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OPTIMALITY AND OPPOSED HANDSHAPES IN TAIWAN SIGN LANGUAGE

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Abstract: This paper provides a linguistic account of opposed handshapes in Taiwan Sign Language (TSL). Examination of TSL opposed handshapes reveals that not all of the 29 logically possible opposed handshape types are attested. Of the ones that are attested, they differ (often drastically) in frequency of occurrence. We provide an analysis of the statistical data using Optimality Theory, showing that the various attested frequencies of opposed handshapes are systematic. The implications of this study for language change and acquisition are explored.

1. Introduction

Handshapes play a central and critical role in sign languages. This paper examines all of the handshapes that belong to the set of what we call *opposed handshapes* in Taiwan Sign Language (henceforth, TSL). We focus on several problems that concern the frequency of occurrence of these handshapes and provide an analysis of these problems by using Optimality Theory (henceforth, OT) as proposed in Prince and Smolensky (1992).

We use the term "handshape" to refer only to the particular configurations that the four fingers and the thumb assume. We are not concerned with which way a hand is facing, namely, its orientation. One sub-type of handshape identified in the studies of sign languages – in particular, American Sign Language (henceforth, ASL) - involves the thumb pad making contact with the pads of some subset of other fingers, or the thumb tip making contact with the tips of some subset of other fingers.[1] In the handshape in the ASL sign SIX,

opposes one finger- the pinky. In ASL EIGHT, the thumb opposes the middle finger. This kind of handshape is referred to in the literature with various names such as contact or opposed handshapes. Here, we refer to them as *opposed handshapes*. Like ASL, TSL has opposed handshapes in its inventory. We provide two examples in (1).

1. a.  b. 

In the handshapes of (1a) and (1b), some fingers are "selected" and some are "unselected". The fingers that oppose the thumb are selected and those that do not oppose the thumb are unselected. In (1a), the index and middle oppose the thumb and all three are therefore selected. The ring and pinky fingers are unselected. In (1b), the selected fingers are the thumb and the index. The middle, ring and pinky are unselected. Note that unselected fingers may be extended (1a) or closed (1b).

An opposed handshape, by definition, always involves the thumb. Handshapes in which, say, the index "opposes" the pinky may be logically possible, however they are physiologically impossible. Though the thumb is always selected in an opposed handshape, there is a choice as to which one(s) of the remaining four fingers is/are selected in opposing the thumb, giving rise to a total of 29 logically possible opposed handshapes. Ann (1993) shows that not all of the logically possible handshapes are attested; nor are they attested with equal frequency in TSL. This paper presents a linguistic account of the frequencies of opposed handshapes first reported in Ann (1993).

The essence of our analysis, framed in terms of OT, is that three types of constraints are necessary to account for the problems involving opposed handshapes in TSL. These are listed in (2).

2. a. Finger Selection Constraints
   b. Adjacency Constraint
   c. Extension Constraint

The Finger Selection Constraints in (2a) and the Adjacency Constraint in (2b) apply to selected fingers. The Finger Selection Constraints are a collection of five constraints that place conditions on the selection of each of the five fingers. Each constraint requires that a particular finger be selected. The Adjacency Constraint requires that selected fingers be adjacent. The Finger Selection Constraints and Adjacency Constraint are ranked, predicting that handshapes in which Selacency Ann

This article is organized as follows. In section 2, we propose the constraints and their ranking with a brief illustration of why they are needed. In section 3, we present statistical data concerning opposed handshapes in TSL along with our analysis of the data. Section 4 provides physiological and crosslinguistic evidence in support of the analysis we advance in section 3. Section 5 discusses the implications for historical change and language acquisition.

2. Outline of Our Proposal

This section is divided into two parts. First we briefly introduce the basic assumptions of OT that are important to our analysis of TSL opposed handshapes. Following this introduction, we lay out in detail the constraints that we propose for TSL opposed handshapes.

2.1. Optimality Theory

OT assumes that Universal Grammar possesses a set of universal constraints that determine the wellformedness of linguistic structures. The basic operation of OT is illustrated in (3). An input enters the system. A function called the Generator (GEN) generates a set of candidate structural descriptions of the input. The Harmony Evaluator (H-EVAL), which contains universal constraints, evaluates these structural descriptions according to how well they obey the set of universal constraints. The output of the grammar is the most well formed or optimal structural description.

