UNIVERSITY OF SOUTHAMPTON

The Psychological Validity of Formational Parameters in Native and Non-native Signers of British Sign Language

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I declare that this thesis is my own work, completed wholly during registered postgraduate candidature at the University of Southampton. No part of this thesis has been submitted elsewhere for consideration as part of another degree.

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UNIVERSITY OF SOUTHAMPTON

ABSTRACT

FACULTY OF SOCIAL SCIENCES

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THE PSYCHOLOGICAL VALIDITY OF FORMATIONAL PARAMETERS IN NATIVE AND NON-NATIVE SIGNERS OF BRITISH SIGN LANGUAGE

by Matthew William Geoffrey Dye

Sign language phonologists have proposed that sign languages have internal structure that is analogous to the phonological structure of spoken words. Furthermore, most theories take the position that the formational structure of signs is distinct from morphological structure - there is a duality of form and meaning. Recently, an alternative theory - semantic phonology - was proposed by Armstrong et al. (1995). This theory states that a sign is not composed of formational parameters, but is an agent-action-patient construction, whose form is directly related to what is represented by that sign. Within this thesis, such representations are termed morphological.

This thesis presents four experimental studies that aim to assess the validity of formational parameters as psychological constructs. The studies employ two experimental paradigms - ordered recall of lists and form priming - with three groups of experimental participants - hearing sign language learners, deaf people who learned sign as a first language (native signers), and deaf people who learned sign language after the age of 6 years (non-native signers). The studies were designed to assess whether sign language was internalised as a formational or morphological code.

Findings from the studies using ordered recall of lists are equivocal, supporting neither formational nor morphological coding. It is proposed that (a) more accurate measures of similarity are required, and (b) it is important to consider the number of items recalled from a list when assessing the effect of list similarity on order errors - findings reported in previous studies have failed to do this.

The study employing a form priming procedure produced more substantive findings. Clear differences were evident in how signs were processed by native and non-native signers. Non-native signers appeared to process signs in terms of global visual characteristics, whereas native signers processed signs in terms of formational parameters. The role of morphological parameters was not assessed. It is concluded that form priming procedures stand to offer more valid and valuable insights than list recall studies, and a model of access to the sign lexicon is proposed for further empirical investigation.

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PREFACE

BSL is the preferred language of approximately 40 000 deaf people in the UK. These people form the UK's Deaf community. For members of this community, their deafness is not a handicap, but a difference. Membership cannot be defined in medical or audiological terms; it is a socio-cultural phenomenon. The language of this community is BSL, a language of which the Deaf community is fiercely proud and defensive. Unlike other minority languages, however, BSL is rarely passed on from parents to children. Only 10% of deaf children are born to deaf parents, the vast majority being born to hearing parents. As a result, most deaf children will not have early exposure to BSL. Often the deafness will be unidentified for several months, and when identified the advice given to parents will be mainly audiological. It is not the usual practice of Health Authorities to provide information about or contact with the Deaf community. This extends to Local Education Authorities as well. Few LEAs provide bilingual-bicultural schools where both BSL and English are taught to deaf children. In addition, many LEAs are not prepared to pay for deaf children to be educated in deaf schools outside of their geographical boundaries. The main result is that an increasing number of deaf children are mainstreamed into hearing schools, attached to partially-hearing units (PHUs).

Partly as a result of such policies, many deaf children will not acquire BSL until much later in life, if at all. Indeed, this is a common argument used by local authorities - when the child grows up they can choose if they want to become members of the Deaf community. One consequence of such a wait-and-see policy is that signed language acquisition will be delayed. It is, of course, an empirical matter as to what the effects of this delayed acquisition will be. This thesis aims to contribute to answering that empirical question. It asks what the effects of delayed sign language acquisition are on linguistic encoding of language. Can late acquirers still think in signs, or do they use speech-based memory codes? How are BSL signs recognised: in terms of their formational parameters, as images, or in terms of actions performed in

space? The studies reported here reflect a concern about the number of academic papers which have suggested that early and late acquirers do not differ in many cognitive aspects of sign language processing.

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The support of my fellow graduate students helped me through periods of calm and lack of motivation, particularly those who completed before me! Latter parts of this thesis involve new applications of computer software, which would not have been possible without the hard work and endeavour of Pete Dargie. Many thanks also to Jim Kyle and colleagues at the Centre for Deaf Studies, University of Bristol. Without their advice, support and interest I would still be floundering.

Adam and Joe helped me through the latter stages of preparation with lots of coffee and patience. Thanks guys. A note of thanks also to my examiners, especially for guiding me through the process of revising the thesis.

Of course, without the financial and moral support of my parents I would never have reached this point on the academic ladder. So, to Glynis, Geoff and Mick, many thanks and all my love.

Matt Dye, August 2001

DEFINITIONS AND ABBREVIATIONS

ASL	*American Sign Language*
Auslan	*Australian Sign Language*
BSL	*British Sign Language*
Cherological	A term often used to replace the word *phonological* in discussions of the structure of signed languages.
H or *dez*	*Handshape*. One of the sign language parameters identified by William Stokoe. Is often referred to as *hand configuration.*
L or tab	*Location*. One of the sign language parameters identified by William Stokoe. Is often referred to as *place of articulation.*
M or sig	*Movement*. One of the sign language parameters identified by William Stokoe.
NZSL	*New Zealand Sign Language*
PHU	*Partially-hearing unit*. These are specialist units attached to regular schools, which support the educational needs of deaf children who study within that school.

1 Thesis Overview

The studies presented in this thesis are aimed at clarifying the following two questions. (1) Are the formational parameters of sign language (handshape, location and movement) psychologically valid constructs? (2) Are they equally valid for native and (fluent) non-native signers? The thesis starts with an account of research into sign language phonology (Chapter 2). No attempt is made to provide a full and complete account of the multitude of phonological theories currently being debated in the sign language literature. Rather the review focuses upon linguistic accounts which have proposed that a sign language phonology contains formational parameters such as handshape, location and movement. In Chapters 3 and 4 respectively, previous research into the psychological validity of sign parameters in terms of long-term and short-term encoding is presented. In terms of the latter, there is a wealth of published literature on working memory and the use of formational coding within short-term memory systems. Much less work has covered longer-term, lexical, representations of signed languages.

Research into the psychological representations of signed languages is relatively new, the first key papers published in the mid-1970's. As a result, there is still some debate as to the validity of formational parameters as psychological constructs. This is in part due to the variation in experimental findings, and the myriad of factors which seem to influence whether evidence for formational representations is obtained. Key among such influences is the linguistic background of deaf participants. Relatively few deaf people are born into deaf families and acquire a sign language as a first language. The vast majority are born into hearing families, acquire a spoken language (with varying degrees of success) as a first language, and learn a sign language later in life. Indeed, even those born into deaf signing families will often have some command of a spoken language. It is perhaps no surprise, therefore, that deaf signers can still display evidence of (sound-based) phonological encoding in short-term memory tasks. The challenge is to devise experimental procedures

that encourage possible sign-based encoding, allowing researchers to establish whether formational parameters have any psychological validity. Such procedures would also allow any differences between native (L1) and non-native (L2) signers to become apparent. Current wisdom is that non-native signers can represent signs in terms of formational parameters. Chapter 5 looks at these issues, examining the alternative coding strategies available to deaf participants and suggesting that a gestural code based upon the motivation of sign forms may be a more valid form of representation for non-native signers. As the form of many signs is driven by what it is they represent, i.e. form and meaning are related, formational and motivational representations may be similar.

Chapter 6 looks at methodological issues related to (a) the experimental paradigms selected for use in this thesis, and (b) doing psychological research with deaf participants. Here, the experimental parameters used in the studies are supported. There is also a discussion of how the experimental paradigms are conducted with a visual-gestural language providing the stimuli, and an explanation of the seemingly low participant numbers in the reported studies.

Chapters 7 through 10 report the four studies conducted for this thesis. These start with three list recall experiments investigating short-term encoding of signs in working memory, and finish with a primed lexical decision study focusing upon longer-term, lexical, encoding. The order in which these studies are presented reflects the order in which they were conducted: first to last.

Chapter 11 brings the findings from these studies together. It presents the thesis' conclusions about how signs are represented in the minds of native and non-native deaf signers, and provides recommendations for future avenues of enquiry as well as making suggestions for the types of experimental paradigm which will best uncover evidence for psychological representations of sign languages.

2 Sign Language Phonology

This thesis is concerned with the process of linguistic encoding in deaf people who use signed languages, in particular users of British Sign Language (BSL). Sign languages are natural languages used by communities of deaf people who have little-or-no access to the spoken language of their hearing peers. Instead of using the speech organs, such as the mouth, tongue and lips, to produce sounds, sign languages use movements of the arms, hands, body and face to convey meaning. These movements are not a form of pantomime, transparent to observers who know nothing of the sign language. Indeed, many sign languages are mutually unintelligible; a signer of BSL would not understand, or be understood by, a signer of American Sign Language (ASL). Rather than being a stylised form of pantomime, much evidence has established that signs - the words of a signed language - are made up of a finite set of formational parameters such as handshape, place of articulation and movement. These parameters are argued to be themselves meaningless; only when combined to form a sign do they become meaningful. In spoken languages, such formational parameters would include manner of articulation, place of articulation and voicing.

This chapter consists of two sections. The first deals briefly with models of phonology and phonetics in spoken language, and introduces some basic concepts of the area. The second part focuses upon alternative models of sign language phonology. This is followed by a discussion of the similarities and differences between these models.

2.1 The Phonetics and Phonology of Spoken Languages

The sounds of a spoken language are composed of features. Each sound (phone) in a language can be defined by a set of such features. Words consist of a string of sounds, which are articulated one after the other to produce the words. The transition from one set of features to another results in coarticulation - the production of one sound influences the production of a subsequent sound (or vice versa). Phonemes are units of sound which are

contrastive in a language. The function of phonemes is to distinguish between words that have different meanings. A spoken language's phonemes can be identified by finding two words which differ in meaning, yet differ in terms of only one sound. For example, the English words "gate" and "date": these differ only in terms of the sound produced at the start of the word ([g] and [d] respectively); both end with the same sound ([eɪt]). Such pairs of words are called minimal pairs, and they allow a phonologist to define the phoneme set of a language. The relationship between phonemes and phones is a one-to-many correspondence: several phones may represent each phoneme. For example the phones [t] and [t^h] represent an unaspirated and aspirated 't' sound respectively. In English, these two sounds never serve to distinguish between two words with different meanings. Thus, in English, [tap] and [t^hap] are the same word, although the first form would rarely be produced. In other languages, such as Thai, aspiration of a consonant can serve to distinguish between two words. So, in English, [t] and [t^h] are two phones that belong to the phoneme category /t/. In Thai, on the other hand, /t/ and /t^h/ are separate phonemes. Once the phonemes of a language have been identified, phonologists describe the phonemes in terms of their features. A phonetician, on the other hand, is more interested in the phones that are produced when articulating phonemes, and looks at how the sounds of a language are produced in terms of their articulations (articulatory phonetics) or the soundwaves that result from those articulations (acoustic phonetics).

2.1.1 Articulatory Phonetics

One way of classifying sounds is in terms of four articulatory features: (1) voicing, (2) place of articulation, (3) manner of articulation, and (4) shape of the tongue (Clark and Yallop, 1995). These features are those commonly used for consonantal sounds, and for [d] and [g] they are given in Table 2.1.

So, both [d] and [g] are produced by vibrating the vocal chords as air passes through from the lungs (voiced), and obstructing the passage of air and building up pressure in the mouth cavity, releasing this air to produce the sound (plosive). They differ in terms of where the tongue produces the

blockage in the mouth cavity: for [d] this blockage is at the ridge at the front of the mouth (alveolar), whereas for [g] the blockage is at the velum at the back of the mouth (velar). The shape of the tongue is not specified, as for these sounds it is given by the shape needed to create a blockage.

Table 2.1: The articulatory features of the sounds [d] and [g].

Articulatory Feature	**Sound**	
	[d]	**[g]**
Voicing	voiced	voiced
Place of articulation	alveolar	velar
Manner of articulation	plosive	plosive
Shape of the tongue	-	-

Such a description is an articulatory phonetic description, and the four parameters can be used to specify the articulations necessary for most sounds in the world's spoken languages. The features do not specify muscle articulation per se. Rather, they specify a mixture of muscle activity and target states of the articulators (the tongue, lips, jaw and vocal chords). A full articulatory phonetic description of a sound would therefore specify the trajectories of the tongue, jaw and lips, as well as the onsets and offsets of vocal chord activity and the degree and direction of pulmonary activity (the exhalation and inhalation of air required to produce sounds).

2.1.2 Distinctive Features

Phonologists describe sounds in terms of distinctive features. The aim of this approach is to develop a set of binary features that can be used to differentiate between the sounds which are contrastive in a language. In a seminal work, Fundamentals of Language, Jakobson and Halle (1956) proposed a set of twelve distinctive features that were intended to allow the differentiation of any sound from any other sound. These features are based upon the articulations necessary to produce a sound, and are binary in nature; a sound either has a feature (+) or it does not (-). The distinctive features of the sounds [d] and [g] are given below in Table 2.2, as suggested by Jakobson and Halle. Some features are not contrastive in a given language. For example, in English the feature *flat* never serves to distinguish between phonologically

important sounds - no two words will differ in meaning because the difference between them is that the first sound is flat for one word and plain for the other. Other languages, such as Russian, do make use of the flat feature (as minimal pairs in Russian can differ because a consonant is flat in one word and plain in the other).

Table 2.2: The distinctive features of the phonemes /d/ and /g/, as proposed by Jakobson and Halle (1956). The two sounds differ in two features: /g/ is 'compact' and 'grave' (indicated by the +), whereas /d/ is 'diffuse' and 'acute' (indicated by the -).

Feature +	**Phoneme**		**Feature -**
	/d/	**/g/**	
Vocalic	-	-	Nonvocalic
Consonantal	+	+	Nonconsonantal
Compact	-	+	Diffuse
Tense	-	-	Lax
Voiced	+	+	Voiceless
Nasal	-	-	Oral
Discontinuous	+	+	Continuant
Strident	-	-	Mellow
Checked	0	0	Unchecked
Grave	-	+	Acute
Flat	0	0	Plain
Sharp	0	0	Plain

Over the years, theorists have proposed different sets of features. The most prominent proposed set of features is that of Chomsky and Halle (1968) in The Sound Pattern of English. Chomsky and Halle proposed a set of twenty-seven features which they claimed were universal. That is, these features can be used to describe the phonemes of all sounds in all languages. Their claim goes beyond the use of such features to describe language sounds. They also hold that these features are used to represent the sounds in the minds of language users. For Chomsky, these features are innately specified, and the acquisition of a language's phonology involves learning which of the features are required to represent the phonemes of that language.

2.1.3 Feature Bundles and Segments

Phonemes are bundles of such features; a bundle of features being referred to as a segment. Despite the widespread acceptance of features within modern phonology, there is much debate about how these features are organised within a segment. The organisation of features within a segment is commonly represented as a feature tree. Figure 2.1 presents an example of a fully-specified feature tree based upon Halle (1992). The representation of the features of the sound [s] in such a feature tree is given in Figure 2.2.

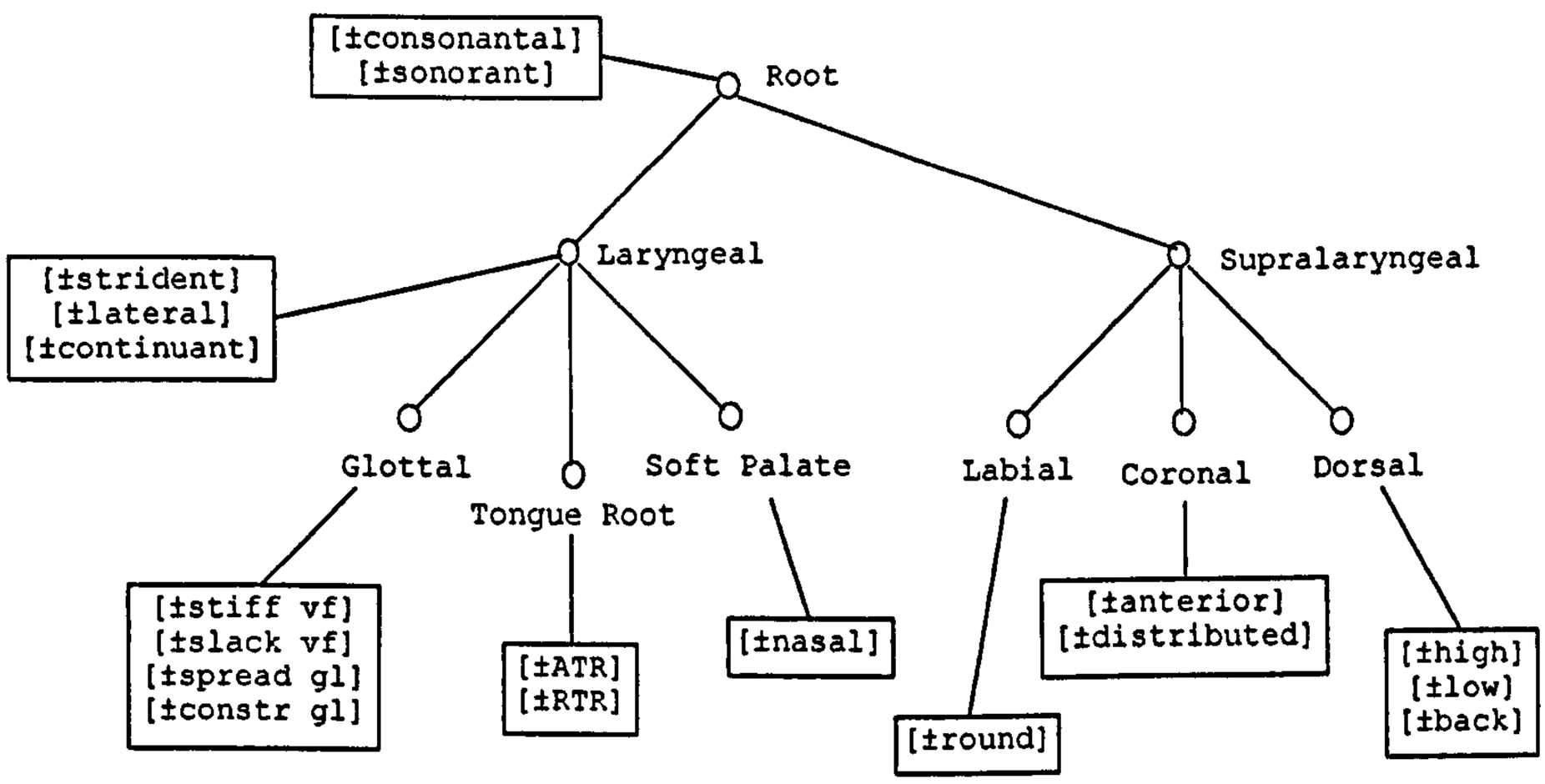


Figure 2.1: A feature tree for spoken languages (based upon Halle, 1992).

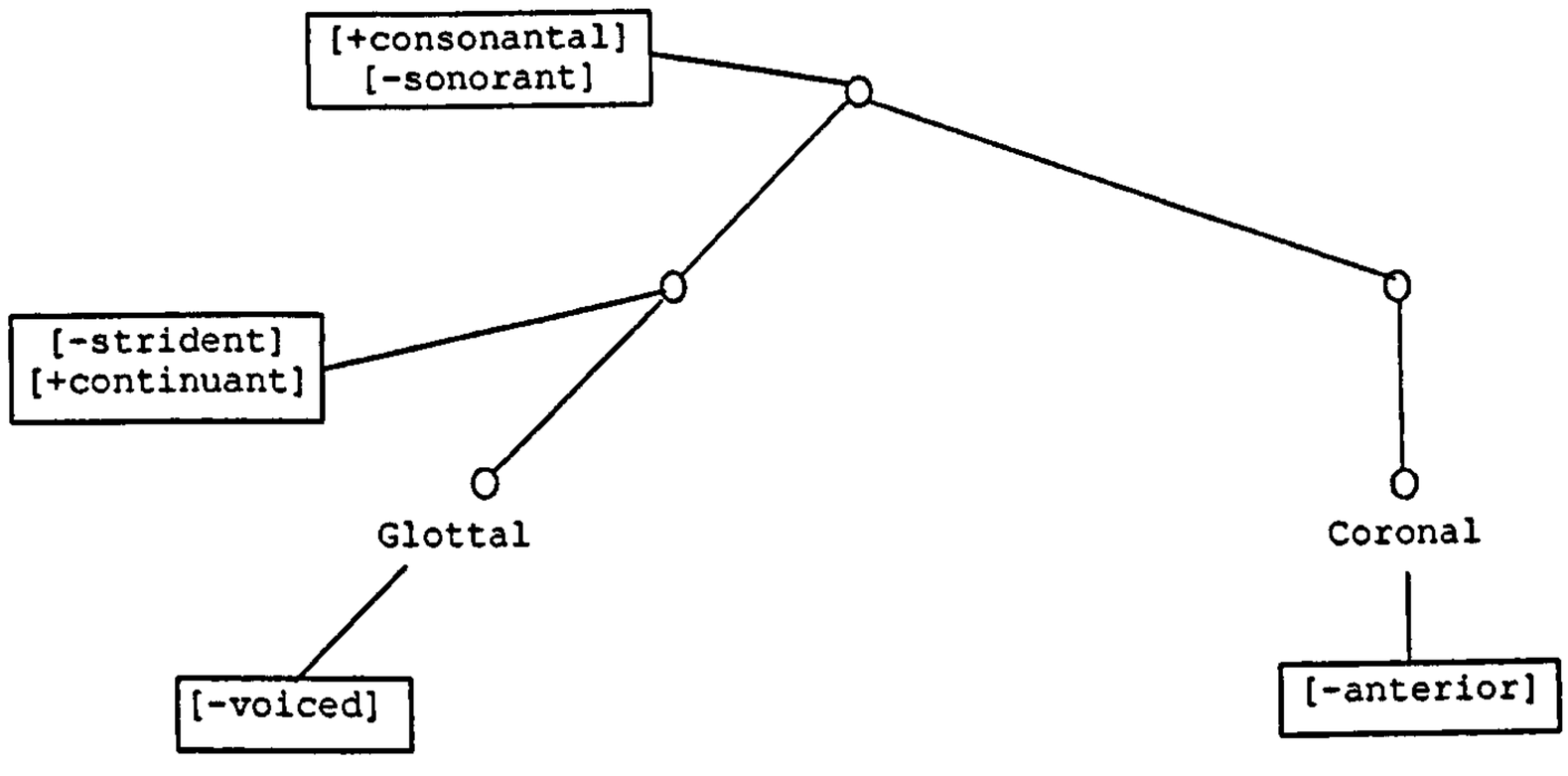


Figure 2.2: A representation of the sound [s]. The circles represent nodes - nodes may be attached to other nodes, or to features. Nonlocalised features connect directly to the root node, which lies along the skeletal (or root) tier. Five other nodes are represented here, each lying along their respective tiers: laryngeal and supralaryngeal, glottal, and coronal.

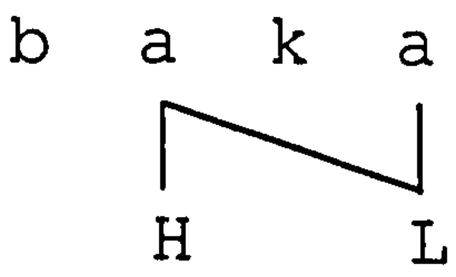
Given a set of segments, each of which is a hierarchically organised bundle of features, how are these segments arranged in the representation of a word? A key approach is that of autosegmental phonology, which was devised at the Massachusetts Institute of Technology by a linguist called John Goldsmith. It was originally devised to account for phenomena found in African tonal languages (see below), but has since been extended to account for phenomena in non-tonal languages. The basic idea is that different types of features are represented on separate tiers. Features on one tier are independent of the features on another tier. For example, tonal features can be represented on a separate tier to other features of a segment. In (α) are two words represented autosegmentally with respect to tonal features.

(α)

```
b  a  k  a          b  a  k  a
   |     |             |     |
   H     H             H     L
```

In (α), the identity of the segments is given on the upper tier and the tone that is associated to those segments is given on the lower tier. The lines indicate association lines that link the tones to the segments. The first word has high tones (H) on both vowels, whereas the second word has a high tone

on the first vowel and a low tone (L) on the second vowel. In such languages, anticipatory assimilation often makes a high tone followed by a low tone sound like a vowel of falling tone when it is articulated. This is represented below in (β) as the low tone associating to the vowel with a high tone. A segment associated with both a high and low tone sounds like a falling tone. When a feature associates with a neighbouring segment or segments, it is called spreading. In (β), the low tone has spread backwards to the preceding vowel. One rule of such spreading is that association lines can never cross.



(β)

We can also autosegmentally represent feature trees, such as that given in Figure 2.1. Here the autosegmental tiers would be laryngeal, supralaryngeal, oral place, glottal, tongue root, soft palate, labial, coronal and dorsal. The phoneme /s/ can be represented as shown in Figure 2.2. Here, the autosegmental tiers are hierarchically arranged. The main tier is the tier occupied by the root node, often referred to as the skeletal tier. Some features are connected directly to this node, and are called 'nonlocalised' features. The root node is connected to two other nodes on two separate tiers: the laryngeal *tier* and the supralaryngeal *tier*. The laryngeal node is connected to two further nodes on the glottal tier and the tongue root tier; these two tiers contain the features. The same principles apply for the supralaryngeal tier. Only the relevant nodes are shown in Figure 2.2.

When a temporal sequence of phonemes occurs in a word, a string of representations such as that shown in Figure 2.3 occurs. Figure 2.3 is a three-dimensional display of two phonemes - [1] and [2] - combined to form a word.

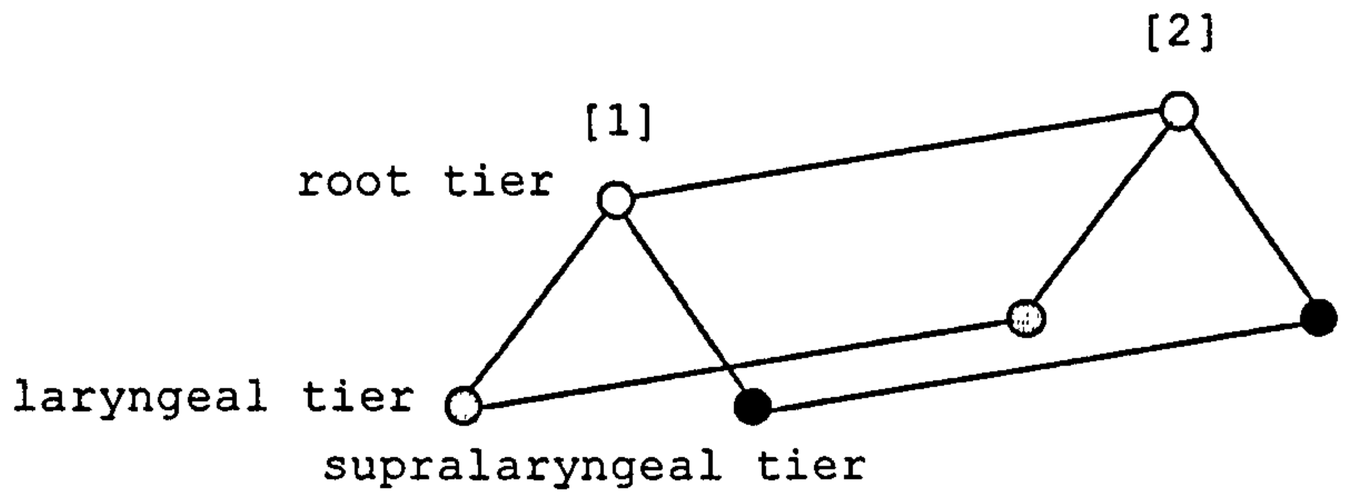


Figure 2.3: This figure is a three-dimensional display of two sound segments - [1] and [2] - combined to form a short word. The sounds are arbitrary for expository purposes, so have been omitted, along with all tiers apart from the skeletal, laryngeal and supralaryngeal. Circles in the diagram represent nodes, to which features may be attached. The root nodes are indicated by white circles, and lie along the skeletal tier; laryngeal nodes by grey circles lying along the laryngeal tier; and supralaryngeal nodes by black circles lying along the supralaryngeal tier.

One particular autosegmental approach is called CV phonology (Clements and Keyser, 1983). In CV phonology, there is a CV tier, which consists of slots to which segments are attached. Taking the word "gate" as an example, the CV phonological representation is given in (γ).

```
C     V     C
|     |     |
|     |     |
g     ei    t
```

(γ)

Consonantal segments associate to the C slots, and vocalic segments to the V slots. Such a representation can be used to explain why some nouns appear to be irregular in their singular and plural forms in an African language called Luganda (Goldsmith, 1989). In Luganda, nouns are prefixed with /mu-/ in the singular, and /ba-/ in the plural. Thus we get:

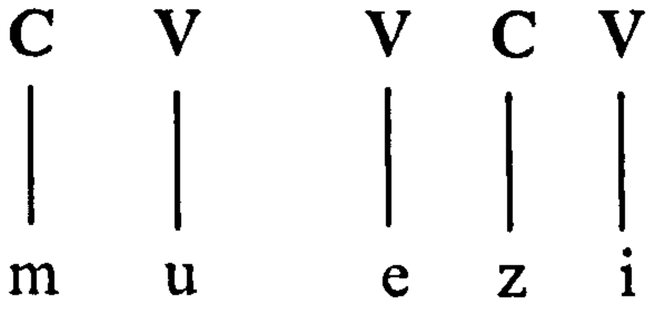
mukazi ('woman')	bakazi ('women')
mulimi ('cultivator')	balimi ('cultivators')

However, for some nouns this is not the case. For example:

mweezi ('sweeper')	beezi ('sweepers')
mwaana ('child')	baana ('children')

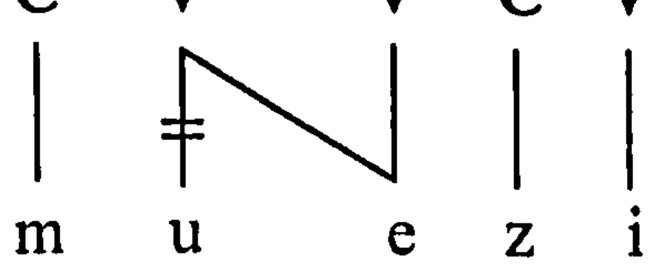
The CV phonology representation of 'mweezi' is given in (δ).

(δ)



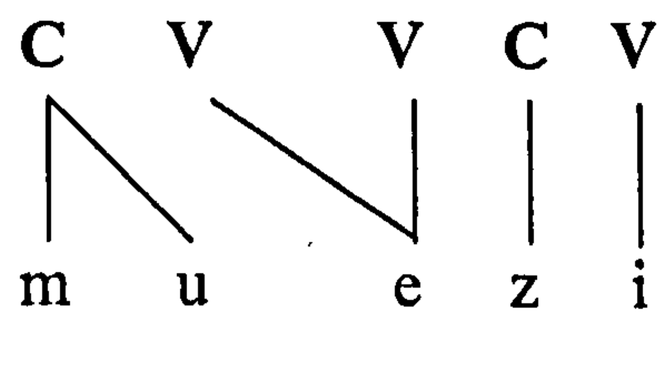
As the vowel sequence /ue/ is not allowed in Luganda, the /u/ segment dissociates from its V slot; the empty V slot associates to the /e/ (shown in (ε)).

(ε)



In Luganda, if an unassociated vocalic segment (such as /u/) has a high tone, it can associate with the slot for the preceding consonantal segment (such as /m/), shown in (ζ).

(ζ)



The result, shown in (ζ), has the phonetic form [m^{w}e:zi]. The [m^{w}] sound is the /m/ with secondary labialisation due to the influence of the high tone /u/, and the [e:] is a long vowel, as it is associated with two V slots. The C and V slots also therefore serve a timing function in CV phonology - one vocalic segment associated to two V slots is a long vowel, for instance - so the CV tier is also called the timing tier.

Phonologists are interested in the representation of words in the language user's mental lexicon. One aim is to describe the contrastive sounds of a language as parsimoniously as possible using distinctive features. Another is to specify phonological rules that explain how a word is articulated in phones given its phonemic representation. That is, given that a lexical entry has a certain phonemic description, how is an articulatory phonetic plan produced such that the articulators can produce that lexical entry. One of the benefits of autosegmental phonology is that the use of autosegmented but associated tiers makes it possible to specify phonological rules that capture the actual phonetic realisations of lexical entries without the need to specify many exceptions.

2.2 The Phonetics and Phonology of Signed Languages

2.2.1 Articulatory Phonetics of Signed Languages

For spoken languages, the key articulators are the tongue, lips, jaw and vocal chords. Activity of these articulators serves to modify characteristics of soundwaves produced by a speaker. In signed languages, the key articulators are the arms and hands (although body posture and activity of the eyes and mouth also play an important role). Currently, there is no clear theory of articulatory phonetics for sign language. There are two main approaches to sign language phonetics in the literature: the first based upon features akin to the distinctive features of phonological theories, the second based upon treating signs as body gestures. The first approach is clearly expressed by Liddell (1984) and Liddell and Johnson (1989). Their approach was originally intended to be a phonological account, and so is summarised below in the

section on sign language phonology. The second approach comes from researchers who have proposed systems based upon muscle activity in the arms and hands. Wilcox (1992), in an analysis of the phonetics of ASL fingerspelling, argues for a dynamic/kinematic approach to phonetics. He argues that the production and perception of fingerspelling is not a matter of producing or perceiving target states. Target states are the positions that the articulators reach in the ideal production of a speech sound or a sign. Rather, the producer produces a series of neuromuscular gestures, never achieving the defined target states of the fingerspelled hand configurations. He also cites some evidence (from Akamatsu, 1985) that deaf children do not learn to perceive target states. The aspect of the fingerspelling stream that appears to be most salient for production (Wilcox, 1992) and perception (Akamatsu, 1985) is the movement trajectory. Wilcox argues strongly that a phonetics of fingerspelling and signed languages should look to the kinematics (motion) of the linguistic signal, and not to hypothesised segments or target states. Once the kinematics is understood, he argues that the underlying control and dynamics of the system (the phonology) can be assessed. Such an approach mirrors that taken by some spoken language researchers, who view speech production as a continuously varying vocal tract state rather than a series of target vocal tract states (Fowler, 1987; Kelso, Saltzman and Tuller, 1986; Studdert-Kennedy, 1987). In a similar vein, although more directly linked to a discussion of sign languages than fingerspelling, Stokoe (1991) and Armstrong, Stokoe and Wilcox (1995) have argued for a description of sign language signs in terms of neuromuscular activity. As an example, Armstrong et al. give the ASL sentence VEHICLE GO-AROUND PERSON. This they describe as:

> *"Unrotated forearm with thumb and first two fingers extended moves (upper arm extension, slight inward rotation and wrist bending) past and around upright index finger of other hand"* (Armstrong et al., 1995, Figure 1.1, p.15).

In agreement with Wilcox (1992) they call for move towards a description of signs as:

"the net effects of several unitary motor acts" (Stokoe, 1991, p. 108)

2.2.2 The Phonology of Signed Languages

Most work on sign language phonology has been done in the United States, and is primarily concerned with ASL phonology. As for spoken language phonology, sign phonologists have focused on determining the distinctive features of signed languages, and rules that specify an articulatory phonetic plan for the actual production of phonemic lexical representations. Research into sign phonology is a more recent discipline than spoken language phonology, and this is apparent in the more diverse approaches currently being taken. Broadly speaking, three different approaches from the last forty years can be identified. These are (a) the formational parameter, (b) the distinctive feature and (c) the semantic phonology approaches.

2.2.2.1 The Formational Parameter Model

Stokoe et al. (1965) saw a sign as a simultaneously occurring feature bundle (see Figure 2.4). These features were handshape (dez), point of contact (tab) and movement type (sig). Later, another feature was added -- orientation of the palm (ori). Each sign is specified once for each of these features, with those features being non-binary in that they can take on a range of possible values. For that reason, they are often referred to as parameters.

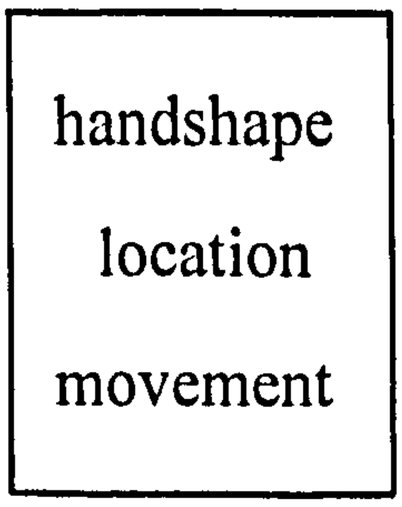


Figure 2.4: Stokoe's model of sign phonology proposed that a sign consisted of a simultaneously represented bundle of features.

Stokoe et al. held that these features were contrastive in ASL. Dez, tab and sig are therefore analogous to manner of articulation, place of articulation and voicing in spoken language phonetics. This differs from the phonology of spoken languages, where a sequence of such 'feature bundles' can be contrastive (e.g. /**bed**/ and /**bæd**/ — here the /**e**/ and /**æ**/ are contrastive; the /**d**/ sounds may be produced slightly differently, but not contrastively). To make this clearer, consider two signs from BSL that are specified for dez, tab and sig (see Table 2.3).

Table 2.3: Two BSL signs, glossed into English as NUMBER and AUNT, represented following the formational parameter model.

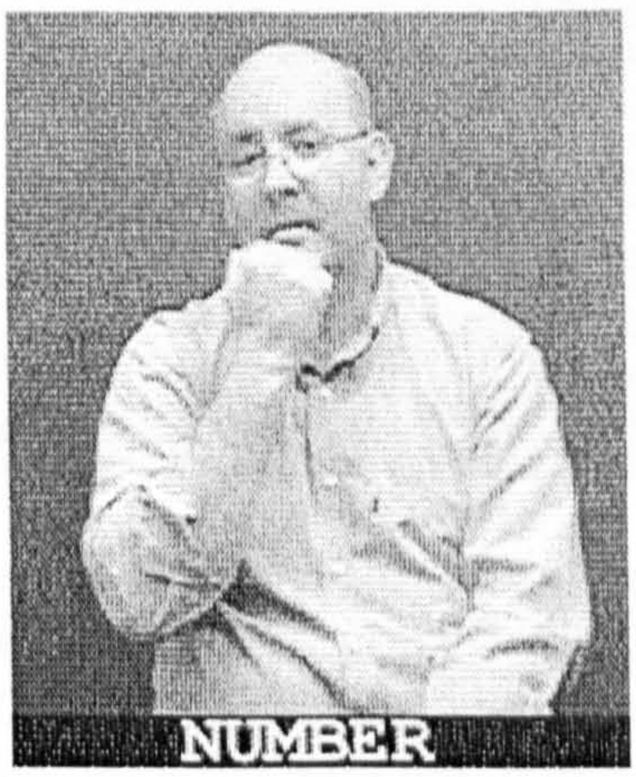
Parameter	**BSL Sign**	
	NUMBER	AUNT
Dez	A	H-bent
Tab	Chin	Chin
Sig	Taps twice	Taps twice

For the formational parameter model, these two signs are minimal pairs, differing only in handshape (dez). This is analogous to the difference between the phones [b] and [g] in spoken language phonetics (see Table 2.4). However, the sounds [b] and [g] are not minimal pairs in spoken languages, as they do not have any meaning. 'Bait' and 'gate' would be minimal pairs, differing in terms of their first segment: /b/ and /g/, but having the same final two segments: /eɪ/ and /t/. So, spoken languages use sequences of segments (feature bundles) to determine minimal pairs, whereas for Stokoe each sign is a single segment (feature bundle). The formational parameter model of sign phonology does not allow for such a sequential analysis. Within the model there is no representation of sequentiality. It is not disputed that signs contain a sequence of events, just that the representation of such sequentiality is not important phonologically.

Table 2.4: Two English sounds, [b] and [g], represented in terms of their formational parameters.

Parameter	English sound	
	[b]	[g]
Manner	Plosive	Plosive
Place	Bilabial	Velar
Voicing	Voiced	Voiced

An example of a formational parameter (Stokoe) representation is given in Figure 2.5. This is taken from a dictionary of BSL (Brien, 1992), and represents the BSL sign for NUMBER, made with the knuckles of the fist tapping the chin twice. The symbols are placed in the order [tab-dez-ori (palm)-ori (finger)-sig]. These correspond to [chin-fist-palm towards signer-fingers pointing up if extended-dez touches tab (repeated)]; in other words, a fist with the palm towards the signer and the fingers pointing up if extended, repeatedly taps the chin.



U A T^ x .

Figure 2.5: The BSL sign NUMBER (from Brien, 1992) and its Stokoe notation. The symbol U refers to the location of the sign (chin), A specifies that the handshape is a fist, T denotes that the palm is oriented towards the signer, ^ that the fingers would point upwards if the hand was extended, and x. that the hand makes contact with the chin repeatedly.

In Stokoe's ASL model, revised for the features of BSL, the notation denotes location, handshape, palm orientation, finger orientation, hand arrangement and movement. As many early researchers considered sign language signs to be a simultaneous bundle of features, e.g. Klima and Bellugi (1979), there is no attempt to clearly specify the sequential nature of a sign (or to express the dependence, or otherwise, of one type of feature on another). Minimal contrasts were used to determine which features distinguished between signs, and it was clear in the notation of two signs which feature distinguished between the signs, and in what way. Below are two examples of minimal pairs in BSL (Brennan et al., 1984), which differ in terms of handshape (dez; see Figure 2.6) and movement (sig; see Figure 2.7) respectively.

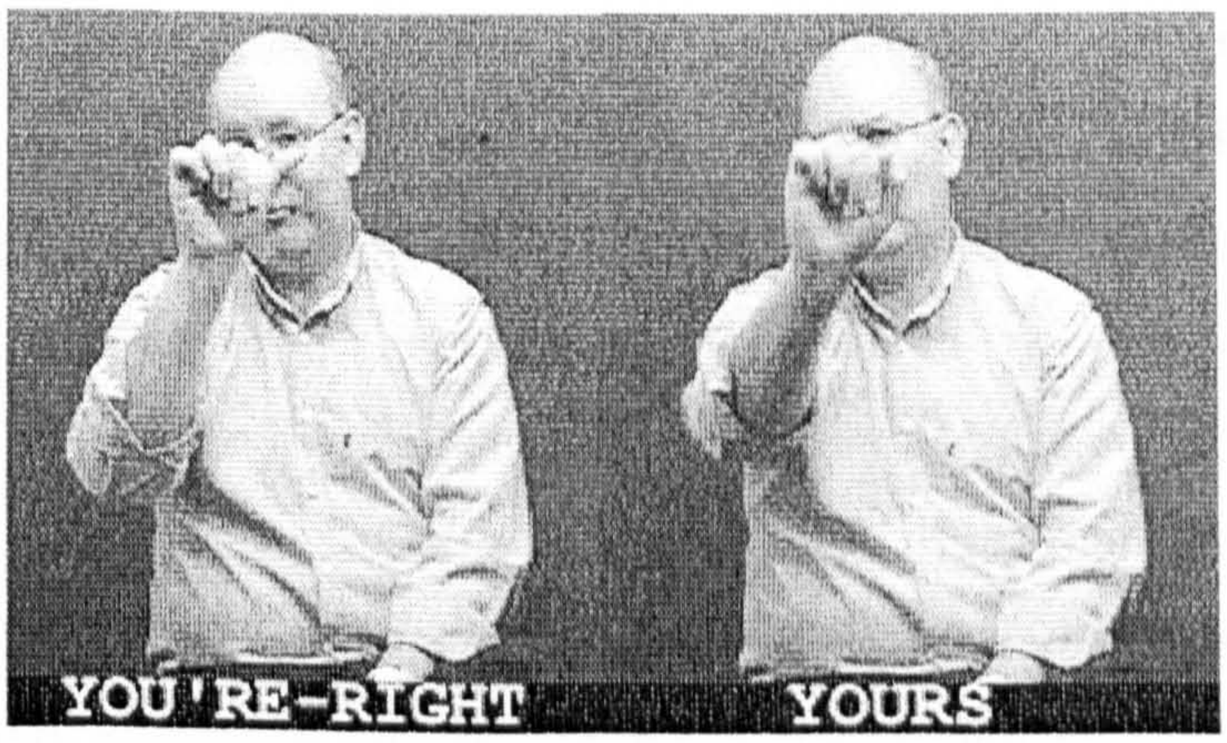


Figure 2.6: A minimal pair of BSL signs differing in handshape. On the left is the BSL sign for RIGHT (as in "Yes, you are right."), which has a fist with the thumb extended. On the right is the BSL sign for YOUR (second person singular possessive), which has a fist with the thumb unextended.

