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# Handshape Articulation in Taiwan Sign Language and Signed Chinese

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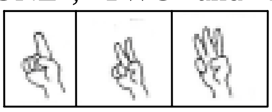
## 1. Introduction

There are many different sounds in the inventory of spoken languages. Among them, some sounds are very common and apparently easy to articulate, while some sounds are rare. Ladefoged and Maddieson (1996) have shown that some places of articulation are used more often than others (e.g. the labial region is used more often than the epiglottal region) and some manners of articulation (such as stops) are more common than others (such as trills). It is clear that some articulations are easier to make than others and some auditory distinctions are easier to maintain than others. The notion of ease of articulation has contributed to the explanation for various linguistic phenomena, such as: (a) inventory of linguistic sounds, (b) distribution facts about the phonetic makeup of different sized consonant inventories, (c) order of acquisition of phonemes by children of different language backgrounds, (d) certain phonological processes, (e) rarity of some sounds across languages (Ann 1993, 1996).

Parallel to spoken languages, in sign languages, some handshapes are easy to articulate, for example, “ONE”, “TWO” and “THREE” (as shown in (1) in Taiwan Sign Language (TSL)). Other handshapes are hard to articulate; for example, the TSL “EIGHT” (see (2)) is hard to articulate for most people. Finally, some handshapes are impossible; for example, the handshape where the ring finger is extended with the rest of the fingers closed is impossible to articulate.

(1) “ONE”, “TWO” and “THREE” (from Smith and Ting 1979, 1984)



(2) “EIGHT” (from Smith and Ting 1979, 1984)

Ann (1993, 1996) has studied the relation between physiology and handshape. From the viewpoint of the physiology and anatomy of hands, she applies three physiologically determined criteria to decide which handshapes are easy to articulate and which are difficult to articulate, rather than just basing the decisions on intuition alone. Ann examines data of two natural sign languages, American Sign Language (ASL) and TSL. Her results show that there is a correlation between the ease of articulation and the frequency of occurrence: the easier a handshape is to articulate the more often this handshape will occur. Clearly, ease of articulation plays a role in the frequency of occurrence of a given handshape.

We wonder if the artificial Signed Chinese (SC) used in Taiwan schools for the deaf will also conform to the physiological constraints of hands or if it will include many signs that do not follow the physiological principals of hands, i.e. are more “unnatural”. In section 2, we will first describe the distinction between TSL and SC. In section 3, we will introduce Ann’s model which can be used to calculate the “ease score” of any given handshape. In section 4, we show the frequency of occurrence of TSL and SC for the handshapes we are concerned with. Then in section 5 we perform two statistical tests to analyze the data. In section 6, we summarize and discuss our results.

## 2. Taiwan Sign Language and Signed Chinese

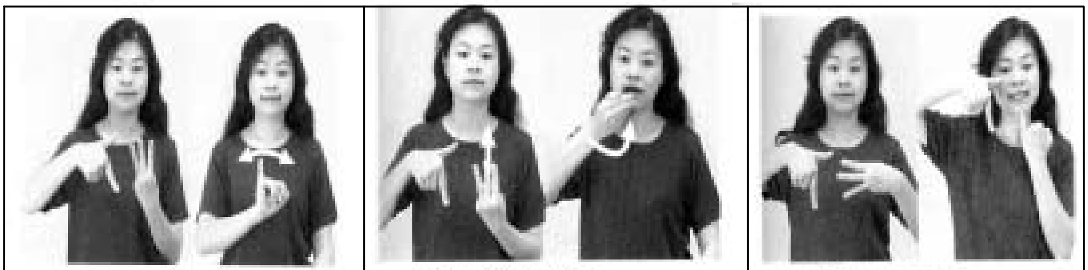
TSL is the primary language used by deaf and hearing-impaired people in Taiwan, which developed from three principal sources (Smith 1989). The first source was the early form of TSL developed spontaneously by the deaf in Taiwan before 1895, and for which unfortunately no information is available now. The second source was Japanese Sign Language (JSL) brought into the deaf education of Taiwan during the 50-year occupation of Japan. Even now, TSL still shares a large amount of vocabulary with JSL. Third, (Mainland) Chinese Sign Language (CSL) was brought to Taiwan by a large number of deaf refugees and former teachers of the deaf from China. The significance of the second influence has led scholars to group TSL into the Japanese Sign Language Family.