3. /input/ " GEN " Candidate 1, Candidate 2, … → H-EVAL " Optimal Candidate

Exemplified in (3), H-EVAL is responsible for determining which of the possible candidate representations is optimal. Within OT, the constraints may be violated. But the costs such violations impose on a grammar vary: violation of a higher-ranked constraint exacts a higher cost than violation of a lower-ranked constraint. Thus, if two candidate representations both violate some constraints, the one that violates a lower ranked constraint (B) is preferred to one that violates a higher ranked constraint (B). In (4), we illustrate this with a tableau, which shows that Candidate 1 is optimal as it violates Constraint B, a lower ranked constraint than Constraint A.

4.

Input	Constraint A	Constraint B
Candidate 1		*
Candidate 2	*	

In (4), '*' indicates that a constraint is violated by a candidate. The pointing finger ' ' indicates that a particular candidate is the optimal output. Note that an optimal candidate may be one that violates the less serious constraint than other candidates (as in (4)) or no constraint at all.

According to OT, Universal Grammar contains a set of structural descriptions for each input and a set of universal constraints. Linguistic variation stems from the fact that languages rank

We identify each of the five constraints by the names of the fingers it applies to. We capitalize the initial letter of the names of fingers when they refer to constraints, and not simply the fingers of a hand. We state the Finger Selection Constraints as parsing constraints in (6) because they resemble the parsing constraints in OT accounts of spoken languages.[3] Thus, 'Parse the index' means that the index must be selected or *parsed* to oppose the thumb. In an opposed handshape in which the thumb opposes only the index, the two constraints – Thumb in (6a) and Index in (6b) - are both satisfied. But such a handshape violates Middle (6c), Ring (6d), and Pinky (6e) as they are not parsed.

These Finger Selection Constraints are ranked with respect to one another. We propose the ranking in (7).

7. Thumb > Index > Middle > Pinky > Ring

According to (7), Thumb is ranked the highest, followed by Index. Middle follows Index, but is ranked higher than Pinky. Ring receives the lowest ranking. At present, we do not have strong linguistic evidence from TSL to determine the relative ranking of Ring and Pinky, although there is some physiological evidence for support the plaTc umb is ranked the highest, followed by Index. Middle follows

impossible) that an opposed handshape might not involve the thumb. The physiological impossibility is captured by the ranking of Thumb as the highest constraint. Opposed handshapes in which the thumb is not selected are not desirable as they violate the most serious of the five Finger Selection Constraints. In this respect, Thumb resembles those constraints in spoken languages that are never violated.

T

handshapes in which the thumb opposes two or three fingers may violate the Adjacency Constraint. We should therefore expect to find more handshapes in which the thumb opposes one finger than handshapes in which the thumb opposes two or three fingers such as [thumb↔index & middle] as in (10a) or [thumb↔index & middle & ring] as in (10b).

10. (a)  (b) 

Some logically possible opposed handshapes in which the thumb opposes two fingers such as [thumb ↔ index & ring] or three fingers such as [thumb↔index & ring & pinky]. are in violation of the Adjacency Constraint. We show in section 3 that none of these handshapes that violate the Adjacency Constraint is attested in TSL, which provides the empirical basis for this constraint and the overall rarity of TSL signs with this kind of handshape.

THE EXTENSION CONSTRAINT. Unlike the Finger Selection Constraints and the Adjacency Constraint that apply to selected fingers, the Extension Constraint applies to unselected fingers. In opposed handshapes, the unselected fingers are those that do not participate in opposing the thumb. We find that, statistically, handshapes with extended unselected fingers are preferred to those in which unselected fingers are closed. To account for this fact, we propose the Extension Constraint.

11. Extension Constraint

In an opposed handshape, unselected fingers must be extended.

We restrict the application of this constraint to opposed handshapes for the time being. But we suspect that this constraint may be part of a larger constraint that governs the behavior of unselected fingers in general. If future studies determine that it is preferable to extend – rather than close- unselected fingers in other handshape types, the reference to opposed handshapes may be dropped.