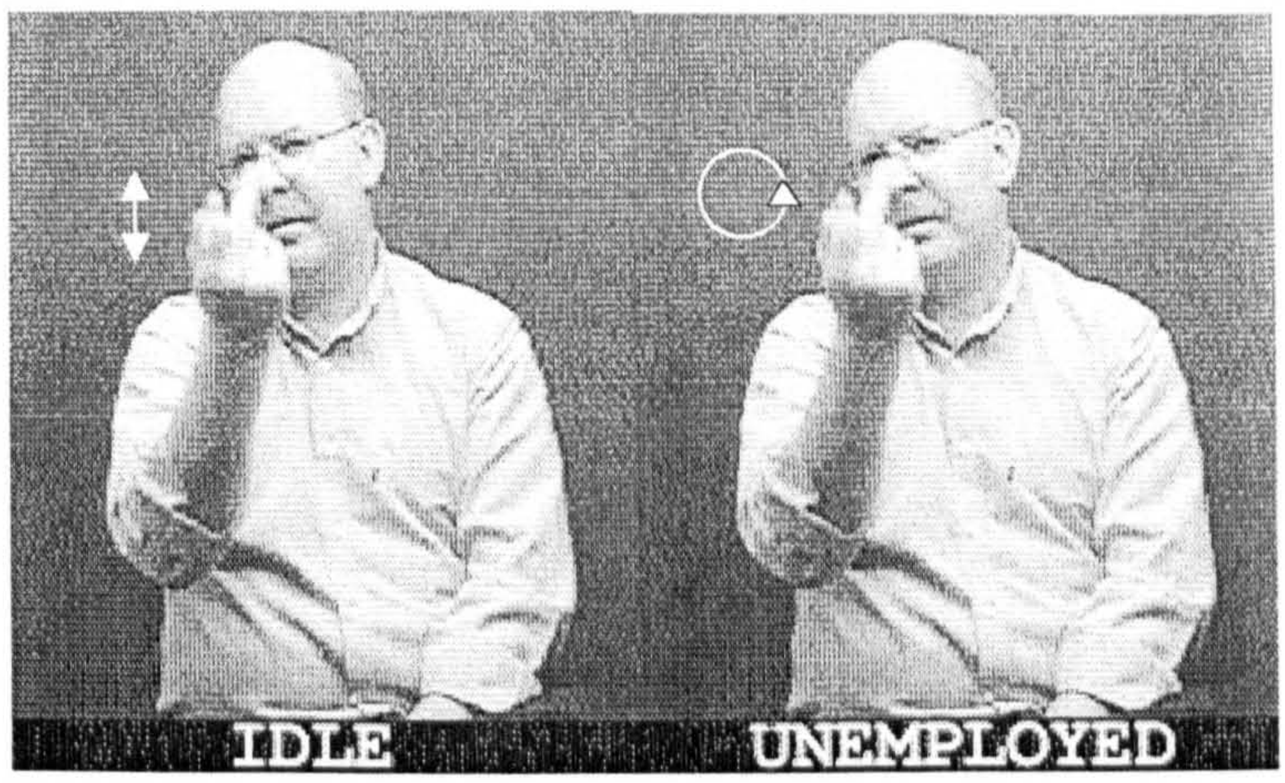


Figure 2.7: A minimal pair of BSL signs differing in movement. On the left is the BSL sign for IDLE, in which the hand moves up-and-down. On the right is the BSL sign for UNEMPLOYED, in which the hand circles in a clockwise direction.

2.2.2.2 Distinctive Feature Models

In the current literature, there are a host of distinctive feature models, all of which take advantage of an autosegmental approach. Three key models are the movement-hold (MH) model (Liddell, 1984; Liddell and Johnson, 1989), the hand tier (HT) model (Sandler, 1989) and the non-segmental model (Wilbur, 1993). Although these three models differ in some ways, it is what they have in common that is interesting here. None of the theories posit parameters that can take on a large range of values. Instead, they argue that there are binary distinctive features similar to those proposed by Chomsky and Halle (1968) and earlier by Jakobson and Halle (1956). They all also incorporate sequences of feature bundles (*q.v.*). These two similarities are best illustrated with reference to the movement-hold model (Liddell, 1984; Liddell and Johnson, 1989).

The Movement-Hold Model

Liddell (1984) argued that it is not single feature bundles that are contrastive in ASL, rather it is sequences of such bundles. He referred to bundles of features as segments, and argued that a sign has "internal, sequential segments rather than a simultaneous bundle of features" (Liddell and Johnson 1989, p. 202). He used such an analysis to demonstrate how the

ASL signs for SIT and CHAIR were different and not identical, as formational parameter analysis would suggest. Supulla and Newport (1978) had found that the ASL sign CHAIR had what they termed as a "hold manner" at the end of its production (i.e. the hands were immobile at the end of the sign). This was in contrast to the corresponding verb sign, SIT, which had a "restrained manner" at its final position, but was not held[1] (see Figure 2.8). Liddell and Johnson (1989) argued that this was an example of a sequential phonological distinction. Liddell and Johnson also examined the case of subject-object agreement in ASL: subject and object are marked in space, a certain position referring to a certain person. Stokoe's formational parameter model is not capable of representing such complexities — "I GIVE TO YOU" and "I GIVE TO HIM" (see Figure 2.9) would have the same representation, as the Stokoe model has no way of distinguishing between two contrastive locations in the signing space.

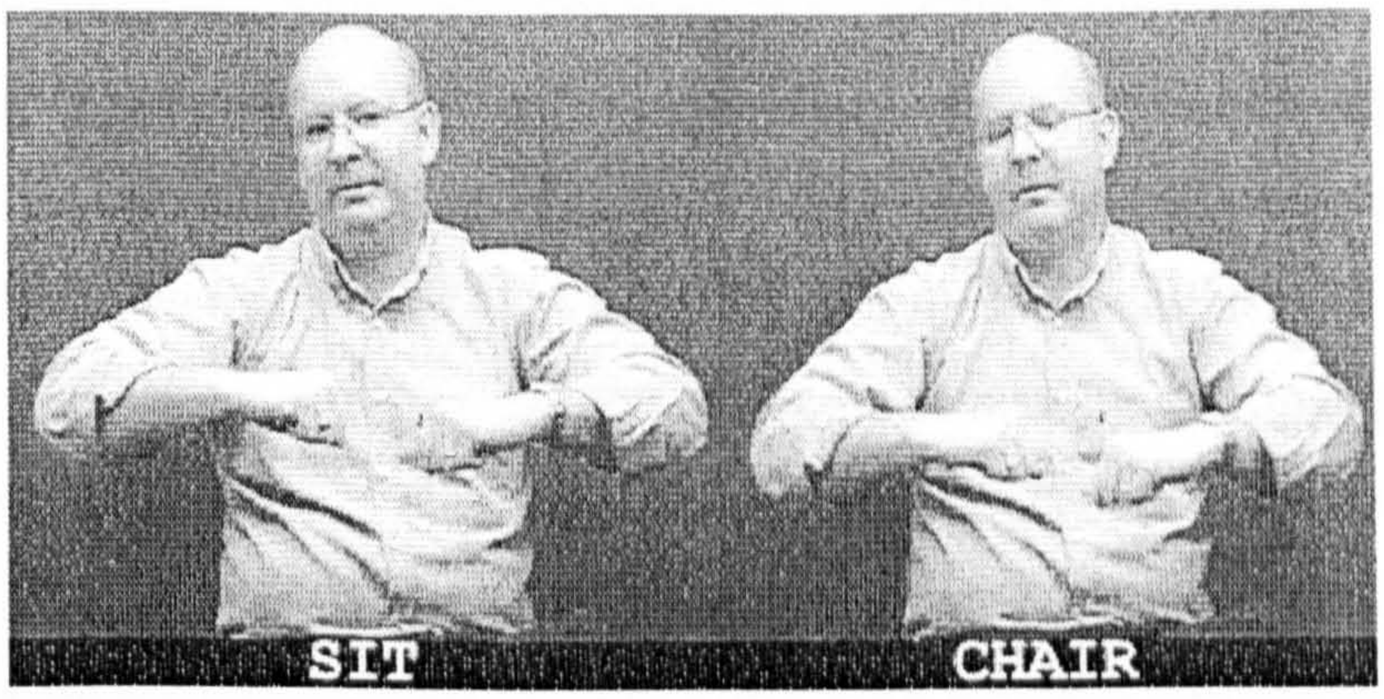


Figure 2.8: A pair of BSL signs that differ in terms of the manner in which they finish. The sign on the left (SIT) is a verb, and it is not held for long in its final position. The sign on the right (CHAIR) is the corresponding noun, and is held in its final position. The difference is very small, and often only detectable on slow-motion replay of videotape.

[1] Supulla and Newport (1978) looked at 100 noun-verb pairs, such as CHAIR-SIT, and found that this distinction held in many cases. Thus the noun signs and verb signs could only be distinguished in terms of the degree of movement at the end of the signs.

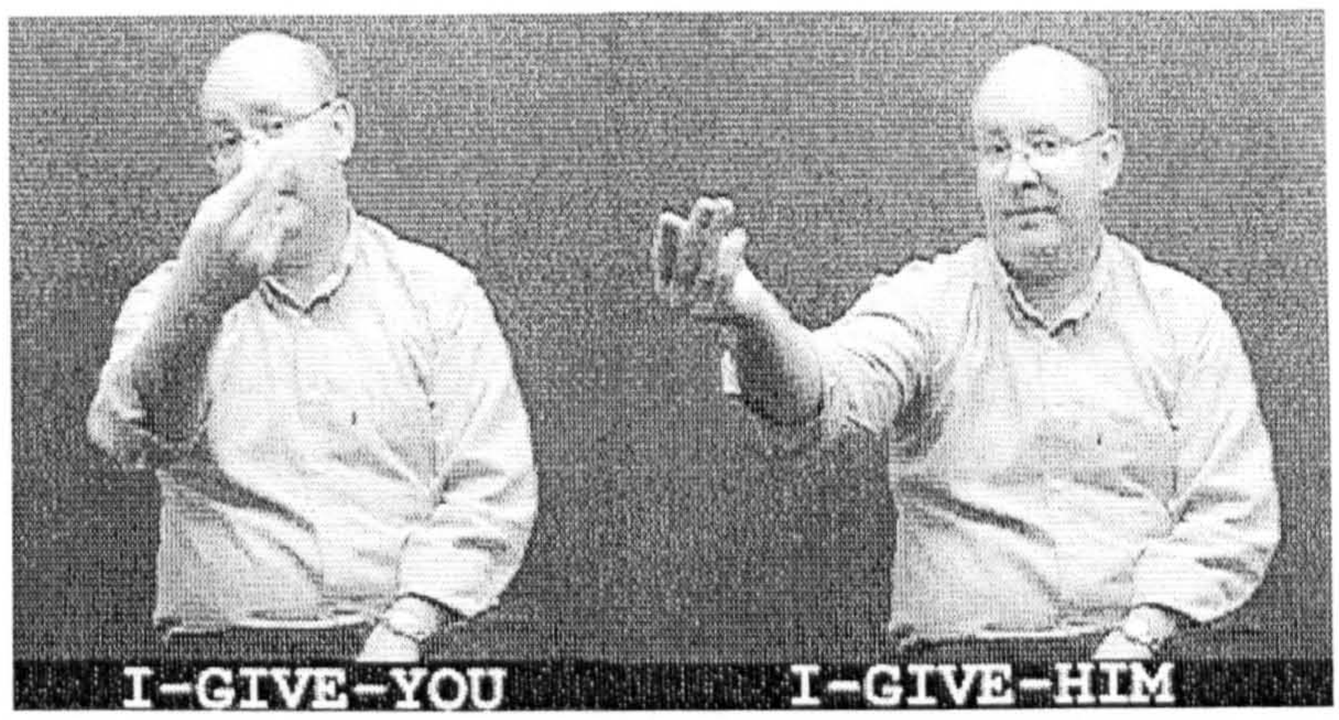


Figure 2.9: The BSL signs for I-GIVE-YOU (left) and I-GIVE-HIM (right). The patient of GIVE is determined by the location to which the signer directs the sign. For I-GIVE-YOU the sign is directed to a point towards the addressee/away from the signer; for I-GIVE-HIM the sign is directed to an arbitrary point in space to the left or right of the addressee/signer.

So what did the MH representation look like? Liddell and Johnson (1989) proposed that signs were made up of segments, each segment consisting of two major components. One component specifies the posture of the hand, the other the activity of the hand. The hand posture component specifies features that describe the orientation of the hand and how its movable parts are arranged — together, these features are termed the articulatory feature bundle. Another set of features describes the activity of the hand. They specify whether the hand is moving, and if so what type of movement that is. These activity features serve to distinguish between periods during which the articulatory bundle is moving, and periods during which they are static. Respectively, they distinguish between two types of segments - holds and movements (henceforth H and M; see Figure 2.10). As these activity features distinguish between two types of segment, they belong to a separate class of features – segmental features – which together form the segmental feature bundle.

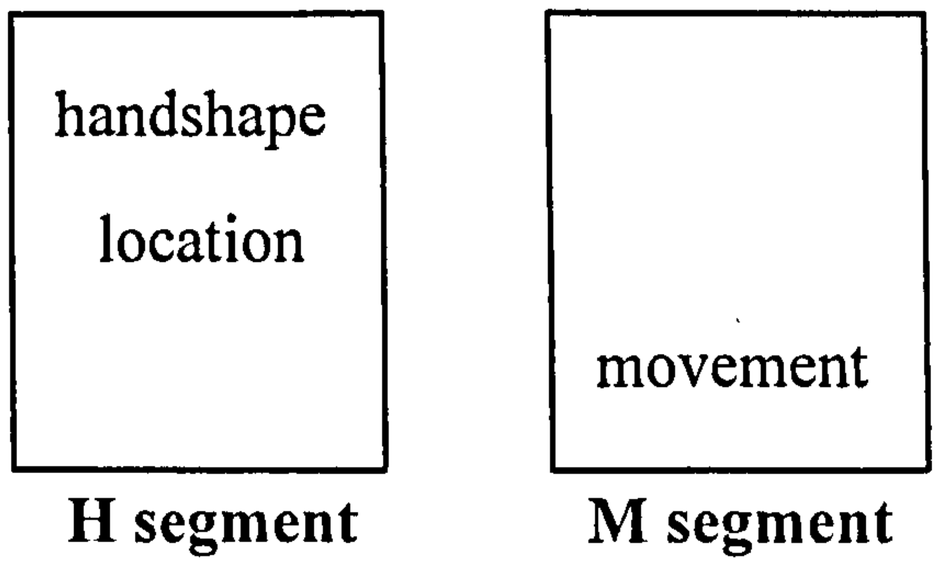


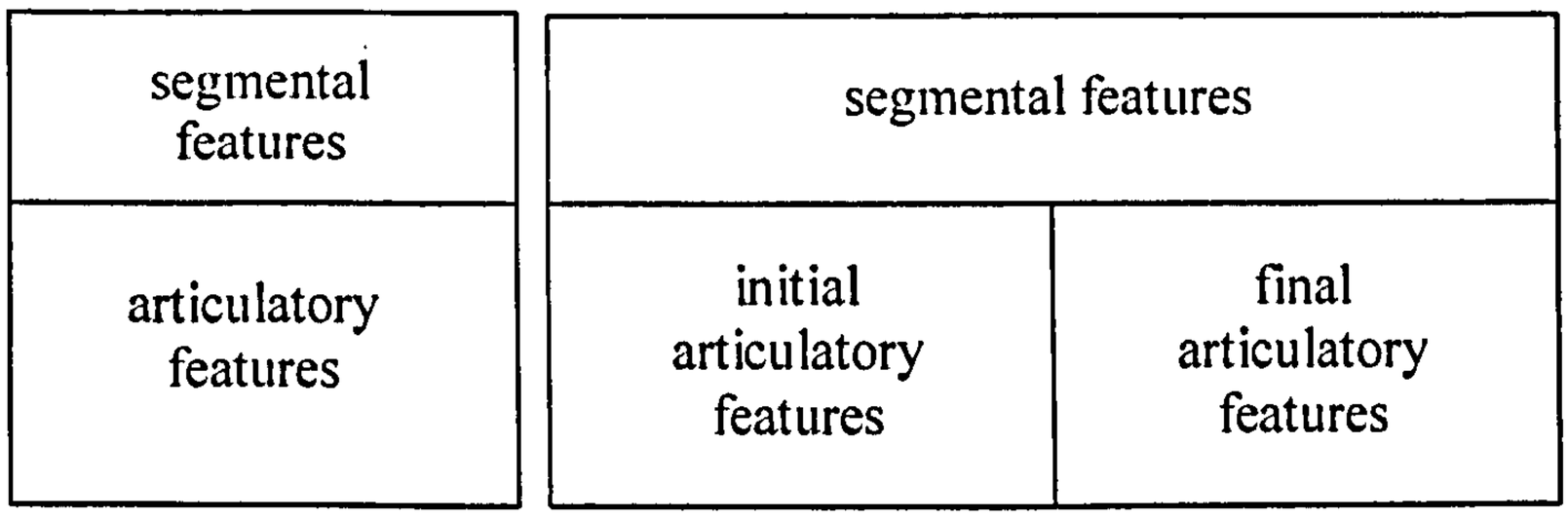
Figure 2.10: Liddell and Johnson (1989) did not represent handshape, location and movement as a simultaneous bundle of features. Handshape and location were assigned to one feature bundle (the H segment), and movement to another feature bundle (the M segment).

The articulatory feature bundle is composed of four groups of features: hand configuration – features specifying how the fingers and thumbs are arranged; point of contact – features indicating the main location of the sign, the part of the hand that points to or touches that location, and the spatial relationship between that hand part and location; facing – features specifying another location and which part of the hand faces that location; and orientation – features specifying a plane towards which part of the hand is faced.

Segmental features define what type of segment the articulatory features belong to, and specify the fine detail of those segments. For Liddell and Johnson, there are five binary or n-ary feature types within the segmental feature bundle: major class – this defines whether the segment is an M or H; contour – this feature describes the type of movement path; plane – a non-straight movement can occur in one of five planes, specified by this feature; quality – these features specify finer details of the segment, including temporal aspects, as well as aspects such as contact; and local movement – these specify small uncountable movements at the finger, wrist or elbow joints.

Liddell and Johnson's (1989) movement-hold model proposed that signs are made up of strings of M and H segments. An H segment has only one bundle of articulatory features associated with it. A M segment has two – one specifying the state prior to the movement, the other specifying the state after the movement (with the segmental bundle specifying the nature of the

transition from one to the other). This is shown diagrammatically in Figure 2.11.



(a) (b)

Figure 2.11: Diagrammatic representations of (a) an H segment, and (b) an M segment.

Obviously, if an M segment is preceded by a H, the M's initial articulatory bundle will be the same as the preceding H's articulatory bundle. The same logic applies when an H follows an M. Assuming two different articulatory bundles (posture a and posture b), this can be represented as in Figure 2.12.

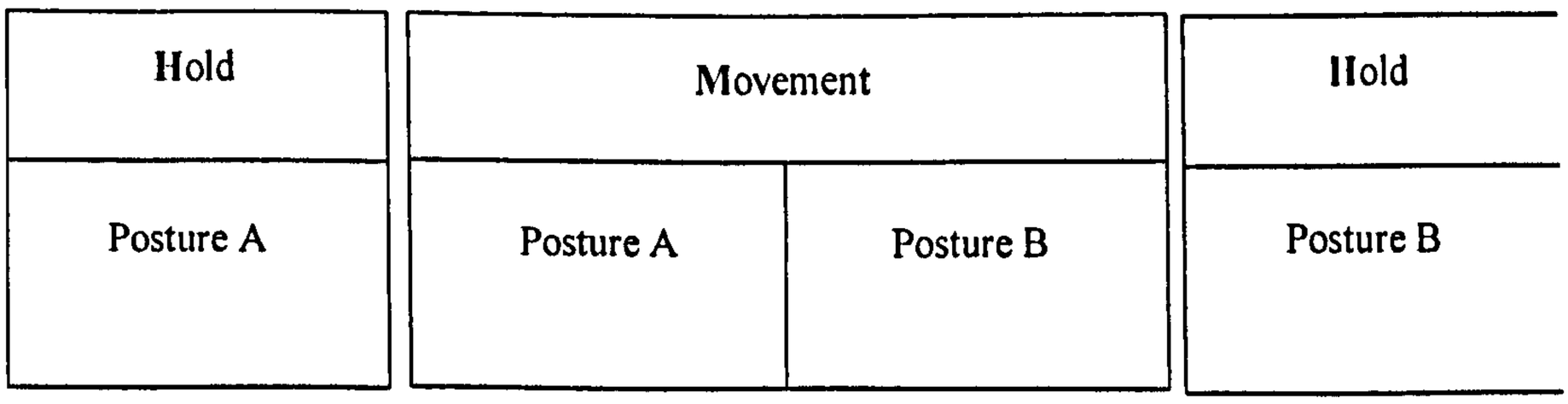


Figure 2.12: A three-segment sign (HMH) with corresponding posture between H_1 offset and M onset, and M offset and H_2 onset.

Liddell and Johnson argue that it makes little sense to represent the redundancy in specifying the same set of articulatory features twice, so they suggest that the articulatory bundles should be represented separately from the segmental bundles (i.e. on a separate tier). Such an autosegmental

representation is shown in Figure 2.13. In such a representation, the segmental feature bundles and articulatory feature bundles are allowed to function independently. The articulatory feature bundles being associated to the segmental feature bundles by association lines preserves the timing of articulations. For this reason, the segmental (MH) tier can be referred to as the timing tier. Liddell and Johnson suggested that non-manual features (NMFs) of ASL (such as lip and eyebrow movements, and body posture changes) should be represented on yet another autosegmental tier.

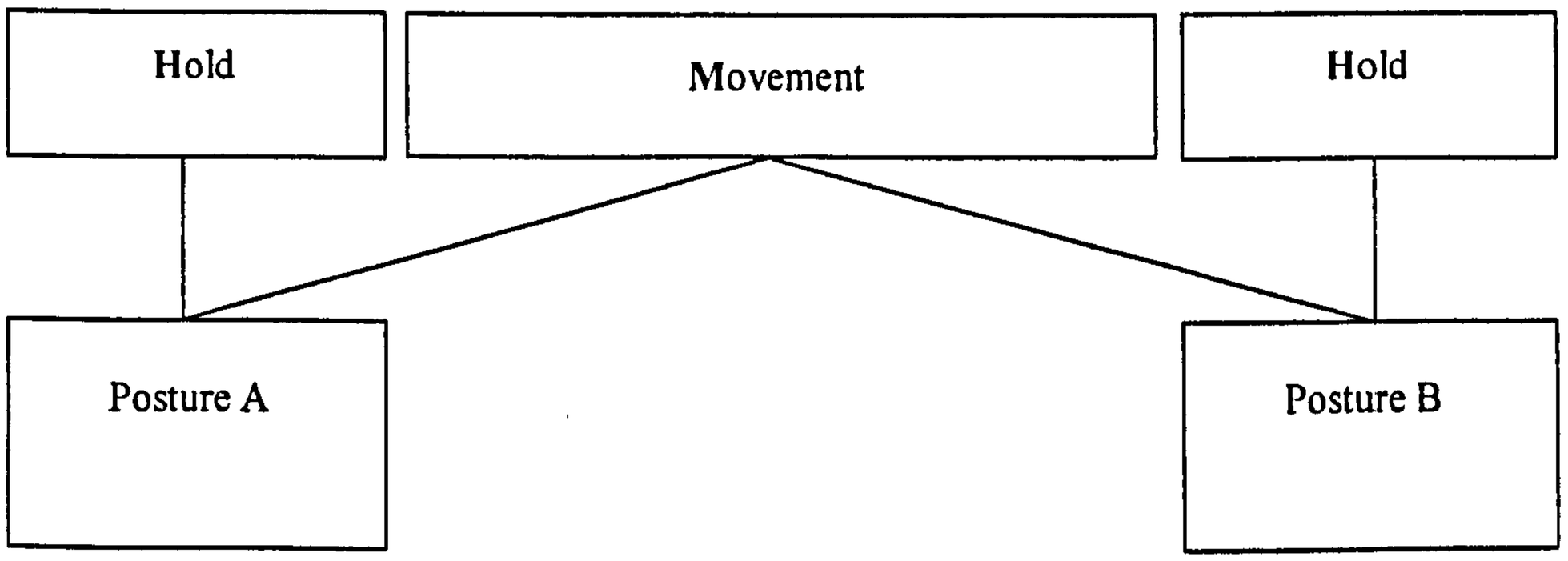


Figure 2.13: An autosegmental representation of the same HMH sign shown in Figure 2.12. The articulatory segments (posture a, posture b) are represented on a separate tier to the segmental bundles (hold, movement).

This could be taken one stage further, removing M segments altogether, assuming that a specification of the movement is redundant given the initial (posture a) and final (posture b) articulatory bundles. Liddell and Johnson argue that there are many ways to get from posture a to posture b, and that the different possible paths can be contrastive. As M segments have a contrastive role in ASL, they must be preserved in a representation that has any phonological significance. The resulting HMH representation is reminiscent of a CVC representation in CV phonology, where the C and V segments are attached to sets of articulatory features, and to segmental features such as [±sonorant] [±vocalic] and [±consonantal] (Chomsky and Halle, 1968). However, in the HMH representation, the M segment does not have its own set of articulatory features — neighbouring H provides these segments.

As the two hands can move semi-independently in the execution of a sign, each hand is represented as a separate string of articulatory features, associated with each other for timing purposes. This gives a total of four autosegmental tiers: the timing (segmental, MH) tier, the non-manual feature tier, and one tier each for the articulatory feature bundles of the dominant and weak hands. The timing tier specifies the segment type (M or H) and finer details of movements (local movements[2] only for H segments). The NMF tier specifies non-manual features, and the two hand tiers specify the articulation and posture of the hands. Tiers are associated via association lines to preserve the timing of the sign's execution, i.e. to make sure that the correct hand postures and facial movements coincide with the appropriate segment during performance of the sign.

One criticism of Liddell and Johnson's (1989) model is that it allows specification of too much phonetic information. Some of that phonetic information is predictable from other pieces of phonetic information, and therefore redundant in a phonological representation. In an attempt to overcome this limitation, Liddell (1990) reformulated the movement-hold model. An example of Liddell's (1990) phonemic representation is given in Figure 2.14. This representation contains twelve autosegmental tiers: the articulatory feature bundle from the previous (phonetic) representation has been split into six separate tiers. These six tiers independently specify hand configuration, point of contact, proximity-spatial relation, location, facing and orientation. Hand configuration is further split into five tiers: finger extension, finger shape, thumb rotation, thumb shape, thumb contact (these are not shown in Figure 2.14).

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[2] Local movements are hand-internal, such as wiggling of the fingers or bending of the fingers at the knuckle joints during execution of the sign.

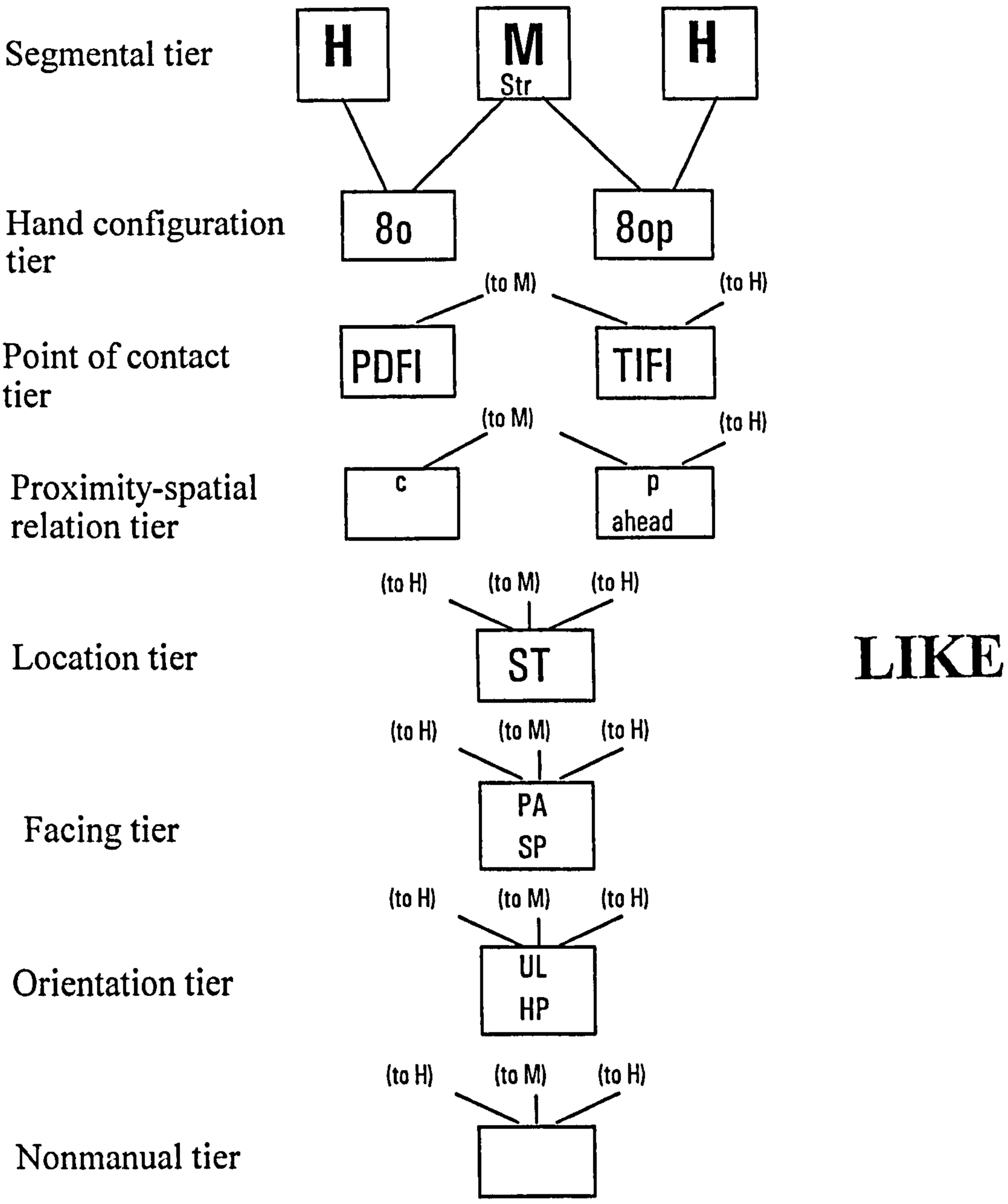

Figure 2.14: The MH model's phonemic representation of the ASL sign LIKE.

Rather than specifying the initial and final features for a feature that does not change, that feature is specified once, and spreads to all pertinent segments on the segmental tier. Where no feature changes, one entry is given, a single change results in two entries, two changes in three entries, and so on.

Liddell's movement-hold model accounts for the differences between verb signs (SIT) and noun signs (CHAIR) by positing a HMH structure for verbs and a HMHH structure for nouns. The two H segments at the end of a noun result in the sign being held for a short while longer (the restrained manner noted by Supulla and Newport (1978). I-GIVE-YOU and YOU-GIVE-ME can be contrasted by changing the specifications of the H segments: I-GIVE-YOU is H_1MH_2, whereas YOU-GIVE-ME is H_2MH_1.

To reiterate, the key differences between the movement-hold (distinctive feature) and the formational parameter models are as follows. The movement-hold model represents signs in terms of binary distinctive features, whereas the formational parameter model has only three parameters that can each take on one of a large range of possible values. The movement-hold model splits signs up into sequences of articulatory feature bundles. The formational parameter model has no representation of sequentiality, placing all of its parameters in one bundle.

These differences also apply to the hand-tier model (Sandler, 1989) and the non-segmental model (Wilbur, 1989). The hand-tier model differs from the movement-hold model in that there is a separate autosegmental tier for hand configuration information in the hand-tier model (see Figure 2.15). The non-segmental model (Wilbur, 1993) differs from both the MH and HT models in that there are no separate segment types. For the movement-hold model there are M(ovement) and H(old) segments, and for the hand-tier model there are M(ovement) and L(ocation) segments. In the non-segmental model there are only sequences of feature bundles, all of which specify the same set of distinctive features.

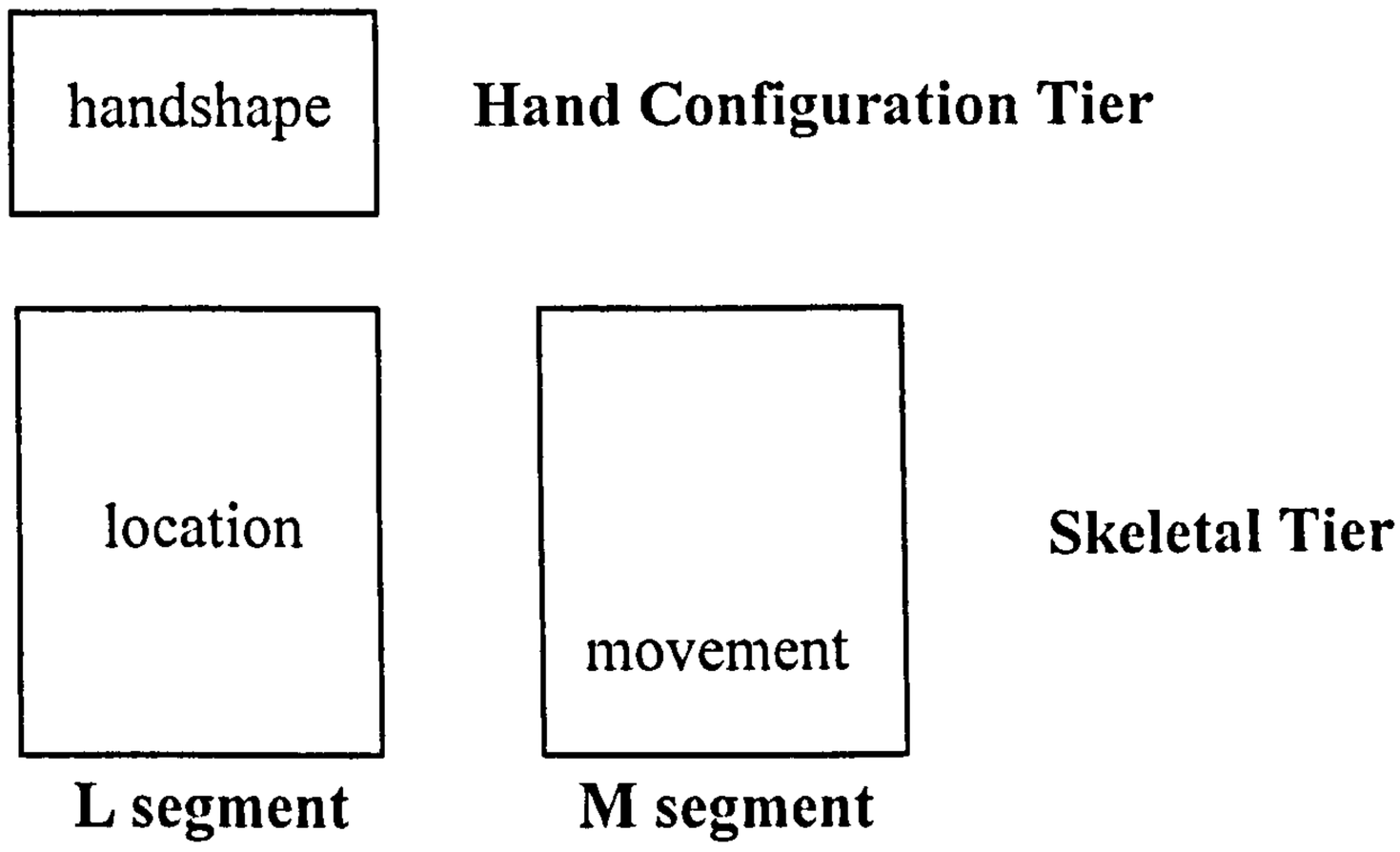

Figure 2.15: The hand-tier model differs from the movement-hold model chiefly by removing handshape features from the feature bundle containing location features, and placing them on a separate autosegmental tier.

2.2.2.3 The Semantic Phonology Model

In a book on the evolution of natural language in primates, Gesture and the Nature of Language, Armstrong et al. (1995) proposed an approach to studying signed languages that was very different from parameter- and feature-based approaches. The authors develop the theory of semantic phonology, first proposed by Stokoe (1991). Semantic phonology argues that signs are not represented in terms of meaningless and distinctive features; they have a syntactic rather than phonological structure. Armstrong et al.'s arguments are couched in terms of a theory of the evolution of language. Their position is that manual gestures constituted the first forms of linguistic communication, and that manual gestures were necessary prerequisites for the development of spoken language. Armstrong et al. argue that in order to communicate in a spoken language, a grasp of syntax is required by the speaker. This is necessary if it is to be made clear which are the subjects and objects in a sentence - expressing who does what to whom depends upon syntax. But for Armstrong et al. there is a problem here:

"to categorize words requires syntax as the sorting principle; but to construct syntactic structure requires words already so sorted" (Armstrong et al., 1995, p.184).

How can this circle be broken? Armstrong et al. claim that the organism must be exposed to the concept of subject-verb-object (SVO) in the form of a manual gesture:

> *"there is no way to do this sorting until the creature doing it has 'seen' an SVO pattern in gesture and thus experienced an obvious demonstration that what acts and the action it performs are distinct but physically and temporally linked"* (Armstrong et al., 1995, p.183-4).

Armstrong et al. invite us to perform a simple task:

> *"If you will, swing your right hand across in front of your body and catch with it the upraised forefinger of your left hand. ... the dominant hand is the agent (it acts), its swinging grasp is the action (verb), and the stationary finger is the patient or object. The grammarians' symbolic notation for this is familiar: SVO. This order is also natural, as natural as the action itself. ... Actions begin with and emanate from an actor."* (Armstrong et al., 1995, p.179).

So, for Armstrong et al., a sign has a syntactic structure. No directly testable model of semantic phonology is put forward by the authors, but we can safely assume that a semantic phonological representation of a sign would be in terms of 'something doing something to something else' - an actor, an action and a patient. One problem with testing such a model is the argument that meaning directly motivates the form of a sign. It is unclear whether it is possible to isolate signs that have similar semantic phonologies and yet are not also similar in terms of the features or parameter values favoured by structural models.

The strong form-meaning relationships posited by semantic phonology have been identified within the self-styled communication systems of deaf

children (Goldin-Meadow, Mylander and Butcher, 1995). The children studied by Goldin-Meadow and colleagues are profoundly deaf (>90dB loss in both ears) children of hearing parents, who have an 'oral' education and no exposure to conventional sign languages such as ASL and BSL. The oral ability of these children (in terms of speech discrimination and production) was poor (as is usual for many young deaf children in 'oral' education systems, see Conrad, 1979) and they relied upon manual gestures for communication. One issue approached by Goldin-Meadow et al. (1995) was that of combinatorial structure. They were interested in whether the gestures produced by these children were holistic (pantomimic) gestures. An analysis of the gestures produced by four children suggested that this was not the case. Rather, a set of handshapes was combined with a set of movements in order to generate a set of meaningful gestures. The object or action being represented motivated the form of the handshapes and the movements. Positioning of the fingers was correlated with the width of the object being represented. This correlation was not, however, analog: the handshape did not always reflect the handshape required to manipulate the object. Rather, a discrete set of handshapes occurred, each of which was used to represent a range of objects with differing width dimensions. Certain movements were used to represent certain actions. For example, short/medium arcing movements were used to indicate the repositioning of an object, whereas a long arcing movement was used to represent the relocation of an object along a path to a certain point. Goldin-Meadow et al. concluded that handshape, movement and orientation function as morphemes within the self-styled manual gesture systems of these children. Such an analysis is compatible with semantic phonology: the referent or the action of the referent motivates the form of the gesture, and this motivation forms part of the internal representation of the gesture. In other words, gestures are not represented independently of what they represent. Semantic phonology appears to give a better account of self-styled gestural systems than it does of conventional sign languages. However, it is hard to see how semantic phonology can account for the structure of signs that have no clear motivation. Whilst the proponents of the theory can provide examples

that match their proposals, it is easy to find examples that they cannot account for. For example, consider the BSL sign BUT. This is formed by extending the index finger of the dominant hand, pointing upwards, and extending the hand forward in a short, sharp motion. It is unclear what the semantic phonology description of this would look like – what is the agent, the patient and the action? Indeed, although semantic phonology can be used to describe many noun and verb signs, other lexical units such as auxiliaries, adjectives and conjunctives do not appear to fit within the model. Moreover, it is not clear whether a semantic phonology account of such systems, and of certain conventional signs, is necessary. Other analyses have been proposed to account for such constructions, such as Wallin's (1996) analysis of such signs in terms of figure, ground and motion (see Section 5.3.3). Figure, ground and motion can be seen as analogues of agent, patient and action, obviating the need for an alternative proposal in semantic terms. It would appear that but for the need to resolve the circularity of syntax acquisition in relation to language evolution, the proponents of semantic phonology theory would not have arrived at their current proposal.

The work presented in this thesis provides an empirical test of the validity of the semantic phonology framework, alongside the more traditional formational parameter framework outlined earlier. As such, the present work seeks to examine whether the criticisms of semantic phonology are empirically, as well as theoretically justified.

3 The Mental Lexicon

Chapters 4 and 5 will look more closely at "working memory", and the encoding of language. Once language has been encoded, the representation can be used in a variety of cognitive tasks. This chapter will look at one of those tasks: word recognition. In order for a word (or sign) to be recognised, it must be mapped onto longer-term representations in the perceiver's mental lexicon. The lexicon contains entries for all known words/signs, and entries include information on phonological form, morphology, syntax and meaning (see Levelt, 1989, for a detailed discussion).

Chapter 5 highlights the range of language codes available to deaf people. This linguistic versatility makes it difficult to draw conclusions about the nature of formational representations of sign language signs. Even with signed stimuli, it is possible that some deaf participants may recode the signs into another form for rehearsal. It will be proposed in Chapter 5 that the nature of serial recall tasks may bias deaf participants towards using a speech-based code, as the properties of that code are better suited to the serial recall task. As bilinguals, most deaf people can use the signed stimuli to access the appropriate entry in their mental lexicon, and retrieve a speech-based phonological form for rehearsal in working memory (utilising the articulatory loop). This chapter looks at the process by which representations in the mental lexicon are accessed. There are two fundamental questions which can be asked of this mapping from encoded representation to mental lexicon: (1) what is the nature of the representations involved, and (2) what is the process by which the mapping takes place? These questions will be addressed for spoken languages, and two key models of lexical access will be described: cohort theory (Marslen-Wilson and Welsh, 1978) and the neighbourhood activation model (NAM; Goldinger, Luce and Pisoni, 1989). This will be followed by a more detailed discussion of published research looking at lexical access and signed languages.