TSL has two major dialects, the Taipei and Tainan dialects. The differences between the two dialects are primarily lexical (Smith 1989). In this article, the TSL data are taken from books of Smith and Ting (1979, 1984), which use primarily the Taipei dialect.

In contrast with TSL, Signed Chinese (SC) is an artificial signed system invented by teachers of deaf schools and some deaf people. SC was invented to unify different dialects used by the deaf, minimize the misunderstandings among deaf people, and add signs that do not exist in the lexicon of TSL (Ministry of Education 2000). Unlike TSL, its morphology and syntax is taken directly from Chinese. SC is also characterized by a large number of Chinese character signs, which can be used to sign Chinese sentences character by character. We show some examples of SC in (3). Note that the morphology of the words matches the Chinese equivalents, and that the form of some of the signs imitates the Chinese characters (for more discussion of character signs, see Ann 1998).

As a natural language used by deaf people in Taiwan, TSL has its own unique grammatical system rather than just adopting the grammar of the local spoken language. For example, Smith (1989) has shown that verbs in TSL have a different morphological system from Chinese. However, only recently have some deaf educators begun to pay attention to deaf culture and the natural sign language used by deaf people in Taiwan (Chen 2001 and Wang 2001).

(3) Fairy (lit. immortal -female), meals (lit. food-food) and whatever (lit. any-how) (from Ministry of Education 2000)



仙女 2-182 (a fairy) | 伙食 2-56 (meals) | 任何 (whatever)

## 3. Ease of articulation of handshapes

Ann (1993, 1996) has analyzed the anatomy and physiology of different handshapes and applies three criteria to calculate the ease scores of each group of handshapes. We just introduce the formula she has used, rather than repeat her detailed description of the physiology of the human hand. The three criteria are the Independent Extensor Criterion (IEC), The Profundus Criterion (PC) and Muscle Opposition in the Configuration of Selected Fingers Criterion (MOC of SFC). IEC checks whether the finger has an independent extensor muscle (YES has a value of ‘0’, NO has a value of ‘1’). PC checks whether middle, ring and pinky fingers act together (YES has a value of ‘0’, NO has a value of ‘1’). MOC of SFC assigns different values to different configurations of handshapes, as listed in (4). Since Ann has argued that different configurations of handshape have different levels of difficulty, she assigns the highest value to the most difficult configuration (curved) and then uses the formula in (5) to calculate the final ease score of handshapes. The higher the score is, the harder the handshape is. From the observation of the articulation of handshapes, she has defined easy, hard and impossible handshapes according their ease scores as listed in (6).

(4) Value of MOC of SFC for the four configurations

Curved = 3; Extended = 2; Bent = 1; Closed = 0

(5) (IEC + PC) x (MOC of SFC) = Final Ease Score

(6) Easy handshapes: ease score = 0
Hard handshapes: 0 < ease score < 4
Impossible handshapes: ease score $\geqq$ 4

Following Ann (1993, 1996), we assume that fingers can take on four different configurations: open, curved, bent and closed. Fingers in each handshape can be divided into one or more groups, in each of which all fingers assume one of the four configurations. For example, the handshapes in (1) are all two-group handshapes: the fingers in one group are closed, while the fingers in the other group are extended. In this paper, we are concerned with two-group handshapes, especially two-group handshapes in which the fingers in one group are closed. We provide tables (from Ann (1993)) of ease scores for two-group handshapes in (7) through (10) (impossible handshapes are starred, difficult handshapes are boxed).