We will take up these constraints again in section 4 in our discussion of the physiological, perceptual and crosslinguistic bases for these constraints. For now, let's turn our attention to the TSL data and our analysis of the data in terms of the constraints proposed here.

3. Data and Analysis

In this section, we present statistical data which show the frequency of occurrence of TSL opposed handshapes. These data are taken from Smith and Ting (1979, 1984). The two Smith and Ting books form a TSL course. All of the signs introduced in the books appear in the glossaries at the end. Following Stokoe, Casterline and Croneberg (1965), these glossaries are arranged by the location in which the sign is produced (i.e. chin, neutral space etc.) and within each location, by handshape. There are a total of 1336 entries in Smith and Ting's glossaries. These entries are counted to arrive at the TSL frequency of occurrence. The data in this paper were presented first in Chapter 5 of the first author's doctoral thesis (Ann 1993). We show that

these statistical data can be accounted for by the proposal laid out in section 2. Our central claim here is that the different frequencies of opposed handshape configurations found in TSL signs reflect a regular pattern, a pattern that may be captured by the interaction of the Finger Selection, Adjacency and Extension Constraints.

In opposed handshapes, the thumb may oppose one, two, three and all four of the remaining fingers. In what follows, we refer to a handshape in which the thumb opposes one finger as 1-

distant second, with a total of 11 occurrences. The thumb↔pinky handshape is attested in two signs, while the thumb↔ring handshape is not attested at all.

These statistical frequencies are accounted for by the ranking of the Finger Selection Constraints proposed in (7). To see how our proposal accounts for these data, consider the tableau in (14).

14.

16.

2-FINGER OPPOSED HANDSHAPES	UNSELECTED FINGERS		COMBINED TOTAL
	EXTENDED	CLOSED	
Thumb↔index-middle	4	5	9
Thumb↔index-ring	0	0	0
Thumb↔index-pinky	0	0	0
Thumb↔middle-ring	10	0	10
Thumb↔middle-pinky	0	0	0
Thumb↔ring-pinky	0	0	0

Thus, the thumb opposes two fingers in a combined total of 19 signs. In comparison with 1-finger opposed handshape that shows up in 101 signs, the number of signs with 2-finger opposed handshapes is rather small. As shown in (17), the number of signs with 3-finger opposed handshapes is much smaller. We find only one sign with a 3-finger opposed handshape in TSL.

17.

3-FINGER OPPOSED HANDSHAPES	UNSELECTED FINGERS		COMBINED TOTAL
	EXTENDED	CLOSED	
Thumb↔index-middle-ring	1	0	1
Thumb↔index-middle-pinky	0	0	0
Thumb↔index-ring-pinky	0	0	0
Thumb↔middle-ring-pinky	0	0	0

Despite the overall small number of attested 2- and 3-finger opposed handshapes, some generalization may be drawn from the data in (16) and (17). Out of the 10 logically possible 2- and 3-finger opposed handshape types, 5 violate the Adjacency Constraint as they involve non-adjacent selected fingers. These are listed in (18).

18. 2-finger opposed handshapes:
a. thumb↔index-ring
b. thumb↔index-pinky
c. thumb↔middle-pinky

3-finger opposed handshapes:
d. thumb↔index-middle-pinky
e. thumb↔index-ring-pinky

None of the handshapes listed in (18) is attested in any TSL sign. This means that all attested 2- and 3-finger opposed handshapes obey the Adjacency Constraint. We take this as evidence that the Adjacency Constraint, which regulates the parsing of selected fingers, operates in TSL.

Consider next the ranking of the Adjacency Constraint in relation to the Finger Selection Constraints as both constraints are relevant to 2- and 3-finger opposed handshapes. One possibility is to rank the Adjacency Constraint below the Finger Selection Constraints. Some evidence from 2-finger opposed handshapes in TSL suggests that this ranking cannot account for the data in (16), specifically, the three 2-finger opposed handshape types in (19). According to (16), the first two types are not attested. The third type is attested in 10 signs.