3.1 Models of lexical access

Several authors have proposed models for the process of lexical access (Marslen-Wilson and Welsh, 1978; Morton, 1969; Goldinger, Luce and Pisoni, 1989). These models are intended to explain how a phonetic input is recognised as a token of a lexical item, and stored information about that item is retrieved. Although contemporary models differ in certain respects, in others they are in broad agreement. Logogen theory (Morton, 1969), cohort theory (Marslen-Wilson and Welsh, 1978) and the neighbourhood activation model (Goldinger, Luce & Pisoni, 1989) all conceive of lexical recognition as the summation of evidence for the hypothesis that a given input is a token of a certain lexical item. This evidence is usually instantiated as activation of a node representing a lexical item, with that activation being derived from bottom-up (phonetic) and top-down (contextual) information. The initial stage is feature extraction, with phonetic features in the input stream being extracted. If a lexical node is associated with the input features, then it receives activation; if not, then its activation is attenuated. Marslen-Wilson (1990) states three basic assumptions which all current theories of lexical access share: (1) the activation metaphor is appropriate for computing the goodness-of-fit between input and stored lexical representations; (2) perceptual processing of the input is based upon competition between simultaneously-active lexical representations; and (3) decisions about the input are based upon the levels of activation of the competing representations.

3.1.1 Cohort theory

Like all current models of lexical access, cohort theory is primarily data-driven: the processing is dependent mostly upon information derived from the input, not from contextual factors. In the original formulation of cohort theory (Marslen-Wilson and Welsh, 1978), it was proposed that the onset of the stimulus determined a restricted set of possible lexical representations (the initial cohort). Given the input [pattern], the word onset - [p] - would determine the initial cohort of possible matches: all lexical representations with an onset of [p]. Subsequent input - [attern] - serves to provide more

evidence for the appropriate representation in the cohort. Processing of the remainder of the first syllable - [at] - would increase the activation of representations starting with [pat] (e.g. pattern, patrol, patronise) and decrease the activation of those cohort members that do not start with [pat] (e.g. part, perfect, pie). Mismatch does not remove all activation from a representation, with the representation retaining some activation. Decisions about the input are made on the basis of competing levels of activation between lexical representations. In cohort theory, a representations 'wins' when its activation level is higher than its nearest competitor's by a threshold value. The activation of one representation does not influence the activation of other cohort members, rather competition occurs at the decision level.

Word frequency is represented in the cohort model by manipulating the resting activation levels of lexical representations (Marslen-Wilson, 1987). High frequency words are assumed to have higher resting levels than low frequency words. They therefore take longer to be removed from the cohort when they do not match the input, and are quicker to 'win' against competing units when those competitors are less frequent in the language.

Latterly, the priority attributed to the word onset has been contested (Marslen-Wilson and Zwitserlood, 1989) and Marslen-Wilson (1990) has proposed a weaker version of the hypothesis. Cohort theory now proposes that word-onset mismatch between an input and a stored representation does not exclude it from the cohort of competing representations. Rather, there is some initial inhibition of mismatching representations, which can be over-ridden by subsequent processing of the input. Thus, although the nonword [dattern] will initially be perceived as [dattern], the lexical system will still be able to determine that it was an intended token of the word [pattern].

3.1.2 Neighbourhood activation model (NAM)

In NAM, the input is postulated to activate a set of acoustic-phonetic patterns (Goldinger, Luce and Pisoni, 1989). The patterns activated are all those similar to the input, whether or not those patterns represent actual words. In this respect, NAM is closer to more recent instantiations of cohort theory.

The patterns corresponding to known words are associated with word decision units, which receive activation when the acoustic-phonetic patterns are activated. The word decision units constantly monitor the incoming acoustic-phonetic patterns, accumulating activation as more matching input is received. Taking the example given above, the input [pattern] initially activates the acoustic-phonetic pattern representation of [p]. All units corresponding to words containing an initial [p] are then activated. The next acoustic-phonetic pattern, /a/, will send activation to all connected word decision units (those units representing words containing an /a/ in their initial nucleus). This will activate both word decision units corresponding to words beginning with /pa/ and those beginning with /a/ and /*a/, where * is any onset. As processing of the input proceeds, activation of the decision unit corresponding to the input increases, and the activation of units corresponding to similar words is attenuated. Once activated, the word decision units also monitor the activity of other units in the system in order for a decision about the input to be made. A decision rule (based on that proposed by Luce, 1959) is used to decide which word decision unit corresponds to the actual input. This rule is a function of the evidence in favour of a given unit divided by the evidence in favour of other activated units (the similarity neighbourhood of the input). Once a criterion value is exceeded by a decision unit, then that information is passed to working memory and the word has been 'recognised'. The decision rule (from Luce, Pisoni and Goldinger, 1990) is:

$$p(ID) = \left(\frac{p(stimulus\,word) \times freq_s}{p(stimulus\,word) \times freq_s + \sum_{j=1}^{n} \{p(neighbour_j) \times freq_j\}} \right)$$

In other words, the probability of correctly identifying the input word (stimulus) is the frequency-weighted probability of the stimulus, divided by the frequency-weighted probability of all representations in the similarity neighbourhood. As more of the input is processed, p(stimulus word) increases as p(neighbour) for all neighbours decreases, until eventually the recognition criterion is reached.

Word frequency does not work by altering the resting levels of the lexical representations. It functions by biasing the decision stage, not perceptual processing. In this respect, NAM differs from cohort theory, where frequency bias enters at the perceptual processing stage.

The purpose of this section of the review is not to present the evidence for and against cohort theory and NAM. Rather it is to merely outline the theories, and place studies of lexical access in the sign language studies field into a theoretical perspective. Any discussion of the relative merits of the two theories will be restricted to studies using one particular experimental paradigm: auditory lexical decision. This paradigm is chosen as it is the closest to that used in the sign language literature: visual lexical decision using sign language signs.

3.2 Auditory lexical decision and phonological priming

3.2.1 Phonological priming and cohort theory

Cohort theory (Marslen-Wilson and Welsh, 1978) predicts that a target preceded by a phonologically similar prime (with a similar *onset*) will be recognised more quickly than when preceded by a phonologically unrelated prime. The input activates units for similar words as well as the presented word, and the residual activation in similar word units will remain for a short period of time (subject to decay). If one of these similar words is presented before activation decays to resting levels, then it will have a 'head-start' and reach criterion level more quickly. As the initial cohort of possible words is determined by the onset of the input, this should occur only if prime and target share onset. This was tested by Slowiaczek and Pisoni (1986), who found that onset similarity between prime and target did not facilitate response to the target in a lexical decision task (in fact, inhibition was observed for large degrees of phonological overlap). However, for an identification in noise (IDN) task, significant facilitation of response was observed as a function of phonological overlap. Slowiaczek and Pisoni concluded that the lexical decision may have taken place in a different level of the system, possibly

using abstract lexical representations, and/or the IDN task involved more reliance upon the processing of phonetic input as the stimuli were degraded. Using spoken word input and a lexical decision task, facilitation of response latency when prime and target overlap at onset has been reported by some authors (Goldinger, Luce, Pisoni and Marcario, 1992) yet not replicated by others (Marslen-Wilson, 1993; Praamstra, Meyer and Levelt, 1994; Radeau, Morais and Dewier, 1989). Yet others have found inhibition of response (Marslen-Wilson, 1990; Slowiaczek and Pisoni, 1986). Slowiaczek and Pisoni (1986) proposed revising cohort theory by adding inhibitory connections between units. Such lateral inhibition would mean that the more activated a unit became, the more it would inhibit phonologically similar neighbours. This would revise the prediction of cohort theory, predicting that onset similarity of prime and target leads to inhibition of response to the target.

3.2.2 Phonological priming and NAM

In NAM, phonetic input corresponding to a stimulus will initially activate all items within that stimulus' similarity neighbourhood. This increases the amount of activation in the neighbourhood which makes it harder for recognition to occur. Thus, words with fewer neighbours are recognised faster than words with many neighbours (Goldinger, Luce and Pisoni, 1989). Priming with a phonologically similar neighbour should therefore increase the amount of activation in the target's neighbourhood, making it harder for the decision unit to reach criterion. NAM thus predicts inhibition of word decision when a target is preceded by a phonologically similar prime. This was tested by Goldinger, Luce and Pisoni (1989) using both high and low frequency primes in an identification in noise. They found that phonological similarity only inhibited response to the target for low frequency primes. Decisions about low frequency words take longer in NAM, and therefore result in more activation of the similarity neighbourhood. A consequence of this is that more residual activation will exist following a low frequency prime than a high frequency prime. For high frequency primes the decision was made quickly, and less activation built up. Thus there was less activation

available to inhibit response to the target following presentation of a high frequency prime.

3.2.3 Other Factors in Lexical Decision

The lexical decision task requires more than lexical access; there is an additional decision stage. In other words, once phonetic evidence has been employed in lexical access, the participant must come to a decision about the lexicality of the stimulus. If a nonword stimulus is similar to a word, then the activation level of the actual word may rise to a high level, with a decision being delayed until mismatch occurs. Thus response times will be slowed when nonwords are similar to real words (Taft and Hambly, 1986). The uniqueness point will also influence lexical decision. The uniqueness point is the stage in processing of a stimulus that enough evidence has been accumulated for the identity of the stimulus to be determined. For example, consider the word "temple". When the first syllable (/temp/) has been processed, there are a number of potential candidates (e.g. temporary, tempestuous, tempt) including the possibility that a nonword has been heard. Once the second syllable (/el/) has been processed, then only one real word candidate remains ("temple") along with the possibility that further information will result in a nonword (e.g. "tempelate"). If the presence of a nonword is flagged earlier in the stimulus (e.g. "prumble"), then evidence for lexical decision is also available earlier unless a full search of the lexicon is engaged. That is, if lexical access runs its full course prior to lexical decision, then the occurrence of nonword information earlier in the stimulus will not speed nonword rejection. Taft and Hambly (1986) indeed argue that processing continues after the point at which a nonword can be rejected. They argue that this additional processing allows the system to check whether the stimulus is a nonword or a mispronounced real word -- further evidence for goodness-of-fit with a lexical entry may indicate mispronunciation.

3.3 Lexical recognition and sign language

It is not possible to draw exact parallels between the processing of spoken and signed languages. Structural differences between the two language types can have effects on the time course of processing. Using a gating task, Emmorey and Corina (1990) investigated the use of phonetic information by native signers of ASL in a sign recognition task. Signs were partitioned into 33 msec parts, and presented to participants in a cumulative procedure. Thus participants saw the first 33 msecs of a sign, then the first 66 msecs, and so on until the whole sign was seen in total. After each clip, participants were required to state the sign being shown. Emmorey and Corina's data suggested that phonetic information was extracted from the signed stimuli in a fixed, linear manner. First the location and orientation of the sign was extracted, followed by the handshape and finally, movement. It was isolation of the movement parameter that led to the identity of the sign being determined. This order was the same for native and non-native signers, although non-native signers were slightly slower in identifying the signs (roughly one video frame, or 33 msecs, slower). Signs located in neutral space were recognised before those located upon the face, presumably because the target location of the sign was achieved earlier for neutral space signs. Although phonetic cues to handshape were available in signs prior to the final configuration being achieved, this information did not result in handshape being isolated prior to location for signs isolated on the face. This was taken to highlight the fixed nature of recognition process, with location always being processed prior to handshape, even when handshape information was available during the transition to the location. The parameters of handshape, location and movement are therefore used in the lexical recognition processes of native and non-native signers. Although this sign processing is sequential, in the way that a monosyllabic spoken word may be processed from onset to coda via nucleus, sign parameters are usually available to the perceptual system simultaneously. Location information may be isolated first, but that information is present through until the sign has been completed. In spoken language, the onset is transient, and is not experienced at the end of a word.

The perseverance of location information means that the lexical nodes/word decision units for signs with that location receive more activity than would be expected on the basis of spoken language models. Conversely, the activation of nodes/units that are not associated with that location pattern will be more attenuated than expected for spoken words. This processing difference influences the predictions of cohort theory and NAM when applied to sign recognition. For cohort theory, location perseverance means that decisions will be delayed. A decision is made on the basis of the difference between activation levels of competing units. Once the difference between the most activated and next most activated units reaches a criterion level, recognition is assumed to have occurred. Location perseverance would serve to keep the activity of competitors high, increasing the time until a clear 'winner' was found. For NAM, location perseverance increases the probabilities of competitors in the similarity neighbourhood. Using Luce's (1959) decision rule, keeping $p(neighbour)_j$ high for all j results in lowering $p(ID)$. More time is required for the system to resolve itself, and for $p(ID)$ to increase to the criterion level. For both cohort theory and NAM, therefore, location perseverance in the execution of the sign (if passed on from the perceptual processing system to the lexicon) would result in delayed decision and an increase in the amount of activation within the cohort/similarity neighbourhood.

3.3.1 Cohort theory and sign recognition

Cohort theory, as applied to signed languages, states that phonological parameters of the signs are used to access lexical representations. If the location parameter defines the initial cohort (in the absence of visual noise or ambiguous locations), then the sign cohort should initially consist of all signs with that location. Further information, handshape and then movement, serves to attenuate the activation of mismatching cohort members and reinforce the activation of congruent cohort members. Location perseverance will keep cohort activity levels relatively high, delaying lexical decision. Within a priming paradigm, cohort theory predicts that prime-target similarity will

facilitate response to the target where prime and target share the same location, as location determines the initial cohort of competitors. Lexical decisions in cohort theory are based on relative activation levels (a criterion difference must be reached for recognition to occur). If the target belongs to the same cohort as the prime, then it will already possess some residual activation from processing of the prime. This residual activation is the source of the facilitation.

3.3.2 NAM and sign recognition

The pattern of activation for NAM is similar to that of cohort theory, except that the similarity neighbourhood is not defined solely by location but by all parameters of the stimulus (location, handshape and movement). In contrast to cohort theory, there is competition between word decision units. The units make their decision on the basis of information about the likelihood of their target matching the stimulus and the likelihood of all competitors matching the stimulus. If a prime and target are from the same similarity neighbourhood, then the target will be processed amidst residual activation in the neighbourhood from prime processing. This increases the amount of competition, and inhibits lexical decision. Here, the residual activation is the source of the inhibition. NAM would predict that this is most likely to be the case for prime-target pairs that share location similarity. Location perseverance means that there will be more residual activation in the similarity neighbourhood, increasing the probability of inhibition. The logic here is similar to that applied to the effects of inhibition for low frequency prime-target pairs (Goldinger, Luce and Pisoni, 1989).

3.3.3 Sign Recognition Data and Models of Word Recognition

A study by Corina and Emmorey (1993) looked at the mapping of perceptual input to lexical representations in the sign lexicon. They used a phonological priming task to assess whether formational similarity primed decisions in a lexical decision task. Native and non-native signers were presented with pairs of signs. After looking at the first sign (the prime),

participants were required to make a lexical decision about the second sign (the target). If they thought the target was an ASL sign, they were to respond "yes"; however, if they thought the target was not an ASL sign, then they were to respond "no". Ninety prime-target pairs were constructed, such that 10 pairs shared the same movement parameter, 10 pairs shared handshape, 10 pairs shared location, 30 pairs shared no parameters, and 30 pairs had a nonsign as a target. Nonsigns were generated such that they did not occur in ASL, although were phonotactically possible given the formational constraints of the language. Corina and Emmorey found that nonsigns were reacted to more slowly than actual ASL signs, and found significant facilitation (faster reaction times) for targets that shared movement with their prime. Interestingly, sharing handshape had no effect on response latency, and sharing location had an inhibitory effect on response time. Given the time course of lexical recognition determined by Emmorey and Corina (1990), it appears that the first parameter to be processed (location) leads to inhibition of lexical decisions, and the final parameter (movement) leads to facilitation. The secondary information source (handshape) had no effect.

Taking the Emmorey and Corina (1990) and Corina and Emmorey (1993) studies together, it is possible to relate the findings with ASL priming to the cohort and NAM theories of word recognition. Assuming location to be the first parameter isolated by native signers, and drawing an analogy with the onset of spoken words, we can propose that the location parameter determines the initial cohort of possible targets. Next one must postulate the processes which led to an inhibition of response to following signs that share the same location. Cohort theory would predict facilitation, as residual activation in the cohort provides a 'head start' for prime-target targets that share location with the prime. This is not what was found by Corina and Emmorey. NAM on the other hand predicts that there will be inhibition of response to the target if it is similar to the prime. This is because residual activity in the lexicon neighbourhood will result in a prolonged *decision* about the nature of the target. However, NAM does not stress the salience of the onset in determining a cohort of possible lexical entries that match the target. It therefore remains

unclear as to why all forms of similarity do not inhibit response to the target, and indeed why shared location *facilitates* response to the target. Before postulating an alternative model to explain the sign recognition process, it is important to examine the study conducted by Corina and Emmorey.

3.3.4 Critique of Corina and Emmorey (1993)

There are three parameters that were not controlled for in Corina and Emmorey's design, all of which could have influenced their results: sign frequency, sign duration and sign uniqueness point.

Goldinger, Luce and Pisoni (1989) showed that phonological similarity induced facilitation of response for low frequency stimuli, but not for high frequency stimuli (as predicted by NAM). The lack of facilitation for handshape may be due to high frequency signs being used in that condition. Whilst frequency norms are not available for ASL (or BSL), replication using alternative stimuli seems appropriate (although the same artifact may influence the replication). Sign duration and sign uniqueness point also have an effect on response time. Longer signs require more processing, and signs with later isolation points will mean longer decision times (Taft and Hambly, 1986). Goldinger (1996) suggests measuring response times from both target onset and target uniqueness point (using the latter as a conservative measure), and either balancing sign duration across conditions or using it as a covariate in any analyses. Possible duration and uniqueness confounds may have contributed to the inhibition found by Corina and Emmorey (1993) for prime-target pairs sharing the same location. Again, replication with alternative stimuli is called for, along with appropriate controls for sign duration and uniqueness point.

3.3.5 Motivation for Experiment 4

Rather than merely trying to replicate the study of Corina and Emmorey (introducing appropriate controls), Experiment 4 aims to extend their design by utilising different levels of phonological similarity. Using the three parameters of handshape, location and movement, three sets of sign-sign

pairs and three sets of sign-nonsign pairs were created. Each set contains prime-target sign pairs sharing either 0, 1 or 2 parameters. It is predicted that overall phonological similarity would lead to facilitation of response to the target, with higher levels of phonological similarity resulting in greater facilitation (relative to a dissimilar prime-target baseline). The prediction of cohort theory is also tested, namely that location similarity should lead to the largest levels of facilitation, as location determines the initial cohort of sign candidates (Emmorey and Corina, 1990).

4 Working Memory

"Working memory" is a model of short-term memory (STM) capabilities, first devised by Baddeley and Hitch (1974). The model is used to explain the retention of linguistic and non-linguistic material over short periods of time. The model has three components: the central executive, the visuospatial sketchpad and the phonological loop (see Figure 4.1). One of the primary functions of the central executive is the regulation of information flow within the system (Gathercole and Baddeley, 1993). Such regulation includes retrieval of information from long-term memory, allocation of input to the other components (the phonological loop and visuospatial sketchpad), and general coordination of activity within the whole working memory system. The visuospatial sketchpad is specialised for the processing of information that is visual or spatial in nature, or of verbal material that has been recoded into images (Gathercole and Baddeley). Finally, the phonological loop deals with the storage and maintenance of verbal material. It is the phonological loop system that forms the focus of this section.

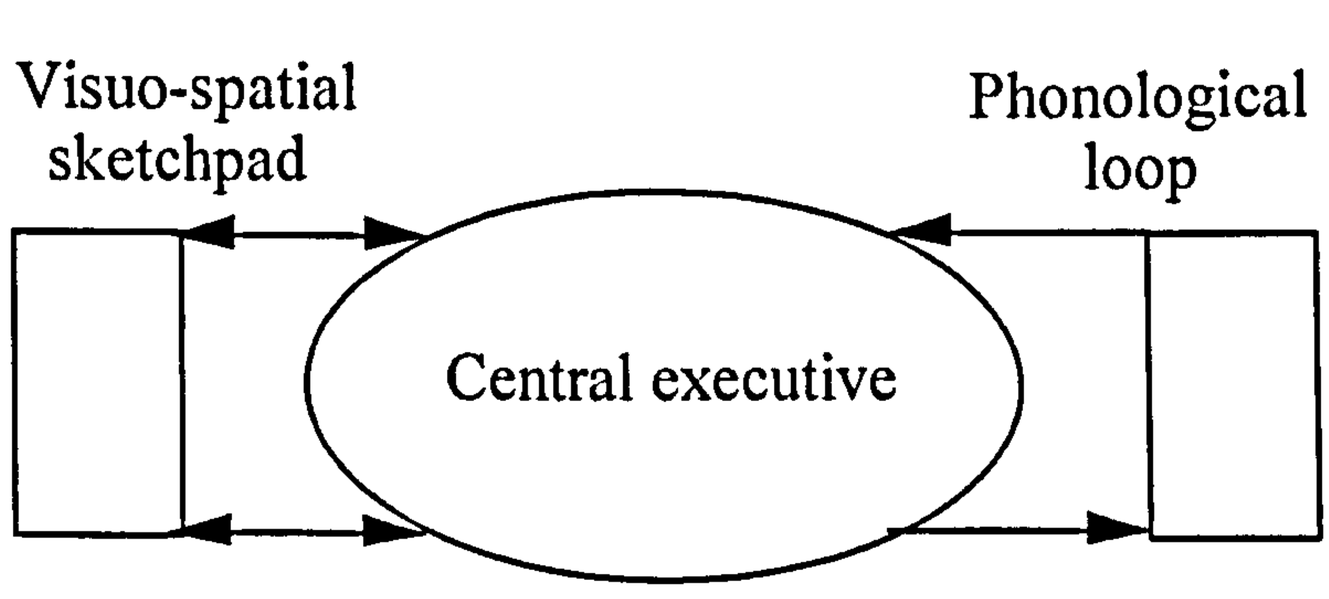

Figure 4.1: Schematic representation of the working memory system (adapted from Gathercole and Baddeley, 1993).

The phonological loop deals with verbal material, and consists of two sub-systems: the phonological store and the articulatory rehearsal loop (Baddeley, 1986; see Figure 4.2). The phonological store is a short-term store, where verbal material is represented in a sound-based code. Material stored in the phonological store is susceptible to interference (from other verbal

material) and decay (over time). The articulatory rehearsal loop has two functions. First, it allows material in the phonological store to be rehearsed and maintained in the store over a longer period of time; second, it facilitates the recoding of non-verbal material (such as line drawings of objects) into a sound-based code, which can then be stored in the phonological store. Support for such a model comes from a wealth of experimental research, which has revealed four key phenomena: the articulatory suppression effect, word length effect, phonetic similarity effect, and irrelevant speech effect.

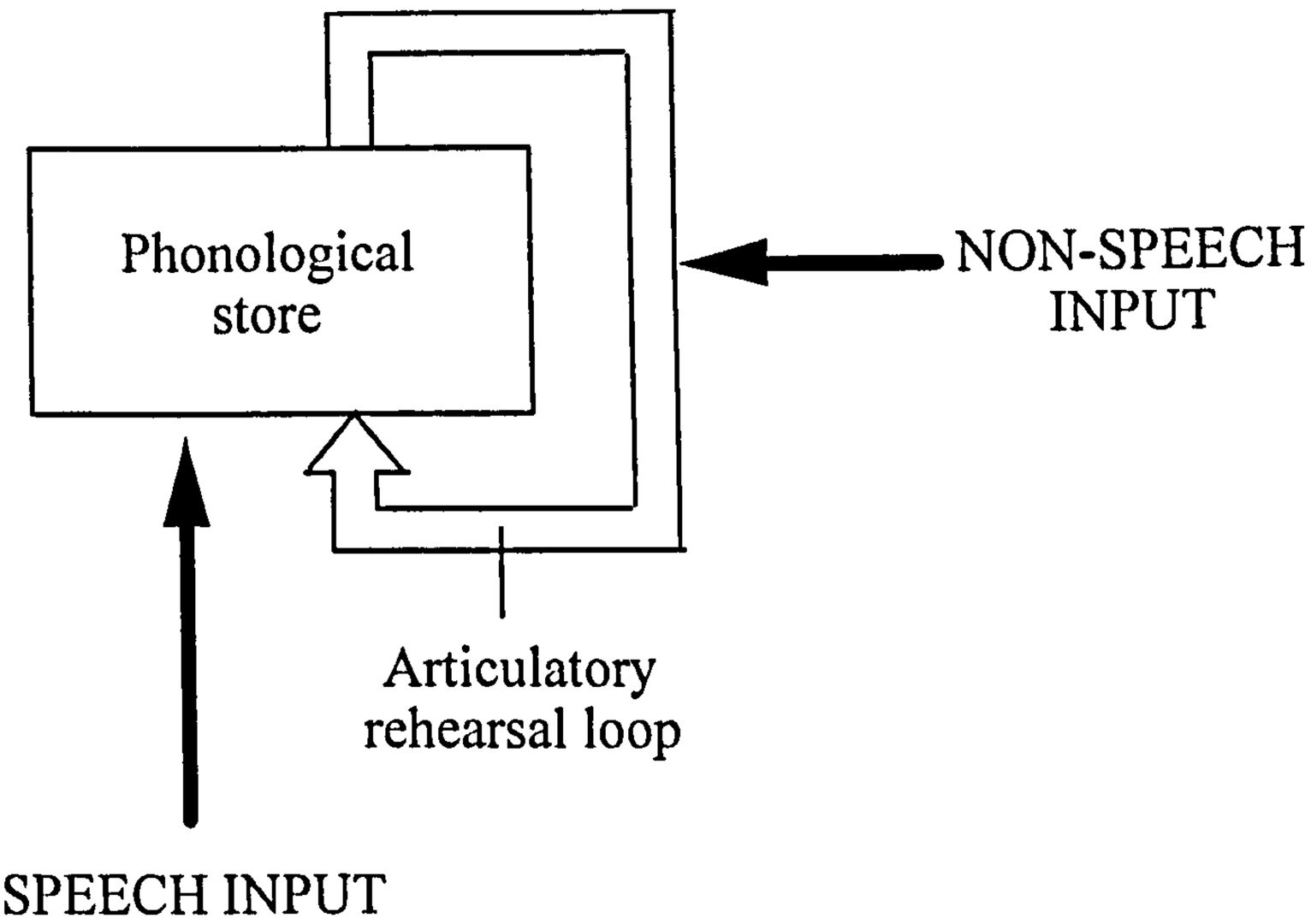

Figure 4.2: A schematic representation of the phonological loop in the working memory model (adapted from Gathercole and Baddeley, 1993).

4.1 Working Memory and Spoken Languages

4.1.1 Articulatory (Speech) Suppression

Articulatory suppression is a technique which requires the participant to constantly repeat irrelevant verbal material, such as "the, the, the" during the presentation of materials that are to be remembered. Engaging in an articulatory suppression task during the presentation of printed words has been found to decrease the amount of such material successfully recalled (Estes,

1973; Peterson and Johnson, 1971). According to the working memory model, articulatory suppression leads to an inability to rehearse the items in the phonological store: articulatory suppression interferes with the performance of the articulatory rehearsal loop. Due to this interference, articulatory suppression also interacts with other phenomena (the word length and phonetic similarity effects) that are related to articulatory rehearsal loop function; further details are given below in the relevant sections.

4.1.2 Word Length

The immediate recall of words is also affected by the amount of time it takes to articulate them (Baddeley, Thomson and Buchanan, 1975). For example, ordered recall (the recall of lists in the same order as that in which they were presented) of lists of three-syllable words is worse than for one-syllable words. Subsequent research (Ellis and Hennelly, 1980; Naveh-Benjamin and Ayres, 1986) has suggested that it is not number of syllables that is important; rather, it is the amount of time required to articulate the words. For example, lists of one-syllable words with short articulation times are better recalled than lists of one-syllable words with longer articulation times. Again, within the working memory model this effect can be attributed to the articulatory rehearsal loop. Items that take longer to articulate also take longer to rehearse. This means that there is less opportunity to rehearse the items and they are therefore more susceptible to decay within the phonological store. In addition, the items may not be properly encoded. This is because the subsequent item is presented before the current item can be internally articulated. Items that take only a short while to articulate are rehearsed faster and more often, and encoded more fully, resulting in a better-maintained memory trace in the phonological store. One prediction of the working memory model is that this word length effect should disappear in the presence of articulatory suppression: if the function of the articulatory rehearsal loop is interfered with (by articulatory suppression) then the differential effects of rehearsing words of different length should disappear. With the presentation of printed word lists, this was found to be the case (Baddeley et al, 1975). The

word length effect is also abolished when spoken word lists are used, although the articulatory suppression sometimes needs to be maintained during recall as well as learning (Baddeley, Lewis and Vallar, 1984).

4.1.3 Phonetic Similarity

Lists of items which are phonetically similar are harder to recall than those which are phonetically dissimilar. Conrad and Hull (1964) first demonstrated this phonetic similarity effect using visually presented letters. Baddeley (1966) showed that short-term recall was influenced by the phonetic similarity of words, yet not by their orthographic or semantic similarity. According to the working memory model this is because the STM store encodes and maintains the information in a phonetic form, and this phonetic code is subject to decay over time (Salamé and Baddeley, 1982).

This phonetic similarity effect does not occur when an articulatory suppression task is performed during learning and the material is presented visually. Again, the working memory model can account for this finding. Articulatory suppression interferes with the operation of the articulatory rehearsal loop. This prevents visual material from being recoded into a phonological form and entering the phonological store. As the phonological similarity effect is a function of phonological store properties, it is not found under these conditions. Speech input has direct access to the phonological store and the effect is therefore maintained even in the presence of articulatory suppression.

4.1.4 Irrelevant Speech

The playing of audible yet irrelevant speech during the learning of word lists causes a decrement in recall performance, even when the lists are presented visually (Colle and Welsh, 1976). Within the working memory model, two processes explain this: (1) speech has direct and automatic access to the phonological store, and (2) the phonological store is susceptible to interference (Gathercole and Baddeley, 1993). So, during the presentation of irrelevant speech, phonetic information from the speech passes into the

phonological store, where it interferes with the representations of items in the word list being remembered. Salamé and Baddeley (1982) report that the greater the phonetic similarity between the irrelevant speech and the to-be-remembered items, the greater the disruption in recall that results.

4.1.5 Summary

The phonological loop component of the working memory model has been successful in accounting for a wide range of data related to the ordered recall of information from short-term memory. The phonological loop has two components: (1) the phonological store and (2) the articulatory rehearsal loop. The phonological store is a short-term store, of limited capacity, that represents information in a phonetic form. The information in the phonological store is susceptible to decay over time, and to interference from irrelevant speech (as speech information has direct and automatic access to the phonological store). The articulatory rehearsal loop allows information to be maintained in the phonological store over a longer period of time by letting the system rehearse the information (subvocal rehearsal). It also facilitates the recoding of non-speech information (such as written words or pictures) into a phonetic form that can then be stored in the phonological store. The next section discusses experimental work on the STM abilities of deaf people who use a sign language as a primary means of communication.

4.2 Working Memory and Sign Language

The working memory model has been shown to give a successful account of a large amount of data. The model is based, however, upon the STM capacities of spoken language users. Does the model also hold for users of sign languages? In this section, research into working memory in deaf people who use sign languages will be outlined. The structure will be similar to the preceding section on working memory in spoken language users in an attempt to draw clear parallels between the two. There is an added complication with Deaf signers however: the majority of deaf people who use a sign language also have some knowledge of the spoken language which is

dominant in their culture. Thus, most deaf college students who use a sign language (and form the main population from which experimental samples are drawn) also have good knowledge of English, as well as the ability to lip-read and articulate English. This raises a further question: under what circumstances will a deaf person use a sign-based or a speech-based representation in working memory? These additional issues will be explored at the end of this section, and the reported linguistic background of deaf participants will be carefully scrutinised there.

Since the 1970s, a body of research has suggested that a phonological loop also exists in the working memory of deaf people who use a sign language as their primary (and in some cases only) means of communication. This phonological loop is argued to consist of a phonological store which holds temporary representations of linguistic input in terms of the formational parameters of signs (Wilson and Emmorey 1997a, 1997b, 1998a, 1998b). These sign-based representations in the phonological store are subject to decay and interference. There is also evidence for an articulatory rehearsal loop that serves to: (1) rehearse and therefore maintain representations in the phonological store (submanual rehearsal) and (2) facilitate the recoding of non-sign stimuli into a sign-based form that can be stored in the phonological store. The evidence for such claims comes from effects that mirror those found for spoken language.

4.2.1 Articulatory (Sign) Suppression

As mentioned previously, articulatory suppression is a technique requiring the repetition of an irrelevant phrase during the presentation of lists of items that are to be recalled shortly after presentation. For sign languages, this involves the repetition of a sign or sign-like gesture during presentation of stimuli. Wilson and Emmorey (1997b) showed lists of signs to 24 deaf college students who were native users of American Sign Language (ASL). The lists were either formationally similar or formationally dissimilar. Similar signs all used the same handshape (a flat palm, or 'B', handshape) but varied in terms of the type of movement they involved and their place of articulation.

The dissimilar signs varied on all three of these parameters but were matched with the similar set in terms of the number of hands involved and the type of movement used. Experimental lists (each of four signs) were constructed from either one of these sets. The lists were presented on video to the participants, who were required to give immediate written ordered recall on pre-formatted response sheets. Each participant participated in a suppressed and a non-suppressed condition. In the non-suppressed condition, participants kept their hands still while attending to the lists; in the suppressed condition, participants "were instructed to move their hands, by changing handshape from a fist to an open hand (...), alternating the two hands" (Wilson and Emmorey, 1997b, pp. 316-7)[3]. For both formationally similar and dissimilar list types, mean number of recalled signs was lower in the suppressed condition than in the non-suppressed condition. In the working memory model the decrement in recall in the suppressed condition can be explained as due to the prevention of rehearsal and/or encoding via the phonological loop. The articulatory suppression task interferes with the function of the articulatory rehearsal loop; there is therefore no rehearsal mechanism to stave off the effects of decay in the phonological store. This suggests that there is a manual/motoric component to the rehearsal process. In the same paper, Wilson and Emmorey (1997b) also report the effects of an articulatory suppression task when the stimuli are lists of pictures. The pictures were line drawings corresponding to the signs presented in the first part of the study (formationally similar and dissimilar). The sign-equivalents of the pictures were agreed with participants prior to testing. They found a significant interaction between formational similarity and the presence of the suppression task. Formationally similar sign lists were harder to recall than formationally dissimilar sign lists only in the absence of the suppression task, and not in the presence of the suppression task. Again, the working memory model can explain the results. In the non-suppressed condition, the articulatory rehearsal loop can recode the pictures into sign-based representations that are then stored in the phonological store. Lists with similar

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[3] Other types of suppression had been tried, including the repetition of actual ASL signs, but these did not produce a significant decrement in performance (Emmorey, personal communication).

sign-based representations will be harder to recall than lists with different sign-based representations because decay and similar encoding makes the representations highly confusable. In the suppressed condition, the suppression task blocks the articulatory rehearsal loop, preventing recoding pictures into sign-based representations. As the pictures are not represented in a sign-based form, there is no effect of formational similarity. The deaf participants may have used an alternative (visual/picture-based) code. However, visual similarity of the stimulus materials was not a controlled variable within the design of the study. Therefore the existence of any coding within the visuospatial sketchpad cannot be adduced from visual similarity effects. In the first experiment reported by Wilson and Emmorey (1997b), where lists of signs were presented, there were 24 participants who were deaf from birth (n=23) or by the age of 2 years (n=1). All considered ASL to be their primary language, and reported acquiring ASL as their first language by the age of 6 years. A large proportion had an elder deaf sibling or parent (n=17), and reported acquiring ASL in infancy. A large number of these participants also helped form the sample of 24 participants required to recall lists of line drawings, and that sample accordingly matched this 'deafness' profile almost exactly. Participants were from Gallaudet University (Washington, DC), California State University (Northridge, CA), or from the San Diego area. The number of participants working at or enrolled on a course at university was not specified, although it can be assumed that the reading age of the individuals in the study was, on average, higher than most of the Deaf signing population. It has been shown that the higher the reading age of a deaf participant, the more likely they are to employ speech-based coding in a serial recall task (Lichtenstein, 1998). The educational background of the participants therefore suggests that they may be able to use a speech-based code in the task administered by Wilson and Emmorey (1997b). It is therefore important that any differences in amount of signs recalled cannot be attributed to aspects of their English gloss. For example, if the formationally similar lists had English glosses that took longer to articulate than the English glosses of the formationally dissimilar lists, then recall performance could be attributed

to English word length and not the formational structure of the signs. In order to control for any effect of speech-based recoding, Wilson and Emmorey had matched the English gloss length of the formationally similar and dissimilar stimuli in terms of number of English syllables. The stimuli from which lists were created were (a) formationally similar: BROOM, PIE, BOOK, SOAP, BABY, DOOR, PAPER, BREAD and (b) formationally dissimilar: KEY, EARTH, SOCKS, EGG, ROCK, PIANO, PUMPKIN, CUP.

Although the 8-item lists are similar in terms of number of English syllables (formationally similar=10, formationally dissimilar=11), there is no information about the syllable lengths of to-be-recalled 4-item lists created from these 8-item lists. In other words, it is not clear that actual experimental lists were controlled for English syllable length. Furthermore, previous research has suggested that it is articulation time and not number of syllables that is related to recall performance (Baddeley, Thomson and Buchanan, 1975). Although number of syllables in an English word is relatively independent of the speaker, articulation time is not. It may have been the case that the formationally similar lists were harder for the deaf participants to articulate, or took them longer to rehearse, and therefore they were more poorly encoded than the formationally dissimilar lists. Again, this 'word length effect' would be abolished by articulatory suppression if recoding into an English speech-based form were blocked by the suppression task. This alternative speech-based explanation assumes that the manual suppression task was capable of interfering with vocal articulatory rehearsal.

4.2.2 Sign Length

There are only two published experimental studies that have looked at the effect of sign length on immediate recall. Kyle (1986) presented lists of long (duration > 1000 msec) and short signs (duration < 640 msec) to four deaf signers of British Sign Language (BSL) and six hearing BSL-English bilinguals[4]. The lists were balanced for length of common English sign

[4] There is no standard for defining a sign as 'long' or 'short'. In effect one is saying that one set of signs is longer in duration than another set.

glosses. A weak but significant effect of sign length was found for both groups, with fewer signs from the 'long' lists being recalled than from the 'short' lists. The finding of a sign length effect for hearing bilinguals was not expected, as it had been predicted that hearing bilinguals would recode into English. Indeed, the effect was stronger for the hearing bilinguals. Kyle analysed the data again using number of segments (moves and holds) as defined by Liddell (1984) as a measure of sign length. Using only those trials where all signs were then unambiguously long or short in terms of number of segments, Kyle (1986) found that two of the deaf signers were better at the long list, and the remaining two were better at the short list. The evidence for a BSL sign length effect in working memory is therefore dependent upon one's measure of sign length. A sign articulation time measure provides stronger evidence than a segment-based measure, as would be predicted from the spoken language literature (Baddeley, Thomson and Buchanan, 1975). However, it is not clear what the relationship between number of segments and sign articulation time was, as Kyle (1986) does not report the exact reclassification of the 'long' and 'short' sign lists. Neither does Kyle report whether or not this effect was abolished by introducing an articulatory suppression effect, as predicted by the working memory model. Wilson and Emmorey (1998a), however, did report a sign length effect for ASL that was eliminated by a concurrent articulatory suppression task. Long signs were defined as those having (a) a large, circular movement, (b) movement that covered some distance, or (c) movement with a change of direction. Short signs were those that involved no change in location, and had only hand internal movement such as tapping. Long and short signs were matched for handshape, approximate location, and number of sign language syllables, using the phonological analysis of Brentari (1990). A probe paradigm was used to control for the effects of production length at recall. In this paradigm participants are presented with a list of stimuli to remember. They are then given one of the signs from that list and asked to indicate its list position. For example, given the list 'DOG-CHAIR-CAR-BOOK' and the probe 'CAR', the correct response would be '3' as the probe occupied the third position in the

list. Deaf signers made more correct responses for 'short' sign lists than lists of 'long' signs, but there was no difference when an articulatory suppression task was performed during stimulus presentation, rehearsal and probe presentation. The suppression task, performed at a minimum rate of one repetition per second, was to form both hands into the ASL 8-handshape (thumb and middle finger make contact) and circle the hands around each other, making contact at the end of each repetition. Although the study did not provide evidence for sign-based representations in STM per se, it strongly suggested that representation is in terms of coded manual gestures, and that overt manual activity interferes with rehearsal of those representations.

4.2.3 Formational Similarity

The existence of a formational code (i.e. a code based upon the phonetic parameters/features of a signed language) in the working memory system of Deaf signers was suggested by Bellugi, Klima and Siple (1975). They presented lists of signs (one sign after another) to deaf ASL-signing participants and asked them to recall the signs at the end of the list (disregarding the order of signs in the list). The serial recall curves (recall probability plotted against serial position of the signs in the list) were similar to those found in hearing participants required to learn a list of words. There were primacy effects and recency effects, i.e. items that were at the start and end of the lists were more likely to be recalled than items in the middle of the list. This suggests that participants were indeed using a limited-capacity memory store, with information decaying over time and rehearsal allowing information to be maintained for longer (producing the recency and primacy curves respectively). Importantly, intrusion errors (mistakes where items from outside of the to-be-remembered list were recalled) made by deaf participants were formational in nature: incorrect responses tended to be similar in formational terms to the desired target response. This is evidence of a manual articulatory code in STM, as formationally similar signs require similar manual articulations in their production.

Assuming the existence of formational coding, Klima and Bellugi (1979) studied the differential effects of handshape, place of articulation and movement on formational similarity effects in STM. Deaf users of ASL were presented with lists of five signs for immediate ordered recall. Lists were formationally similar in that they were composed of signs with either: (1) the same handshape, (2) the same place of articulation, or (3) the same type of movement. Participants were required to recall the sign lists in any order they liked, as long as they specified at which point in the list each sign occurred. They found that relative to control lists: (1) similarity of handshape improved recall, (2) similarity of movement had no effect, and (3) similarity of place of articulation led to a decrement in recall performance. The responses of participants within each of these three categories were analysed to examine the effects of different handshapes, movements and locations. Klima and Bellugi's results suggest that both handshape and movement provide cues for recall, and do not interfere with each other within the phonological store. The most salient aspect of signs in this respect is place of articulation. Signs sharing the same place of articulation led to interference within the phonological store, particularly those articulated on the hand. The data reported by Klima and Bellugi (1979) can be linked to the discussion of formational parameters in lexical access (see Section 3.3). Klima and Bellugi report that place of articulation (i.e. location) is the most salient aspect of the sign signal, and appears to play a dominant role in short-term memory coding. Emmorey and Corina (1990) report that, in a gating task, location is the first parameter to be isolated, and Corina and Emmorey (1993) report that when prime and target share location, response to the target is inhibited. Three experimental paradigms – gating, form priming and ordered recall – therefore converge to suggest that sign language parameters do play a role in mental processing, and that of these parameters it is location that plays a key role.

Poizner, Bellugi and Tweney (1981) separately examined the effects of formational similarity, semantic similarity and degree of iconicity on recall of sign lists. They presented deaf signers of ASL with lists of signs (each four

signs in length) that were similar formationally, semantically or iconically[5] (along with control lists for comparison). They found that only formational similarity led to poorer immediate ordered (written) recall of the sign lists compared with control lists. They used three sets of formationally similar signs (see Table 4.1); all of which were identical in terms of place of articulation (in front of the signer's body) and the number of hands required (both hands).

Formationally similar list 1 differed "only minimally" (p.1149) in handshape (index or index plus middle finger extended), differing primarily only in terms of movement. The set consisted of the ASL signs for: SOCKS, KNIFE, MONTH, TEMPERATURE, TAPE, CHAIR, NAME and EGG. Similar list 2 was similar in terms of handshape (flat palm, with fingers closed together or spread) and dissimilar in terms of movement: AMERICA, MACHINE, FORT, CHEESE, MOVIE, PAPER, SOAP and SCHOOL. Similar list 3 again shared a similar hand configuration, with two fingers (closed together or spread) extending from a closed fist: PRISON, PLUS, TENT, SALT, NAME, EGG, TRAIN and CHAIR.

Table 4.1: Summary of lists employed by Poizner et al. (1981) in Experiment 1.