(7) One-finger handshapes, rest of fingers closed

Predicted final ease scores

| | Extended | Curved | Bent |
|---|---|---|---|
| Thumb | 0 | 0 | 0 |
| Index | 0 | 0 | 0 |
| Middle | *4 | *6 | $\boxed{2}$ |
| Ring | *4 | *6 | $\boxed{2}$ |
| Pinky | $\boxed{2}$ | $\boxed{3}$ | $\boxed{1}$ |

(8) Two-finger handshapes, rest of fingers closed

Predicted final ease scores

| | Extended | Curved | Bent |
|---|---|---|---|
| Th-In | 0 | 0 | 0 |
| Th-Mi | *4 | *6 | $\boxed{2}$ |
| Th-Ri | *4 | *6 | $\boxed{1}$ |
| Th-Pi | $\boxed{2}$ | $\boxed{3}$ | $\boxed{1}$ |
| In-Mi | $\boxed{2}$ | $\boxed{3}$ | $\boxed{1}$ |
| In-Ri | *4 | *6 | $\boxed{2}$ |
| In-Pi | $\boxed{2}$ | $\boxed{3}$ | $\boxed{1}$ |
| Mi-Ri | *4 | *6 | $\boxed{2}$ |
| Mi-Pi | *4 | *6 | $\boxed{2}$ |
| Ri-Pi | $\boxed{2}$ | $\boxed{3}$ | $\boxed{1}$ |

(9) Three-finger handshapes, rest of fingers closed

Predicted final ease scores

| | Extended | Curved | Bent |
|---|---|---|---|
| Th-In-Mi | $\boxed{2}$ | $\boxed{3}$ | $\boxed{1}$ |
| Th-In-Ri | *4 | *6 | $\boxed{2}$ |
| Th-In-Pi | $\boxed{2}$ | $\boxed{3}$ | $\boxed{1}$ |
| Th-Mi-Ri | *4 | *6 | $\boxed{2}$ |
| Th-Mi-Pi | *4 | *6 | $\boxed{2}$ |
| Th-Ri-Pi | $\boxed{2}$ | $\boxed{3}$ | $\boxed{1}$ |
| In-Mi-Ri | $\boxed{2}$ | $\boxed{3}$ | $\boxed{1}$ |
| In-Mi-Pi | $\boxed{2}$ | $\boxed{3}$ | $\boxed{1}$ |
| In-Ri-Pi | $\boxed{2}$ | $\boxed{3}$ | $\boxed{1}$ |
| Mi-Ri-Pi | 0 | 0 | 0 |

(10) Four-finger handshapes, rest of fingers closed

Predicted final ease scores

| | Extended | Curved | Bent |
|---|---|---|---|
| Th-In-Mi-Ri | $\boxed{2}$ | $\boxed{3}$ | $\boxed{1}$ |
| Th-In-Mi-Pi | $\boxed{2}$ | $\boxed{3}$ | $\boxed{1}$ |
| Th-In-Ri-Pi | $\boxed{2}$ | $\boxed{3}$ | $\boxed{1}$ |
| Th-Mi-Ri-Pi | 0 | 0 | 0 |
| In-Mi-Ri-Pi | 0 | 0 | 0 |

## 4. **Frequency of occurrence of handshapes**

In this section, we compare tokens of TSL and SC in regards to their ease scores. Calculations for TSL are from Ann (1993, 1996) using data from Smith and Ting (1979, 1984). Because SC dictionaries also include TSL signs, when we count the tokens of handshape in SC, we only count the signs in Ministry of Education (2000) that do not also occur in Smith and Ting (1979, 1984). We also follow Ann in assuming that the bent configuration can always be a free variant of the extended configuration (Ann 1993, 1996). Therefore, the bent handshapes always include the same tokens as the extended handshapes. However, some handshapes with the extended configuration are impossible, for example, the handshape where the ring finger is extended with the rest of the fingers closed; however the handshape is not impossible if the finger is merely bent rather than extended. Tables (11) through (14) show the numbers of tokens for both TSL and SC.