19. a. thumb↔index-ring not attested
    b. thumb↔index-pinky not attested
    c. thumb↔middle-ring attested in 10 signs

If the Adjacency Constraint is ranked below the Finger Selection Constraints, we predict that (19a) and (19b) are more desirable than (19c). Though (19a) and (19b) violate the Adjacency Constraint while (19c) does not, the lower ranking of the Adjacency Constraint makes it irrelevant in determining which handshape type is optimal. (19c) violates Index, a higher ranked constraint than the Adjacency Constraint. (19a) and (19b) satisfy Index. Consequently, (19a) and (19b) are more desirable than (19c) according to the H-Eval.

The second possibility is to assign the Adjacency Constraint a higher ranking than the Finger Selection Constraints. This ranking predicts that (19c) is more desirable than (19a) and (19b), which violate a higher ranked constraint, namely, the Adjacency Constraint.[5] This is illustrated in (20), where AC is short for the Adjacency Constraint.

20.

Types of handshape	AC	Thumb	Index	Middle	Pinky	Ring
thumbinde234.6 331.2 43.8 19.8 re f 3e 1.8 re f 503.4 33 Tc (thumb) Tj re0 Ring						

22. 

The sign CHUANG (BED) involves two hands. Both assume the handshape in (22) and the tips of the opposed fingers of both hands contact each other, forming the shape of a bed. That is, the four extended fingers represent the four poles of a Chinese bed. The middle and ring fingers represent the flat surface for sleep. Given the structure of a bed, a handshape in which the outer fingers – index and pinky – are extended best represents the four standing poles of a bed. The remaining six instances of the handshape in (22) are glossed in Smith and Ting (1979, 1984) as: LANG (WOLF), LONG (DRAGON), HU LI (FOX), SHANG DANG (DECEIVED), PIAN (SWINDLE) and YING XIAN (SLY) (two forms). We take (22) to be iconic in the signs which name animals in that the opposed fingers represents the animal's snout and the extended fingers represent the ears. In addition, we take the use of the handshape in (22) in signs that mean "sly", "deceived" or "swindle" to be semantic extensions of the same sign. Excluding the iconic signs, there are two TSL signs in which the handshape in (22) is not iconic: a) ZHONG ZI (RICE

data that show the frequency of occurrence for 1-, 2- and 3-finger opposed handshapes, together with the total number of handshapes in which the thumb opposes all four fingers.

24.

TYPES OF HANDSHAPES	UNSELECTED FINGERS		COMBINED TOTAL
	EXTENDED	CLOSED	
1-Finger Opposed Handshape	63	38	101
2-Finger Opposed Handshape	14	5	19
3-Finger Opposed Handshape	1	0	1
4-Finger Opposed Handshape	Not Applicable		75

According to (24), there are 101 signs that make use of 1-finger opposed handshapes in TSL. 4-finger opposed handshapes rank second in number with a total of 75 signs.[6] 2- and 3-finger opposed handshapes rank last with a combined total of 20 signs. In absolute numbers, 4-finger handshapes are attested less frequently than 1-finger handshapes. But this comparison is a bit deceptive. The reason for this has to do with the total number of logical possibilities of a given type of handshape.

Recall that there are 8 types of 1-finger opposed handshapes. In contrast, there is one logically possible type of 4-finger opposed handshape. If we divide 101 (the number of 1-finger opposed handshape types) by 8, each type of 1-finger handshapes is attested roughly 13 times, a much smaller number than 75. This comparison reveals that 4-finger opposed handshape is attested most frequently,[7] followed by 1-m u c h s m a l l 2 u 3 T c 0 0 l e s 3 j u N c 0 0 l e e a l s t h a t f i n

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handshapes. How can we account for the fact that the exact opposite obtains: 1-finger opposed handshapes are attested more often than 2 and 3-finger opposed.