Similarity	List Number	Sign Parameters		
		Handshape	Location	Movement
Formational	1	G or V	Same	Different
Formational	2	B or 5	Same	Different
Formational	3	H or V	Same	Different
Control	4	Different	Different	Different
Control	5	Different	Different	Different
Control	6	Different	Different	Different

Control lists (see Table 4.1) were matched for ease of recall (based on data from a previous study) and serial position. The signs within lists were dissimilar in terms of formational parameters. Dissimilar list 4 was matched with list 1 and consisted of the ASL signs for: APPLE, PRESIDENT, SENTENCE, SOAP, RUSSIA, YEAR, FORT and HELICOPTER. Dissimilar list 5 was matched

[5] High iconicity signs were those where the deaf participants agreed to a large extent on what the relationship was between the form of the sign and its meaning; low iconicity signs were those where there was little or no agreement on the form-meaning relationship.

with similar list 2, consisting of: SPRING, CHURCH, MILK, TURTLE, YEAR, SOAP, SPAIN and COP. Dissimilar list 6 was matched with similar list 3 and was formed from the ASL signs for: WATER, COKE, ONION, YEAR, TURTLE, PRESIDENT, HOLLAND and JESUS.

Participants were thirteen deaf college students from California State University, "most of [whom] came from deaf families and had learned ASL as a native language" (p.1149). Recalled signs were scored in three ways: a) the number of lists perfectly recalled, b) the number of items recalled in correct serial position and c) the number of items recalled regardless of correct serial position. For all three scoring methods, for all three comparisons (1 with 4, 2 with 5, 3 with 6), there was a significant effect of formational similarity, with dissimilar lists recalled more accurately than similar lists. Although the English gloss length of the signs was not controlled for, a count of syllable numbers suggests that the effect being due to English word length is unlikely (set 1 = 11, set 4 = 16 / set 2 = 14, set 5 = 9, set 3 = 9, set 6 = 15). A word length effect (assuming that the differences hold for articulation time as well as for number of syllables) would work against predictions for the set 1/set 4 and set 3/set 6 comparisons. This is because on average the word length is longer for the formational control lists, which would make them harder (not easier) to recall if a speech-based code was used. Interestingly, there was an effect of handshape similarity different to that reported by Klima and Bellugi (1979): in this study handshape similarity impaired serial recall, in the Bellugi and Klima (1979) study it improved recall. The difference may have been due to tighter control of formational parameters of the stimuli, or the effect may have been due to similarity of location (see Table 4.1). In a separate study, Poizner, Bellugi and Tweney (1981) varied the semantic similarity of sign lists, based upon category membership. They presented semantically similar (all countries or all fruit and vegetables) and semantically dissimilar lists (controlled for ease of recall and serial position) to twenty deaf adults who again "came from deaf families and had learned ASL as a native language" (p.1152). The immediate written serial recall of the participants was scored in the same way as the previous experiment. For the number of lists recalled

correctly and the number of items recalled in correct serial order there was no significant effect of semantic similarity. For the number of items correctly recalled regardless of their accuracy in serial position, one semantically similar set was recalled better then its control set. The semantically similar set consisted of the ASL signs for: JAPAN, CANADA, HOLLAND, SPAIN, AMERICA, RUSSIA, ENGLAND and SCOTLAND. The semantically dissimilar set consisted of the ASL signs for: YEAR, INSECT, WATER, ONION, SENTENCE, TURTLE, COKE and COP.

Although the similar set has more syllables (18) then the dissimilar set (13), suggesting that similar lists would have usually taken longer to articulate in a speech-based form, the lack of an effect for ordered recall marking (for items and lists) argues against a speech-based explanation. Rather, it appears that the semantic category (country) helps in retrieving which items are in STM but offers no clue as to the order in which those items were presented. In a third study, Poizner et al. asked nineteen deaf adults (mostly from deaf families with ASL as a native language) to rate the iconicity of over 100 ASL signs. The signers were asked to indicate the link between a sign and its referent. Signs for which there was a high level of agreement were classed as high in iconicity and signs where there was little agreement were classed as low in iconicity. The signs were also classified according to the imageability of their referents (using norms from Paivio, Yuille and Madigan (1968)) as high in imageability or low in imageability. These two factors, iconicity and imageability, were crossed to produce four types of list. These lists were presented to the same deaf adults who rated their iconicity. The participants were required to provide ordered written recall immediately after list presentation. For all three scoring methods, only imagery significantly affected recall (high imageability increased recall performance). Although this does not rule out an iconic code in STM per se, it does suggest that iconicity is not an aid to recall in a STM task. The evidence from the studies reported by Poizner, Bellugi and Tweney (1981) strongly supports the use of a sign-based code in 'native' signers of ASL.

Kyle (1986) found similar results to Klima and Bellugi (1979) using signers of BSL. He presented deaf signers (some born to deaf parents and some born to hearing parents) and hearing BSL-English bilinguals with lists of BSL signs. Lists were free to vary in one of four parameters (handshape, movement, place of articulation or orientation), all the other three parameters remaining constant (see Table 4.2). Each list consisted of five items. For the first, second and third items in each list, immediate ordered signed recall did not differ between lists. For the last two items of each list, however, signs from lists differing in place of articulation were better recalled than those from lists differing in movement, which were in turn better recalled than signs from lists differing in handshape. Assuming that these effects are due to formational similarity, it would appear that place of articulation makes a larger contribution to intralist similarity than movement, which in turn makes a larger contribution than handshape. This mirrors the findings of Klima and Bellugi (1979), suggesting that place of articulation plays a key role in determining the formational similarity effect. As Kyle (1986) did not use control lists (differing in terms of all four parameters), the independent effects of these parameters in BSL cannot be accurately assessed from the results he reports.

Table 4.2: Summary of lists employed by Kyle (1986).

Similarity	List	Sign Parameters			
		Dez	**Tab**	**Ori**	**Sig**
Formational	1	BB	Different	Fingertips extended outwards	Away from body
Formational	2	Different	Front of body	Fingertips extended outwards	Out and down
Formational	3	GG	Front of body	Index finger pointing up or outward	Different
Formational	4	AA	Front of body	Different	Out and down

4.2.4 Irrelevant Signing

There is no published literature on the effect of irrelevant signing on STM during encoding. Clearly there is a confound caused by the modality. In studies of irrelevant speech, stimuli are presented visually and the irrelevant

speech auditorily. Deaf signers do not have access to the auditory modality, and both stimuli and irrelevant signing would need to be presented visually, causing obvious attentional confounds.

4.2.5 Summary

There is some evidence to suggest that the STM system of deaf sign language users can support coding and rehearsal based upon the manual articulation of signs. The evidence mirrors that of STM for speech, with effects of sign similarity, sign length and manual articulatory suppression. However, the effects do not seem as clear as they are for studies of spoken language recall. There are two potential factors that may have led to this. The first concerns native fluency: in the absence of standardised tests of sign language fluency, and with experimenters relying upon the self-reports of experimental participants, it is hard to assess whether all participants within a study are 'native signers'. It is possible that some participants within a sample will rely less upon sign-based coding, resorting to visual or speech-based coding strategies. The choice of strategy may depend upon native fluency in the signed language as well as the availability of alternative codes and the demands of the memory task itself. Secondly, most studies have looked at formational similarity: this is the similarity of items in terms of their handshape, location and movement (and sometimes orientation). While the formational structure of a sign may be phonologically salient, it is not necessarily equally salient for short-term memory coding. If the STM code is visual (as opposed to acoustic) or articulatory in nature, i.e. a phonetic code, then formational similarity may not be a good measure of the psychological similarity of stimulus items. In other words, no identity exists between the phonological and phonetic form of signs, although the two are obviously highly correlated. A better measure of stimulus similarity may be obtained by using a measure based upon a finer-grained visual representation of signs or based upon the articulations required to produce them. A better measurement may in turn lead to stronger more replicable effects. Furthermore, there is a potential theoretical confound when it comes to assessing the results of studies

which have manipulated formational similarity. This confound relates to the theory of semantic phonology proposed by Stokoe (1991) and Armstrong, Stokoe and Wilcox (1995). The use of alternative coding strategies, more detailed measurements of similarity and the implications of semantic phonology are discussed in Chapter 5.

5 Alternative Linguistic Encoding Strategies

There is a problem in using ordered recall paradigms from the spoken language literature to assess a working memory system that may use a sign-based store and articulatory rehearsal process. The problem is that deaf people often have access to two linguistic codes (Lichtenstein, 1985/1998; MacSweeney et al., 1996): a sign-based code, and a speech-based code. Deaf people, even those for whom a sign language is a native and preferred language, live within and are exposed to the dominant hearing culture and language. This exposure extends to education, with the vast majority of deaf pupils attending hearing schools (mainstreaming) or schools for the Deaf. In both settings there is very little education in sign language, and little or no teaching of sign language. Classes are usually conducted in spoken English, and deaf students are encouraged to use amplification devices and lip reading for comprehension and to practice the generation of intelligible speech for expression (often referred to as the 'oral' method of deaf education). As a result, deaf students often have access (albeit limited) to two forms of communication: signing and speaking.

5.1 Evidence for Mixed Coding in Deaf Signers

Hanson (1982) presented native signers of ASL with four types of word list: (1) formationally similar lists in that all sign translations shared the same handshape and location (the other hand), (2) phonetically similar lists (monosyllabic words which rhymed) and (3) graphemically similar lists (4-5 letter monosyllabic words containing the string EA, but with differing pronunciations of that string) and (4) control lists in which signs differed formationally, phonetically or graphemically. Examples of words used in a formationally similar list are: KNIFE, EGG, NAME, PLUG, TRAIN, CHAIR, TENT and SALT. In the phonetically similar word lists were words such as: TWO, BLUE, WHO, CHEW, SHOE, THROUGH, JEW and YOU. Graphemically similar words were, for example: BEAR, MEAT, HEAD, YEAR, LEARN, PEACE, BREAK and DREAM. In one experiment, written words were presented one-at-a-time to

eight "native signers of ASL" from three university colleges in the San Francisco and Washington DC areas. Following the presentation of each list, one of the words from the list was presented again (the probe word). Participants were required to indicate which word came after this probe word by pointing to a picture on a response board (probed ordered recall). Phonetically similar lists were harder for these participants to recall than phonetically dissimilar (control) lists. There were no significant effects of either formational or graphemic similarity. Hanson concluded that the words were recoded into a speech-based code in working memory. The same design was used in another experiment, but signs were presented (rather than words) to seven severely-to-profoundly deaf "native signers of ASL" from the Salk Institute for Biological Studies (University of California, San Diego) and California State University (Northridge). In this experiment, formationally similar lists were harder to recall than formationally dissimilar (control) lists. It was concluded that the signs were stored in a sign-based code. Hanson's findings suggest that the nature of the stimulus is important in determining the code used to represent stimuli in STM. Of the eight participants who were presented with written words as stimuli, two were college graduates and the other six enrolled at college at the time the study was conducted. Although Hanson did not report information on English fluency and articulation abilities, it is perhaps safe to assume that participants possessed these skills to some degree given their level of educational attainment. The finding of a phonetic similarity effect for these deaf signers is not therefore so surprising. Nor would it be surprising in the signed presentation group if they were also college-level students. However, Hanson does not report the level of educational achievement for these participants. Assuming that those signed presentation participants could also have selected a speech-based coding strategy, Hanson's data suggests that stimulus modality is an important determinant of coding strategy.

Hanson repeated the first experiment (omitting the graphemically similar and dissimilar lists) using a free recall paradigm. In free recall, phonetic similarity has been shown to aid recall in hearing participants

(Watkins, Watkins and Crowder, 1974). Hanson (1982) presented the stimuli as written words for free recall to two groups of deaf participants, each consisting of eight "native signers of ASL": (1) a group presented only with the written words, and (2) a group presented with the written words who were also instructed to think of corresponding signs to help them in the task. Phonetic similarity did not aid the recall of either group, suggesting that it may not have been used as a strategy in this free recall task. Formational similarity of sign equivalents led to better recall for only two out of five formationally similar stimulus sets (compared with formationally dissimilar control sets) for the participant group asked to think of corresponding signs. Hanson attributed the lack of generality to "the sign analog of phonetic similarity [not being] completely captured in the present design of experimental stimuli" (p.578). Although no evidence of speech-based coding was found for the free recall task, Hanson warns about concluding that speech-based coding was not used: "no evidence of speech-based coding by deaf participants will be obtained if participants are using pronunciations different from those anticipated by the experimenter" (p.579). In support of this warning she cites Hanson (1980), who reported that deaf adults sometimes differ from hearing adults in perception of printed word rhymes.

In order to assess the role of presentation format, stimulus properties and linguistic background on immediate recall, Hamilton and Holzman (1989) presented lists of items to participants of varying linguistic background and knowledge. Lists were either (1) formationally similar (the more parameter values they shared the more similar they were considered to be, and all signs were articulated on the face), (2) phonetically similar or (3) control lists. Stimuli were presented on videotape with an ASL-English hearing bilingual as the model. Presentation was either (1) oral (mouth patterns of the model), (2) signed or (3) oral and signed (simultaneously). The participants responded by writing the English glosses of the sign lists in the same order as they were presented (written ordered recall). They found a phonetic similarity effect in the oral presentation condition and a formational similarity effect in the signed presentation condition. Simultaneous (bimodal) presentation led to better

recall performance for those participants who had linguistic experience of both ASL and English.

In a recently published paper, Lichtenstein (1985/1998) reports the results of a written ordered recall experiment using 86 deaf ASL users. Four types of list were presented as words to the participants: (1) phonetically similar lists, (2) formationally similar lists (they were all articulated in the same place, in most cases upon the palm of the other hand), (3) graphemically similar lists and (4) control lists. He also measured the ability of each participant to discriminate speech sounds and produce intelligible speech. Lichtenstein found evidence for sign recoding in some participants, although this was not significantly correlated with age of acquisition or years of instruction in ASL. For those participants who displayed sign recoding there were no significant formational similarity effects. For most of the remaining participants there were significant phonetic similarity effects. Use of phonological coding was significantly correlated with speech discrimination and speech intelligibility scores.

Studies such as those reported above suggest that the major determinant of sign-based coding is not the linguistic capabilities of the deaf participant. Rather, task demands seem to have an influential role in determining how deaf signers will code material presented to them in a STM task such as immediate ordered recall. The task manipulation most likely to induce sign-based coding is the presentation of signs (Hamilton and Holzman, 1989; Hanson, 1982; Klima and Bellugi, 1979; Wilson and Emmorey, 1997b; Wilson and Emmorey, 1998a); this is presumably because signs have direct and automatic access to a sign-based store. Written or oral presentation, on the other hand, usually results in a phonetic similarity effect (Hamilton and Holzman, 1989; Hanson, 1982; Lichtenstein, 1985/1998), suggesting speech-based recoding of the stimuli. Such speech-based recoding does seem to be influenced by the speech articulation and discrimination capacities of the deaf participant (Lichtenstein, 1985/1998). The effect of response mode is less clear. Experiments using signed stimuli with written recall have found evidence of a formational similarity effect (Hamilton and Holzman, 1989;

Klima and Bellugi, 1979). Signed response has also led to a formational similarity effect when line drawings were presented as stimuli (Wilson and Emmorey, 1997b).

A sign-based phonological loop with both a phonological store (Wilson and Emmorey, 1998a) and an articulatory rehearsal loop (Wilson and Emmorey, 1997a,b) has been shown to mediate sign-based representations in short-term recall tasks. Despite the heterogeneous linguistic backgrounds of deaf signers and the availability of more than one linguistic code, signed stimuli and response formats have been shown to reveal evidence of sign-based coding. Furthermore, several authors have reported formational similarity effects using sign-based testing procedures in an immediate recall task (*q.v.*). Although many models of sign phonology are in broad agreement that the representation of signs is in terms of abstract formational properties (Liddell and Johnson, 1989; Sandler, 1989; Stokoe et al., 1965; Wilbur, 1993) one particular theory, semantic phonology, argues against this (Armstrong et al., 1995; Stokoe, 1991) and is discussed in the next section.

5.2 The Nature of the STM Code in Deaf Signers

The literature summarised above opens up two key questions about the working memory of deaf signers. The first issue relates to the nature of the STM code. Formational theories (parameter or feature-based) argue that lists of signs which share formational parameters (particularly place of articulation, see Klima and Bellugi, 1979 and Kyle, 1986) have greater psychological similarity and will therefore be recalled less well than lists of signs with varying formational parameters. Semantic phonology argues that a list of signs which have similar agent-action representations will be harder to recall than a list of signs which have different agent-action representations. The evidence so far is in favour of formational theories. However, a potential confound exists that means semantic coding in STM cannot be ruled out. Semantic phonology states that the form of a sign is motivated by what it represents semantically. It therefore follows that signs that have similar agent-action representations will also have similar formational representations. In

order to assess the predictions of the semantic phonology hypothesis properly, the effects of semantic/motivational and formational similarity must be dissociated.

The second issue relates to the linguistic background of the participants. For those signers with very early exposure to sign language it is possible to see how the ability to manipulate formational representations could have been formed during early development. However, most deaf signers receive relatively late exposure to sign language, with early communication being predominantly gestural and visual. It is not clear what impact such late acquisition has on STM function. Given the sample of deaf college students available for the research reported in this thesis, it is important to bear in mind that the memory structures they have may not support sign-based coding in terms of formational parameters or distinctive features. Many of them grew up in the absence of a formal sign language such as BSL. Rather, phonetic (sound-based) or gestural codes (see Goldin-Meadow et al., 1995) may be employed by such participants.

5.2.1 Semantic Phonology and STM Coding

Short-term memory research using spoken language users has suggested that short-term memory codes the physical properties of incoming stimuli. Speech information is therefore coded in a phonetic or phonological form, not in terms of its semantic properties (Baddeley, 1966). However, in signed languages there appears to be an overlap between what a sign looks like (its physical form) and its semantic properties (what it means). This goes beyond visual motivation, where a sign resembles its referent or some aspect of that referent. Kyle and Woll (1985) provide a number of examples from British Sign Language. For example, signs involving a fist with an extended thumb are often employed in signs whose meaning has a positive connotation: GOOD, BETTER, FRIEND, HEALTH, NICE and WISE are just a few examples. A fist with the little finger extended is often seen in signs with a negative connotation: BAD, WORSE, FAIL, REJECT, UGLY and ROTTEN to name but a few. Similarly, signs relating to emotions are often located upon

the body trunk (FEEL, ANGRY, INTERESTED), whereas signs relating to cognitive processes are often located upon the head (KNOW, THINK, UNDERSTAND). Kyle and Woll also report on a cross-linguistic comparison of 15 different sign languages by Woll (1983). They note that signs which have to be spontaneously generated (for they are not lexicalised) are often produced in a similar way by signers of different sign languages. They provide the example of 'skateboard'. Most of the signers in Woll's study used three features to convey the concept of a skateboard: (1) its shape (oval with wheels), (2) its movement (the fact that it moves forward and side-to-side), and (3) how someone interacts with it (by standing on it and balancing with their arms). Similar findings were obtained for other items that were not lexicalised. It appears that these three aspects of the referent are universally important: (1) what it looks like, (2) how it moves, and (3) what you do with it. It therefore comes as no surprise that lexicalised signs (which themselves had to be created at some time in the past) also often employ some of these aspects of referents in their form.

Mainstream sign linguistics maintains that there is duality of patterning in signed languages. The iconic motivation of a sign or any kind of form-meaning relationship is dismissed as a by-product of how the language has evolved: visual languages draw upon visual entities for inspiration. For one kind of sign language phonology, however, the form-meaning relationship is taken as the central component. Semantic phonology (Stokoe, 1991; Armstrong et al., 1995) states that the formational properties of a sign are semantic. Individual parameters are motivated by, and carry, meaning in all signs. Signs are iconic gestures, motivated by what they represent, but they have a phonological structure that is semantic in nature. This structure is agent-action-patient: signs represent something performing an action on something else. Each component of a sign - handshape, location, movement - represents a real world entity and action, and the execution of the sign specifies the relationships between these entities and actions. A more detailed discussion of semantic phonology was given in Section 2.2.2.3. Figure 5.1 shows a sign which fits within the framework proposed by semantic

phonology. Here the agent is a bird, represented by the hooked index and middle fingers of the right hand; the patient is the wire, represented by the extended index finger of the left hand; and the action is one of sitting, represented by the agent coming to rest on the patient. Such a sign, however, is polymorphemic: it contains more than one morpheme. Such a sign may not have any meaning when executed in isolation. It contains two classifiers: the right V handshape used to represent an animal, and the left G handshape, used to represent a long, thin object. Only the context of the signed discourse would allow the V and G handshapes to be understood as a bird and a wire respectively. This type of sign can be analysed into parts (see Wallin, 1996), but it is clearly a specific type of sign and cannot be used as sole support for the claims of semantic phonology.

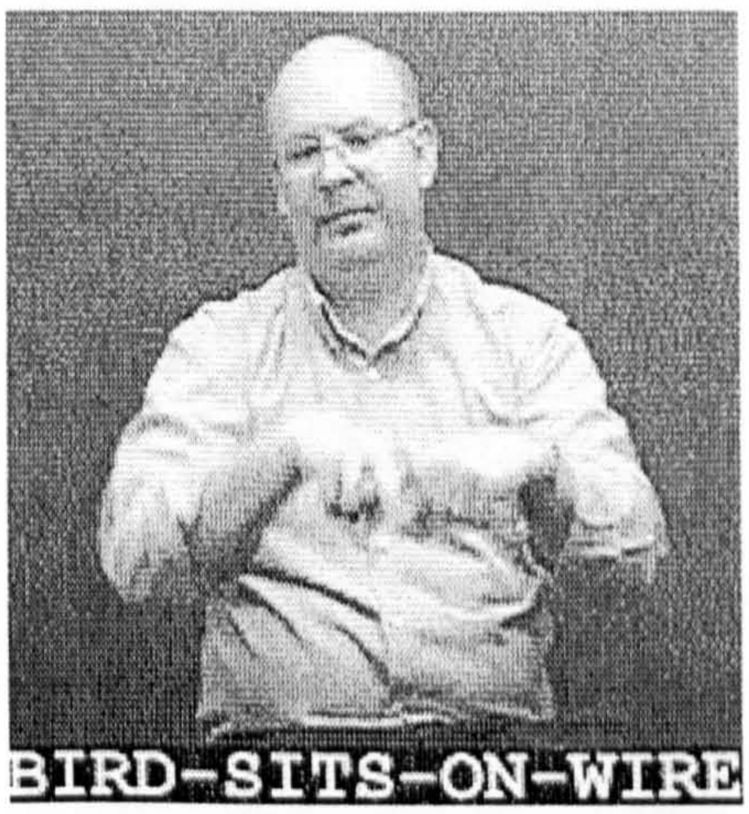

Figure 5.1: A sign meaning BIRD-SITS-ON-A-WIRE.

Now consider another sign, this time a monomorphemic one — BROOM. This sign is understandable in isolation (context is not required for its meaning to be known). The sign is produced by holding two fists, one above the other, in front of the body and moving them forwards and backwards twice. In semantic phonology terms, the agent is an animate thing performing a grasping action (the fists), the patient is a thin, cylindrical object (denoted by the choice of fists and not some other handshape) and the action is a to-and-fro movement of the thin, cylindrical object. Clearly, such a

description relates to the iconic nature of the sign BROOM, which would appear to be motivated by the action of sweeping a floor with a broom. The argument is reminiscent of Kyle and Woll's (1985) observation that spontaneously generated signs utilise what the referent looks like (the long thin handle), how it moves (forwards and backwards) and how a person interacts with it (grasping the handle).

For more abstract signs, however, a semantic phonological description is less clear. Consider the BSL sign for NUMBER/DATE/MATHEMATICS (Figure 5.2). For such abstract signs it is hard to specify who is the agent, who or what is the patient and what the action is. The agent is represented by the fist, the patient by the chin, and the action by the double-tap contacting the chin.

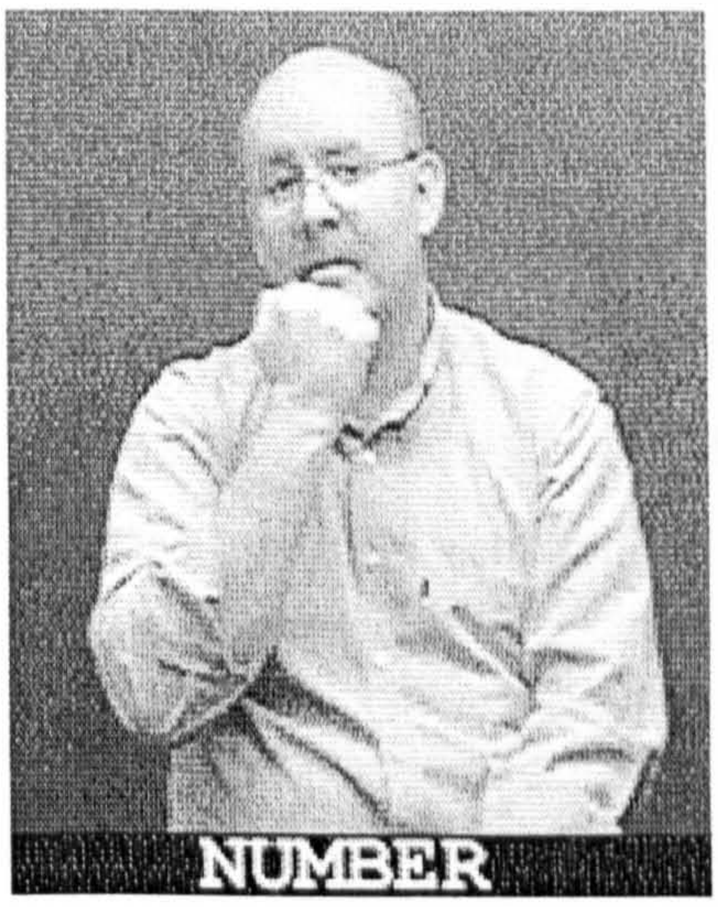

Figure 5.2: The BSL sign for NUMBER/DATE/MATHEMATICS.

Even if a semantic phonological description could be given for all signs within a sign language, it would not necessarily follow that these representations were encoded in the short-term memories of deaf sign language users. Previous research into short-term memory coding in deaf signers (see section 4.2) does not answer this question, however, as formationally similar signs may also be semantically similar (in semantic phonology's terms).

5.2.2 Home Sign and Self-Styled Gestural Systems

Ninety percent of deaf children are born to hearing parents (Dye and Kyle, 2000), and often have (a) delayed exposure to sign language, and (b) impoverished access to spoken language. Access to sign language is often delayed because of lack of information from local health services, a lack of contact with the local Deaf community, delayed identification of deafness, and mainstreaming of deaf children within hearing schools advocating an oral-aural philosophy. Access to spoken language can be severely limited for profoundly deaf children, especially if identification of deafness is late and the fitting of hearing aids delayed. Even with hearing aids, of course, access to spoken language will not be comparable with the access afforded to hearing children. Such children often rely upon gesture for communication with hearing parents, siblings and other family members. These gestures are idiosyncratic, not forming part of a conventionalised sign language, and usually understood only by close family members. Such gestures are often termed "home sign" or "self-styled gesture systems". Such gestural systems were once considered to be non-linguistic, based upon pantomime and purely iconic gestures. However, research by Susan Goldin-Meadow and her colleagues at the University of Chicago has challenged this notion, suggesting that these systems do have internal structure.

Goldin-Meadow, Mylander and Butcher (1995) studied the gesture systems of four deaf children. The children were severely or profoundly deaf, and born to hearing families. Their parents had chosen to educate them through the 'oral' method, and did not use a conventional sign language with them. Nor did they socialise or have any contact with Deaf adults. As a result the children themselves had no contact with a conventional sign language, and only minimal spoken language skills. The children used idiosyncratic self-styled gesture systems to communicate with hearing people. Goldin-Meadow et al. analysed a total of 3042 gestures produced by these children when they were aged between 2 years 10 months and 4 years 11 months. The gestures were recorded on videotape during seven free-play sessions with their mother, each session normally lasting 1-2 hours. In order to be classified as a gesture, a

child's manual productions had to (1) be directed at another person (i.e. communicative), (2) not involve actual manipulation of an object or person, and (3) not be a ritual act or part of a game.

The researchers coded the form and meaning of handshapes and motions. A total of 28 handshape forms were identified. There were 5 basic handshape forms: Fist, O, C, Palm and Point. In addition there were 3 less frequently observed forms: Thumb, V and L. Twenty other forms were identified on the basis of variation along 3 parameters: (1) shape of the palm and fingers, (2) breadth of the palm, and (3) distance between the fingers and the thumb. Handshape meanings were based upon classifying gestures as representing a HAND (manipulating an object), OBJECT (representing an aspect of the referent itself) or TRACE (representing the motion of a referent, but no physical aspect of the referent itself). These categories contained further subdivisions. For example, OBJECTs would be defined in terms of their width, shape and length. Goldin-Meadow et al. then mapped the forms onto the meanings, finding systematic relationships between the handshape forms used and the types of referent they were used to represent. Examples of their findings based upon the HAND gestures of one child, David, are given in Table 5.1. The form-meaning relationships were similar, but did differ, for each of the four deaf children studied. Eighty to 90% of the gesture sets corresponded with the systems proposed by Goldin-Meadow et al..

Table 5.1: Handshape form-meaning relationships for the HAND gestures of one deaf child, David (from Goldin-Meadow et al., 1995)

Handshape form	Handshape meaning
FIST	Handle an object 0-2 inches wide and >3 inches long, e.g. *balloon string*
CMedium	Handle an object 2-3 inches wide, e.g. *cup*
CLarge	Handle an object 2-5 inches wide, e.g. *horn*
Palm	Handle a surface 3-5 inches, e.g. *drawer*

The same procedure was used to analyse the form-meaning relationships of gesture *motions*. Initially, a set of 11 motion forms was

identified, including LinearPath, ShortArc, Revolve and NoMotion. These were then associated with a set of motion meanings, incorporating change location in path, move back-and-forth and bend amongst others. Again, a systematic relationship between these forms and meanings was identified for each child, with 70-90% of gestures conforming to the system. Examples of form-meaning relationships for the motion aspects of one child's (Kathy's) gestures are given in Table 5.2.

Table 5.2: Motion form-meaning relationships for the gestures of one deaf child, Kathy (from Goldin-Meadow et al., 1995)

Motion form	Motion meaning
Circle	Reposition by moving in a circles, e.g. *go-around*
Revolve	Rotate around an axis. e.g. *turn-around*
NoMotion	Hold or exist in place, e.g. *vacuum-hold*

Of course, the handshape and motion of a gesture cannot exist in isolation. Goldin-Meadow et al. next examined how handshape and motion forms were combined with the children's gesture systems. They observed that most handshape forms could be found combined with more than one motion form, and vice versa. This suggests that the gestures are not holistic, but are products of a componential morphological system. Although these children's systems are highly iconic, Goldin-Meadow et al. point out that they cannot be fully understood without knowing a specific child's system; when older, the children were observed correcting the gestures of communicative partners. In this sense, they point out, the systems contain some degree of arbitrariness.

Goldin-Meadow et al.'s analysis is morphological. They identified handshape and motion morphemes within self-styled gesture systems. It is highly reminiscent of the semantic phonology proposed by Armstrong et al. (1995). There are two key differences between the proposals. Firstly, semantic phonology claims to provide a description of conventional signed languages, not just self-styled gesture systems. Secondly, semantic phonology claims that the gesture morpheme (as described by Goldin-Meadow et al., 1995) is identical to the gesture phoneme, i.e. for signed languages the phonological is the morphological.

5.3 Motivation for Experiments 1, 2 and 3

Technically, the signs of a sign language can be analysed and represented in various ways. For example, they can be analysed into a list of features, represented as images, or translated into spoken words (glosses). The question asked here is: how are the signs of a sign language represented psychologically. Specifically, Experiments 1 to 3 investigate how signs from British Sign Language (BSL) are represented in short-term memory (STM). Two types of theories of sign language phonology guided the investigations: formational theory and semantic theory.

5.3.1 Formational Theories

Most theories of sign language phonology discuss signs in terms of formational parameters (Liddell and Johnson, 1989; Sandler, 1989; Stokoe, Casterline and Croneberg, 1965; Wilbur, 1993). There is broad agreement that the major parameters are handshape, place of articulation, and movement. However, the relation between the value of a parameter (e.g. the handshape parameter taking the value bent-B) and the meaning of a sign is arbitrary. For example, in BSL the parameter values for the sign MORNING are (1) handshape: a flat palm bent perpendicularly at the first knuckles of the four fingers, (2) place of articulation: the tips of the first four fingers make contact with the contralateral side of the upper chest, and (3) movement: the sign is executed by moving the hand to the ipsilateral side of the upper chest. The parameter values are not completely independent (in that there are language-specific rules governing their combination) and do not bear meaning by themselves (i.e. they are not morphemes). A meaning-bearing unit is formed only when these parameters are combined to form a sign. This mirrors the approach of spoken language phonology, where the individual sounds (phonemes) used to construct words also have no meaning. A meaningful word is formed by combining phonemes (e.g. /b/, /t/, /æ/) in some particular ways (e.g. /bæt/ or "bat"). Again, each language has rules governing how phonemes can be combined.

5.3.2 Formational Codes in STM

The psychological significance of formational parameters for Deaf signers has been suggested by studies of STM using signs. It has been shown that lists of signs with similar formational parameters are harder to recall than lists of signs with dissimilar parameters (Hamilton and Holzman, 1989; Kyle, 1986; MacSweeney, Campbell and Donlan, 1996; Poizner, Bellugi and Tweney, 1981; Wilson and Emmorey, 1997b). The interference between formationally similar signs indicated that these formational parameters might be used to represent/code the signs in STM.

However, when constructing lists of formationally similar signs, researchers have not been careful to control for iconic similarity. Hence, their results have not ruled out the role of iconicity in coding signs in STM. Iconicity of a sign refers to the degree to which the form of the sign relates to its referent as assessed by judges (c.f. Hoemann, 1975; Klima and Bellugi, 1979, Chapter 1). Poizner et al. (1981) found that lists of iconic signs were not recalled any differently to lists of non-iconic signs when the imagery value of their referents was controlled for. However, iconic similarity *per se* was not varied in their study. Some sign lists were highly iconic and others were less iconic. To establish whether coding was in terms of the iconicity of the signs, it would have been necessary to have iconically similar and dissimilar lists, i.e. lists of signs that were iconic in similar ways or for similar reasons, and lists of signs which were iconic but in differing ways and for differing reasons. Therefore their results lend no argument for STM codes, suggesting only that iconicity does not facilitate STM performance (or reduce the burden on memory). It is also important to distinguish between signs that are iconic, and those for which semantic phonology can provide a description. There are iconic signs for which there is no clear agent-action-patient description. For example, the BSL sign for TREE. This is formed by extending the thumb and four fingers of the dominant hand, pointing them upwards, and resting the elbow on the down-turned palm of the non-dominant hand and making a small twisting motion. This sign is clearly iconic, motivated by the shape of a tree. Yet there is no clear agent, action or patient. Whilst this again highlights a

weakness of semantic phonology theory, it also means that analyses based upon iconicity data cannot necessarily be used to counter the predictions of semantic phonology theory – the signs accounted for by semantic phonology theory are a subset of iconic signs within a sign language.

5.3.3 Semantic Theory with Semantics Defined by Morphology

A recent theory of sign language phonology (semantic phonology; Armstrong, Stokoe and Wilcox, 1995; Stokoe, 1991) has proposed that signs have a semantic structure. A great number of contrasts can be made using configurations and movements of the hands and arms. According to semantic phonology, the purpose of configuring and moving the arms and hands is to represent ideas. Noun-like ideas are represented by configuring the hands and arms to resemble the object (or by pointing), and verb-like ideas are represented by movement, which is more or less faithful to the action being depicted (Stokoe, personal communication). Thus, according to semantic phonology, signs have a morpho-syntactical structure: a sign is a combination of an object and a verb. As an example, consider one BSL sign for HORSE-RIDING (see Figure 5.3). For semantic phonology, the handshape of the sign HORSE-RIDING is not accidental. It represents the gripping of a long, thin object (the reins of the horse) by the rider. Thus the sign is a combination of an object (the reins of a horse) and a verb (the circular pulling on the reigns). In semantic phonology each of the elements of a sign conveys meaning. The handshapes, places of articulation and movements all combine to convey meaning, and convey meaning individually. In this sense, the phonology of a sign language is the morphology of that sign language: no clear distinction can be made between the two.

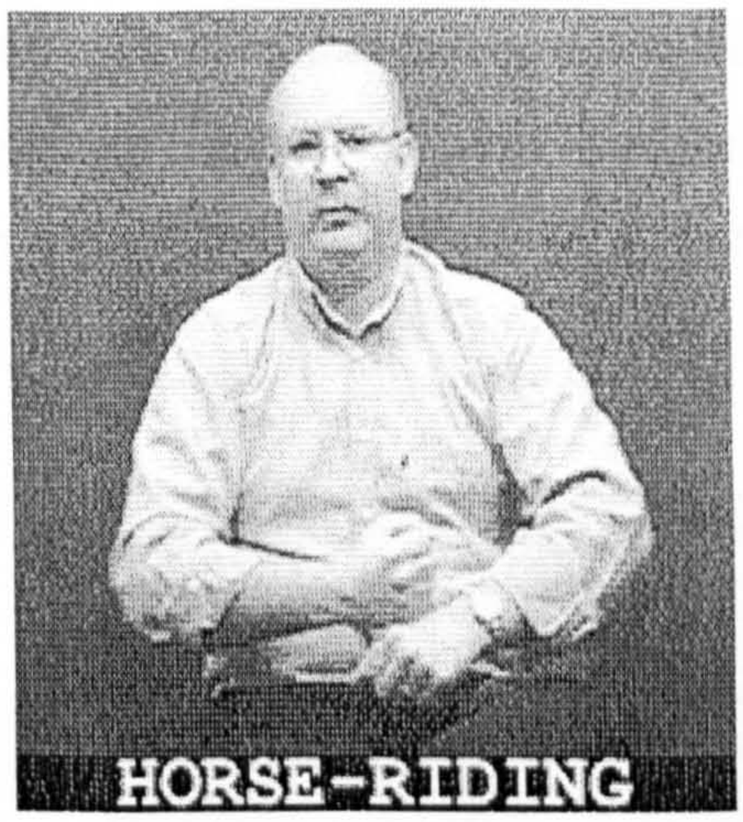

Figure 5.3: One BSL sign for HORSE-RIDING is formed by taking two fists and placing them on top of each other (contacting) in front of the stomach. The sign is executed by making a circling motion in front of the chest, keeping both fists pressed together.

The semantic/morphological aspects of signs can be further illuminated by the work of Wallin (1996). Wallin examined polymorphemic signs in Swedish Sign Language. Polymorphemic signs are single signs that contain more than one morpheme, i.e. they contain more than one meaning-bearing unit. These signs were analysed into three aspects of meaning: figure, ground and motion. Each aspect of meaning is conveyed by a formational parameter, i.e. phonemes are acting as morphemes. Let us consider an analysis of the sign BIRD-ON-A-WIRE (Figure 5.4) in terms of the approach taken by Wallin. This contrasts with the semantic phonology analysis of this sign reported in Section 5.2.1. In Wallin's terms, the figure is the bird, the ground is the wire and the motion is the sitting of the bird on the wire. Formationally, the sign consists of a handshape (the active hooked V-hand), a place of articulation (the passive G-hand) and a movement (the active hand moves to contact the passive hand and is held there). The handshape represents the bird, the place of articulation represents the wire, and the movement represents the situating of the bird upon the wire. So, each formational parameter functions as a morpheme, and carries some meaning. Nor are the formational parameters arbitrarily chosen. For example, the G-hand used to denote the cable is chosen because it has similar physical properties - both have a large extension along

the horizontal dimension, and small extensions along the vertical and saggital dimensions. In polymorphemic signs, common in all natural sign languages, the distinction between phonology and morphology, between form and meaning, is blurred.

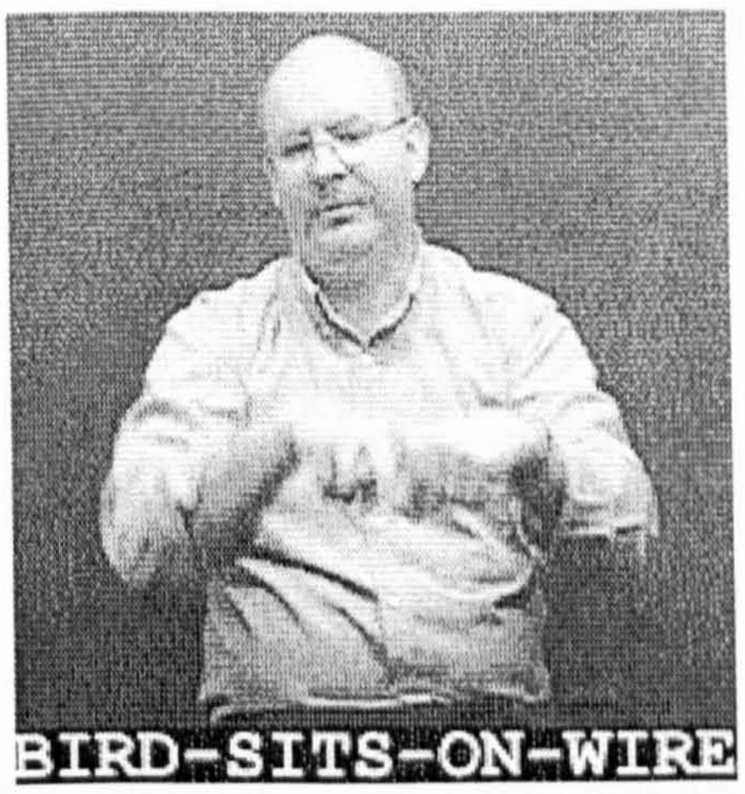

Figure 5.4: A polymorphemic sign meaning BIRD-SITS-ON-WIRE. The sign contains more than one morpheme in that the active hand denotes the bird, the passive hand represents the wire, and the movement of the active hand in relation to the passive hand denotes that the bird is situated upon the wire.

Note that semantic phonology is referring to all signs within a sign language, not just polymorphemic signs. Although a sign language user may not be aware of these semantic/morphological aspects of signs, it is clear that the motivational structure of a sign could influence its form. It is therefore important to take the motivational structure of signs into account when assessing the influence of formational similarity on short-term recall.

5.3.4 Psychological Evidence for Semantic Codes in STM

Poizner, Bellugi and Tweney (1981) presented native signing participants with lists of signs to remember. Immediate ordered recall was required. Lists were either semantically similar or dissimilar. Similar lists consisted of signs from the same semantic category (countries or fruit and vegetables). Dissimilar lists were formed from signs whose referents belonged to different semantic categories. The number of signs recalled in correct list

position for semantically similar lists was not significantly different from the number recalled for semantically dissimilar lists. For free recall, some semantically similar lists were recalled more accurately than semantically dissimilar lists. Taken together, these findings suggest that participants could use semantic category membership as a cue to free recall, but that semantic information did not form part of the STM code. Semantic phonology, however, is not concerned with category membership. It is concerned with how the form of a sign is directly motivated by properties of the referent. The nearest research to this within the literature is that on self-styled gestural systems developed by prelinguistically deaf children who do not have access to a formal signing system such as ASL or BSL. Goldin-Meadow, Mylander and Butcher (1995) report an analysis of the gestural systems of four such children. The analysis took the form of isolating form-meaning pairings in the spontaneous gestures of these children. They found that the children used certain handshapes to refer to items (or actions upon items) that had certain physical properties. These handshapes were directly motivated by the properties of the referents. However, they did not vary in an analog manner. A certain handshape was used to refer to a range of objects with similar properties. In addition, the movement involved within a gesture was motivated by the action being depicted. Goldin-Meadow et al.'s analysis went one step further in showing that the handshapes and movements were not combined into a holistic whole. Handshapes and movements could be componentially combined in order to create meaning in the gesture. The children were consistent in their use of these gesture components, and one child was observed to correct the gesture of a sibling (so that the gesture conformed to his gestural system). In a separate study, Goldin-Meadow, Butcher, Mylander and Dodge (1994) showed that such gestural systems were capable of distinguishing between nouns and verbs, by using distinct gestures for the two grammatical categories. Such a system displays many properties of formal linguistic systems, although the systems of different children are not conventional in the sense that different children will use different handshapes for different categories of object (Goldin-Meadow et al., 1995). There are

clear parallels between the structure of self-styled gestural systems and the structures proposed by semantic phonology. Self-styled gestural systems have close form-meaning relationships, yet the forms are used in componential ways in the creation of meaningful gestures. It may be that deaf signers who have delayed access to formal sign systems (non-native signers) represent the signs of those languages in a gestural way, and could be said to possess a 'semantic phonology'.