(11) One-finger handshapes, rest of fingers closed

| | Extended | | Curved | | Bent | |
|---|---|---|---|---|---|---|
| | TSL | SC | TSL | SC | TSL | SC |
| Thumb | 101 | 139 | 6 | 1 | 101 | 139 |
| Index | 196 | 227 | 28 | 36 | 196 | 227 |
| Middle | 0 | 0 | 0 | 0 | 4 | 4 |
| Ring | 0 | 0 | 0 | 0 | 3 | 2 |
| Pinky | 20 | 12 | 5 | 3 | 20 | 12 |

(12) Two-finger handshapes, rest of fingers closed

| | Extended | | Curved | | Bent | |
|---|---|---|---|---|---|---|
| | TSL | SC | TSL | SC | TSL | SC |
| Th-In | 54 | 43 | 25 | 15 | 17 | 10 |
| Th-Mi | 0 | 0 | 0 | 0 | 0 | 0 |
| Th-Ri | 0 | 0 | 0 | 0 | 0 | 0 |
| Th-Pi | 32 | 18 | 0 | 0 | 32 | 18 |
| In-Mi | 67 | 44 | 19 | 12 | 67 | 44 |
| In-Ri | 0 | 0 | 0 | 0 | 0 | 0 |
| In-Pi | 1 | 2 | 0 | 0 | 1 | 0 |
| Mi-Ri | 0 | 0 | 0 | 0 | 0 | 0 |
| Mi-Pi | 0 | 0 | 0 | 0 | 0 | 0 |
| Ri-Pi | 0 | 0 | 0 | 0 | 0 | 4 |

(13) Three-finger handshapes, rest of fingers closed

| | Extended | | Curved | | Bent | |
|---|---|---|---|---|---|---|
| | TSL | SC | TSL | SC | TSL | SC |
| Th-In-Mi | 17 | 19 | 9 | 2 | 17 | 19 |
| Th-In-Ri | 0 | 0 | 0 | 0 | 0 | 0 |
| Th-In-Pi | 3 | 2 | 0 | 0 | 0 | 0 |
| Th-Mi-Ri | 0 | 0 | 0 | 0 | 0 | 0 |
| Th-Mi-Pi | 0 | 0 | 0 | 0 | 1 | 0 |
| Th-Ri-Pi | 0 | 0 | 0 | 0 | 0 | 0 |
| In-Mi-Ri | 15 | 46 | 5 | 6 | 15 | 46 |
| In-Mi-Pi | 0 | 0 | 0 | 0 | 0 | 0 |
| In-Ri-Pi | 16 | 2 | 0 | 0 | 0 | 0 |
| Mi-Ri-Pi | 18 | 13 | 0 | 0 | 18 | 13 |

(14) Four-finger handshapes, rest of fingers closed

| | Extended | | Curved | | Bent | |
|---|---|---|---|---|---|---|
| | TSL | SC | TSL | SC | TSL | SC |
| Th-In-Mi-Ri | 1 | 1 | 1 | 0 | 1 | 1 |
| Th-In-Mi-Pi | 0 | 0 | 0 | 0 | 0 | 0 |
| Th-In-Ri-Pi | 0 | 0 | 0 | 0 | 0 | 0 |
| Th-Mi-Ri-Pi | 0 | 0 | 0 | 0 | 0 | 0 |
| In-Mi-Ri-Pi | 11 | 12 | 1 | 1 | 11 | 12 |

## 5. Analyzing the data

### 5.1 Chi-square test

First we tested each set of handshapes with the chi-square test, which can tell us whether the data is distributed randomly. The chi-square test results in a p-value. If the p-value is below 0.05, the results are significant, which indicates the handshapes are not distributed randomly. We first tested TSL and SC separately, and found that the p-values are all below 0.05 except for the 3-finger curved and 4-finger curved handshapes (Tables (15) through (18)). The results tell us that most handshapes in both TSL or SC are not distributed randomly, i.e. some handshapes occur significantly more often than other handshapes. However, the distribution of 3-finger curved and 4-finger curved handshapes show that these two sets of handshapes may be distributed randomly. Actually, these two sets of handshapes occur with very low frequency in TSL and SC, making these statistical results unreliable.