This is where the Adjacency Constraint comes in. Neither 4-finger opposed handshapes nor 1-finger opposed handshapes can violate the Adjacency Constraint. Only 2- and 3-finger opposed handshapes may violate the Adjacency Constraint. Recall that 6 of the 12 logically possible 2-finger opposed handshape types and 4 of the 8 logically possible 3-finger handshapes violate the Adjacency Constraint. As opposed handshape types that violate the Adjacency Constraint are not attested at all in TSL, they disproportionately affect the number of attested signs with 2- and 3-finger opposed handshapes. To see this more clearly, let's see the comparison of the numbers of logically possible opposed handshapes involving 1, 2, and 3 fingers once those handshape types that violate the Adjacency Constraint are removed.

25. a. 1-finger opposed handshape: 8
    b. 2-finger opposed handshape: 6
    c. 3-finger opposed handshape: 4

According to (25), 1-finger opposed handshapes have the highest number of types that obey the Adjacency Constraint, followed by 6 and 4 for 2- and 3-finger opposed handshapes, respectively. As there are more 1-finger opposed handshape types that conform to the Adjacency Constraint, it is not surprising that 1-finger opposed handshapes occur more than 2-finger opposed handshapes, which in turn occur more than 3-finger opposed handshapes.

In TSL, we see the statistical results of two competing types of constraints. The Finger Selection Constraint favor 4-finger opposed handshapes and disfavor 1-finger opposed handshapes. The Adjacency Constraint favors 4- and 1-finger opposed handshapes at the expense of 2- and 3-finger handshapes. As both types of constraints favor 4-finger opposed handshapes, they are attested most frequently. 1-finger opposed handshapes, which conforms to the Adjacency Constraint, is statistically more frequent than 2- and 3-finger opposed handshapes, which may disobey the adjacency requirement.

3.4. The Extension Constraint and unselected fingers

The distinction between "groups" of fingers in a particular handshape was made early in the literature. Handshapes are thought of as containing a maximum of two groups of fingers. The essential insight stated in Mandel (1981:81-84) is that one group is "selected" and the other is "unselected." This has never been abandoned, although it has taken different forms throughout the years. A handshape in which all fingers participate has only one group. But some handshapes have two groups of fingers, one group of fingers assuming one configuration and the other assuming a different configuration. So far, we have focussed on accounting for the statistics involving the selected fingers of an opposed handshape. But most opposed handshapes have two groups of fingers: a subset of index, middle, ring, and pinky participate in opposing the thumb (the selected fingers), and some other fingers doing something else (the unselected fingers). The unselected fingers can assume two configurations: a) extended and b) closed (Mandel 1981:82). We now examine a problem we have heretofore ignored.

Compare the number of opposed handshapes in which unselected fingers are extended with that of opposed handshapes in which unselected fingers are closed. These numbers are shown in (26) with a breakdown in terms of the number of selected fingers opposing the thumb.

26.

1,2 and 3-FINGER OPPOSED HANDSHAPES	UNSELECTED FINGERS	
	EXTENDED	CLOSED
1-Finger Opposed Handshape	63	38
2-Finger Opposed Handshape	14	5
3-Finger Opposed Handshape	1	0
Total	78	43

connection with opposed handshapes discussed in this paper, they hold of any sign that makes use of handshape, since every handshape requires that either all the fingers or a sub-set of fingers participate.

According to (27), the thumb is most mobile. The index finger comes next in terms of mobility, followed by the middle and the pinky. The ring finger is the least mobile of the five digits. We suggest that the relative mobility of the five fingers forms part of the basis for the ranking of the Finger Selection Constraints.

As the proposed ranking of the five Finger Selection Constraints has some physiological basis, we do not expect all aspects of the proposed ranking to be determined completely by individual sign languages. Some aspects of the ranking are expected to hold of other sign languages: e.g. the ranking of Thumb above Index, and the Ranking of Index above Middle, Pinky and Ring. The ranking of Index above Middle, Pinky and Ring is reflected in the Opposition Hierarchy which Mandel (1981, 99) proposes for ASL and supported by the data from ASL and other sign languages. In her study of TSL and ASL, Ann (1993, 272) finds that ASL has a total of 79 handshapes in which the thumb opposes the index. In contrast, the combined total of handshapes in which the thumb opposes the middle, ring or pinky is 4. In a crosslinguistic survey of what Woodward calls "single finger contact" handshape (what we call 1-finger opposed handshapes) in 9 sign languages (including ASL, but not TSL), Woodward (1987) finds that handshapes in which the index alone opposes the thumb are attested most frequently followed by handshapes in which the middle finger alone opposes the thumb. Handshapes in which the pinky alone opposes the thumb come next, with the handshapes in which the ring alone opposes the thumb attested least frequently in the sign languages surveyed. The ranking of Middle and Pinky above Ring is not expected to vary crosslinguistically, either. From the physiological perspective, the ring finger is the weakest, a point supported by Woodward's crosslinguistic data on single finger contact and extension handshapes.