Experiment 1 uses a serial ordered recall task (see Section 6.1.1) to examine the effects of two types of list similarity (formational and morphological) which are factorially crossed to create 4 experimental conditions. Signs within formationally similar lists share the same handshape, and signs within morphologically similar lists depict an action upon similar types of object. Lists are presented to two groups of participants: deaf native BSL signers and hearing BSL learners. Hearing BSL learners were selected as they provide better controls in terms of language acquisition history (see Section 6.2.1.2).

Experiment 2 uses the same design as Experiment 1, with the addition that all participants are required to perform an articulatory (speech) suppression task This was introduced to discourage the use of speech-based coding.

Experiment 3 makes certain amendments to the design, resulting from experiences with Experiments 1 and 2. Lists are longer and drawn from larger sets of potential stimuli, presentation rate is faster, and the formationally dissimilar/morphologically similar condition is removed. In addition, native signers are directly compared to non-native signers of BSL.

6 Methodological Issues

This thesis focuses upon the mental representation of language in native and non-native users of British Sign Language. It investigates the nature of (1) short-term representations and (2) long-term (lexical) representations and the structure of the lexicon. In order to do this, two established paradigms were selected from the literature: serial ordered recall and form priming. Methodological issues using these paradigms are discussed below. Where appropriate, relevant design details from published sign language studies are included. The experiments also involve a specific group of participants: deaf people who use British Sign Language as their primary means of communication. Sign language proficiency among the British Deaf community is highly variable. Very few members of the community were born to deaf parents, and consequently a majority were delayed in their acquisition of BSL. Nearly all of the Deaf community will have received an oral-aural education, based upon amplifying sound and increasing access to spoken English. Following the section on experimental design, the characteristics of deaf signing participants in experimental samples will be discussed.

6.1 Experimental Design

6.1.1 Serial Ordered Recall (SOR)

SOR is a technique used to investigate the structure and function of short-term/working memory processes and representations. The task requires participants to view a list of items, which must then be recalled following presentation. Importantly, the order of recall must follow the order of presentation. Participants must start recall with the first list item, then the second list item, and so on until the final list item. They are not allowed to go back and recall an item that could not previously be remembered.

6.1.1.1 Experimental Parameters

Presentation-Recall Time Lag

The time lag between list offset and recall onset can be varied, resulting in immediate SOR (onset-offset time = 0 msecs) or delayed SOR (onset-offset time > 0 msecs), which can vary from a few seconds to several days. In Experiments 1, 2 and 3, immediate recall is employed, i.e. the offset-onset time is 0 seconds.

Intra-list Similarity

Another important independent variable is the relationship between list items (intra-list similarity). List items can be semantically similar (e.g. share the same category membership) or dissimilar, and/or formationally similar (e.g. have similar phonetic properties) or dissimilar. The degree of similarity can also be varied. In order to examine the psychological validity of formational parameters of sign languages, handshape, location and movement were used to assess intra-list similarity in Experiments 1, 2 and 3. Similarity was scored on the basis of the number of these parameters shared by signs, calculated in a pairwise manner.

Stimulus Set Used to Generate Lists

Another variable is how the lists are constructed. In particular, the sets of signs from which lists are made up. Although one sign language study reports never repeating a sign within the procedure (Logan et al., 1996), it is more common for lists to be created from a smaller set of items, with those items being repeated within the procedure. One measure of the extent to which this occurs is the number of times a sign is repeated in different lists within the procedure. For most studies the number of sign repetitions (as a proportion of the number of lists used overall) is 0.5, i.e. each sign occurs in half of the lists used. This was the case for the studies reported by Wilson and Emmorey (1998a; 32 lists presented per condition), Wilson and Emmorey (1997b; 16 lists) and Poizner et al. (1981; 16 lists). The study reported by Hamilton and Holzman (1989) repeated signs approximately every 1.5 lists (a proportion of 0.67). Interestingly, no studies report controlling for serial position of the repeated signs within lists (presumably because it is assumed

that, all things being equal, the probability of recall is roughly the same for all signs within an experimental set).

In Experiments 1 and 2, the stimulus set was quite small. Indeed, the lists of 5 items were drawn from sets of 5 items. Thus each sign was repeated in each list, albeit in different serial positions. Such high repetition of stimulus items may be used as a cue by participants during recall. Experience with the stimulus sets will enable participants to 'fill in the blanks' by making deductions from signs already recalled. Thus, in Experiment 3, lists of 7 items were drawn from sets of 10.

List Length

The number of signs used within a list is another important variable. The fewer the number of signs, the easier the SOR task is to perform. List lengths in the sign language literature vary, with researchers using lists of length four (Poizner et al., 1981; Wilson and Emmorey, 1997b; Wilson and Emmorey, 1998a), five (Hamilton and Holzman, 1989), six (Logan et al., 1996) and seven (Logan et al., 1996) items.

Experiments 1 and 2 used lists of 5 items, as these had previously been shown to reveal effects of intra-list similarity. However, in an attempt to increase the difficulty of the task/cognitive load, lists of 7 items were employed in Experiment 3.

Inter-Stimulus Interval

It is also possible to vary the inter-stimulus interval (ISI) and the stimulus duration. The ISI is the time between the offset of one item and the onset of the subsequent item. Again, this can vary from zero msecs (no ISI) to several seconds. The stimulus duration is the length of time for which each stimulus is displayed. This can vary from a few msecs (such that there is no conscious registration of the stimulus) to several seconds.

In the sign language literature, ISI is reported only by Wilson and Emmorey (1998a), who give an ISI of 0 msecs. A more commonly reported detail is the number of signs presented per second (rate of presentation). The most commonly reported rate is 1 sign per second (Poizner, Bellugi and Tweney, 1981; Wilson and Emmorey, 1997b; Wilson, Bettger, Niculae and

Klima, 1997), although 0.8 signs per second (Wilson and Emmorey, 1998a) and 0.67 signs per second (Logan, Maybery and Fletcher, 1996) have also been reported. Some authors, e.g. Hamilton and Holzman (1989) do not report the rate of presentation used.

For Experiments 1 and 2, determining the ISI was limited by the technology available. The lists were filmed 'live' for presentation on SVHS videotape, and ISI was thus greater than 0 and variable. Stimuli in Experiment 3 were presented as digital video clips via a personal computer. This allowed the ISI to be set at 0 milliseconds and held constant.

6.1.1.2 Dependent Variables

Recall of the stimulus items involves the retrieval and articulation (spoken or written) of item and order information. The participant must not only attempt to recall the items correctly, but is required to recall them in the correct serial position. Consequently, several measures of performance can be taken.

Item Recall

It is possible to assess the number of items recalled regardless of serial position. That is, a recalled item is scored as correct if it occurred in the target list, irrespective of whether it was recalled in the correct position. Recalled items which were not in the target list, or which are recalled incorrectly (e.g. recall of hat when the target was fat) are scored as incorrect.

Ordered Item Recall

This is a more conservative measure of performance. A recalled item is scored as correct only when it is recalled correctly and in the correct serial position. If an item is recalled incorrectly, or in the wrong position, then it is scored as incorrect.

Error Type

Two types of error are possible: item errors and order errors. It is also possible to investigate the nature of the errors.

Item errors can be of two main types, i.e. omission or form. An omission error occurs when a target item is not recalled, and a form error

occurs when a target is recalled incorrectly (e.g., hat is recalled when the target is fat). Which items are not recalled, and the nature of the form errors can also be measured. The number of form errors produced in Experiments 1, 2 and 3 was small, so no conclusive analysis of these errors could be made.

Order errors are more varied, e.g. substitution, transposition and intrusion errors. A substitution error occurs where a list item is recalled in the wrong list position, displacing or overwriting the item that should have been recalled there (e.g. recalling fat - hat instead of cat fat hat). A transposition error is similar, and occurs when the list positions of two or more items are swapped at recall (e.g. recalling hat fat cat instead of cat fat hat). An intrusion error occurs when a non-list item is recalled, replacing or displacing a target item (e.g. recalling cat fat bat instead of cat fat hat).

In Experiments 1 to 3 the number of order errors was calculated. In line with all previous studies reported in the literature, this did not take into account whether errors were substitutions, transpositions or intrusions. Furthermore, a dependent measure hitherto unemployed in sign language studies was used. This was the number of order errors per item recalled (see Section 6.1.1.3).

6.1.1.3 Potential Artifacts

As highlighted by Saint-Aubin and Poirier (1999), care must be taken when analysing the number of order errors produced by a participant. This is because the number of order errors is dependent upon the number of items recalled. The more items that a participant recalls, the more likely is the chance of an order error. For example, consider the target list hat-mat-pat-rat-fat. If a participant recalls only two items (e.g. *-mat-*-*-rat), then the maximum number of order errors is two. The more items that are recalled, the greater chance of an order error (e.g. mat-hat-fat-pat-rat). Not controlling for this can conflate item and order effects. For example, where a manipulation results in enhanced recall of items, this could appear to lead to increase in the number of order errors. Saint-Aubin and Poirier suggest expressing the number of order errors as a proportion of the number of items generated in the

response. Using this method, an error score of 1 would indicate that all recalled items were incorrectly ordered, and a score of 0.25 would indicate that a quarter of all recalled items were incorrectly ordered.

A strict ordered scoring heavily penalises responses which differ from the desired response in terms of only one missing list item. For the target list hat-mat-pat-rat-fat, consider the response mat-pat-rat-fat. This response has correctly preserved the order and identity of the last four list items, but has omitted the first list item. Strict scoring would result in a score of zero, which would not reflect the actual performance of the participant. These problems can be overcome by using the proportion of errors, given the number of items recalled by each participant, as suggested by Saint-Aubin and Poirier.

6.1.2 Form Priming

Form priming is a technique used to investigate the nature of long-term (lexical) phonological representations, and to elucidate the structure and organisation of the mental lexicon. There are two main types of form priming: direct and mediated. In both paradigms, participants are presented with two items: a prime and a target. Participants are required to make a response to the target item.

In direct form priming, the prime and target are related formationally (i.e. in terms of their phonological structure) and differ in other respects (semantically, morphologically and syntactically). For example, the prime cricket and the target thicket may be presented. In mediated form priming, the target is not formationally related to the prime. Instead, the target is semantically related to an item that is formationally related to the prime (the mediator). For example, a participant may be presented with the prime fair and the target rabbit. In this example, the mediator would be hare, which is semantically related to the target and formationally related to the prime).

6.1.2.1 Experimental Parameters

Prime-Target Similarity

The formational overlap between the prime and target can be manipulated. For words, this may involve overlap of word onset, presenting pairs such as meat-meek, or word rhyme, presenting pairs such as table-fable. For each type of overlap, the number of overlapping segments can be manipulated, e.g. mate-meek has a one segment overlap (C**-C**), whereas meat-meek has a two segment overlap (CV*-CV*).

In Experiment 4, the formational parameters (handshape, location and movement) of the sign were used to determine prime-target similarity. In different conditions, different combinations of these parameters were shared. This allows the analysis to look at the general effects of degree of similarity, as well as the effects of sharing specific parameters.

Method of Presentation

The prime and target can be presented in the same modality (unimodal presentation) or in differing modalities (cross-modal presentation). With unimodal presentation, the prime and target are both auditory or both visual, whereas for cross-modal presentation one stimulus is auditory and the other visual (Zwitserlood, 1996).

Experiment 4 uses sign language signs presented by digital video. This allows only for unimodal presentation, with both prime and target presented in the visual modality.

Response to Target

Many different responses to the target item can be elicited from the participant. The most common are lexical decision (e.g. Goldinger, Luce, Pisoni & Marcario, 1992; Marslen-Wilson, 1990; Marslen-Wilson, Tyler, Waksler & Older, 1994) and naming (e.g. Radeau, Morais & Segui, 1995; Slowiaczek & Hamburger, 1992). In a lexical decision task, the participant must decide whether the target is a real word or a nonword. For example, the target hat should be responded to as a real word but the target hap should be

responded to as a nonword. In a naming task, the participant is required to verbally articulate the target.

Technological limitations meant that Experiment 4 focused solely upon lexical decision. This type of response could be accurately gauged by the use of a response box connected to the personal computer. Using a naming task would require special equipment to determine the onset of the participants' movements when responding. This was not available, and the financial and time costs involved were impractical. It is also possible to utilise psychophysiological recordings such as ERP measures (see Section 6.1.2.2 below). Again the use of techniques was not technologically or financially plausible given available facilities.

Stimulus Onset Asynchrony (SOA) and Inter-stimulus Interval (ISI)

A final variable is the timing of the target and the prime. SOA refers to the time delay from the onset of the prime to the onset of the target. This is related to the ISI, which is the time delay from the offset of the prime to the onset of the target (see Figure 6.1), and the duration of the prime.

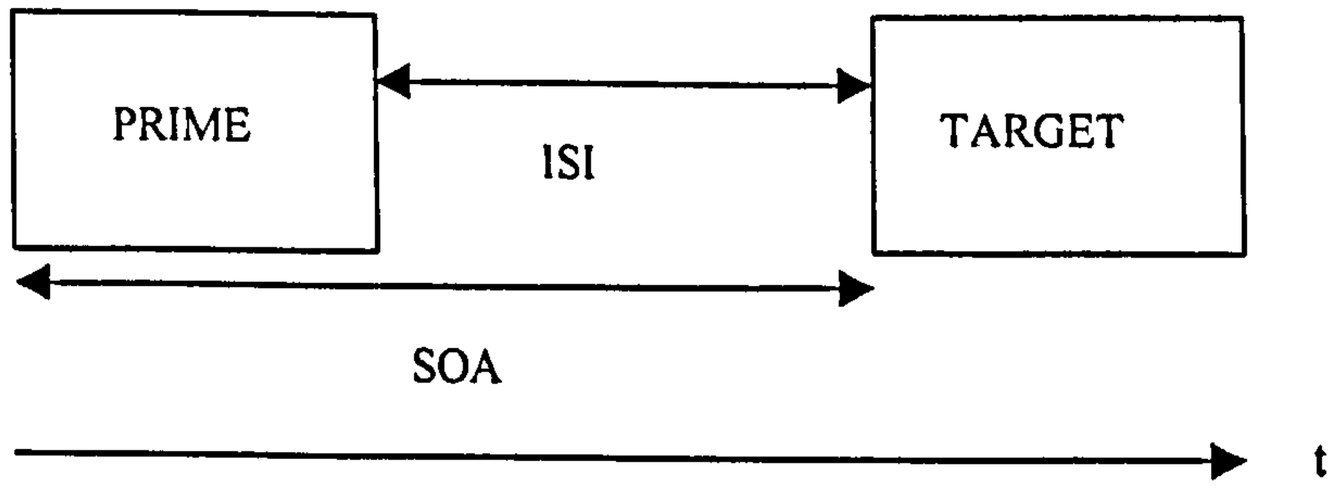

Figure 6.1: The relationship between stimulus onset asynchrony and inter-stimulus interval.

The SOA for any pair is therefore equal to the duration of the prime plus the ISI. If the primes are all of equal duration, then this relationship is systematic for all trials, and both the SOA and the ISI can be held constant. If the prime duration varies, then either the SOA or the ISI can be held constant over all trials (but not both).

Using sign language signs means that the duration of the prime cannot be held constant. Computationally, it was easier in Experiment 4 to hold the ISI constant and allow the SOA to vary. Holding the SOA constant by varying the ISI would have required more complex coding and greater computational resources.

6.1.2.2 Dependent Variables

Reaction Time

The most common dependent variable for form priming is reaction time (Zwitserlood, 1996). Reaction time (RT) measures are only analysed for correct responses. A faster RT for form similar trials than for form dissimilar (control) trials indicates that the prime facilitated the target. A slower RT for form similar trials than for control trials indicates inhibition of the target by the prime (Zwitserlood, 1996).

Event-related Potentials (N400)

Event-related potentials (N400) can also be used as a dependent measure. Discussion of this is beyond the scope of this thesis, and the necessary equipment was not available to take such measurements.

6.1.3 Potential Artifacts

Zwitserlood (1996) points out two potential artifacts that can result from the form priming paradigm. Where the percentage of form related pairs is high, participants may expect form-related trials. This can lead to slower responses for unexpected trials, magnifying the size of any test-control comparisons. For this reason, the proportion of related and unrelated trials should be equal. In addition, the experimenter should include form-related trials when a nonword is the target (i.e. on word-nonword trials). If not, then participants will show a bias towards "yes" responses on word-word trials in a lexical decision task, speeding their decision.

Using an equal number of form-related and form-unrelated trials in Experiment 4 would have resulted in a prohibitive number of trials. As run, the experiment required 1 hour to conduct per participant. An equal number of

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related and unrelated trials would have boosted this to nearer 2 hours, resulting in unacceptable levels of fatigue in participants. Form-related trials where the targets were nonwords were included in Experiment 4. Indeed, the lexicality of primes and targets were factorially combined with prime-target similarity factors.

Two other factors can influence results in form priming studies: (1) uniqueness points of targets, and (2) frequency of targets in the language.

The uniqueness point in a target is the point at which enough information is available for it to be recognised. For example, take the English word "onion". In a lexical decision task, after the first few phonemes (representing "oni-") there is only one possible real word target: "onion". No other words start with these three letters. So a decision can be made about the identity of the target if it is a word after only a few phonemes have been processed. A decision about the lexical status of the target can be made once a few more have been processed. For a longer word with more common syllabic/morphemic elements, such as "understandable", the situation is different. Even at the point "underst-" there is more than one possible "winner" (understand, understood, understated, understeer, etc.). A lexical decision can only be reliably made much later, once a nonword target such as "understoodly" can be identified or ruled out. Clearly the location of uniqueness points within words, and the point at which the target can no longer match any lexical entry for nonwords, will influence the time course of any lexical decision. For the signs used in Experiment 4 (a form priming study) these points are unknown. However, the location of these points appears to be related to the length of a target (although the correlation will not be exact — for some signs of long duration, the uniqueness point may be early in the signs' production). The length of targets can therefore be used as a covariate in analyses of reaction times.

Frequency is another factor known to influence reaction time in lexical decision tasks. Targets with high frequencies are recognised more quickly than targets with low frequencies. This frequency effect is taken as evidence for lexical processing of target items (Zwitserlood, 1996). However, frequency

measures for BSL are unavailable, nor was there time to collect and analyse the data necessary to calculate frequency measures for the signs used in Experiment 4. To date there has been only one published study that has reported frequency measures for a signed language. McKee and Kennedy (1999) report frequency measures for 1,000 New Zealand Sign Language signs. These measures are based upon a corpus of over 50 hours of NZSL, involving 80 Deaf people discussing over 30 topics in different registers. Clearly the time required to record, collate, transcribe, enter and analyse such an amount of data was beyond the scope of the research project reported in this thesis. In interpreting the results of Experiment 4 it has been assumed that BSL sign frequency is evenly distributed across all experimental conditions, and that it's effect is therefore equal for all experimental conditions.

6.2 Participants

There are two important issues related to participants when doing sign language research: participant selection and participant recruitment. The first stage, participant selection, is about defining the target population for the research. In other words, which population is the experimental sample to be representative of? Once the target population has been determined, then the sample to be used in the experiments must be contacted and their involvement elicited. This is the second stage: participant recruitment. Although these stages are not independent of each other, they will be discussed separately here for the sake of clarity.

6.2.1 Participant Selection

This thesis is interested in the memory processes of deaf people who use British Sign Language. Immediately, two criteria for inclusion in the target population are apparent: participants must be deaf and use British Sign Language. Furthermore, as the thesis is investigating normal memory processes, participants must not suffer from any neurological condition that will impair memory or language processing; it must be a non-clinical target population. Developmental considerations are also relevant, with children

excluded from the target population: the interest is in mature, fully developed memory processing. However, these considerations are not sufficient. In particular, two areas need to be more fully considered: (1) degree/onset of deafness and (2) sign language use.

6.2.1.1 Degree and Onset of Deafness

Research by Conrad (1979) suggests that degree of deafness is related to memory coding strategy, although not necessarily highly predictive of coding strategy. With a sample of all deaf school-leavers in the UK at the time the study was conducted, Conrad found that those with a higher degree of deafness were less likely to use speech-based coding in short-term memory tasks. It is important to note, however, that the study found evidence of internal speech in 40-50% of profoundly deaf school-leavers (Conrad). Most sign language memory studies have used participants who are either severely (e.g. Hamilton & Holzman, 1989; Hanson, 1982) or profoundly (e.g. Hanson, 1990; Logan et al., 1996) deaf. Some studies quote an audiological measure of hearing loss (e.g. a loss greater than 80dB in Wilson & Emmorey, 1997b and Wilson & Emmorey, 1998a), and others give no indication of the degree of deafness in their sample (e.g. Poizner et al., 1981). Whilst it may seem preferable to give a precise account of hearing loss in dB, it is not always possible. Many participants will not know their average loss, and official records are not always available. Researchers are often reliant upon the self-report of their participants, who are usually only able to express their deafness as mild, severe or profound.

Related to degree of deafness, is onset of deafness. Deaf people become deaf at different ages and for different reasons. In a study of the deaf population of the Avon district in England, Kyle and Allsop (1982) report that the majority of the population (54.9%) did not know the cause of their deafness, with a further 28.6% citing only 'illness'. Only a small percentage cited 'family' as a cause of deafness (suggesting congenital inheritance from a deaf parent or parents). The same study revealed that most of the experimental population were deaf from birth (72.6%), with a mean onset of

deafness at just over 1 year of age. Previous research has focused on participants deaf from birth (e.g. Hamilton & Holzman, 1989; Hanson, 1990; Wilson & Emmorey, 1997a,b; Wilson & Emmorey, 1998a,b), although some define their participants as prelingually deaf (e.g. Hanson, 1982) and others give no information about age of onset (Poizner et al., 1981). Participants who are deaf from birth will have minimal experience of clear spoken language, and are thus less likely to have developed a full phonological system based upon a spoken language (Dodd, 1976; Dodd, 1987). In turn, they are implicitly assumed to be less able to use speech-based coding in short-term memory tasks, and therefore more likely to use alternative strategies such as sign-based coding. This leads to the second important consideration: experience with sign language.

6.2.1.2 Experience with Sign Language

Deaf Children of Hearing Parents (DCHP)

Most deaf people (90-95%) are born to hearing parents. Diagnosis of deafness is often late, and followed by the fitting of aids to hearing such as amplification devices (or nowadays, possibly cochlear implants). In the UK, their age, social background and geographical location will have determined the type of school they attended. They may have been mainstreamed within a hearing school, attended a bilingual-bicultural school which taught in BSL and English, or most likely attended a specialist deaf school (often residential).

Choice of school will have had a critical bearing on their exposure to BSL. In hearing schools and most deaf schools there will have been no signing officially allowed (an oral-aural approach to deaf education is dominant within the UK). In deaf residential schools, there will have been the opportunity to interact with deaf peers and a consequent covert use of BSL. Even so, the availability of an adult language model will have been rare. Those educated more recently may have attended a bilingual-bicultural school, and they will have been exposed to BSL from deaf adult language models working with hearing teachers within the school. Still, that exposure may not

start until the age of 4 or 5 years, long after most hearing children already have a good grasp of spoken language.

Deaf Children of Deaf Parents (DCDP)

Kyle (1986) estimates that the number of deaf people severely deaf from birth is 1 in 2,000. Of these, only 1 in 20 are from deaf families. Thus, the number of severely deaf individuals from deaf families is likely to be approximately 1 in 40,000, or roughly 1,500 individuals within the United Kingdom.

Most of these children, but not all, will have experienced BSL growing up within a signing environment. For them, BSL will be a first language, of which they are native users. Acquisition research has suggested that the time course of language acquisition for these children is similar to that of hearing children learning a spoken language (Bonvillian & Folven, 1990; Bonvillian et al, 1990; Folven et al., 1984; Orlansky & Bonvillian, 1984; Pettito and Marentette, 1991). They are also more proficient processors of sign language than those who acquire it at a later stage of development (Mayberry, 1993, 1994; Mayberry & Eichen, 1991; Mayberry & Fischer, 1989).

Within the sign language memory literature, the deafness of participants' parents is an important demographic variable. Although some studies do not mention it (e.g. Hanson, 1982), others state the number of participants who have deaf parents (e.g. Hamilton & Holzman, 1989; Wilson & Emmorey, 1997; Wilson & Emmorey, 1998) or declare that 'most' participants had deaf parents (Poizner et al., 1981).

Hearing Learners of BSL

Hearing learners of a signed language also provide a potentially useful control group in studies of sign language encoding. Hearing learners can have levels of sign skill comparable to those of non-native signers, but also possess relatively 'normal' first language acquisition. The extent to which hearing learners can encode signs in terms of their linguistic properties thus provides a measure of the effects of delayed acquisition without the potential confound of delayed first language acquisition and any concomitant cognitive deficits.

Participants in Experiments 1 and 2 were fluent Deaf signers of BSL and hearing learners of BSL. Although hearing learners provide a useful control, as noted above, their selection was highly driven by a lack of Deaf participants for participation in those experiments. Experiment 3 was conducted in an environment where there was greater access to Deaf signers, and thus uses two groups of Deaf participants: native (DCDP) and non-native (DCHP) signers.

6.2.2 Effects of Sign Acquisition on Memory Coding

Two papers in the sign coding literature provide data about distinct groups differentiated in their acquisition history: Hamilton & Holzman (1989) and Wilson & Emmorey (1997b).

Hamilton & Holzman (1989) report a serial ordered recall study using three groups of deaf participants: DAS, DDP_1 and DDP_2. The DAS group were deafened after the age of 6 years; they were postlingually deaf. Thus, although profoundly deaf, their first language was spoken English. The DAS group had all used ASL or signed American English for at least two years. The DDP_1 and DDP_2 groups were congenitally deaf and born to deaf parents. They were all severely/profoundly deaf, and had ASL as a first language. Both groups had spoken English as a second language, although they differed in their fluency. Those in DDP_1 were fluent speakers, defined as having good speech intelligibility scores (using a measure devised by the National Technical Institute for the Deaf, Rochester, NY). The DDP_2 group were non-fluent speakers, not meeting the intelligibility criteria set by the experimenters. When stimuli were presented orally (a person seen speaking the stimulus words on a monitor), all of the deaf participant groups recalled fewer items for phonologically similar lists than for control lists. This indicates that all groups were able to use, and employed, a speech-based coding strategy when stimuli were presented orally. When stimuli were presented manually (a person seen signing the stimulus words on a monitor), all deaf groups recalled fewer items from formationally similar lists than from control lists. This indicates sign-based coding of stimuli when they were presented as signs. It is important to

note that there was no evidence for sign-based coding with oral presentation, and no evidence of speech-based coding with manual presentation. All groups, including those deafened after the age of 6 years, were capable of employing speech-based and sign-based coding strategies. The main determinant of coding strategy seemed to be mode of presentation: participants maintained the mode of presentation as the mode of representation. With simultaneous presentation (stimulus words were both spoken and signed), recall was better than for manual or oral presentation modes, and there were no effects of list type. Hamilton & Holzman suggest that:

> *"[the presence of] sign[s] alleviated the negative effects of phonological similarity for some subjects and, conversely, the speech accompanying the sign[s] alleviated the negative effects of cherological similarity for other subjects"* (Hamilton & Holzman, 1989, p. 547).

However, it is not clear this is an automatic process, or whether the participants selected the most appropriate coding strategy given the nature of the task and stimuli on any given trial. The data presented by Hamilton & Holzman therefore suggests that mode of presentation is a more effective predictor of coding strategy than linguistic background of the participants. Even participants deafened after the age of 6 years provided evidence of sign-based coding. However, caution must be taken when interpreting the data, due to methodological limitations of the study. Hamilton and Holzman used the same stimuli as Shand (1982). Hanson & Lichtenstein (1990), using Shand's stimuli, demonstrated a cherological similarity effect for hearing people with no knowledge of ASL. This was using written word stimuli, which previous research has suggested does not elicit sign-based STM coding (Hanson, 1982; Krakow & Hanson, 1985; Lichtenstein, 1985/1998). Hanson & Lichtenstein (1990) interpreted this as a confound due to (1) more syllables in the cherologically similar word list, (2) more letters in the cherologically similar word list, and (3) less visual distinctiveness in the cherologically similar word

list. Although Hamilton & Holzman (1989) presented their stimuli manually, more likely to induce sign-based coding (Hanson, 1982), the greater syllable length for the cherologically similar lists may have introduced a confound due to word length (Baddeley, Thomson & Buchanan, 1975). That is, if coded cherologically, then cheremic similarity would result in worse recall than a control list, and if coded orally, then greater word length would result in worse recall than a control list.

Wilson & Emmorey (1997b) report two serial ordered recall tasks using twenty-four deaf participants in each task. All participants had acquired ASL before the age of 6 years, and had a hearing loss greater than 80dB in their best ear. Most participants were deaf from birth, with 1 participant in the first task deaf before 2 years, and 2 participants in the second task deaf before 2 years. In task one, seventeen participants were from deaf families, and seven were from hearing families; in task two there were fourteen from deaf families and ten from hearing families. Wilson & Emmorey considered those with deaf parents to be 'native signers' and those with hearing parents to be 'nonnative' signers. However, when reporting their results they do not include parental deafness as a factor in any analysis. Without such an analysis, it is not possible to assess whether their findings of sign coding in working memory can be applied to both the 'native' and 'nonnative' groups. In the discussion of their results, Wilson & Emmorey point out the small effect size found when compared to data from hearing participants using spoken language. They reason that deaf participants may have had a multitude of available codes, thus lessening the effect size when the effect is dependent upon the presence of one particular form of coding. Given the mixture of 'native' and 'nonnative' signers, this seems to be a strong possibility.

6.2.3 Sample Size, ANOVA and Interpretation of Non-significant Findings

The target population for the experiments reported in this thesis means that participant numbers are low for all experiments. Indeed, participant numbers are low for most studies reported in the literature. As Analysis of

Variance (ANOVA) is used as the main form of analysis in most of this thesis, it is important to be clear about how such low sample sizes influence the interpretation of inferential analyses for all studies reported in this thesis.

Low sample sizes mean that statistical power can be very low when using ANOVA to explore effects within the data. Experiment 1 reports the statistical power for the ANOVAs performed on data from a relatively small sample size (see Chapter 7). Studies with Deaf signers, and the consequent sample sizes, therefore result in the risk of not detecting effects due to lack of power. This caveat applies to all non-significant trends reported in this thesis. As a result, where effects are predicted on the basis of existing literature, this thesis often supplies an interpretation for alpha levels greater than 0.05 (but less than 0.10). Care must be taken when relying upon such effects; hence their interpretation is only pursued where there are strong *a priori* theoretical reasons for doing so.

7 Experiment One: Ordered Signed Recall of Lists Varying in Formational and Morphological Similarity

7.1 Introduction

As indicated in Section 4.2, studies on the recall of signs over short periods of time have consistently found that lists of formationally similar signs are harder to recall than lists of formationally dissimilar signs (Klima and Bellugi, 1979; Poizner et al., 1981). Such findings have been used to suggest that signers encode signs in short-term memory in terms of their formational parameters; lists of signs with similar formational parameters result in similar codes in short-term memory, and more confusion in recall. However, signs with similar motivations may also have similar forms, as the motivation of the sign may directly influence its formational structure. It is not clear then whether the mental representation of a sign is formational or semantic/morphological. The present study intended to address the issue by using a design in which the factors of formational similarity and morphological similarity were crossed in an immediate recall task. Two levels of each factor were used: similar and dissimilar.

Four sets of signs were devised. The signs in each set were either morphologically similar (in that they represented similar actions performed upon similar types of object) or morphologically dissimilar (different actions upon different types of object), and formationally similar (same handshape and location) or formationally dissimilar (different handshapes and locations). If the sign code is morphological then, irrespective of formational similarity, lists of signs which represent similar actions performed upon similar objects (morphologically similar lists) will be harder to recall than lists of signs which represent different actions performed upon dissimilar objects (morphologically dissimilar lists), as the signs in morphologically similar lists will have similar short-term memory codes. If the code is formational then, irrespective of morphological similarity, lists of formationally similar signs will be harder to recall than lists of formationally dissimilar signs, because the signs in formationally similar lists will have similar short-term memory codes.

Two groups of participants were involved in the experiment. Deaf native signers of BSL, and hearing learners of BSL. The use of hearing signers provides a useful control sample. It is assumed that the hearing learners will recode the signs into an English speech-based code. If the deaf signers do the same, then a similar pattern of results should emerge for the both groups of participants. In addition, BSL is a primary means of communication for Deaf signers, and secondary for hearing learners. Thus the groups differ in terms of early and current communication experience.

Current theories of STM coding in deaf signers predict that formational similarity will lead to poorer recall in an ordered serial recall task. In the current experiment, for deaf signers, this would predict a significant main effect of formational similarity that did not interact with morphological similarity. Signs from formationally similar lists will be recalled less accurately than signs from formationally dissimilar lists, irrespective of morphological similarity. Semantic morphology theory predicts, for deaf signers, a main effect of morphological similarity that does not interact with formational similarity. Signs from morphologically similar lists will be recalled less accurately than signs from morphologically dissimilar lists, irrespective of formational similarity. It is assumed that hearing learners of BSL will recode the signs into a speech-based code. These effects therefore should not be evident for hearing BSL learners.

7.2 Method

7.2.1 Participants

Participants were nine profoundly deaf signers of BSL and seven hearing BSL learners who were all employed or studying at the Centre for Deaf Studies (University of Bristol) or the Visual Language Centre (University of Wolverhampton). All deaf signers reported using BSL on a regular basis, and claimed to have been users of sign language before the age of 6 years. Hearing learners also used sign language on a regular basis, and had passed the CACDP BSL Stage 2 examination (or equivalent). Further

demographic data are presented in Table 7.1 and Table 7.2. All participants agreed to have their responses recorded by video camera prior to initiation of the study, and all were paid for their participation.

Table 7.1: Mean age of participants in Experiment 1.

Group	M	SD	Range	n
Deaf signers	26.00	7.82	20-47	9
Hearing learners	25.63	2.45	23-30	7

Table 7.2: Deafness demographics of Deaf sample in Experiment 1.

Gender	Age	Onset of deafness	Cause of deafness	Level of Deafness	dB loss in best ear	Lip-reader?	Deaf relatives?	Primary language
F	25	birth	N/K*	Profound	95	Y	N	BSL
M	24	birth	rubella	Severe	N/R	Y	N	English
M	25	3	N/R†	Severe	N/R	Y	N	BSL
F	26	birth	N/K	Profound	N/R	Y	Y	BSL
F	23	N/R	N/R	N/R	N/R	N/R	Y	BSL
F	21	birth	hereditary	Profound	N/R	Y	Y	BSL
F	29	birth	rubella	Severe	80dB	Y	N	English
M	47	birth	N/R	Profound	N/R	Some	N	BSL
F	22	2	maternal illness	Profound	N/R	Some	N	Cantonese

* N/K indicates that the cause of deafness was not known
† N/R indicates that no response was given

7.2.2 Stimuli

Twenty BSL signs were selected for the study. All referred to concrete objects, were easily glossed into English, and were commonly known signs for Deaf signers and hearing learners of BSL (actual sign familiarity data is not available for BSL). Five signs were formationally and morphologically similar (FM, see Figure 7.1a), five were formationally and morphologically dissimilar (fm, see Figure 7.1b), five were only formationally similar (Fm, see Figure 7.1c) and five were only morphologically similar (fM, see Figure 7.1d). The English glosses of the twenty signs are shown in Table 7.3.

7.2.2.1 Criteria for formational similarity.

Signs in formationally similar lists (FM, Fm) shared the same handshape (a fist) and place of articulation (neutral space in front of the

signer)[6]. They differed in terms of the number of hands used, orientation and type of movement (see Section 2.2.2.1), analogous to the HAND gestures analysed by Goldin-Meadow et al. (1995). Formationally dissimilar lists (fM, fm) contained signs that differed in terms of all parameters (handshape, place of articulation, orientation, movement and number of hands used). If a pair of signs shared handshape or movement, then that pair was given a similarity score of 1; if a pair of signs shared articulation, then that pair received a score of 2. Articulation was given extra weighting following the weighting system employed by Hamilton and Holzman (1989), as a result of the findings reported by Klima and Bellugi (1979), These marks were cumulative, such that a pair of signs that shared all three parameters received a similarity score of 4. Mean similarity scores for each list (averaged over all 10 sign pairs in each list) were FM = 1.8, Fm = 1.7, fM = 0.0 and fm = 0.1.

Table 7.3: English glosses of signs used in Experiment 1.

Stimulus Set	Sign 1	Sign 2	Sign 3	Sign 4	Sign 5
FM	SAW	BAR	IRON	SNOOKER	CANOE
fM	RING-PULL	CONTACT-LENS	RING	SALT	STAMP
Fm	BICYCLE	GRINDER	BONE	JAIL	CHAIR
fm	SWEET	TROUSERS	RADIO	VASE	BADGE

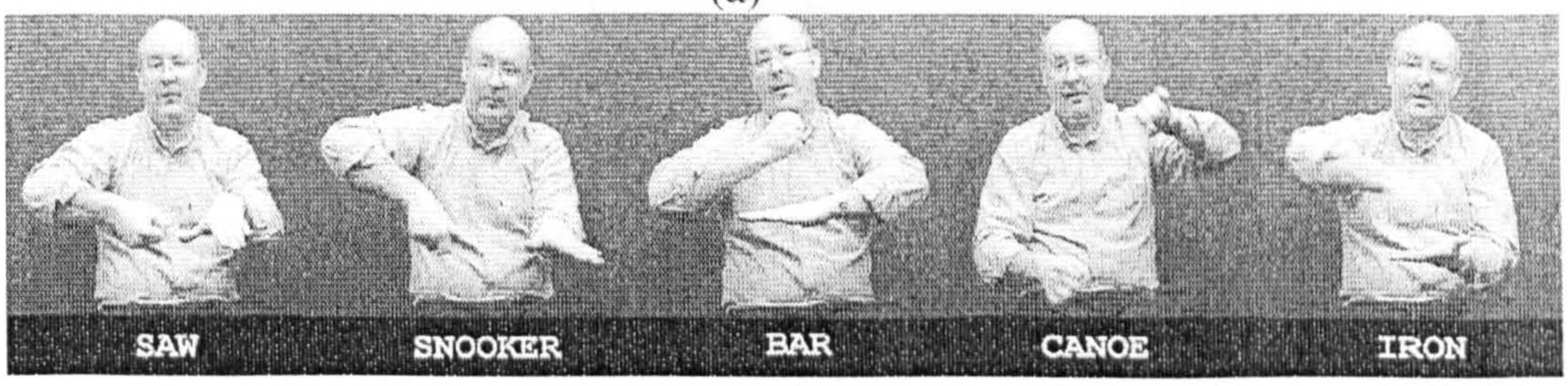
7.2.2.2 Criteria for morphological similarity.

Morphologically similar lists contained signs representing an animate agent manipulating an object (see Section 2.2.2.3). In the FM list, the objects were thin and cylindrical (e.g. CANOE, SNOOKER); in the fM list, the objects were small (e.g. CONTACT-LENS, STAMP). The choice of thin and cylindrical objects resulted in the use of a fist (A-hand) for all signs in the list; the choice of small allowed the signs in the list to vary in terms of handshape. Morphologically dissimilar lists were composed from signs that depicted varying agent-action constructions. It was not clear how a metric of

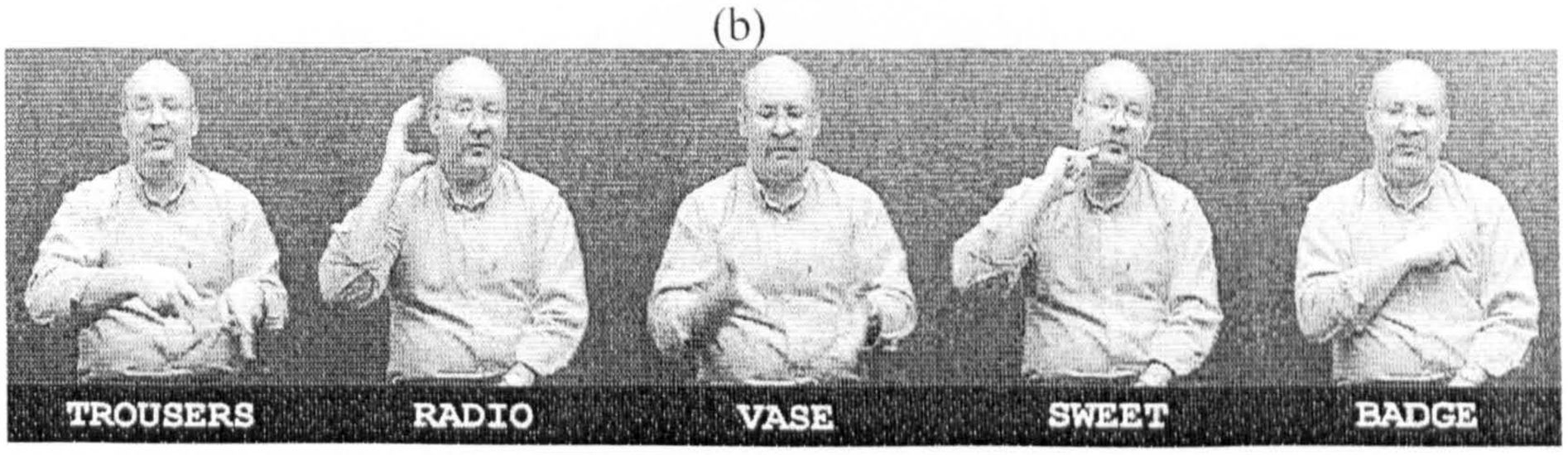
[6] Except sign 3 in the Fs list (BONE), which is articulated on the left elbow.

semantic/morphological similarity could be constructed, and no such metric was employed in this study.