(15) One-way chi-square test for one-finger handshapes

| | TSL-Ext | TSL-Cur | TSL-Ben | SC-Ext | SC-Cur | SC-Ben |
|---|---|---|---|---|---|---|
| Chi square | 456.14 | 69.33 | 456.14 | 561.07 | 123.25 | 561.07 |
| df | 4 | 4 | 4 | 4 | 4 | 4 |
| p-value | < **0.05** | < **0.05** | < **0.05** | < **0.05** | < **0.05** | < **0.05** |

Note: df means “degree of freedom”

(16) One-way chi-square test for two-finger handshapes

| | TSL-Ext | TSL-Cur | TSL-Ben | SC-Ext | SC-Cur | SC-Ben |
|---|---|---|---|---|---|---|
| Chi square | 318.34 | 158.1 | 322.4 | 227.52 | 96.17 | 204.53 |
| df | 9 | 9 | 9 | 9 | 9 | 9 |
| p-value | < **0.05** | < **0.05** | < **0.05** | < **0.05** | < **0.05** | < **0.05** |

(17) One-way chi-square test for three-finger handshapes

| | TSL-Ext | TSL-Cur | TSL-Ben | SC-Ext | SC-Cur | SC-Ben |
|---|---|---|---|---|---|---|
| Chi square | 37.69 | 46.86 | 46.36 | 43.51 | 5 | 47.28 |
| df | 9 | 9 | 9 | 9 | 9 | 9 |
| p-value | < **0.05** | < **0.05** | < **0.05** | < **0.05** | > 0.05 | < **0.05** |

(18) One-way chi-square test for four-finger handshapes

| | TSL-Ext | TSL-Cur | TSL-Ben | SC-Ext | SC-Cur | SC-Ben |
|---|---|---|---|---|---|---|
| Chi square | 38.83 | 3 | 38.83 | 42.77 | 4 | 42.77 |
| df | 4 | 4 | 4 | 4 | 4 | 4 |
| p-value | < **0.05** | > 0.05 | < **0.05** | < **0.05** | > 0.05 | < **0.05** |

We then compared SC with TSL using a two-way chi-square test to see if SC shows significantly difference pattern from TSL. The results are listed in (19) through

(22). The p-values are all greater than 0.05: we do not find significant differences between TSL and SC. The results suggest that although TSL is natural and SC is artificial, we cannot find differences between TSL and SC in the distribution of handshapes alone.

(19) Two-way chi-square test for one-finger handshapes

| TSL vs. SC | Extended | Curved | Bent |
|---|---|---|---|
| Chi square | 4.97 | 5.05 | 5.44 |
| df | 2 | 2 | 4 |
| p-value | > 0.05 | > 0.05 | > 0.05 |

(20) Two-way chi-square test for two-finger handshapes

| TSL vs. SC | Extended | Curved | Bent |
|---|---|---|---|
| Chi square | 1.05 | 0.01 | 0.43 |
| df | 3 | 1 | 4 |
| p-value | > 0.05 | > 0.05 | > 0.05 |

(21) Two-way chi-square test for three-finger handshapes

| TSL vs. SC | Extended | Curved | Bent |
|---|---|---|---|
| Chi square | 0.45 | 6.29 | 0.68 |
| df | 4 | 1 | 1 |
| p-value | > 0.05 | > 0.05 | > 0.05 |