The aspect of the ranking in (6) that may vary crosslinguistically is the relative strength of Middle and Pinky. Some aspects of the physiology favor the middle finger over the pinky. The middle finger is a bit closer and more mobile than the pinky and therefore easier for it to oppose the thumb. But the pinky has its advantage as well as it "has a special muscle (opponens digiti minimi) to oppose it to the thumb" according to Mandel (1981). The comparable strength of Middle and Pinky is reflected in the statistics as well. According to Ann (1993, 272), ASL has two signs in which the thumb opposes the middle. This is only slightly more (but statistically insignificant) than one occurrence each for thumb↔ring and thumb↔pinky. In a related study of "single finger extension" handshapes in the 9 sign languages, Woodward (1982) finds that handshapes with the extended pinky are attested slightly more that handshapes with the extended middle. What Woodward's study shows is that with respect to some specific configuration, the pinky finger may be more mobile than the middle and consequently attested more in sign languages.

THE ADJACENCY CONSTRAINT. We proposed the Adjacency Constraint to account for the fact that there is not a single TSL sign that makes use of opposed handshapes with non-adjacent selected fingers. This constraint also plays an important role in explaining the frequencies of occurrence of opposed handshapes that involve different numbers of selected fingers. Mandel (1981) proposes a similar condition that governs selected fingers in ASL. As this constraint is proposed for ASL, it is clearly not specific to TSL. We can understand the basis of the Adjacency Constraint partly by looking at hand physiology. The juncturae tendinum are three ligamentous bands located on the back of the hand that connect the fingers. One connects the index to the middle. A second connects the middle to the ring. The third connects the ring to the pinky. The bands pull on each other and cause the fingers to be affected by each other's

movements. Some of the opposed handshapes involving non-adjacent selected fingers such as thumb↔index-pinky, thumb↔middle-pinky, thumb↔index-ring-pinky, thumb↔index-middle-pinky, etc. are physiologically harder, though not impossible. When we look at the Adjacency Constraint in relation to hand physiology, we may understand it as an attempt by sign languages to control the ease of signing, favoring those handshapes that are easier to sign physiologically.

THE EXTENSION CONSTRAINT. This constraint is proposed in conjunction with TSL frequency data. However, it is not applicable just to TSL. The preference for unselected fingers to be extended in opposed handshapes is evidenced in ASL. Ann (1993) shows that there are a total of 97 signs with opposed handshapes in which unselected fingers are extended. In sharp contrast, opposed handshapes with closed unselected fingers are attested in only 5 signs in ASL. The clear preference for unselected fingers to extend rather than close may be understood from the point of view of perception.

When we look at opposed handshapes from the view of perception, it is not hard to understand why it is preferable to extend unselected fingers in opposed handshapes. Opposition requires that the four fingers – index, middle, ring, and pinky - be bent at the metacarpophalangeal and/or proximal interphalangeal joints if they are selected in opposing the thumb. Extending the unselected fingers render them maximally different from the selected fingers. In contrast, closing the unselected fingers makes them similar to selected fingers. Extending unselected fingers has the effect of increasing visual acuity, while closing unselected 1978 Tj 0etdiscus TD -0.1lng t8the point of view o32SL. Thtion.

of documentation of earlier TSL signs, the analysis of opposed handshape configurations proposed here makes specific claims about the markedness of various opposed handshapes and consequently the direction of diachronic handshape change. For instance, according to the analysis, 4-finger opposed handshapes are optimal and least marked, followed by 1-finger opposed handshapes. 2- and 3-

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