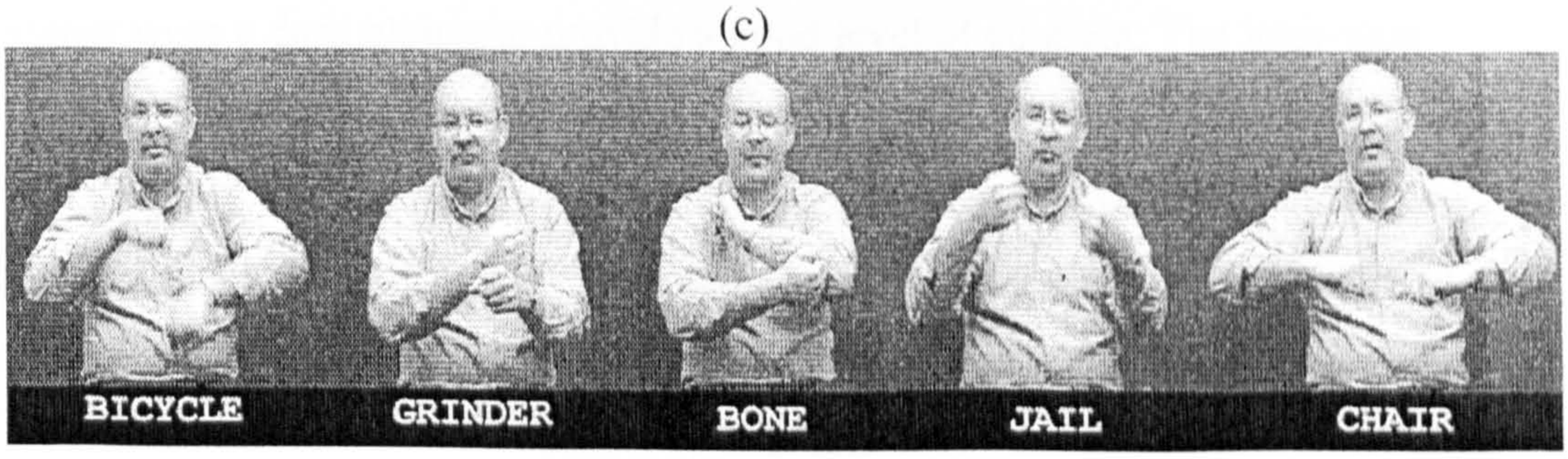
(a)



(b)



(c)



(d)

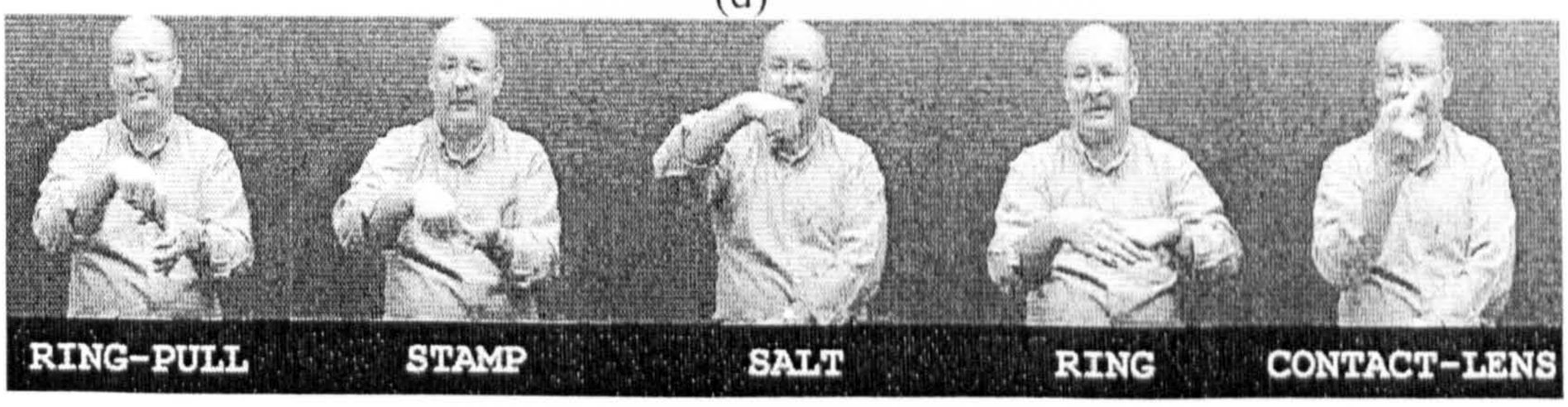


Figure 7.1: (a) The formationally and morphologically similar (FM) list, (b) the formationally and morphologically dissimilar (fm) list, (c) the formationally similar but morphologically dissimilar (Fm) list, and (d) the formationally dissimilar but morphologically similar (fM) list.

7.2.2.3 Stimulus preparation

Lists of signs were generated from the set of twenty BSL signs. The number of syllables of English glosses of each list was approximately equal. Each list contained all the signs from one of the stimulus groups, and four lists (one from each stimulus group) were copied onto videotapes using a Latin Square design. This process was repeated using a different ordering of the signs, giving a total of eight videotapes (A-H).

A practice tape, consisting of four lists (each containing just four signs) was constructed. The signs used for the practice tape did not appear in the experimental set and the lists were neither formationally nor morphologically similar.

A Deaf native signer of BSL signed all signs on all lists. Each of the eight lists was recorded separately with a list intonation (as reported by the Deaf signing model). Signs were recorded against a white background, and the signer wore a dark blouse to provide a good level of contrast. The inter-sign interval was approximately 1000 msecs, with signs having an average duration of 750 msec. The resulting presentation rate was therefore 0.65 signs/sec (i.e. approximately 2 signs every 3 seconds). Inter-list intervals were not fixed, as participants were not given a fixed time in which to articulate their ordered recall.

7.2.3 Design

The factors of formational and morphological similarity were crossed in an immediate ordered recall task. For each list the number of items recalled in correct serial order was recorded. Lists were presented in eight blocks, which occurred in a different and random order for each participant as a control for order effects. The order of signs within a list was also varied in order to control for intra-list order effects. Lists were presented to both deaf signers and hearing learners of BSL, although the hypotheses were only for the former group.

7.2.4 Apparatus

The videotapes were played to participants on a Panasonic LG 14-inch portable colour television (combined with a VCR). Responses were recorded using a Panasonic S-VHS MS2 Movie Camera, mounted behind the television so that participants did not need to alter their positioning in order to respond.

7.2.5 Procedure

Participants were brought into a quiet room and seated in front of a TV-VCR unit. They were told that they would be shown short lists of signs on the television, and that their task was to sign those lists back to a video camera mounted above the television in the order in which they had just seen them. The practice tape was then played, and any further questions were addressed. Once the participant was comfortable with the task, the eight videotapes (A-H) were played one at a time, in a different (randomly determined) order for each participant. The only constraint upon order of video presentation was that tapes from set A-D were alternated with tapes from set E-H. After each list, the tape was paused by the experimenter and the participant was allowed to respond, before restarting the tape. Participants were asked to indicate signs in the list that they had forgotten using a sign glossable as DISAPPEARED-FROM-MIND or FORGOTTEN.

7.2.6 Scoring

The experimenter scored the videotaped responses. Unclear or unknown responses were referred to a Deaf native signer. For each list, an item-and-position score was calculated. For item-and-position scoring, the participant scores 1 for each sign recalled in correct list position (scoring 5 for a perfectly recalled list). For each participant, for each stimulus group, the number of items recalled in correct list position was calculated. An item-only score was not calculated. As participants were instructed to recall the signs in the list order, they may have withheld item responses where they were unsure of the position. For this reason, a measure of the number of items recalled regardless of serial position would be both underestimated and unreliable.

7.3 Results

The number of items recalled in correct list position (item-plus-position scoring) was counted for each list type (FM, Fm, fM, fm), block (1-8) and participant.

Figure 7.2 presents means by block for the deaf and hearing groups for each of the four list types over the 8 blocks. In general, performance improved as the block number increased (presumably a learning effect), and hearing learners of sign started to improve before Deaf signers. No differences in improvement between the sign lists are apparent. This learning effect was significant, $F(7, 98) = 8.32$, $p < .005$. Analyses were restricted to data from blocks 1 and 2 in order avoid the influence of ceiling effects, which may disguise any differences in recall between the list types.

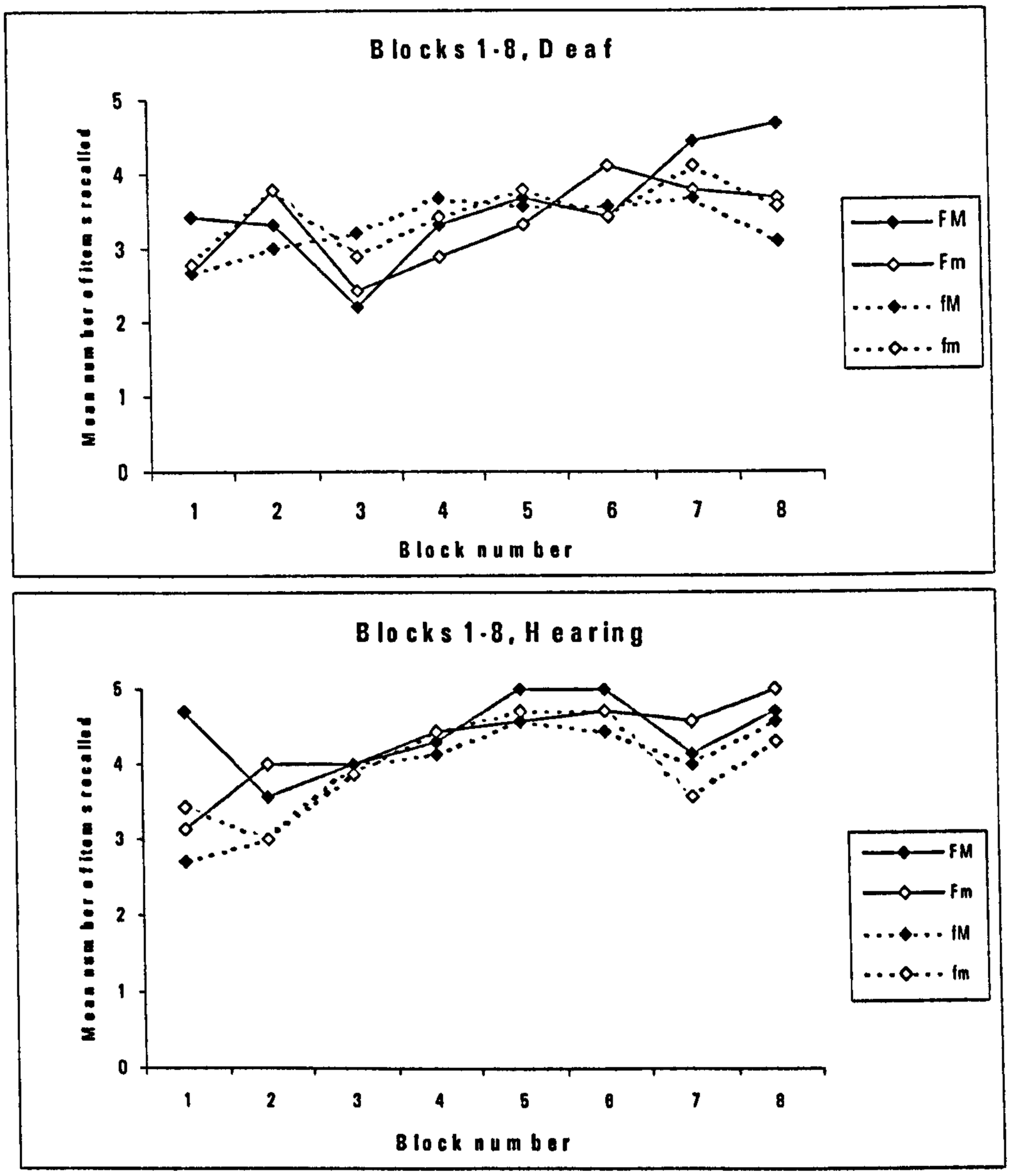


Figure 7.2: Mean number of items recalled in correct serial position by presentation block and list type for deaf signers of BSL (upper panel) and hearing learners of BSL (lower panel).

Table 7.4: Errors by List Similarity for Deaf Signers, Experiment 1.

List Type	Mean	SE (Mean)	SD
Item Errors			
FM	1.11	0.57	1.72
Fm	1.28	0.41	1.24
fM	1.56	0.48	1.45
fm	1.17	0.71	2.12
Order Errors			
FM	1.00	0.67	2.00
Fm	1.00	0.44	0.32
fM	1.22	0.46	0.39
fm	1.00	0.37	0.12
Order Errors per Item			
FM	0.15	0.09	0.28
Fm	0.15	0.07	0.20
fM	0.20	0.08	0.23
fm	0.15	0.05	0.17

Table 7.5: Errors by List Similarity for Hearing Signers, Experiment 1.

List Type	Mean	SE (Mean)	SD
Item Errors			
FM	0.22	0.20	0.53
Fm	1.21	0.81	2.15
fM	1.29	0.65	1.72
fm	1.36	0.61	1.60
Order Errors			
FM	1.29	0.61	1.60
Fm	0.43	0.30	0.79
fM	1.71	0.61	1.60
fm	0.86	0.40	1.07
Order Errors per Item			
FM	0.14	0.07	0.17
Fm	0.06	0.04	0.10
fM	0.21	0.06	0.17
fm	0.11	0.05	0.14

Examination of the item error scores suggests that recall of items was achieved with a high degree of success. On average, participants (deaf and hearing) failed to recall just over one item. For hearing signers there appear to be far more items recalled correctly for the FM list, suggesting that the

similarity of form and morphological motivation were a useful cue to recalling items in combination.

The order error scores provide data about the number of items recalled in an incorrect serial position. For deaf signers, these errors are evenly distributed across different list types with one item (on average) being recalled in the wrong serial position. For hearing signers, on the other hand, there appears to be a greater number of order errors for lists of signs with similar morphological motivations. This suggests that hearing signers may be coding the signs in terms of their morphological characteristics.

Order errors per item controls for a potential confound: recalling more items results in a greater probability of making an order error. Using this measure the data appear to tell the same story. For deaf signers there is still little difference between list types. However, if a hearing signer recalls an item, it appears there is a greater chance of recalling it in the wrong serial position if the list contains signs with similar morphological motivations.

In order to test the experimental hypotheses, two-way repeated measures ANOVAs were performed separately for deaf and hearing participants to examine the effects of formational and morphological similarity for each of the three dependent measures.

7.3.1 Deaf Participants

7.3.1.1 Item Errors

For deaf participants, neither main effect nor the two-way interaction approached significance for the number of item errors produced (Table 7.6).

Table 7.6: Results of Two-way ANOVA, Item Errors, Deaf participants, Blocks 1 and 2, Experiment 1

Effect	F	df	Sig.	Power
FORM	0.39	1, 8	0.550	0.09
MORPH	0.17	1, 8	0.692	0.07
FORM * MORPH	1.51	1, 8	0.254	0.19

7.3.1.2 Order Errors

For deaf participants, neither main effect nor the two-way interaction approached significance for the number of order errors produced (Table 7.7).

Table 7.7: Results of Two-way ANOVA, Order Errors, Deaf participants, Blocks 1 and 2, Experiment 1

Effect	F	df	Sig.	Power
FORM	0.12	1, 8	0.738	0.06
MORPH	0.15	1, 8	0.719	0.06
FORM * MORPH	0.05	1, 8	0.822	0.06

7.3.1.3 Order Errors per Item

For deaf participants, neither main effect nor the two-way interaction approached significance for the number of order errors produced per item recalled (Table 7.8).

Table 7.8: Results of Two-way ANOVA, Order Errors per Item, Deaf participants, Blocks 1 and 2, Experiment 1

Effect	F	df	Sig.	Power
FORM	0.33	1, 8	0.581	0.08
MORPH	0.27	1, 8	0.620	0.07
FORM * MORPH	0.18	1, 8	0.684	0.07

7.3.2 Hearing Participants

7.3.2.1 Item Errors

For hearing participants, there was a significant main effect of formational similarity: $\underline{F}$ (1, 6) = 8.94, $p < .05$. No other effects approached significance (Table 7.9). The data in Table 7.5 show that the significant main effect of formational similarity was due to hearing participants making more items errors from formationally dissimilar lists ($\underline{M}$ = 1.33) than from formationally similar lists ($\underline{M}$ = 0.72). Although this appears to be due to the influence of the FM lists, and not the Fm lists, the interaction was not significant.

Table 7.9: Results of Two-way ANOVA, Item Errors, Hearing participants, Blocks 1 and 2, Experiment 1

Effect	F	df	Sig.	Power
FORM	*8.94*	*1, 6*	*< 0.05*	*0.70*
MORPH	2.51	1, 6	0.164	0.27
FORM * MORPH	3.23	1, 6	0.122	0.33

7.3.2.2 Order Errors

For hearing participants, neither main effect nor the two-way interaction approached significance for the number of order errors produced (Table 7.10).

Table 7.10: Results of Two-way ANOVA, Order Errors, Hearing participants, Blocks 1 and 2, Experiment 1

Effect	F	df	Sig.	Power
FORM	2.84	1, 6	0.143	0.30
MORPH	1.64	1, 6	0.248	0.19
FORM * MORPH	0.00	1, 6	1.000	0.05

7.3.2.3 Order Errors per Item

For hearing participants, neither main effect nor the two-way interaction approached significance for the number of order errors produced per item recalled (Table 7.11).

Table 7.11: Results of Two-way ANOVA, Order Errors per Item, Hearing participants, Blocks 1 and 2, Experiment 1

Effect	F	df	Sig.	Power
FORM	2.42	1, 6	0.171	0.26
MORPH	1.45	1, 6	0.274	0.18
FORM * MORPH	0.11	1, 6	0.753	0.06

7.3.3 Serial Position

The data from blocks 1 and 2 were collapsed across list type in order to examine the effect of serial position. The data reported in Table 7.12 and

Table 7.13 suggest that, for both deaf and hearing participants, signs occurring earlier in a list are more likely to be recalled than signs occurring later in a list. The number of items recalled in correct list position was entered into a two-way mixed ANOVA, with serial position as a within subjects factor and experimental group (deaf, hearing) as a between subjects factor. There was a significant main effect of serial position, $F(4, 11) = 20.05$, $p < .001$, with signs earlier in the list recalled more accurately than signs later in the list. The interaction between serial position and group was not significant: $F(4, 11) = 0.72$, $p = 0.596$. Finally, there was no significant effect of group: $F(1, 14) = 0.39$, $p = 0.543$. Simple contrasts were performed to further analyse the significant serial position differences (see Table 7.14). Items at list position 1 ($M = 0.90$) were recalled more accurately than items at list position 2 ($\underline{M} = 0.82$); $F(1, 4) = 9.21$, $p < 0.01$. In turn, items at list position 2 ($\underline{M} = 0.82$) were recalled more accurately than items at list position 3 ($\underline{M} = 0.58$); $F(1, 4) = 21.11$, $p < .001$. No other contrasts approached significance.

Table 7.12: Proportion of Items Recalled Correctly for each List Position, Hearing participants, Blocks 1 and 2, Experiment 1

List Position	Mean (SE)
1	0.91 (0.04)
2	0.82 (0.04)
3	0.59 (0.07)
4	0.57 (0.04)
5	0.55 (0.05)

Table 7.13: Proportion of Items Recalled Correctly for each List Position, Deaf participants, Blocks 1 and 2, Experiment 1

List Position	Mean (SD)
1	0.89 (0.03)
2	0.82 (0.06)
3	0.57 (0.09)
4	0.51 (0.11)
5	0.40 (0.09)

Table 7.14: Simple Contrasts for Effect of Serial Position, All participants, Blocks 1 and 2, Experiment 1.

Simple Contrast	F	df	Sig.
Position 1 vs. Position 2	*9.21*	*1, 4*	*0.009*
Position 2 vs. Position 3	*21.11*	*1, 4*	*< 0.001*
Position 3 vs. Position 4	0.58	1, 4	0.461
Position 4 vs. Position 5	3.31	1, 4	0.090

7.4 Discussion

Data were collected from four types of list, varying factorially in their formational and morphological similarity. There were three dependent measures: (1) the number of items recalled (regardless of whether they were recalled in the correct list position), (2) the number of order errors made, where items were recalled correctly, but in the wrong list positions, and (3) the number of order errors made per list item correctly recalled.

All participants (Deaf signers and hearing learners of BSL) improved in terms of the number of items recalled as they were exposed to more blocks of trials. The improvement for Deaf signers was not as pronounced as that for hearing learners. Given that only four lists of (five) signs were used, each list being shown eight times (four times in one order, four times in another), improvement in recall performance is not a surprising result. Clearly participants noticed the repetition of stimuli and both groups reported using mnemonic and imagery techniques to help them as the task progressed. Indeed, the majority of participants reported constructing meaningful narratives to help them recall lists, and reported these as more helpful in later trials. It has been reported that deaf children use spontaneous rehearsal strategies in a similar way to their hearing peers, although the deaf children's strategies are less efficient (Liben, 1979). The fact that both groups improved suggests that all participants may have employed some kind of strategy to improve performance. It would also appear that the strategies employed by the Deaf participants were less effective or less efficient than those utilised by the hearing participants. An alternative is simply that the repetitive nature of the task boosted performance in later trials. The superior improvement of hearing

learners may therefore be attributed to more efficient rehearsal of stimulus items.

The data reported in Experiment 1 support neither formational theories of STM representation nor morphological theories such as semantic phonology. For Deaf signers there were no significant effects of either formational or morphological similarity, and these factors did not significantly interact. However, hearing learners of BSL recalled more items correctly when items within a list were formationally similar. The most likely interpretation is that hearing learners are using the formational similarity as a cue to recall. They recode the signs into a speech-based code for storage and rehearsal, and then 'retranslate' into BSL for signed recall. Knowing that the sign must possess a certain handshape reduces the number of possible options when translating from the speech code into BSL. Thus the number of alternative words is reduced.

Deaf signers showed evidence of subvocal rehearsal (mouth movements and self-reports) and may also have been recoding into English. The lack of a list of items with similar speech properties precludes firm conclusions from being drawn. Indeed, the data do not allow any firm conclusions to be drawn about the type of encoding either the Deaf or hearing signers employed. It is interesting to note that the formational similarity of some lists was not used as a cue for recalling items.

It is important to note that statistical power is low for most effects; an acceptable power level is usually 0.80. A very large increase in sample size would be required to attain this level of statistical power, an increase beyond the limitations imposed by participant recruitment problems (see Section 6.2.3). Care must be taken, therefore, when accepting null hypotheses on the basis of non-significant trends.

Three main alternatives are apparent: (1) the signs were encoded in terms of their formational or morphological parameters, but the design was not sensitive enough to pick up the effects of this encoding; (2) the signs were encoded as 'signs' but not formationally or morphologically - possibly using a visual or image-based code; (3) the signs were recoded into a speech-based

form, and the Deaf signers were not cognitively sophisticated enough to use the formational similarity as a cue to recall. The final option is feasible, as some authors have reported the use of phonological speech-based codes by Deaf participants (Hamilton & Holzman, 1989; Hanson, 1982; Lichtenstein, 1985/1998) based upon phonetic similarity effects in the recall of visually presented words. However, studies using signed presentation of stimuli have consistently found no phonetic similarity effect (Hamilton & Holzman, 1989; Hanson, 1982). Nevertheless, Experiment 1 was repeated (see Experiment 2) with the addition of an oral articulatory suppression task. This task was intended to discourage the use of a speech-based code by both groups of participants.

Serial position effects are consistent to those commonly reported for ordered recall tasks: earlier list items are recalled more accurately, but later items are recalled more poorly. This is taken to indicate more rehearsal time for earlier list items, with ordered recall instructions meaning that recall of later items is interfered with by the articulation of those earlier items, hence the lack of a recency effect.

8 Experiment Two: Ordered Signed Recall of Lists Varying in Formational and Morphological Similarity with Articulatory (Speech) Suppression

8.1 Introduction

The results of Experiment 1 suggested that the participants may have had access to, and employed, a speech-based code. Despite the use of signed stimulus lists and a signed recall format, participants may have recoded BSL signs into English in order to maintain and rehearse items for this ordered recall task. One way in which recoding can be prevented is by interfering with the articulatory rehearsal loop of the STM store. Presenting participants with an articulatory suppression task during stimulus presentation (Baddeley, Lewis & Vallar, 1984) can do this. MacSweeney, Campbell and Donlan (1996) have used vocal articulatory suppression with Deaf participants in an examination of coding strategies in British Deaf teenagers. The suppression task they used was the repetition of the English word 'because' during stimulus presentation. Such a task can be used with Deaf participants, although in hearing participants it does depend upon voicing of the word if not upon its perception by the speaker; the suppression effect persisting in hearing participants when auditory feedback is prevented (Macken & Jones, 1995). Experiment 1 was therefore repeated with two modifications: (a) participants were required to articulate (voiced or unvoiced) the word 'the' during list presentation (intended to prevent recoding of signs into a speech-based code) and (b) after the practice trials, only two experimental blocks of trials were run for each participant (in order to shorten testing time and avoid the ceiling effects due to practice observed in Experiment 1).

8.2 Method

8.2.1 Participants

Participants were eight profoundly deaf signers of BSL who were all employed or studying at the Centre for Deaf Studies (University of Bristol). There were also eight hearing learners of BSL, who were also employed or

studying at the Centre for Deaf Studies (Bristol). Requirements for use of and exposure to BSL were the same as in Experiment 1. Demographic data are presented in Table 8.1 and Table 8.2.

Table 8.1: Mean age of participants in Experiment 2.

Group	M	SD	Range	n
Deaf signers	38.88	11.91	23-55	8
Hearing learners	35.50	5.37	29-43	8

Table 8.2: Deafness demographics of Deaf sample in Experiment 2.

Gender	Age	Onset of deafness	Cause of deafness	Level of deafness	dB loss in best ear	Lip-reader?	Deaf relatives?	Primary language
F	23	birth	premature birth	Profound	119dB	Y	N	English
M	44	birth	hereditary	Profound	N/R	N	Y	Bilingual
F	55	birth	hereditary	Profound	N/R	Some	Y	BSL
M	36	birth	maternal illness	Profound	N/R	Some	N	BSL
M	22	birth	rubella	Profound	N/R	Y	N	BSL
F	40	birth	hereditary	Severe	N/R	Some	Y	BSL
M	54	birth	rubella	Profound	N/R	Y	N	Bilingual
F	34	birth	N/R	Profound	N/R	N	Y	BSL

All participants agreed to have their responses recorded by video camera prior to initiation of the study, and offered their participation for free.

8.2.2 Stimuli

Same as in Experiment 1.

8.2.3 Materials

Same as in Experiment 1.

8.2.4 Design and Procedure

The design and procedure were similar to that in Experiment 1 except for the following details. Only two of the videotapes were selected for presentation to each participant, such that each list type was seen twice and each pair did not use the same stimulus order. During list presentation, participants were instructed to repeatedly articulate the word 'the'. For Deaf participants this articulation could be either voiced or unvoiced.

8.2.5 Scoring

Same as in Experiment 1.

8.3 Results

The number of list items recalled in correct list position (item-plus-position scoring) was calculated for each group (Deaf, hearing) and list type (FM, Fm, fM, fm). Descriptive statistics are presented in Table 8.3 for Deaf participants and in Table 8.4 for hearing participants.

For deaf signers there do not appear to be large discrepancies in the number of item errors made as a function of list similarity. However, for both order errors and order errors per item, morphologically similar lists appear to result in more errors than do morphologically dissimilar lists. This suggests the possibility of encoding in terms of morphological parameters of the signs.

Table 8.3: Errors by List Similarity for Deaf Signers, Experiment 2.

List Type	Mean	SE (Mean)	SD
Item Errors			
FM	1.69	0.71	2.00
Fm	2.13	0.80	2.25
fM	1.94	0.52	1.46
fm	1.44	0.64	1.81
Order Errors			
FM	2.13	0.48	1.36
Fm	1.63	0.46	1.30
fM	2.38	0.32	0.92
fm	1.88	0.40	1.13
Order Errors per Item			
FM	0.33	0.06	0.17
Fm	0.28	0.06	0.16
fM	0.40	0.06	0.17
fm	0.28	0.06	0.18

For hearing signers, morphological similarity appears to result in fewer item errors, more order errors and more order errors per item. This suggests that morphological similarity can act as a cue for recalling items, yet interferes with the recall of items in the correct order. Once again, this may be due to encoding in terms of morphological, not formational, parameters.

Table 8.4: Errors by List Similarity for Hearing Signers, Experiment 2.

List Type	Mean	SE (Mean)	SD
Item Errors			
FM	1.61	0.60	1.79
Fm	2.28	0.41	1.24
fM	1.78	0.34	1.01
fm	2.00	0.50	1.50
Order Errors			
FM	1.89	0.42	1.27
Fm	0.78	0.28	0.83
fM	1.44	0.60	1.81
fm	0.78	0.22	0.67
Order Errors per Item			
FM	0.28	0.07	0.20
Fm	0.17	0.06	0.19
fM	0.25	0.11	0.34
fm	0.14	0.05	0.15

In order to test the experimental hypotheses, two-way repeated measures ANOVAs were performed separately for deaf and hearing participants to examine the effects of formational and morphological similarity for each of the three dependent measures.

8.3.1 Deaf Participants

8.3.1.1 Item Errors

For deaf participants, neither main effect nor the two-way interaction approached significance for the number of item errors produced (Table 8.5).

Table 8.5: Results of Two-way ANOVA, Item Errors, Deaf participants, Blocks 1 and 2, Experiment 2

Effect	F	df	Sig.
FORM	0.78	1, 7	0.406
MORPH	0.04	1, 7	0.857
FORM * MORPH	2.56	1, 7	0.154

8.3.1.2 Order Errors

For deaf participants, neither main effect nor the two-way interaction approached significance for the number of order errors produced (Table 8.6).

Table 8.6: Results of Two-way ANOVA, Order Errors, Deaf participants, Blocks 1 and 2, Experiment 2

Effect	F	df	Sig.
FORM	0.18	1, 7	0.681
MORPH	2.55	1, 7	0.155
FORM * MORPH	0.00	1, 7	1.000

8.3.1.3 Order Errors per Item

For deaf participants, neither the main effect of formational similarity nor the two-way interaction approached significance for the number of order errors produced per item recalled (Table 8.7). However, the main effect of morphological similarity did approach significance ($p < .10$). More order errors per item were made for morphologically similar lists ($\underline{M} = 0.37$) than for morphologically dissimilar lists ($\underline{M} = 0.28$).

Table 8.7: Results of Two-way ANOVA, Order Errors per Item, Deaf participants, Blocks 1 and 2, Experiment 2

Effect	F	df	Sig.
FORM	0.23	1, 7	0.644
MORPH	*3.83*	*1, 7*	*0.091*
FORM * MORPH	0.68	1, 7	0.436

8.3.2 Hearing Participants

8.3.2.1 Item Errors

For hearing participants, there was a significant main effect of morphological similarity: $F(1, 8) = 7.21$, $p < .05$. No other effects approached significance (Table 8.8). The data in Table 8.4 show that the significant main effect of morphological similarity was due to hearing participants making more items errors in morphologically dissimilar lists ($\underline{M} = 2.14$) than in morphologically similar lists ($\underline{M} = 1.70$).

Table 8.8: Results of Two-way ANOVA, Item Errors, Hearing participants, Blocks 1 and 2, Experiment 2

Effect	F	df	Sig.
FORM	0.03	1, 8	0.865
MORPH	*7.21*	*1, 8*	*< .05*
FORM * MORPH	1.54	1, 8	0.249

8.3.2.2 Order Errors

For hearing participants, there was a significant main effect of morphological similarity: $F(1, 8) = 7.21$, $p < .05$. No other effects approached significance (Table 8.9). The data in Table 8.4 show that the significant main effect of morphological similarity was due to hearing participants making more order errors in morphologically similar lists ($\underline{M} = 1.67$) than in morphologically dissimilar lists ($\underline{M} = 0.78$).

Table 8.9: Results of Two-way ANOVA, Order Errors, Hearing participants, Blocks 1 and 2, Experiment 2

Effect	F	df	Sig.
FORM	0.17	1, 8	0.695
MORPH	*7.21*	*1, 8*	*< .05*
FORM * MORPH	0.31	1, 8	0.594

8.3.2.3 Order Errors per Item

For hearing participants, neither main effect nor the two-way interaction approached significance for the number of order errors produced per item recalled (Table 8.10).

Table 8.10: Results of Two-way ANOVA, Order Errors per Item, Hearing participants, Blocks 1 and 2, Experiment 2

Effect	F	df	Sig.
FORM	0.11	1, 8	0.755
MORPH	3.37	1, 8	0.104
FORM * MORPH	0.00	1, 8	0.974

8.3.3 Serial Position

The data from blocks 1 and 2 were collapsed across list type in order to examine the effect of serial position. The data reported in Table 8.11 and Table 8.12 suggest that, for both deaf and hearing participants, signs occurring earlier in a list are more likely to be recalled than signs occurring later in a list. The number of items recalled in correct list position was entered into a two-

way mixed ANOVA, with serial position as a within subjects factor and experimental group (deaf, hearing) as a between subjects factor. There was a significant main effect of serial position, $F(4, 11) = 50.73$, $p < .001$, with signs earlier in the list recalled more accurately than signs later in the list. The interaction between serial position and group was not significant: $F(4, 11) = 0.89$, $p = 0.504$. Finally, there was no significant effect of group: $F(1, 14) = 0.55$, $p = 0.469$. Simple contrasts were performed to further analyse the significant serial position differences (see Table 8.13). Items at list position 1 ($M = 0.78$) were not recalled more accurately than items at list position 2 ($\underline{M} = 0.71$); $F(1, 4) = 4.33$, $p > 0.05$. Items at list position 2 ($\underline{M} = 0.71$) were recalled more accurately than items at list position 3 ($\underline{M} = 0.30$); $F(1, 4) = 62.26$, $p < .001$. No other contrasts approached significance.

Table 8.11: Proportion of Items Recalled Correctly for each List Position, Hearing participants, Blocks 1 and 2, Experiment 2

List Position	Mean (SE)
1	0.78 (0.05)
2	0.75 (0.04)
3	0.38 (0.05)
4	0.31 (0.06)
5	0.27 (0.04)

Table 8.12: Proportion of Items Recalled Correctly for each List Position, Deaf participants, Blocks 1 and 2, Experiment 2

List Position	Mean (SE)
1	0.78 (0.07)
2	0.67 (0.08)
3	0.23 (0.07)
4	0.31 (0.06)
5	0.27 (0.07)

Table 8.13: Simple Contrasts for Effect of Serial Position, All participants, Blocks 1 and 2, Experiment 2.

Simple Contrast	F	df	Sig.
Position 1 vs., Position 2	4.33	1, 4	0.056
Position 2 vs., Position 3	*62.26*	*1, 4*	*<0.001*
Position 3 vs., Position 4	0.02	1, 4	0.881
Position 4 vs., Position 5	1.45	1, 4	0.249

8.4 Discussion

In Experiment 1, lists of signs were presented to deaf signers and hearing learners of sign language for immediate recall. All participants improved as testing progressed, with both deaf and hearing participants reaching ceiling performance by the fourth block of lists. This suggests that both groups were able to recruit strategies to improve performance, possibly involving deeper processing and meaningful linking of stimulus items. Data from both groups of participants, along with experimenter's observations and self-reports, provided correlational evidence that both deaf signers and hearing learners may have been using a speech-based code to perform the task. It is well established that deaf signers have access to more than one STM code, including visual codes (Conrad, 1979), sign-based codes (Poizner et al., 1981) and phonological speech-based codes (Dodd & Campbell, 1987) among others. However, previous studies have suggested that in recall tasks the use of signed stimuli (rather than words or pictures) encourages the use of a sign-based code (Hamilton & Holzman, 1989; Hanson, 1982). Why then would deaf signers have employed a speech-based strategy/code in Experiment 1? One possible factor is the experimental task itself: an ordered recall task. It may be that the temporal nature of the speech channel supports retention of temporal order, whereas spatial languages like BSL are better supported by memory for spatial location (cf. Wilson & Emmorey, 1998b). Deaf participants may therefore have selected a code that was suited to the task in hand: retention and recall of a temporal sequence of items.

In order to control for possible speech-coding, Experiment 2 was designed to discourage the use of a speech-based code. Introducing an oral articulatory suppression task (repeating the word 'the' during stimulus presentation either voiced or unvoiced) did this.

For hearing participants, this removed any benefit to recall obtained on the basis of formational similarity, replacing it with a benefit due to morphological similarity. In addition, morphological similarity led to a greater

number of order errors by hearing participants. However, when the number of order errors was controlled for the number of items recalled, the effect of morphological similarity failed to reach significance. This suggests that the greater number of order errors for morphologically similar lists is attributable to a greater number of items being recalled for those lists, and not to encoding in terms of morphological parameters. It remains to interpret why there was shift from using formational cues to recall to using morphological ones when the suppression task was introduced. A possible explanation lies in the type of strategy that the hearing signers employed. It may be the case that the suppression task placed a greater cognitive load on the participants, and they therefore failed to notice the formational similarity of list items which could be used a cue to recall (see Discussion of Experiment 1). Rather, as reported by many participants in informal post-test interviews, they imagined engaging in a sequence of events in order to remember the list items. This may have brought to the fore morphological properties of the signs, as these are based upon how one interacts with the objects represented by the signs.

For Deaf participants, there was also an effect of morphological similarity upon recall. While it had no significant effect upon either the number of items recalled, or the number of order errors made, its effect on the number of order errors per item recalled approached significance. The data suggest that items from morphologically similar lists, when recalled, were more likely to be recalled in the wrong list position than items recalled from morphologically dissimilar lists.

8.4.1 Theoretical Issues

8.4.1.1 Nature of the sign language code

What then is the evidence for formational and/or morphological coding in the STM of deaf signers and hearing learners of a sign language? In the absence of an oral suppression task (Experiment 1), the ordered recall paradigm employed here offers no clear answers. However, the introduction of an oral suppression task (Experiment 2) significantly changed the pattern of

the data. There was evidence of sign-based coding for Deaf signers, but not for hearing learners. For Deaf signers, the data suggests that the short-term memory code is morphological in nature.

8.4.1.2 Linguistic background of participants

Not all Deaf participants share the same coding resources in STM. Some Deaf people are never exposed to a sign language, and as such could not be expected to develop a sign language code. All of the participants in this study were sign language users, but their linguistic experience still varied greatly (as it does in the Deaf sign language-using community generally). Some profoundly deaf participants were deaf from birth, regarded BSL as their first language, had relatives who were Deaf BSL users, and were not competent lip-readers. One may choose to designate such participants as 'native' signers. It is these 'native' signers one expects to be most likely to have available (and employ) a sign-based code. Others became deaf early in life (after 2 to 3 years), were severely (but not profoundly) deaf, had no Deaf relatives, were proficient lip-readers, and regarded English as their first language. One could refer to these as 'non-native' signers. It is not clear whether these 'non-native' signers have access to a sign-based code, and whether they would choose to employ them in the presented task. Most participants, however, were somewhere between these two extremes. For these participants the terms 'native' and 'non-native' are difficult to assign, and may even be of little value in assessing their ability to use a sign-based code in STM. At present there are no standardised tests of sign language fluency, one measure which may prove useful in determining which participants are more likely to employ a sign-based code. One assumption of this study is that all participants could employ a sign-based code in STM. That assumption is more likely to hold for some participants than others. The small size of the samples used (see later) effectively prohibits further division of the deaf experimental group into 'native' and 'non-native' categories, even if one had a principled set of criteria along which to make such a division.

However, it could be argued that it is of great importance to separate the two groups within an experimental design. The patterns of performance obtained may differ for the two groups, and combining them may mask some effects and generate other spurious effects. Indeed, it is possible that the effects of morphological similarity in Experiment 2 can be attributed to non-native signers. The argument being proposed here is that, for deaf children who are not exposed to a formal sign language when young, the articulatory store/rehearsal loop can store and rehearse manual gestures. That is, the STM store is involved in the cognitive processing of gesture prior to information being transferred to linguistic modules -- it is functioning as a cognitive resource for those deaf children (see Lillo-Martin, 1997, p. 100). If one assumes that the articulatory store and rehearsal loop is predisposed towards accepting and rehearsing linguistic input, then one must account for how non-linguistic manual gestures may gain access to the store/loop in deaf children who are not exposed to a formal sign language. The answer may lie in the self-styled gestural systems employed by some deaf children (Goldin-Meadow and Feldman, 1977). In a series of studies looking at the communicative productions of deaf children without access to a conventional language model, Susan Goldin-Meadow and her colleagues have discovered language-like properties in the gestures of those deaf children. Their research has suggested that in self-styled gestural systems (or "home signing"): (1) the gestures used by deaf children are stable over time (Goldin-Meadow, Butcher, Mylander and Dodge, 1994), (2) the children distinguished lexically between nouns and verbs (Goldin-Meadow et al., 1994), (3) deaf children can inflect gestures used as verbs (Goldin-Meadow et al., 1994), and (4) the gestures used by deaf children can be analysed componentially (Goldin-Meadow, Mylander and Butcher, 1995). In other words, the manual gestures of deaf children have similar properties to the signs of formal sign languages and words of formal spoken languages. Goldin-Meadow, McNeill and Singleton (1996) argue that when manual gesture must carry full responsibility for communication, then it is no longer tied to speech and is constrained by its role in symbolic communication. If this is the case, then the function of STM would still be to

process symbolic and communicative input and pass that input, albeit limited compared to full natural language input, on for further linguistic processing. The morphological similarity effect in recall of the lists for deaf signers in Experiment 2 could therefore be attributed to a gestural code based upon componential parameters from self-styled gestural systems such as those investigated by Goldin-Meadow and colleagues.

8.4.1.3 Defining similarity

The problem of defining a priori what is and is not similar applies to both formational and morphological similarity, although it is perhaps more acute for the latter[7]. The morphologically similar/formationally dissimilar list was formed from signs which represented an agent manipulating a small object. It is not clear whether the morphological similarity of this list is the same as for the other (formationally similar) list containing items representing an agent grasping a thin, cylindrical object. The strong tie between formational and morphological similarity (morphological similarity entails formational similarity) may mean that morphological theories such as semantic phonology (Stokoe, 1991) cannot be explicitly tested by factorial designs which rely upon the structure of stimulus items.

Putting aside the notion of morphological similarity, it is not clear why a formational similarity effect was not more generally obtained. This is particularly so for the morphologically dissimilar lists where similarity had been more reliably controlled for. One interpretation is that the Deaf signers were predominantly non-native, and as such did not have the cognitive capacity to represent the formational structure of the signs in STM (*q.v.*). Another possibility lies in the formational similarity of the items – maybe they were not all that similar (see footnote). As for the 'native' and 'non-native' categories mentioned previously, there is as yet no principled a priori method of determining the intra-list similarity of a set of sign language stimuli. The

stimuli selected for this study were chosen along lines reported in the literature, and decisions were based upon handshape, location of the sign, and the type of movement involved. When devising a set of similar sounding speech stimuli, one would not confine oneself to a decision based upon 'consonants' and 'vowels'. More fine-grained approaches are possible based upon the distinctive or articulatory features of the sounds, such as 'voicing', 'tongue position', and 'lip-rounding'. Using a sign similarity metric based upon feature sets such as those proposed by Sandler (1989) or Liddell and Johnson (1989) may provide a more sensitive research tool. At present, however, it is not clear how such a metric could be implemented.

8.4.1.4 Strategies and task demands

The nature of the task, ordered recall, may have determined the initial (possible) choice of a speech-based code (Experiment 1). The syntax of spoken languages is based upon the temporal order of words in the speech stream. The sentence "John gave the book to Mary " changes meaning if the order of the 'John' and 'Mary' elements is reversed. Sign languages do not generally work in this way. The agent and patient in such a sentence would be determined spatially. Rather than remembering whether John or Mary was the first word in the sentence, a signer would have to remember (a) which spatial location indicated John and which Mary, and (b) the movement path of the sign GIVE. Temporal order is not as important as spatial location. In the ordered recall task is it is the temporal order of a set of unconnected signs that is to be remembered. A speech code may be a more efficient way of encoding this information.

Things changed with the introduction of an oral suppression task. Repeating the word 'the' during stimulus presentation should impair the recoding process that is required for representing signed stimuli in a speech-based code. The suppression task can be deemed effective in that there is

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[7] There is still a problem in determining whether two signs are formationally similar or not. For example, the BSL sign FLOWER can be made with an O-handshape or an F-handshape. It is the same sign, yet the form of the handshape differs. At the same time, smaller handshape changes can result in two different meanings, such as ORDER and AFTERNOON (Bencie Woll, personal

evidence for sign-based coding for Deaf participants in Experiment 2. For Deaf signers the code seems to be morphological in nature (*q.v.*). Clearly, sign-based codes can be used to perform an ordered recall task, although they appear to only have been selected in this study when a speech-based code was blocked. The use of an articulatory suppression task can, however, have other effects. Data from hearing participants in Experiment 2 suggests that the additional load on working memory impairs attention to formational properties of the stimulus items for that group. It may also have had additional effects upon the processing of the Deaf participants. Clearly a design which did not require the use of an articulatory suppression task would be more desirable.

8.4.1.5 Sign-based coding in hearing learners

In Experiment 1, hearing learners of BSL recalled more items from formationally similar lists than from formationally dissimilar lists. All of the hearing learners in this study had some education in sign language linguistics. They were all therefore aware of the way in which signs can be analysed in terms of handshape, location and movement. This explicit knowledge was brought to the task by at least one participant, who reported that she used sign location as a cue to recall of the sign lists. Her technique was to remember the order of locations (e.g. head, chest, cheek, hand, and waist) and use that information as cues to the identity of the signs. It would also have been possible for the hearing participants to note the handshape similarity of the stimulus items and use this information to restrict the set of possible alternatives when recoding from a speech-based code back into BSL for output.

