[Note]

[Note]Source: http://www.eatonhand.com/mus/mus079.htm

Figure D.4 Flexors pollicis longus of the Thumb[Note]

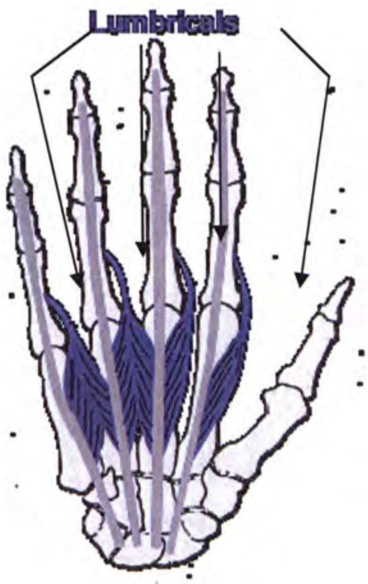


[Note]Source: http://classes.kumc.edu/sah/resources/handkines/images/efflxpollilong.gif

Figure D.5 Flexor pollicis brevis of the Thumb (the crossed part)[Note]

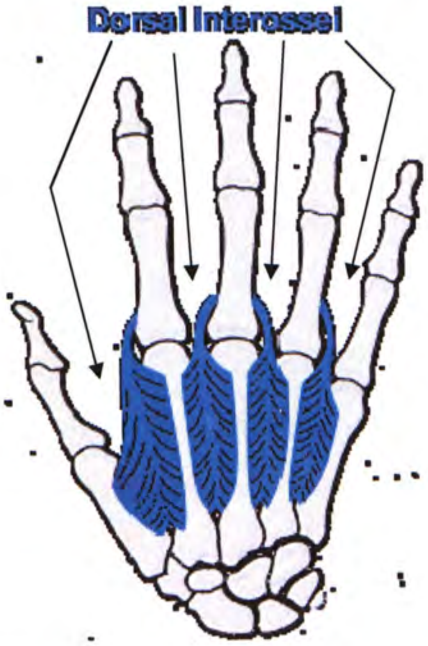
[Note]Source: http://www.eatonhand.com/mus/mus040.htm

Figure D.6 Lumbricals (one set of intrinsic muscles)[Note]



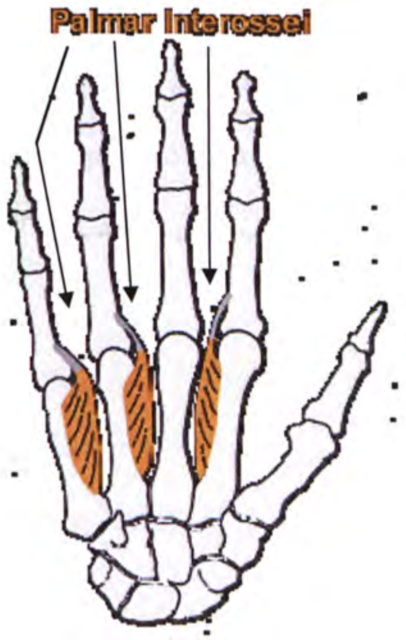
[Note]Source: http://classes.kumc.edu/sah/resources/handkines/images/inlumbri.gif

Figure D.7 Dorsal interossei (one set of intrinsic muscles)[Note]



[Note]Source: http://classes.kumc.edu/sah/resources/handkines/images/intrmaindor.gif

Figure D.8 Palmar interossei (one set of intrinsic muscles)[Note]



[Note]Source: http://classes.kumc.edu/sah/resources/handkines/images/inpalinteros.gif

Appendix E

E.1 How to calculate the handshape scores?

Any handshape can be assigned a '+' or '-' to the three criteria mentioned above. A '+' indicates ease and it is always worth 0; whereas '-' indicating difficulty is always worth 1. This can be applied to the algorithm proposed by Ann (1993):

$(IE/SS + P/JT)$ X $MOC_{\text{of selected fingers}}$[1]

where:

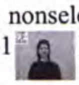
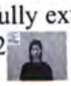
IE/SS = independent extensor/sufficient support

P/JT = profundus/juncturae tendinum

MOC = muscle opposition in configuration

The algorithm says that the numerical value of independent extensor/sufficient support criterion is added to that of the profundus/juncturae tendinum criterion. The sum is then multiplied by the value of the MOC. The MOC scores are repeated here: curved (3), extended (2), bent (1), and closed (0).

Criteria two and three can be phrased as two questions. Criterion two can be phrased as, 'Does each finger in this group have either an independent extensor or sufficient support

[1]The definitions of 'selected fingers' are different between Ann's (1993) study and the current study. Ann (1993) states that 'selected fingers can be in any configuration but closed' and 'the unselected fingers are either all fully extended or all fully flexed.' In the current study, selected fingers are those which are 'foregrounded' (Mandel 1981), they are usually those (potentially) involved in hand-internal movements or those involved in body or non-dominant hand contact. Selected fingers can be closed, otherwise, there is no way to represent the handshape [S] () theoretically. It is because if no fingers are selected in this handshape, there is no way to further specify for the finger configuration [base and nonbase flexed]. Moreover, all fingers are selected in this handshape because they are volitionally closed, not that they are in a resting posture. As such, selected fingers can be closed. Secondly, there are signs with nonselected fingers being neither fully extended nor fully flexed, they are only lax, e.g. RICE (see Clip E-1 ) and PURPLE (see Clip E-2 ).

to extend?' Criterion three can be phrased as 'Are the middle, ring and pinky either all included or all excluded from the most flexed group?' If the answer to these questions is positive, a '+' (score 0) is given; and if the answer is negative, a '-' (score 1) is given.

Each handshape can then get a score by putting the numerical values put into the algorithm.

E.2 Justification for the algorithm

Ann (1993) claims that the scores for criteria one and two should be added together because of two reasons. First, these two criteria account for all the fingers which could take part in a handshape. Second, these two criteria contribute equally to the difficulty of a handshape.

The score of the third criterion is multiplied by the sum of the first two criteria. It aims at capturing the intuition that "the effect of configuration upon the particular fingers which act together is in some sense magnified by which combination of fingers is configured in which fashion" (Ann 1993:166). In other words, two fingers cannot act together independently of their configuration; rather, the two fingers can act together only if they are properly equipped to assume that configuration (Ann 1993).

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