(22) Two-way chi-square test for four-finger handshapes

| TSL vs. SC | Extended | Curved | Bent |
|---|---|---|---|
| Chi square | 0.003 | 0.75 | 0.003 |
| df | 1 | 1 | 1 |
| p-value | > 0.05 | > 0.05 | > 0.05 |

## 5.2 Spearman's Rank Correlation

The above tests merely check if handshapes are distributed in any pattern at all. We also want to know if Ann's model correctly predicts the specific pattern of handshapes found in the data. The Spearman's rank correlation is an objective quantitative test to find out the correlation between two variables. According to Ann's model, we predict that the lower a handshape's ease score is, the more often this handshape should occur in TSL and SC. We thus expect a strong negative correlation (i.e. a correlation coefficient **r** close to -1). Again, a p-value below 0.05 indicates a significant result.

(23) Spearman's rank correlation test

(Note: **r** is corrected for ties)

| | Model vs. TSL | Model vs. SC |
|---|---|---|
| one-finger handshapes | **r** = -0.859 | **r** = -0.845 |
| | p = 0.0013 < **0.05** | p = 0.0016 < **0.05** |
| two-finger handshapes | **r** = -0.613 | **r** = -0.615 |
| | p = 0.001 < **0.05** | p = 0.0009 < **0.05** |
| three-finger handshapes | **r** = -0.249 | **r** = -0.212 |
| | p = 0.1793 > 0.05 | p = 0.2545 > 0.05 |
| four-finger handshapes | **r** = -0.240 | **r** = -0.405 |
| | p = 0.3696 > 0.05 | p = 0.1289 > 0.05 |

The results show that one-finger and two-finger handshapes have strong correlations with Ann's model. This is equally true for TSL and SC. However, three-finger and four-finger handshapes do not show a strong correlation with this model.

Ann (1993) also found that her predictions were not well supported by three-finger and four-finger handshapes in TSL. Some handshapes with a low ease score should be articulated quite often, but actually never occur in the real language. For example, the handshape where middle, ring and pinky fingers are curved with the rest closed is supposed to be an easy handshape, but it never occurs in either TSL or SC. Likewise, some handshapes are predicted to be difficult, but occur more often than other handshapes with the same ease score. The best example is the handshape where the index, middle and ring fingers are bent (extended) with the rest closed. As shown in the third picture of (1), this handshape is frequently used to represent part of character signs, both in TSL or SC.

## 6. Discussion

From previous sections, we know that physiology does play a role in the articulation of different handshapes. Easy handshapes tend to occur more often than hard handshapes. Even in SC, handshapes are still subject to the physiological constraints. Ann's model provides ease scores for handshapes, which can be used to successfully predict the frequency of occurrence handshapes. However, we have seen that three-finger and four-finger handshapes occur with very low frequency compared to one-finger and two-finger handshapes, which is not predicted by Ann's model. The real distribution of handshapes implies that the handshapes with more than two fingers are actually harder than those with one or two fingers. Clearly, more work needs to be done to develop a more sophisticated model of ease of articulation in sign languages.

Examining the TSL and SC data carefully, we also find that among the three-finger and four-finger handshapes, character signs are the most common. The handshape in (24) is predicted to be hard. However, it occurs more frequently than other handshapes with the same ease score in both sign systems. A reasonable explanation comes from the culture. TSL, as a minority language of Chinese society, has incorporated some signs from the hearing society to represent the shape of the Chinese characters (Ann 1998). The handshape (24) is always used to represent characters containing three horizontal or vertical strokes or a similar configuration, as illustrated in (3).

(24)

Moreover, Ann (1998) also studied handshapes and the combination of handshapes in TSL and character signs. Her results show that combinations of handshapes do have a different phonological behavior from the native TSL. For example, the handshape combinations and points of contact between two hands in character signs differ from the native TSL signs. The results suggest that what differs between SC and TSL does not lie in handshape alone. After all, the articulation of handshapes is in a large part constrained by physiology. More research into the phonological differences between TSL and SC is required for a deeper understanding of the natures of these two systems.

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