8.4.2 Methodological considerations

There are certain methodological concerns in the present studies that need to be addressed. These concerns are centred on the experimental design and procedure.

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communication).

8.4.2.1 Experiment 2 limited to two blocks

The design for Experiment 2 was limited to only two blocks of trials. The reasons for this were two-fold. An initial analysis of data from Experiment 1 suggested that data from blocks 3 through 8 were at ceiling level. Additionally, the design of Experiment 2 was limited to two blocks in order to decrease the burden on Deaf participants. Asking Deaf signers to engage in an oral articulation task was a sensitive procedure. As members of the British Deaf community, many participants feel a great pride in their use of BSL. In most cases this sense of pride came after years in an educational system which forced them to learn to perceive and produce a spoken language. The same educational system to this day has a negative attitude towards the use of sign language by deaf children. The experiment was conducted under this political climate, and the sensitivities of Deaf participants had to be taken into account when asking them to engage in a task involving the production of spoken English.

8.4.2.2 Between subject design

The two experiments were run at different times, with different participants. Given the large degree of heterogeneity in the deaf population it would have been preferable to use the same deaf participants in both experiments. This would have controlled for individual factors such as linguistic background and language fluency. Obtaining the sample and running the study required a lot of traveling and time, and such a course of action was not possible under the temporal and financial limitations of the research.

8.4.2.3 Randomisation of presentation order

Presentation order was determined using a Latin Square design in Experiment 1. Even so, the small number of participants will have reduced the efficacy of this method. Such a design was not possible in Experiment 2 due to the reduced number of blocks in that design. It would have been preferable to use a randomised presentation order both within and between

lists. This would have required the use of digital video technology and high-specification computing equipment. Such equipment was not available; nor was it practicable in a study that was conducted at four different sites around the UK.

8.4.2.4 Sample size and selection

One major concern of this study is the sample size. There were operational and financial difficulties in obtaining large numbers of Deaf signers for participation in the study. As a result the sample sizes were in single figures, and as a result the generalisability of the findings can be brought into question. The small sample size could have been balanced by using a within subject design, reducing the degree of error by factoring out individual differences (but see Section 8.4.2.2).

8.5 Conclusions

In the absence of an oral articulatory suppression task (Experiment 1), the data were inconclusive. It was not possible to determine whether Deaf signers employed formational or morphological coding. Introducing an oral suppression task (Experiment 2) forced both sets of participants to adopt an alternative coding strategy in order to perform the task. For Deaf signers there was evidence for this code being based upon both the morphological characteristics of the sign stimuli. The morphological aspect of the code may have become available during cognitive development as a result of using self-styled manual-gestural systems or visual action-based codes. There are, however, some methodological improvements that need to be made when following up these findings and seeking replication. The mixed linguistic backgrounds of Deaf participants needs to be more closely controlled for: those exposed to BSL from an early age may use a solely formational code, with those brought up in the absence of a formal signing system more reliant upon morphological aspects of the language. Also, clearer and more accurate measures of formational and morphological similarity are required if the data are not to be attributed to ambiguities in stimulus selection. The number of

potential list items should also be increased, so that participants do not become over-familiar with the response set.

9 Experiment Three: Immediate Serial Recall of Sign Lists by Native and Non-native Signers of BSL

9.1 Introduction

9.1.1 Methodological Changes from Experiments 1 and 2

The design of Experiment 3 differs from that of Experiment 1 in five key ways. Experimental lists were presented as digital video clips on a PC in order to facilitate counterbalancing of presentation order. The precise effects of the suppression tasks used in Experiments 1 and 2 were not clear. So the experimental lists were designed to be harder to recall without the need for a suppression task. In order to do this, the list length was increased from 5 to 7 items, and the rate of presentation was also increased. The increase in both number of items and rate of presentation was planned to provide an increase in cognitive load from baseline (Experiment 1), as did the suppression task used previously. As the fM category of signs proved to be both theoretically and practically awkward, the fM condition was removed from Experiment 3. Non-native signers were used rather then hearing learners of BSL. Whilst hearing learners of BSL provided a useful control group in Experiments 1 and 2, Experiment 3 focused more closely upon differences between Deaf native and non-native signers.

9.1.2 Hypotheses for Experiment 3

Native signers represent signs formationally in STM and have access to sign-based lexical representations. The pattern of results should indicate fewer item errors and more order errors (per item recalled) for formationally similar lists when compared with formationally dissimilar lists.

Non-native signers, particularly those who used gesture as children, represent signs in STM as actions/gestures formed on the basis of meaningful parameters. There will be fewer item errors and more order errors (per item recalled) only when lists are morphologically similar, relative to morphologically dissimilar lists.

H_1: Native signers will generate fewer item errors for the formationally similar lists, relative to the formationally dissimilar lists **and** native signers will generate more order errors per item for formationally similar lists, relative to formationally dissimilar lists.

H_2: Non-native signers will generate fewer item errors for morphologically similar lists, relative to the morphologically dissimilar lists **and** non-native signers will generate more order errors per item for morphologically similar lists, relative to morphologically dissimilar lists.

9.2 Method

9.2.1 Participants

Participants were ten native signers of BSL (native) and ten non-native signers of BSL (non-native). Participants were allocated to the native group if they reported learning BSL before the age of 5 years. Demographic, linguistic and family data for participants are given in Table 9.1 and Table 9.2. Participants were tested individually in one 40-minute session, and were paid GBP£4 for their participation.

Table 9.1: Demographic characteristics of Native Signers in Experiment 3.

Gender	Age Deaf	Father Deaf	Mother Deaf	Sibling Deaf	Other Deaf	Age First Saw BSL	Age First Learned BSL	Self-rated Sign Skill	First Language	Age
Female	Birth	Yes	Yes	No	Yes	< 5 years	< 5 years	Very good	BSL	42
Male	Birth	Yes	Yes	Yes	No	< 5 years	< 5 years	Very good	BSL	40
Male	Birth	Yes	Yes	Yes	Yes	< 5 years	< 5 years	Very good	BSL	21
Female	Birth	No	No	Yes	No	< 5 years	< 5 years	Very good	BSL	35
Female	< 3 yrs	Yes	Yes	Yes	Yes	< 5 years	< 5 years	Very good	BSL	46
Female	Birth	Yes	Yes	Yes	Yes	< 5 years	< 5 years	Very good	BSL	46
Male	Birth	Yes	Yes	Yes	Yes	< 5 years	< 5 years	Very good	BSL	21
Male	Birth	Yes	Yes	Yes	Yes	< 5 years	< 5 years	Very good	BSL	45
Female	Birth	Yes	Yes	Yes	Yes	< 5 years	< 5 years	Good	BSL/English	16
Female	Birth	Yes	Yes	Yes	Yes	< 5 years	< 5 years	Good	BSL	20

Table 9.2: Demographic characteristics of Non-native Signers in Experiment 3.

Gender	Age Deaf	Father Deaf	Mother Deaf	Sibling Deaf	Other Deaf	Age First Saw BSL	Age First Learned BSL	Self-rated Sign Skill	First Language	Age
Female	Birth	No	No	No	No	6-10 yrs	6-10 yrs	Very good	English	23
Male	< 6 yrs	No	No	Yes	No	6-10 yrs	6-10 yrs	Good	English	40
Female	Birth	No	No	No	No	11-18 yrs	11-18 yrs	Good	Hebrew	45
Female	Birth	No	No	Yes	No	11-18 yrs	> 18 yrs	Average	English	24
Female	< 3 yrs	No	No	No	No	6-10 yrs	6-10 yrs	Good	English	39
Male	Birth	No	No	Yes	No	6-10 yrs	11-18 yrs	Good	English	25
Female	Birth	No	No	Yes	No	6-10 yrs	6-10 yrs	Very good	English	18
Male	Birth	No	No	No	No	6-10 yrs	6-10 yrs	Average	BSL	19
Female	< 3 yrs	No	No	No	No	11-18 yrs	11-18 yrs	Good	Cantonese	26
Female	Birth	No	No	No	No	11-18 yrs	> 18 yrs	Good	BSL	31

9.2.2 Stimuli and Materials

9.2.2.1 Recording, Editing and Presentation

Stimuli were lists of BSL signs presented as QuickTime™ movie files. The stimuli were recorded using a Sony digital camcorder (Model No.DCR-TRV900E), with a native BSL signer as a model. The model sat on a chair without arms, in front of a plain blue background in order to enhance stimulus contrast. The stimulus tape was converted to 25 frame per second QuickTime™ format using AV Capture™ on an IBM PC and edited into lists using Quick Editor™. Stimuli were displayed on a 15" colour monitor, with a screen resolution of 1024 * 768 pixels and a 75 Hz refresh rate. They were presented using Apple QuickTime Player 4.0, with each trial initiated manually by the experimenter. Two deaf signing informants certified that the stimuli were easily identifiable at a distance of 60 cm. Signs within lists were presented consecutively, with no inter-stimulus interval, and an approximate presentation rate of 1.7 signs per second.

9.2.2.2 List Manipulation

Lists were created from three sets of BSL signs: (1) a formationally similar set which represented similar actions (FM), (2) a formationally similar set which did not represent similar actions (Fm), and (3) a formationally dissimilar set which did not represent similar actions (fm).

The FM set contained the BSL signs: BAR, SAW, CANOE, SNOOKER, IRON, PRAM, BUS, BAG, GYM and MOTORBIKE. The formational parameters of these signs are given in Table 9.3. These signs represented similar actions in that they all represent a person grasping a thin cylindrical object, i.e. they share the agent, action and patient properties (see Table 9.4).

Table 9.3: Formational Parameters of Signs from the FM Set.

Gloss	Formational Parameters[8]				Duration[9]
	Hands	Handshape	Location	Movement	
BAR	2	A (B)	NS (Chest) C	Short, backward	1933
SAW	2	A (C)	NS (Abdomen) C	Forward-and-back	2400
CANOE	2	A A	NS (Abdomen) C	Left-and-right	2433
SNOOKER	2	A (B)	NS (Abdomen) C	Wrist flexion	2033
IRON	2	A (B)	NS (Abdomen) C	Left-and-right	2500
PRAM	2	A A	NS (Abdomen) C	Forward-and-back	2000
BUS	2	A A	NS (Abdomen) C	Up-and-down	1750
BAG	1	A	NS (Abdomen) R	Up-and-down	1700
GYM	2	AA	Chest LR	Forward-and-back	2067
MOTORBIKE	2	AA	NS (Abdomen) LR	Twisting of wrist	2067

Table 9.4: Semantic Descriptions of Signs from the FM Set.

Gloss	Actor	Action	Patient	Mimetic Description
BAR	Person	Grasping + Pulling	Beer Pump	Pulling a pint of beer
SAW	Person	Grasping + Pulling + Pushing	Saw Handle	Sawing some wood
CANOE	Person	Grasping + Moving Sideways	Canoe Paddle	Paddling a canoe
SNOOKER	Person	Grasping + Pushing	Snooker Cue	Cueing a snooker ball
IRON	Person	Grasping + Moving Sideways	Iron Grip	Ironing some clothes
PRAM	Person	Grasping + Pushing	Pram Handle	Pushing pram
BUS	Person	Grasping + Turning	Steering Wheel	Driving a bus
BAG	Person	Grasping + Lifting	Bag Grip	Lifting a bag
GYM	Person	Grasping +Lifting	Dumbbell grip	Lifting weights
MOTORBIKE	Person	Grasping + Twisting	Bike throttle	Revving a motorbike

The Fm set contained the signs: FERRY, FAMILY, KNIFE, FATHER, KISS, DIVORCE, TENT, TOWER, NEWS and LUNCH. The formational

[8] Hands is the number of hands required to articulate the sign; the 'A' handshape consists of a fist, and the handshape given in parentheses is the handshape upon which the A-hand acts (AA means that two A handshapes act in parallel); NS means the 'neutral space' in front of the signer, with the height indicated in brackets and the horizontal position indicated afterwards (C = central, R = right, L = left).

[9] Duration is measured from initial resting position to final resting position (in milliseconds)

parameters of these signs are given in Table 9.5. The actions depicted by the signs do not share agent, action and patient properties (see Table 9.6).

Table 9.5: Formational Parameters of Signs from the Fm Set.

	Formational Parameters[10]				
Gloss	**Hands**	**Handshape**	**Location**	**Movement**	**Duration**
FERRY	2	HH	NS (Abdomen) C	Forwards	2233
FAMILY	2	H(H)	NS (Abdomen) C	Circling	2133
KNIFE[11]	2	HH	NS (Abdomen) C	Tapping1	1833
FATHER	2	HH	NS (Abdomen) C	Tapping1	1433
KISS	2	H(H)	NS (Abdomen) C	Downwards	1433
DIVORCE	2	HH	NS (Abdomen) C	Sideways	1567
TENT	2	HH	NS (Abdomen) C	Down and Apart	1567
TOWER	2	HH	NS (Chest) C	Up and Together	1733
NEWS	2	HH	NS (Chest) C	Forward and Back	1400
LUNCH	2	HH	NS (Mouth) C	Up and Down	1467

Table 9.6: Semantic Descriptions of Signs from the Fm Set.

Gloss	**Actor**	**Action**	**Patient**	**Mimetic Description**
FERRY	None	None	None	Ferry bow moving forwards
FAMILY	None	None	None	None
KNIFE	Person	Tapping long flat objects together	Two knives	Person tapping two knives together
FATHER	None	None	None	None
KISS	None	None	None	Kiss transferred from lips to another's mouth
DIVORCE	None	None	None	Two people together then moving apart
TENT	None	None	None	Outlining sides of a tent
TOWER	None	None	None	Outlining sides of a tower
NEWS	None	None	None	None
LUNCH	Person	Moving long flat objects towards mouth	Knife and fork	Transferring food from plate to mouth using cutlery

The fm set contained the signs: GLASSES, PRISON, PEN, VIDEO-CAMERA, RUSSIA, LIST, DRAWER, BALL, TEDDY-BEAR and BOOK. The formational parameters of these signs are given in Table 9.7. The actions depicted by the signs do not share agent, action and patient properties (see Table 9.8).

[10] The H-handshape consists of a fist with the index and middle fingers extended; NS means the 'neutral space' in front of the signer, with the height indicated in brackets and the horizontal position indicated afterwards (C = central).
[11] KNIFE and FATHER are differentiated by the orientation of the palms and fingers

Table 9.7: Formational Parameters of Signs from the fm Set.

Gloss	Formational Parameters				Duration
	Hands	Handshape	Location	Movement	
GLASSES	2	VV	Eyes LR	Tapping	1800
PRISON	2	AA	NS (Chest) C	Forwards	1633
PEN	1	G^	NS (Chest) L-R	Wiggling + sideways	1667
VIDEO-CAMERA	2	G. (A)	NS (Chest) L-R	Sideways	1667
RUSSIA	1	G	Chin C	Sharp rightward	1633
LIST	2	A. (B)	NS (Abdomen) C	Downward	1900
DRAWER	2	5.	NS (Abdomen) C	Backwards	2033
BALL	2	BB	NS (Abdomen) C	Downward	1833
TEDDY-BEAR	2	AA	Chest C	Tapping	1833
BOOK	2	BB	NS (Abdomen) C	Palm rotation	2133

Table 9.8: Semantic Descriptions of Signs from the fm Set.

Gloss	Actor	Action	Object	Mimetic Description
GLASSES	Person	Positioning	Spectacles	Putting on spectacles
PRISON	Person	Clasping Together	-	Clasping hands together for handcuffs
PEN	Person	Grasping	Pen	Writing
VIDEO-CAMERA	Person	Panning	Video camera	Panning a camera L-R
RUSSIA	None	None	None	None
LIST	Person	Moving Down	List Items	Moving through a list of items
DRAWER	Person	Grasping + Pulling	Drawer Handles	Pulling out a drawer
BALL	None	None	None	Outlining a ball
TEDDY-BEAR	Person	Grasping	Teddy bear	Grasping a teddy bear to the chest
BOOK	Person	Opening	Book	Opening a book

From each sign set, ten 7-item lists were generated using a Latin Square method to control for presentation order. The lists were generated such that each sign appeared seven times, once in each serial position, and no sign was repeated within a list. This generated thirty lists, ten from each set.

The lists were entered into a one-way ANOVA with list duration as the dependent variable and list type as a between subject factor. There was no significant effect of list type: F (2, 19) = 0.86, $p > .10$. Descriptive statistics are given in Table 9.9.

Table 9.9: Mean list durations (milliseconds) for the different list types.

List type	M	SD	n
FM	1820	65	10
Fm	1737	262	10
fm	1813	30	10

9.2.3 Design

An immediate serial recall task was presented to two groups of participants (native, non-native). The similarity of signs within a list was manipulated for each participant (FM, Fm, fm), and measures were taken of (1) the number of items recalled in correct serial position, (2) the number of items that were not successfully recalled (regardless of serial position) and (3) the number of items recalled in the correct list but wrong serial position (as a proportion of the total number of items recalled within a list).

9.2.4 Procedure

Participants were seated in a quiet room and the procedure was explained to them in BSL by the experimenter. The experimenter took part in two phases: (1) linguistic background interview, and (2) list recall.

9.2.4.1 Linguistic Background Interview

Prior to the experimental procedure, the participants were given a structured interview in BSL. The aim of the interview was to obtain information about factors that may influence language preference and coding strategy within the experimental procedure. Questions focused on language acquisition, family background and schooling. A copy of the questionnaire can be found in Appendix A.

9.2.4.2 List Recall

Practice Lists

Four 5-item practice lists (containing items not present in the experimental lists) were shown to participants in order to familiarise them with the task. Recall was to follow a strict serial procedure, with the

participants calling first the item in the position one, then position two, and so on. They were not allowed to go back to correct a response or fill in a blank response. Response mode was signed, and participants were asked to use the sign DISAPPEARED-FROM-MIND if they could not recall a sign at a given serial position. Participants were corrected after each practice trial, and experimental trials were only initiated when they were aware of what was required.

Experimental Lists

Each participant was presented with fifteen experimental 7-item lists (five from each list set). These were selected randomly from the complete set of thirty lists, and presented in five blocks, with one list from each set in each block. The order of lists within a block was also randomised. The recall procedure was the same as for the practice trials.

9.3 Results

In order to test the hypotheses, it was necessary to divide the participants into native and non-native groups. This was done using age of acquisition of BSL (AoA) and deaf relatives. Those who reported seeing and learning BSL before the age of 5 years and had at least one deaf relative (either father, mother or a sibling) were placed within the native group; all other participants were placed into the non-native group. An independent samples t-test confirmed that the groups did not significantly differ in terms of age at interview ($t(18) = 0.86$, $p > .05$). Onset of deafness was evenly distributed for the two groups, and could not be used to distinguish between them (Table 9.10). However, 90% of those in the native group stated that they considered BSL to be their native language, compared to only 20% of the non-native group (Table 9.12). The factor that most clearly differed for the two groups was self-rated sign skill (Table 9.11). Eight out of ten of the native group rated their own signing as 'very good', and six out of ten non- native participants rated themselves as 'good'. This provides some support for using age of acquisition (with a 5-year cut-off point) and deaf genealogy as a basis for determining experimental group.

Table 9.10: Onset of Deafness by Age of Acquisition.

Onset of deafness	**Native (N = 10)**	**Non-native (N = 10)**
	n	n
At birth	9	7
Before 3 years	1	2
After 6 years	0	1

Table 9.11: Self-rated Sign Skill by Age of Acquisition.

Self-rated sign skill	**Native (N = 10)**	**Non-native (N = 10)**
	n	n
Very good	8	2
Good	2	6
Average	0	2

Table 9.12: Expressed Native Language by Age of Acquisition.

Expressed native language	**Native (N = 10)**	**Non-native (N = 10)**
	n	n
BSL	9	2
BSL/English bilingual	1	0
Spoken Language	0	8

Strict scoring according to serial recall incorporates both item and order information. In order to get an item correct, it must be both correctly identified and recalled at the correct position in the list. Following Saint-Aubin & Poirier (1999), errors were scored in order to examine the effects of list similarity on item and order recall separately. Item errors were calculated as the number of items not recalled (regardless of serial position). Order errors were scored as the number of items correctly recalled but in an incorrect serial position. Order errors per item, following Saint-Aubin & Poirier (1999), was calculated as the probability of an order error at a list position given that an item was recalled at that list position. Means for number of item and order errors, and order errors per item, are given in Table 9.13 for native signers and Table 9.14 for non-native signers.

Table 9.13: Errors by List Similarity for Native Signers, Experiment 3.

List Type	Mean	SE (Mean)	SD
Item Errors			
FM	4.38	0.24	0.77
Fm	3.76	0.40	1.27
fm	3.60	0.56	1.76
Order Errors			
FM	0.40	0.06	0.20
Fm	0.29	0.05	0.17
fm	0.23	0.03	0.11
Order Errors per Item			
FM	0.60	0.08	0.27
Fm	0.53	0.08	0.25
fm	0.51	0.09	0.28

Table 9.14: Errors by List Similarity for Non-native Signers, Experiment 3.

List Type	Mean	SE (Mean)	SD
Item Errors			
FM	3.46	.22	0.69
Fm	3.98	.24	0.75
fm	3.24	.24	0.77
Order Errors			
FM	0.28	0.03	0.10
Fm	0.34	0.05	0.16
fm	0.28	0.04	0.14
Order Errors per Item			
FM	0.59	0.07	0.23
Fm	0.61	0.05	0.17
fm	0.58	0.06	0.18

9.3.1 Native Signers

9.3.1.1 Item Errors

The number of items not recalled by native signers were entered into a one-way repeated measures ANOVA, with list similarity (FM, Fm, fm) as the repeated measure. This revealed no significant effect of list type on the number of items not recalled (see Table 9.15).

Table 9.15: Results of Repeated Measures ANOVA, Native Signers, Item Errors, Experiment 3

Effect	F	df	Sig.
LISTTYPE	.560	2, 8	.592

9.3.1.2 Order Errors

For each participant, the number of items recalled in the wrong serial position was calculated. These were entered into a one-way repeated measures ANOVA, with list similarity (FM, Fm, fm) as the repeated measure (Table 9.16). This revealed a significant main effect of list type ($\underline{F}$ (2, 8) = 6.58, $p < .05$). Paired t-tests were used to further test the experimental hypotheses (Table 9.17). These revealed that formationally and morphologically similar (FM) lists ($\underline{M}$ = 0.40) and formationally similar but morphologically dissimilar (Fm) lists ($\underline{M}$ = 0.29) generated more order errors than formationally and morphologically dissimilar (fm) lists ($\underline{M}$ = 0.23).

Table 9.16: Results of Repeated Measures ANOVA, Native Signers, Order Errors, Experiment 3

Effect	F	Error df	Sig.
LISTTYPE	*6.58*	*2, 8*	*.020*

Table 9.17: Paired t-test comparisons, Native signers, Order errors, Experiment 3

Paired comparison	t	df	Sig. (1-tailed)
FM-Fm	1.32	9	.110
FM-fm	*2.39*	*9*	*.021*
Fm-fm	*1.90*	*9*	*.045*

9.3.1.3 Order Errors per Item

Although the data on order errors supports the hypothesis that Deaf native signers code signs in terms of the formational parameters of BSL and not in terms of morphological parameters, it is important to correct the data for the number of items recalled (following Saint-Aubin & Poirier, 1999). The

number of order errors made per item recalled was entered into a one-way repeated measures ANOVA, with list type (FM, Fm, fm) as the repeated measure (Table 9.18). There was no significant effect of list type. The effect of formational similarity in increasing the number of order errors appears to be attributable to the greater number of items recalled for those lists by native signers. Recalling more items means that there is a greater probability of making an order error. When this is controlled for, the effect of formational similarity on order errors drops out.

Table 9.18: Results of repeated measures ANOVA, Native signers, Order errors per item, Experiment 3

Effect	F	Error df	Sig.
LISTTYPE	0.88	2, 8	.450

9.3.2 Non-native Signers

9.3.2.1 Item Errors

The number of items not recalled by non-native signers were entered into a one-way repeated measures ANOVA, with list similarity (FM, Fm, fm) as the repeated measure (Table 9.19). This revealed a significant main effect of list type ($\underline{F}$ (2, 8) = 9.06, $p < .01$). Paired t-test comparisons (Table 9.20) revealed that formationally similar and morphologically dissimilar (Fm) lists ($\underline{M}$ = 3.98) resulted in more item errors than formationally and morphologically similar (FM) lists ($\underline{M}$ = 3.46) and formationally and morphologically dissimilar (fm) lists ($\underline{M}$ = 3.24).

Table 9.19: Results of one-way ANOVA, Non-native signers, Item errors, Experiment 3

Effect	F	Error df	Sig.
LISTTYPE	*9.06*	*2, 8*	*.009*

Table 9.20: Paired t-test comparisons, Non-native signers, Item errors, Experiment 3

Paired comparison	t	df	Sig. (1-tailed)
FM-Fm	*-1.463*	*9*	*.089*
FM-fm	.600	9	.282
Fm-fm	*4.454*	*9*	*.001*

It was hypothesised that non-native signers will generate fewer item errors for morphologically similar lists, relative to the morphologically dissimilar lists. Thus the data are inconclusive. Where both lists are formationally similar (the FM-Fm comparison) the hypothesis is supported, but the 'fm' lists generate the fewest item errors.

9.3.2.2 Order Errors

For each participant, the number of items recalled in the wrong serial position was calculated. These were entered into a one-way repeated measures ANOVA, with list similarity (FM, Fm, fm) as the repeated measure (Table 9.21). There was no significant effect of list type on the number of order errors made by non-native signers.

Table 9.21: Results of one-way ANOVA, Non-native signers, Order errors, Experiment 3

Effect	F	Error df	Sig.
LISTTYPE	1.83	2, 8	.221

9.3.2.3 Order Errors per Item

The number of order errors made per item recalled was entered into a one-way repeated measures ANOVA, with list type (FM, Fm, fm) as the repeated measure (Table 9.22). There was no significant effect of list type.

Table 9.22: Results of one-way ANOVA, Non-native signers, Order errors per item, Experiment 3

Effect	F	Error df	Sig.
LISTTYPE	0.28	2, 8	.760

9.4 Discussion

Two groups of participants (native and non-native signers of BSL) were tested using an ordered recall paradigm. The effect of intra-list item similarity upon the number of items omitted and the number of ordering errors was investigated. Item errors are assumed to reflect the role of trace decay in the short-term memory store, and indicate errors in the reintegration of decayed memory traces. Order errors are assumed to be linked to the interpretation of reformed memory traces. List similarity should lead to an increase in the number of items recalled, if the STM representation is based upon those similarity parameters. This is because list similarity provides a cue to reintegration of item memory traces. The same similarity should, however, lead to more order errors. This is because the reintegration of similar decayed traces should lead to a similar and confusable set of memory items.

9.4.1 Item Errors

It was hypothesised that formational similarity would result in more items correctly recalled by native signers. This prediction was based upon native signers encoding signs in terms of their formational parameters, and then using the similarity of the memory traces to aid in reconstruction of list items at recall. However, there was no significant effect of list type on the number of item errors made. No support for the hypothesis was obtained.

For non-native signers, the results were inconclusive. The Fm lists generated more item errors than either FM or fm lists. It is therefore not possible to conclude that either formational or morphological similarity leads to fewer item errors.

9.4.2 Order Errors

For native signers of BSL, formational similarity (regardless of morphological similarity) led to more order errors in recall. This measure therefore supports the hypothesis that for native signers formational similarity will lead to more order confusions at recall.

For non-native signers there was no indication within the data that formational or morphological similarity of list items had any effect upon order recall.

9.4.3 Order Errors per Item

The more items that a participant recalls, the more likely they are to make order errors (Saint-Aubin and Poirier, 1999). The order errors made by participants were therefore expressed as the number of order errors per item, i.e. given that an item was recalled, the probability that it was recalled in the wrong list position was calculated. For this measure, there was no significant effect of list type for either native or non-native signers.

9.4.4 Conclusions

Analysis of order errors provided some support for formational coding in the working memory of native signers of BSL. However, when the number of items recalled in each of the conditions by this group was taken into account, the effect of formational similarity was no longer significant. For non-native signers, item error data was inconclusive with regard to the experimental hypothesis, and order errors (as well as an order error measure adjusted for the number of items recalled) indicated evidence of neither formational nor morphological coding.

These data are not in agreement with those reported in Experiment 2. There, evidence was obtained for coding that was morphological in nature. It is important, therefore, to examine the differences between Experiment 2 and Experiment 3.

10 Experiment Four: Sign-based Formational Priming in a Lexical Decision Task

10.1 Introduction

Psychologists have given much attention to serial ordered recall and the short-term memory processes in deaf people who use signed languages. This experiment attempts to employ an alternative paradigm to assess whether the formational aspects of signs are encoded by Deaf signers — form priming. Form priming is a technique used to investigate word recognition processes. That is, given a linguistic input, how does the linguistic system recognise that input as a token of a particular word. In order for a word, or sign, to be recognised, it must first be encoded. That encoded information can then be mapped onto long-term lexical structures in the recognition process. Thus, establishing that the formational parameters of BSL are used to access lexical representations is equivalent to finding formational similarity effects in a serial ordered recall paradigm. Both provide evidence that signs have been encoded in terms of their formational parameters. Morphologically similar signs were not employed in this experiment as it proved too complex a task to formulate a sufficient number of related pairs.

10.1.1 Hypotheses

The cohort theory of lexical access states that the initial set of candidates will be determined by the onset of a word. According to Emmorey and Corina (1990), the first formational parameter to be isolated in the recognition process is location. Cohort theory therefore predicts that a prime will facilitate response to a target if they both share the same location. Furthermore, this should occur for sign-sign pairs only, locating the effect as a lexical one. It is predicted that this will be the case for native signers, but not for non-native signers who acquired BSL after the age of 6 years. For native signers, it may also be the case that formational parameters do not have an effect in isolation, but interact with other parameters. The two parameters that

are most intimately linked in (formational) phonological theories are location and movement.

For non-native signers, it is predicted that formational parameters of stimulus signs will not influence lexical access. Rather, it would appear more likely that the visual similarity of prime-target pairs would influence lexical access. It is therefore predicted that it will be the number of parameters shared by prime and target that influences non-native processing (as the greater the number of parameters shared, the greater the visual similarity), but that there will be no effects of specific formational parameters such as handshape, location and movement.

10.2 Method

10.2.1 Participants

There were two groups of participants: 12 native signers of BSL who learned the language at home from their family (see Table 10.1) and 12 non-native signers of BSL who came from hearing families and acquired BSL later in life (see Table 10.2).

Table 10.1: Personal, Deafness and Language Characteristics of Native BSL Signers in Experiment 4

Gender	Age Deaf	Father Deaf	Mother Deaf	Sibling Deaf	Other Deaf	Age First Saw BSL	Age First Learned BSL	Self-rated Sign Skill	First Language	Age
Female	Birth	Yes	Yes	No	Yes	< 5 years	< 5 years	Very good	BSL	42
Male	Birth	Yes	Yes	Yes	No	< 5 years	< 5 years	Very good	BSL	40
Male	Birth	Yes	Yes	Yes	Yes	< 5 years	< 5 years	Very good	BSL	21
Female	Birth	No	No	Yes	No	< 5 years	< 5 years	Very good	BSL	35
Female	Birth	Yes	Yes	Yes	Yes	< 5 years	< 5 years	Very good	BSL	46
Female	Birth	Yes	Yes	Yes	Yes	< 5 years	< 5 years	Very good	BSL	46
Male	Birth	Yes	Yes	Yes	Yes	< 5 years	< 5 years	Very good	BSL	21
Male	Birth	Yes	Yes	Yes	Yes	< 5 years	< 5 years	Very good	BSL	45
Female	Birth	Yes	Yes	Yes	Yes	< 5 years	< 5 years	Good	BSL/English	16
Female	Birth	Yes	Yes	Yes	Yes	< 5 years	< 5 years	Good	BSL	20
Male	Birth	Yes	Yes	Yes	No	< 5 years	< 5 years	Very good	BSL	22
Female	Birth	Yes	Yes	Yes	Yes	< 5 years	< 5 years	Very good	BSL	29

Table 10.2: Personal, Deafness and Language Characteristics of Non-native BSL Signers in Experiment 4

Gender	Age Deaf	Father Deaf	Mother Deaf	Sibling Deaf	Other Deaf	Age First Saw BSL	Age First Learned BSL	Self-rated Sign Skill	First Language	Age
Female	Birth	No	No	No	No	6-10 years	6-10 years	Good	BSL/English	31
Female	Birth	No	No	No	No	11-18 years	11-18 years	Good	BSL	30
Male	< 3 years	No	No	No	No	11-18 years	11-18 years	Good	Paget-Gorman	20
Female	Birth	No	No	No	No	11-18 years	11-18 years	Good	English	30
Female	Birth	No	No	No	No	6-10 years	6-10 years	Good	English	28
Male	Birth	No	No	No	No	6-10 years	6-10 years	Average	English	19
Female	Birth	No	No	No	No	6-10 years	6-10 years	Good	English	46
Male	Birth	No	No	No	No	11-18 years	11-18 years	Good	English	22
Female	< 6 years	No	No	No	No	6-10 years	6-10 years	Average	English	28
Male	Birth	No	No	No	No	11-18 years	11-18 years	Good	English	32
Female	Birth	No	No	No	No	11-18 years	11-18 years	Very good	BSL/English	32
Female	< 3 years	No	No	No	No	6-10 years	11-18 years	Average	English	24

10.2.2 Stimuli

Stimuli were 381 BSL signs, and 381 nonsense signs. Nonsense signs were generated by four deaf native signers and one BSL interpreter. Although legal within the linguistic rules of BSL, the nonsense signs do not occur within the language. All signs were recorded using a Panasonic digital camcorder (Model No. NV DS25B). The signers wore plain clothes and were filmed in front of a blue background to maximise contrast. Signs were edited into Video for Windows™ movie files using QuickEditor 6.0 video-editing software. Each movie file was 384 pixels wide and 288 pixels high, with a frame rate of 25 fps. No signs were repeated within the procedure, except in the recognition task, in order to prevent repetition priming.

Five-hundred and eighty signs were used to create 300 prime-target sign pairs for use in the lexical decision task. The relationship between the two signs within each pair determined to which condition they were assigned. In total there were 30 conditions, each with 10 sign pairs. Twenty-eight conditions were formed by factorially combining prime lexicality (sign, nonsign), target lexicality (sign, nonsign), handshape similarity (same, different), location similarity (same, different) and movement similarity (same, different), excluding the four conditions where handshape, location and

movement were shared by prime and target (see Appendix B). The additional two conditions were identity pairs, where the prime and target were the same stimulus (sign-sign and nonsign-nonsign).

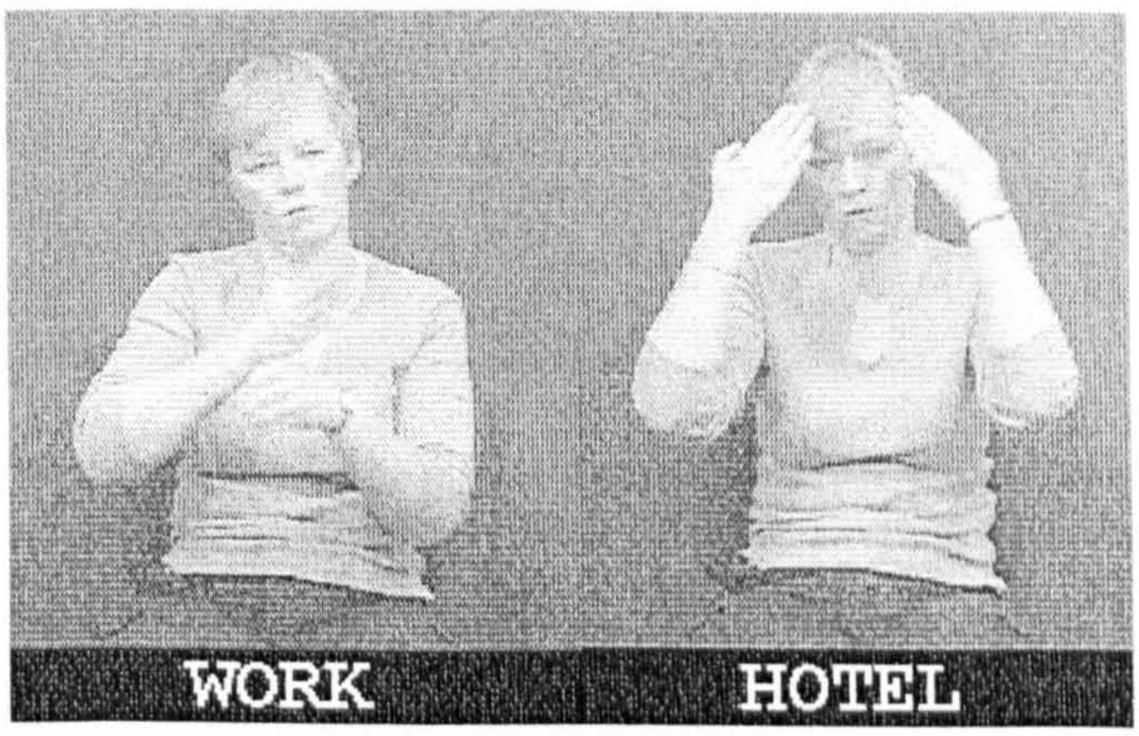


Figure 10.1: A pair of BSL signs sharing handshape only (WORK and HOTEL)

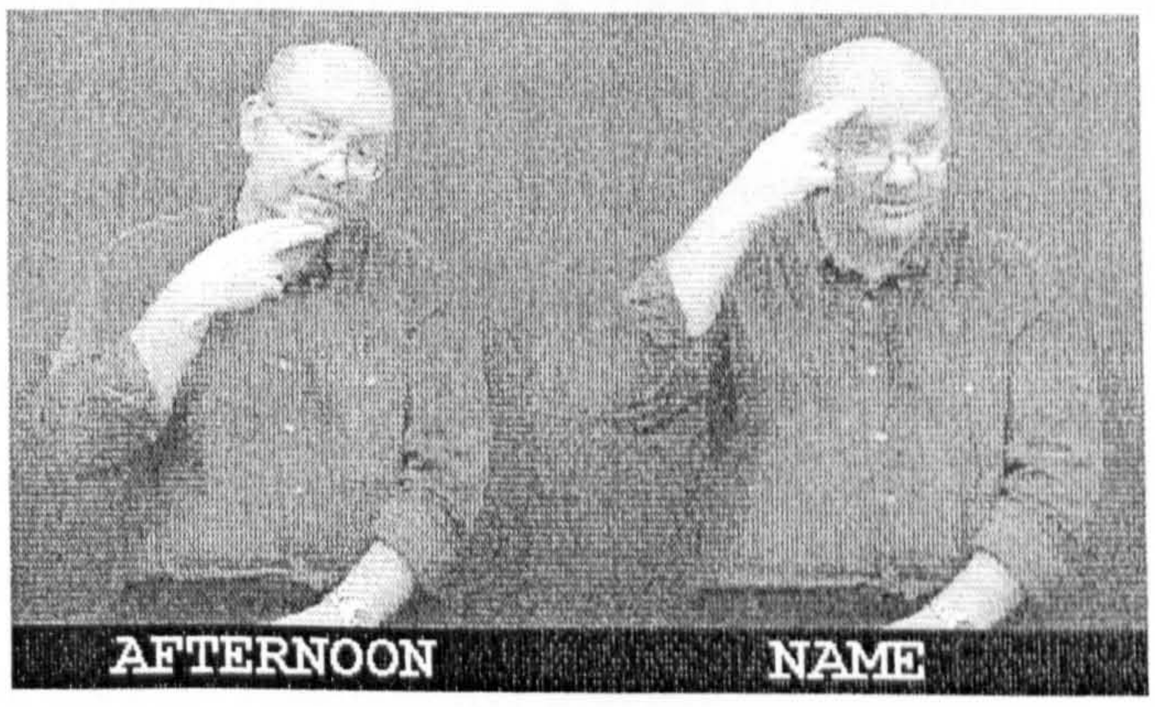


Figure 10.2: A pair of BSL signs sharing handshape and movement (AFTERNOON and NAME)

Figure 10.3: A pair of nonsense signs sharing handshape and location (047 and 048)

Previous studies have used the same stimulus repeatedly as a target, observing the differential effects of varying primes on that target. Such a design requires a between subjects design in order to avoid repetition of the target sign producing priming due to its repeated presentation. The scarcity of native signers for the present study necessitated a within subjects design, and therefore different targets were used on each trial. The order of signs within a pair was fixed for all participants.

A further 150 signs were used as distractors within a sign recognition task. The relationship between these distractor signs and the recognition targets was not manipulated. Thirty signs were used as practice items, and two signs were used for response key practice.

10.2.3 Design

Two separate groups of participants (native and non-native signers) participated in each of the experimental conditions in a primed lexical decision task. Measures were taken of response accuracy (correct or incorrect) and response latency (milliseconds from onset of second clip) within each condition, in response to the second sign of each pair. The priming task was presented in ten blocks, with two pairs from each condition in each block. Blocks were presented in the order 1-10 or 10-1, counterbalanced across

participants in each experimental group. The same signer was not used in consecutive blocks.

Following each priming block was a recognition task, using stimuli seen as the first item of pairs in the previous priming block, plus an equal number of distractor items. For each participant the proportion of correct responses was calculated. The purpose of this recognition task was to encourage participants to pay attention to the first item of each pair in the priming task and thereby ensure processing of the prime. A pseudo Latin square procedure was used to assign primes from different conditions to the recognition blocks, such that each condition was equally represented across the recognition blocks. Each recognition block used the same signer as in the previous priming block.

10.2.4 Materials

Stimuli were presented to participants using specially written software (SignPrime version 6.2) on an IBM PC with a 15" diameter screen. Participants responded using a specially designed response box, with three buttons: red, green and black. For half of the participants, the red button was used to issue a NO response, the green for YES, and the black to initiate the next trial. For the remainder, the roles of the red and green buttons were reversed.

10.2.5 Procedure

The procedure consisted of four different phases: (1) key press practice, (2) priming practice, (3) a priming task and (4) a recognition test.

10.2.5.1 Key Press Practice

This initial phase was intended to familiarise participants with the response procedures. Participants were presented with a series of trials, each one being the presentation of the BSL sign for either YES or NO (eight times each). They were required to press the green button if they saw the sign YES, and the red button if they saw the sign NO. The black button initiated the next trial. The number of trials was set to a minimum of 10, with the phase

stopping after five consecutive correct responses had been made. Piloting had shown that 15 trials were sufficient to (a) generate consecutive correct responses, and (b) asymptote the response time, for 4 out of 5 pilot participants.

10.2.5.2 Priming Practice

Participants were told that they would see a sequence of two signs in the middle of the computer screen. Their task was to decide if the second sign was a real BSL sign or a made-up nonsense sign. If they thought that YES it was a real sign, they were instructed to press the green/red button, and to press the red/green button if they thought NO it was a nonsense sign. Pressing the black button initiated the next trial. After each response, the participants were told whether they were RIGHT or WRONG, and whether their response was EARLY, GOOD or LATE. If a response was made within the first 20% of the clip's duration, the response was classified as EARLY; if the response occurred after 100% of the clip's duration had been viewed, then it was classified as LATE. All other responses were classified as GOOD. This was done in order to encourage participants to (a) not respond too early, and (b) not spend too long considering the lexical status of the second sign. In all, there were twelve practice trials, with pairs sharing none of the three parameters. There were equal numbers of sign-sign, sign-nonsign, nonsign-sign and nonsign-nonsign pairs. The interval between signs within a pair was 50 msecs, and there was a period of 500 msecs between the participant cueing the next trial and the first sign of the pair appearing. The practice session could be repeated using the same set of twelve pairs if the experimenter felt the participant was experiencing problems.

10.2.5.3 Priming Task

The priming task proper was split into ten blocks, with a recognition test following each priming block. Within each block, there were 30 pairs of signs (see Design). The pairs used within each block are given in Appendix C. The items within each block were fixed, but randomly ordered for each

participant. The procedure was the same as for the practice priming block, except no feedback on performance was given. The interval between the prime and target was 50 msecs, with onset of the first sign 500 msecs after the participant cued the next trial.

10.2.5.4 Recognition Task

Following each priming block, participants were presented with 30 signs from the first items in each pair, and 30 distractor items. Their task was to decide whether the signs they saw had been presented in the previous priming block. The order of presentation was randomly determined for each participant, and a maximum of three consecutive targets or distractors was presented.

10.3 Results

10.3.1 Recognition Phase

The recognition phase of the design was employed to encourage participants to attend to the prime during the priming phase. In order to check whether participants had indeed attended to the prime, the hit rate and false alarm rate was calculated for each participant. These rates were then used to calculate d' and β values (see Table 10.3).

Table 10.3: Summarised recognition data for native and non-native participants in Experiment 4.

Group	N	Hit Rate	False Alarm Rate	d'	β
Native signers	12	.75 (.11)	.18 (.05)	1.65	0.93
Non-native signers	12	.76 (.09)	.20 (.11)	1.63	0.83

Native and non-native signers did not differ significantly on *hit rate*, t (22) = 0.12, p > .05, *false alarm rate*, t (22) = 0.48, p > .05, *d'*, t (22) = 0.10, p > .05 or *β*, t (22) = 0.78, p > .05.

For non-native signers, one participant displayed a d' value less than 2 standard deviations below the non-native group mean (d' = 0.18, HR = .57, FAR = .51). This value was so low that either (a) the participant had not

attended to the primes, or (b) was unclear about what they had been instructed to do. As a result, this participant was removed from all further analyses (both 'by subjects' and 'by stimuli' analyses).

10.3.2 Priming Phase

For the priming data the two dependent measures were (1) accuracy of lexical decision, and (2) reaction times for correct responses. There were five independent variables: (1) group (native or non-native signers of BSL), (2) lexicality of the prime (sign or nonsign), (3) lexicality of the target (sign or nonsign), (4) number of parameters shared by prime and target (0, 1 or 2), and (5) specific parameters shared by prime and target (handshape only, location only, movement only, handshape and location, handshape and movement, location and movement).

The priming data were analysed in three ways: (1) by subjects, (2) by stimuli, and (3) by stimuli with target clip duration as a covariate. The latter analyses, using target clip duration as a covariate, focused solely upon the reaction time data.

The data are reported here in a nested fashion: type of analysis (by subjects or by stimuli) > measurement of phonological overlap (number of parameters shared or specific parameters shared) > dependent measure (accuracy or reaction time).

10.3.2.1 Analysis By Subjects

Number of Parameters Shared

Accuracy of Lexical Decision

Table 10.4 and Table 10.5 present the lexical decision accuracy for non-native and native signers in each experimental condition expressed as the proportion of trials where the lexical decision was correct.

Table 10.4: Means (and Standard Errors) of Accuracy Rates by Number of Parameters Shared in Experiment 4, for native BSL signers (N = 12).

Number of Parameters Shared	Sign Prime		Nonsign Prime	
	Sign Target	Nonsign Target	Sign Target	Nonsign Target
0	0.90 (0.02)	0.92 (0.02)	0.94 (0.02)	0.95 (0.02)
1	0.92 (0.02)	0.92 (0.01)	0.89 (0.02)	0.90 (0.02)
2	0.92 (0.01)	0.89 (0.02)	0.92 (0.02)	0.92 (0.02)

Table 10.5: Means (and Standard Errors) of Accuracy Rates by Number of Parameters Shared in Experiment 4, for non-native BSL signers (N = 11).

Number of Parameters Shared	Sign Prime		Nonsign Prime	
	Sign Target	Nonsign Target	Sign Target	Nonsign Target
0	0.88 (0.03)	0.83 (0.03)	0.97 (0.01)	0.95 (0.03)
1	0.94 (0.02)	0.92 (0.01)	0.86 (0.02)	0.91 (0.01)
2	0.90 (0.01)	0.89 (0.02)	0.92 (0.01)	0.92 (0.01)

The accuracy data were entered into a four-way mixed ANOVA, with prime (sign or nonsign), target (sign or nonsign) and parameters shared (0, 1 or 2)[12] as within subjects factors, and group (native or non-native) as a between subjects factor. No effects were significant at the $p = .05$ level.

Prior to analysis of reaction times, accuracy data was checked with a view to removing participants who were outliers. Outliers were assessed by experimental condition. No participant had accuracy rates more than 2 standard deviations from the mean for more than three of the thirty conditions. As a result, data from all participants was analysed for response time.

Reaction Time for Correct Responses

Initially, reaction time outliers were removed from the data to be analysed. Outliers were determined for each experimental group, by each experimental condition. Two native signers and one native signer were slower by two standard deviations in ten or more of the thirty conditions. As a result, these participants were removed from the data set prior to analysis of reaction

times. Mean reaction times for native signers are reported in Table 10.6 and Figure 10.4; for non-native signers they can be found in Table 10.7 and Figure 10.5.

Table 10.6: Means (and Standard Errors) of Reaction Times (msec) by Number of Shared Parameters in Experiment 4, for native BSL signers (N = 10).

Number of Parameters Shared	Sign Prime		Nonsign Prime	
	Sign Target	Nonsign Target	Sign Target	Nonsign Target
0	1217 (43)	1245 (49)	1288 (33)	1297 (51)
1	1217 (28)	1279 (36)	1288 (35)	1312 (41)
2	1205 (31)	1326 (42)	1258 (39)	1359 (42)

Table 10.7: Means (and Standard Errors) of Reaction Times (msec) by Number of Shared Parameters in Experiment 4, for non-native BSL signers (N = 10).

Number of Parameters Shared	Sign Prime		Nonsign Prime	
	Sign Target	Nonsign Target	Sign Target	Nonsign Target
0	1325 (38)	1387 (36)	1445 (38)	1457 (38)
1	1272 (28)	1369 (43)	1427 (33)	1436 (44)
2	1283 (26)	1441 (39)	1343 (37)	1427 (41)

[12] The identity pairs (HLM) were excluded from the accuracy analysis.

Figure 10.4: Effect of number of parameters shared on reaction times by prime-target lexicality for native signers in Experiment 4.

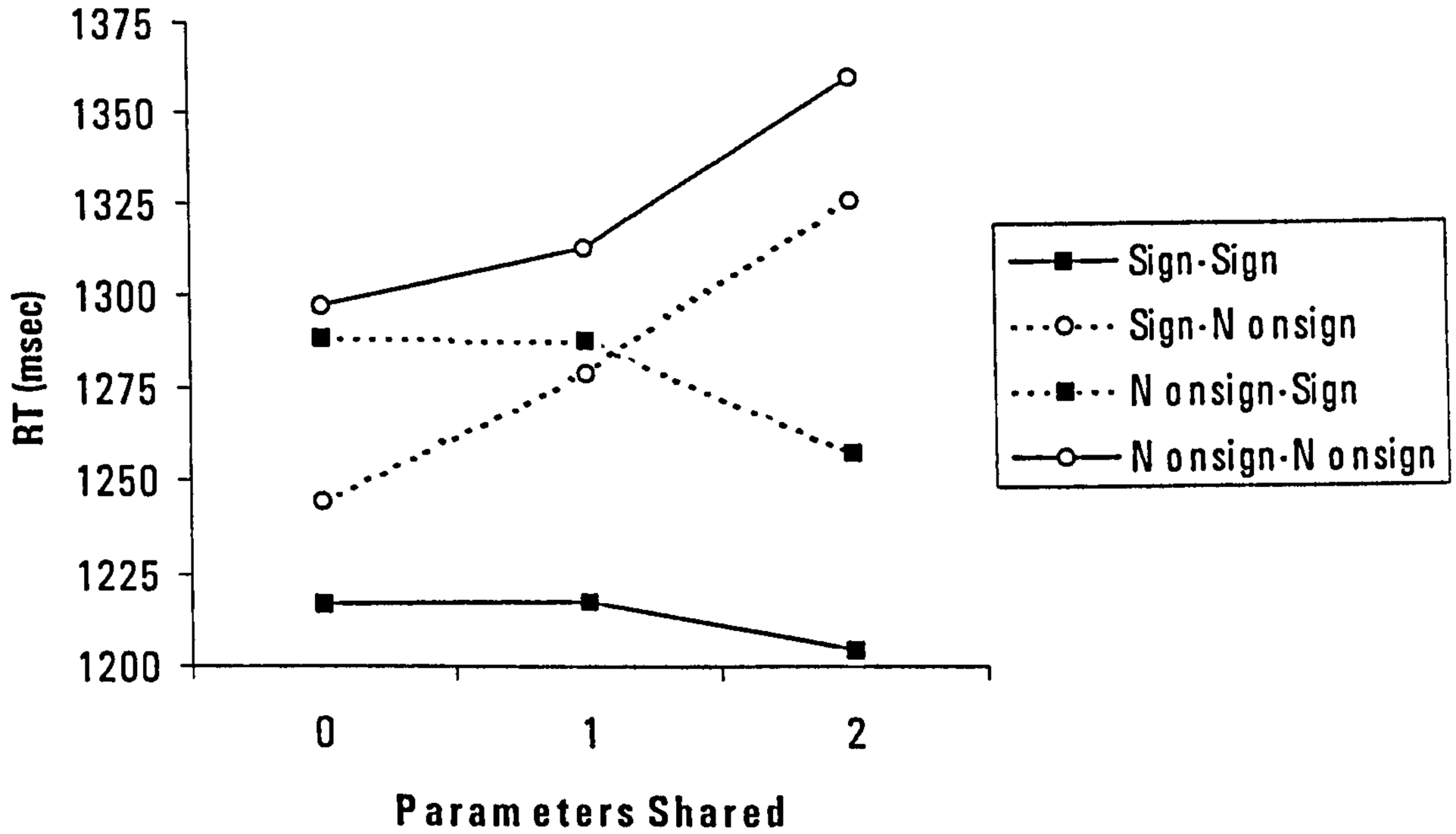
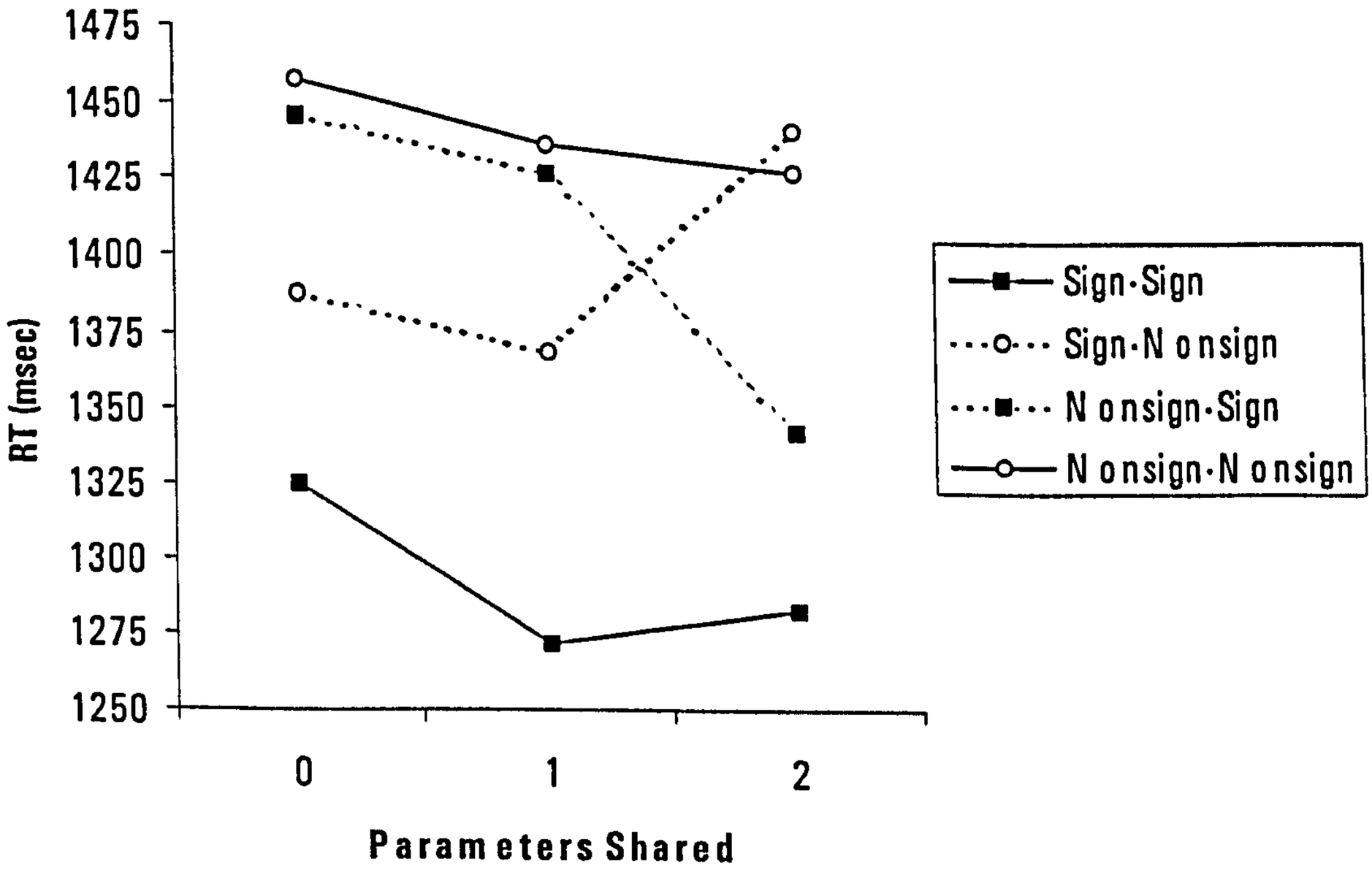


Figure 10.5: Effect of number of parameters shared on reaction times by prime-target lexicality for non-native signers in Experiment 4.



The reaction time data were analysed in terms of the number of parameters by which the prime and target overlapped. It was hypothesised that for sign-sign pairs, increased overlap should lead to facilitation of response to the target sign. The hlm[13] conditions were assigned to parameters shared = 0, the Hlm/hLm/hlM conditions to parameters shared = 1, and the HLm/HlM/hLM conditions to parameters shared = 2. The HLM conditions were not included in this analysis.

These data were initially entered into a three-way mixed ANOVA with prime (sign or nonsign) and target (sign or nonsign) as within subjects factors, and group (native or non-native) as a between subjects factor. The significant effects are reported in Table 10.8.

Table 10.8: Significant effects from the three-way mixed ANOVA performed on reaction time data, Experiment 4.

Effect	F	df	Sig.
Prime	110.92	1, 18	< .001
Target	20.80	1, 18	< .001
Group	4.49	1, 18	< .05
Prime by Target	12.20	1, 18	< .005

Prime, Target and Group

The main effect of prime revealed that sign primes (M = 1289) led to faster responses to the targets than did nonsign primes (M = 1356) for both native and non-native signers. The same was true of targets, with sign targets (M = 1283) leading to faster responses than nonsign targets (M = 1363) for both native and non-native signers. There was also a significant main effect of group, with native signers (M = 1271) reacting faster to targets than non-native signers (M = 1374).

Prime by Target Interaction

The significant interaction between prime and target was further analysed using paired t-tests. These revealed effects of prime for both sign and

[13] h/H indicate parameter handshape, l/L location, m/M: movement. An uppercase letter for a given parameter indicates that the prime and target are similar with respect of the given parameter; lowercase letter indicates that they are different. HLM pairs are identical.

nonsign targets, alongside effects of target for sign and nonsign primes (see Table 10.9). Difference scores (indicating facilitation due to prime lexicality) were then calculated for pairs with sign targets and pairs with nonsign targets. The difference scores were entered into a one-way ANOVA with target lexicality as a within subjects factor. There was a significant main effect of target lexicality: $F(1, 18) = 12.20$, $p < .005$. Facilitation due to prime lexicality is greater when targets are signs ($M = 88.19$) than when targets are nonsigns ($M = 40.52$). The same procedure was used for prime lexicality as a within subjects factor, calculating difference scores (indicating facilitation due to target lexicality) for pairs with sign primes and pairs with nonsign primes. There was a significant main effect of prime lexicality: $F(1, 18) = 12.20$, $p < .005$. Facilitation due to target lexicality is greater when primes are signs ($M = 87.82$) than when primes are nonsigns ($M = 40.14$).

Table 10.9: Paired t-tests for prime by target interaction, by subjects analysis, reaction time data for Experiment 4.

Effect of ...	for ...	t	df	Sig.
Prime	Sign Targets	9.30	19	< .001
Prime	Nonsign Targets	3.42	19	< .005
Target	Sign Primes	6.76	19	< .001
Target	Nonsign Primes	3.07	19	< .01

Parameters Shared

The next analysis examined the effect of parameters shared for native and non-native signers separately. The groups were analysed separately as it was hypothesised that the pattern of findings would differ on the basis of early language experience. For each experimental group, their data were entered into a one-way repeated measures ANOVA, with parameters shared (0, 1, 2) as the between subjects factor. Separate analyses were conducted for sign-sign, sign-nonsign, nonsign-sign and nonsign-nonsign pairs. The results of these analyses are reported in Table 10.10.

Table 10.10: One-way ANOVAs examining Effect of Number of Parameters Shared on Reaction Times, By Subjects Analysis, by Prime-Target Lexicality and by Group.

Pair Type	Native Signers			Non-native Signers		
	F	df	Sig.	F	df	Sig.
Sign-Sign	0.22	2, 8	n.s.	2.01	2, 8	n.s.
Sign-Nonsign	20.73	2, 8	< .002	5.70	2, 8	< .05
Nonsign-Sign	1.89	2, 8	n.s.	12.34	2, 8	< .005
Nonsign-Nonsign	6.55	2, 8	< .05	5.30	2, 8	< .05

Parameters Shared for Native Signers

For the sign-nonsign and nonsign-nonsign pairs, there was inhibition of response to the nonsign target when it shared two parameters with the prime ($F(1, 9) = 18.40$, $p < .005$ and $F(1, 9) = 6.41$, $p < .05$ respectively) but not when it shared only one parameter with the prime ($F(1, 9) = 1.61$, $p < .05$ and $F(1, 9) = 0.40$, $p > .05$ respectively).

Parameters Shared for Non-native Signers

For pairs with nonsign primes (nonsign-sign and nonsign-nonsign), there was facilitation of response to the target when it shared two parameters with the prime ($F(1, 9) = 6.41$, $p < .002$ and $F(1, 9) = 11.17$, $p < .01$ respectively), but not when it shared only one parameter with the prime ($F(1, 9) = 0.77$. $p > .05$ and $F(1, 9) = 2.99$, $p > .05$ respectively). For sign-nonsign pairs, response to the target was inhibited when the target shared two parameters with the prime ($F(1, 9) = 6.68$, $p < .05$), but not when it shared only one ($F(1, 9) = 1.00$, $p > .05$).

Identity Priming

Finally, the presence of identity (repetition) priming was checked for by comparing pairs that shared no parameters with identical pairs. For native signers, reaction to a sign target was facilitated when preceded by the same sign ($t(9) = 5.62$, $p < .001$). The same was not true for identical nonsign-nonsign pairs ($t(9) = 0.82$, $p > .05$). For non-native signers also, identical sign-sign pairs facilitated response to the target ($t(9) = 5.97$, $p < .001$) and identical nonsign-sign pairs did not ($t(9) = 2.21$, $p > .05$).

Summary of By Subjects Findings for Number of Parameters Shared

A. Native and non-native signers did not differ in the accuracy of their lexical decisions
B. Native and non-native signers made the same number of errors for sign and nonsign targets
C. Sign primes resulted in faster reactions to the target than did nonsign primes
D. Sign targets were responded to faster than nonsign targets
E. These lexicality effects appeared to be additive, such that sign-sign pairs were responded to faster than nonsign-sign or sign-nonsign pairs
F. Native signers responded correctly to targets faster than non-native signers
G. For native signers, nonsign targets were accurately rejected slower when preceded by a prime sharing two parameters; this was found for sign and nonsign primes
H. For non-native signers, targets were accurately rejected or accepted faster when preceded by nonsign primes that shared two parameters with them
I. For non-native signers, nonsign targets were rejected more slowly when preceded by sign primes with which they shared two parameters
J. For both native and non-native signers, there was facilitative repetition priming for sign-sign pairs, but not for nonsign-nonsign pairs

Effect of Specific Parameters

Reaction Time for Correct Responses

The data reported in Table 10.6 and Table 10.7 are repeated in Table 10.11 and Table 10.12 in terms of the specific parameters shared by the prime and target: handshape, location and/or movement.

Table 9.23: Methodological Differences between Experiment 2 and Experiment 3.

Experiment 2	Experiment 3
• suppression	• no suppression
• 5-item lists	• 7-item lists
• 5-sign pool of potential signs	• 10-sign pool of potential signs
• slower rate of presentation	• higher rate of presentation
• video presentation	• computer presentation
• 4 conditions (FM, Fm, fM, fm)	• 3 conditions (no fM lists)
• data from 2 of each list type	• data from 5 of each list type
• no native/non-native distinction	• native and non-native groups

Some of the differences reported in Table 9.23 seem unlikely to have influenced the results. These include the style of presentation (video or computer), dropping a condition (fM) in Experiment 3, and the amount of data collected from each list type. Using longer lists, drawn from larger pools and presented at a faster rate was intended to make the task harder, thus preventing ceiling effects from obscuring any inter-list differences. Indeed, most of the differences between Experiments 2 and 3 should have resulted in greater experimental power and the effects of formational and/or morphological similarity being more likely to be found.

It is possible that the formational similarity effect is a weak one, which proves hard to replicate. This possibility presents two options: (1) formational and/or morphological coding is rarely used, even by Deaf signers, or (2) the experimental design is not sensitive enough to the differences that exist. In an attempt to rule out the first explanation, Experiment 4 uses an alternative paradigm to try to establish that signs can be encoded in terms of formational parameters.

Table 10.11: Means (and Standard Errors) of Reaction Times (msec) for Each of the Conditions by Specific Parameters Shared in Experiment 4, for native BSL signers (N = 10).

	Sign Prime		Nonsign Prime	
	Sign Target	**Nonsign Target**	**Sign Target**	**Nonsign Target**
hlm†	1217 (43)	1245 (49)	1288 (33)	1297 (51)
Hlm	1210 (23)	1257 (46)	1257 (40)	1257 (47)
hLm	1210 (31)	1267 (33)	1321 (44)	1322 (41)
hlM	1232 (34)	1313 (38)	1285 (31)	1358 (41)
HLm	1224 (35)	1360 (46)	1272 (45)	1396 (54)
HlM	1215 (40)	1293 (42)	1249 (38)	1315 (38)
hLM	1175 (25)	1324 (43)	1254 (42)	1368 (46)
HLM	1095 (29)	---	---	1257 (42)

† h/H indicate parameter handshape, l/L location, m/M: movement. An uppercase letter for a given parameter indicates that the prime and target are similar with respect of the given parameter, lowercase letter indicates that they are different. HLM pairs are identical.

Table 10.12: Means (and Standard Errors) of Reaction Times (msec) for Each of the Conditions by Specific Parameters Shared in Experiment 4, for non-native BSL signers (N = 10).

	Sign Prime		Nonsign Prime	
	Sign Target	**Nonsign Target**	**Sign Target**	**Nonsign Target**
hlm†	1325 (38)	1387 (36)	1445 (38)	1457 (38)
Hlm	1277 (29)	1356 (47)	1411 (38)	1447 (51)
hLm	1243 (28)	1361 (48)	1463 (40)	1420 (38)
hlM	1297 (31)	1390 (44)	1406 (38)	1441 (48)
HLm	1340 (26)	1491 (41)	1349 (34)	1468 (49)
HlM	1257 (38)	1417 (43)	1339 (39)	1371 (41)
hLM	1253 (26)	1413 (39)	1340 (44)	1443 (37)
HLM	1230 (39)	---	---	1391 (51)

† h/H indicate parameter handshape, l/L location, m/M: movement. An uppercase letter for a given parameter indicates that the prime and target are similar with respect of the given parameter, lowercase letter indicates that they are different. HLM pairs are identical.

The data were analysed using paired t-tests, comparing the baseline condition (hlm) with each experimental condition, separately for sign-sign, sign-nonsign, nonsign-sign and nonsign-nonsign pairs. Analyses for the latter three prime-target types were only performed where the sign-sign analysis was statistically significant. The sign-sign analysis is the comparison of interest with respect to the study's hypotheses, the other three analyses being used to

assess whether any sign-sign effects were prelexical or lexical in origin. Native and non-native signers were entered into separate analyses.

One Parameter Shared - Handshape

For both native and non-native signers, there were no significant differences between the hlm and Hlm conditions for sign-sign pairs.

One Parameter Shared - Location

For native signers there was no significant difference between the hlm and hLm conditions for sign-sign pairs. For non-native signers, however, location had a facilitatory effect. For sign-sign pairs, there was a significant difference between the hlm and hLm conditions: $t(9) = 2.97$, $p < .02$. Non-native signers responded quicker to targets sharing location with the prime ($\underline{M}$ = 1243) than to targets sharing no parameters with the prime ($\underline{M}$ = 1325). This effect was not significant for sign-nonsign, nonsign-sign and nonsign-nonsign pairs, suggesting that the effect is not prelexical.

One Parameter Shared - Movement

For both native and non-native signers, there were no significant differences between the hlm and hlM conditions for sign-sign pairs.

Two Parameters Shared - Handshape and Location

For both native and non-native signers, there were no significant differences between the hlm and HLm conditions for sign-sign pairs.

Two Parameters Shared - Handshape and Movement

For native signers, there was no significant difference between the hlm and HlM conditions for sign-sign pairs. For non-native signers there was a significant difference: $\underline{t}(9) = 3.00$, $p < .02$. The effect was facilitatory, with reaction times in the HlM condition ($\underline{M}$ = 1257) faster than those in the hlm condition ($\underline{M}$ = 1325). However, a significant facilitatory effect was also found for the nonsign-sign ($\underline{t}(9) = 4.96$, $p < .002$) and nonsign-nonsign ($\underline{t}(9) = 6.41$, $p < .001$) conditions. The effect for nonsign-sign pairs reveals that nonsigns can also prime signs in respect of these parameters, suggesting that the effect is not lexical.

Two Parameters Shared - Location and Movement

For both native and non-native signers, there were no significant differences between the hlm and hLM conditions for sign-sign pairs.

Summary of By Subjects Findings for Specific Parameters Shared

A. For native signers, there were no significant effects of specific parameters shared for sign-sign pairs
B. For non-native signers, shared location facilitated reaction times by 82 milliseconds for sign-sign pairs - the same effect was not found for sign-nonsign, nonsign-sign and nonsign-nonsign pairs
C. For non-native signers, shared handshape and movement facilitated reaction times by 68 milliseconds for sign-sign pairs - the same effect was found for nonsign-sign (106 milliseconds) and nonsign-nonsign (66 milliseconds) pairs, however

10.3.2.2 Analysis by Stimuli

Analysis by stimuli provides a 'double-check' on results obtained within by subjects analyses. It also allows clip duration to be introduced as a covariate. For each sign pair used in this study, the clip duration of the target is a known and fixed variable. There is reason to believe that targets of short duration will be responded to faster than targets of a longer duration. The information needed to make a decision about the lexical status of a target will usually be available earlier for targets of shorter durations. Analyses reported for 'by stimuli' analyses are therefore reported both with and without target clip duration as a covariate.

Number of Parameters Shared

Accuracy of Lexical Decision

The data were entered into a three-way mixed ANOVA, with prime (sign, nonsign) and target (sign, nonsign) as between stimuli factors, and group (native, non-native) as a within stimuli factor. There was only one significant effect, that of group, F (1, 296) = 10.75, $p < .002$, with non-native signers (M = 0.92) responding more accurately than native signers (M = 0.90). Descriptive statistics are reported in Table 10.13 and Table 10.14.

Table 10.13: Means (and Standard Errors) of Accuracy Rates by Number of Parameters Shared in Experiment 4 by Stimuli, for native BSL signers (N = 12).

Number of Parameters Shared	Sign Prime		Nonsign Prime	
	Sign Target	Nonsign Target	Sign Target	Nonsign Target
0	0.90 (0.05)	0.91 (0.05)	0.92 (0.02)	0.94 (0.02)
1	0.92 (0.02)	0.92 (0.03)	0.88 (0.03)	0.90 (0.02)
2	0.90 (0.03)	0.87 (0.04)	0.90 (0.03)	0.91 (0.02)

Table 10.14: Means (and Standard Errors) of Accuracy Rates by Number of Parameters Shared in Experiment 4 by Stimuli, for non-native BSL signers (N = 11).

Number of Parameters Shared	Sign Prime		Nonsign Prime	
	Sign Target	Nonsign Target	Sign Target	Nonsign Target
0	0.90 (0.06)	0.86 (0.06)	0.98 (0.01)	0.94 (0.02)
1	0.95 (0.01)	0.92 (0.03)	0.90 (0.03)	0.92 (0.03)
2	0.91 (0.03)	0.92 (0.03)	0.93 (0.03)	0.95 (0.02)

Prior to reaction time analyses, fifteen sign pairs were rejected from further analysis for native signers, and sixteen pairs for non-native signers. A pair was rejected if it's accuracy rate was less than two standard deviations below the mean accuracy rate of all sign pairs (calculated for each experimental group separately).

Reaction Time for Correct Responses

Initially, outliers were removed from the data set. A further fifteen sign pairs were removed from the native data set, and eleven pairs from the non-native, as they resulted in reaction times greater or less than two standard deviations from the mean for all remaining signs. Mean reaction times by pair type and number of parameters shared are shown in Table 10.15 for native signers and Table 10.16 for non-native signers. For native signers there is a possibility of a speed/accuracy trade-off. In some analyses the duration of the target clip is included as a covariate. For interpretation of these analyses, the estimated marginal means are reported in Table 10.20 and Figure 10.6 for native signers, and in Table 10.21 and Figure 10.7 for non-native signers.

Table 10.15: Means (and Standard Errors) of Reaction Times by Number of Parameters Shared in Experiment 4 by Stimuli, for native BSL signers (N = 12).

Number of Parameters Shared	Sign Prime		Nonsign Prime	
	Sign Target	Nonsign Target	Sign Target	Nonsign Target
0	1300 (50)	1327 (45)	1335 (53)	1404 (43)
1	1284 (24)	1377 (29)	1346 (31)	1402 (25)
2	1269 (25)	1397 (33)	1290 (29)	1448 (28)

Table 10.16: Means (and Standard Errors) of Reaction times by Number of Parameters Shared in Experiment 4 by Stimuli, for non-native BSL signers (N = 11).

Number of Parameters Shared	Sign Prime		Nonsign Prime	
	Sign Target	Nonsign Target	Sign Target	Nonsign Target
0	1369 (68)	1454 (46)	1502 (55)	1496 (45)
1	1328 (26)	1418 (29)	1446 (38)	1512 (29)
2	1321 (31)	1455 (29)	1382 (34)	1508 (30)

Initially, the data were entered into a three-way mixed ANOVA with prime (sign, nonsign) and target (sign, nonsign) as between stimuli factors, and group (native, non-native) as a within stimuli factor. There were significant main effects of group (F (1, 259) = 97.29, $p < .001$), prime (F (1, 259) = 11.90, $p < .002$) and target (F (1, 259) = 35.39, $p < .001$), and a significant two-way interaction between prime and group (F (1, 259) = 5.64, $p < .02$).

Prime, Target and Group

Sign primes (M = 1347) resulted in faster reactions to targets than did nonsign primes (M = 1422). Sign targets (M = 1332) were responded to more quickly than nonsign targets (M = 1437). Finally, native signers (M = 1347) responded to targets more quickly than non-native signers (M = 1422).

Prime by Group Interaction

Analysis of the effect of prime performed separately for native and non-native signers revealed a significant effect of prime for both groups: F (1, 269) = 6.22, $p < .02$ and F (1, 272) = 18.89, $p < .001$ respectively. For both groups, sign primes led to faster responses to the target signs. The effect of

group was analysed separately for sign and nonsign prime pairs using within-subjects ANOVAs. There was a significant effect of group for both sign primes ($\underline{F}$ (1, 132) = 32.67, $p < .001$) and nonsign primes ($\underline{F}$ (1, 129) = 65.57, $p < .001$), with native signers responding faster in both analyses.

For each sign pair, the advantage or disadvantage due to group was calculated. These difference scores indicate the degree to which native signers were quicker or slower at responding than were non-native signers. The difference scores were entered into a one-way ANOVA with prime lexicality as a between-subjects factor. The effect of prime was significant: $\underline{F}$ (1, 263) = 5.47, $p < .05$. The response advantage to native signers was greater when primes were nonsigns ($\underline{M}$ = 81.64) than when primes were signs ($\underline{M}$ = 50.38). This suggests that although both groups' responses are slowed when primes are nonsigns (compared to when primes are signs), the effect is greater for non-native signers than it is for native signers. One possible interpretation is that native signers are better able to utilise information in nonsigns than are non-native signers.

Clip Duration as a Covariate

At this stage, clip duration for the target sign from each pair was introduced as a covariate. For both native and non-native groups, clip duration was a significant covariate: $\underline{F}$ (1, 269) = 692.04, $p < .001$ and $\underline{F}$ (1, 272) = 119.95, $p < .001$.

For native signers there remained a significant effect of target ($\underline{F}$ (1, 269) = 15.66, $p < .001$) but the significant effect of prime dropped out ($\underline{F}$ (1, 269) = 2.46, $p > .05$). Sign targets ($\underline{EM}$[14] = 1316) were reacted to faster than nonsign targets ($\underline{EM}$ = 1378).

For non-native signers, both the effect of prime ($\underline{F}$ (1, 272) = 13.90, $p < .001$) and target ($\underline{F}$ (1, 272) = 10.03, $p < .005$) remained significant. Sign primes ($\underline{EM}$ = 1390) led to faster responses to the targets than did nonsign primes ($\underline{EM}$ = 1452), and sign targets ($\underline{EM}$ = 1394) were reacted to more quickly than nonsign targets ($\underline{EM}$ = 1448).

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[14] EM indicates the estimated mean, taking into account the effect of the covariate.

Parameters Shared

The next analysis examined the effect of parameters shared on reaction times for native and non-native signers separately. For each experimental group, their data were entered into a one-way ANOVA, with parameters shared (0, 1, 2) as the between stimuli factor. Separate analyses were conducted for sign-sign, sign-nonsign, nonsign-sign and nonsign-nonsign pairs. The results of these analyses are reported in Table 10.17 — the effect of parameters shared did not reach significance for any of the comparisons made for either group.

Table 10.17: One-way ANOVAs examining Effect of Number of Parameters Shared on Reaction Times, By Stimuli Analysis, by Prime-Target Lexicality and by Group.

Pair Type	**Native Signers**			**Non-native Signers**		
	F	df	Sig.	F	df	Sig.
Sign-Sign	0.19	2, 65	n.s.	0.28	2, 64	n.s.
Sign-Nonsign	0.67	2, 61	n.s.	0.32	2, 62	n.s.
Nonsign-Sign	0.85	2, 59	n.s.	1.73	2, 62	n.s.
Nonsign-Nonsign	0.83	2, 63	n.s.	0.03	2, 65	n.s.

Clip Duration as a Covariate

Again, clip duration was introduced to the analyses as a covariate. For all eight comparisons, clip duration was a significant covariate (see Table 10.18). Introducing the covariate had little impact upon the effect of sharing parameters. For native signers it had no effect at all in terms of statistical significance. For non-native signers, the effect of parameters shared became significant for nonsign-sign pairs (see Table 10.19). Analysing the estimated means using a K-matrix revealed that when the nonsign prime shared one parameter with the sign target, the response was facilitated by 134 msec ($p < .01$). Sharing two parameters facilitated the response by 180 msec, and was also significant ($p < .005$).

Table 10.18: One-way ANOVAs examining Effect of Target Clip Duration as a Covariate on Reaction Times, By Stimuli Analysis, by Prime-Target Lexicality and by Group.

Pair Type	Native Signers			Non-native Signers		
	F	df	Sig.	F	df	Sig.
Sign-Sign	34.10	1, 65	< .001	45.35	1, 64	< .001
Sign-Nonsign	36.87	1, 61	< .001	24.28	1, 62	< .001
Nonsign-Sign	62.72	1, 59	< .001	64.78	1, 62	< .001
Nonsign-Nonsign	15.07	1, 63	< .001	11.65	1, 65	< .001

Table 10.19: One-way ANOVAs examining Effect of Number of Parameters Shared on Reaction Times with Target Clip Duration as a Covariate, By Stimuli Analysis, by Prime-Target Lexicality and by Group.

Pair Type	Native Signers			Non-native Signers		
	F	df	Sig.	F	df	Sig.
Sign-Sign	0.98	2, 65	n.s.	0.95	2, 64	n.s.
Sign-Nonsign	1.01	2, 61	n.s.	0.38	2, 62	n.s.
Nonsign-Sign	1.12	2, 59	n.s.	4.89	2, 62	< .02
Nonsign-Nonsign	1.07	2, 63	n.s.	0.43	2, 65	n.s.

Identity Priming

Finally, the presence of identity (repetition) priming was checked for by comparing pairs that shared no parameters with identical pairs. For native signers, reaction to a sign target was neither facilitated nor inhibited when preceded by the same sign ($\underline{F}$ (1, 16) = 3.98, $p > .05$). The same was true for identical nonsign-nonsign pairs ($\underline{F}$ (1, 18) = 0.01, $p > .05$). For non-native signers also, identical sign-sign pairs neither facilitated nor inhibited response to the target ($\underline{F}$ (1, 15) = 1.50, $p > .05$) and neither did identical nonsign-sign pairs ($\underline{F}$ (1, 16) = 0.36, $p > .05$).

Again, clip duration was introduced as a covariate in the analyses. For native signers, clip duration was a significant covariate for identical sign pairs ($\underline{F}$ (1, 16) = 5.00, $p < .05$) and identical nonsign-nonsign pairs ($\underline{F}$ (1, 18) = 6.45, $p < .02$). Introducing the covariate reveal a marginally significant effect of identity priming for sign-sign pairs, $\underline{F}$ (1, 16) = 3.96, $p = 0.066$, but not for nonsign-nonsign pairs $\underline{F}$ (1, 18) = 0.74, $p > .05$ respectively. For non-native

signers, clip duration was a significant covariate for identical sign pairs ($\underline{F}$ (1, 15) = 17.14, $p < .002$) but not for identical nonsign-nonsign pairs ($\underline{F}$ (1, 16) = 0.15, $p > .05$). Introducing the covariate did not reveal any significant effects of identity priming: $\underline{F}$ (1, 15) = 2.84, $p > .05$ and $\underline{F}$ (1, 16) = 0.44, $p > .05$ respectively.

Table 10.20: Estimated Means (and Standard Errors) of Reaction Times by Number of Parameters Shared in Experiment 4 by Stimuli with Clip Duration as a Covariate, for native BSL signers (N = 12).

Number of Parameters Shared	Sign Prime		Nonsign Prime	
	Sign Target	Nonsign Target	Sign Target	Nonsign Target
0	1304 (37)	1330 (45)	1367 (36)	1375 (43)
1	1293 (20)	1376 (25)	1320 (22)	1417 (26)
2	1257 (21)	1404 (28)	1304 (21)	1445 (23)

Table 10.21: Estimated Means (and Standard Errors) of Reaction times by Number of Parameters Shared in Experiment 4 by Stimuli with Clip Duration as a Covariate, for non-native BSL signers (N = 11).

Number of Parameters Shared	Sign Prime		Nonsign Prime	
	Sign Target	Nonsign Target	Sign Target	Nonsign Target
0	1372 (44)	1458 (45)	1548 (43)	1469 (49)
1	1339 (23)	1420 (25)	1414 (25)	1522 (28)
2	1308 (24)	1445 (27)	1398 (25)	1507 (27)

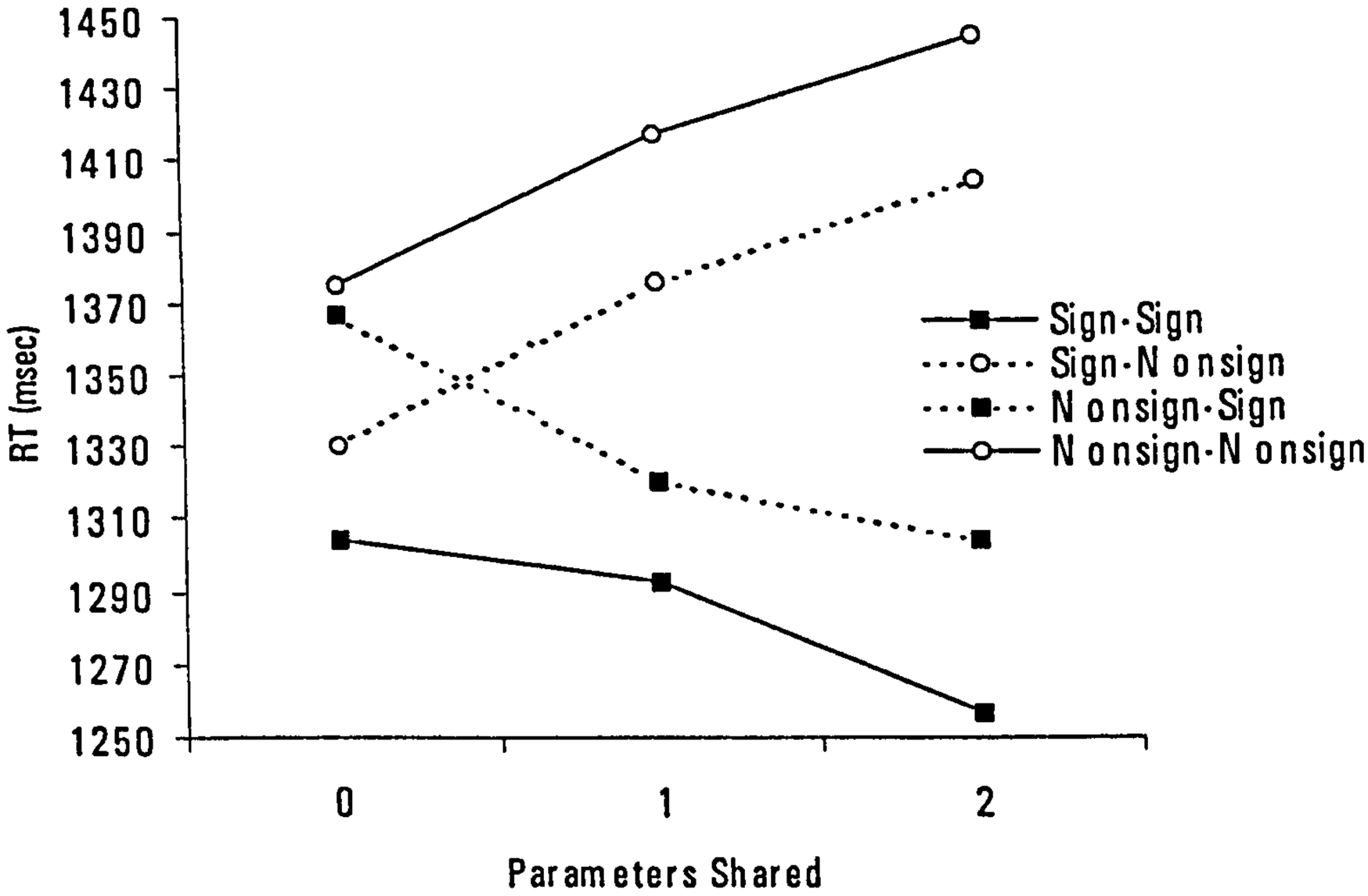

Figure 10.6: Estimated Effect of Number of Parameters Shared on Reaction Times, By Stimuli Analysis with Target Clip Duration as a Covariate, for Native Signers in Experiment 4.

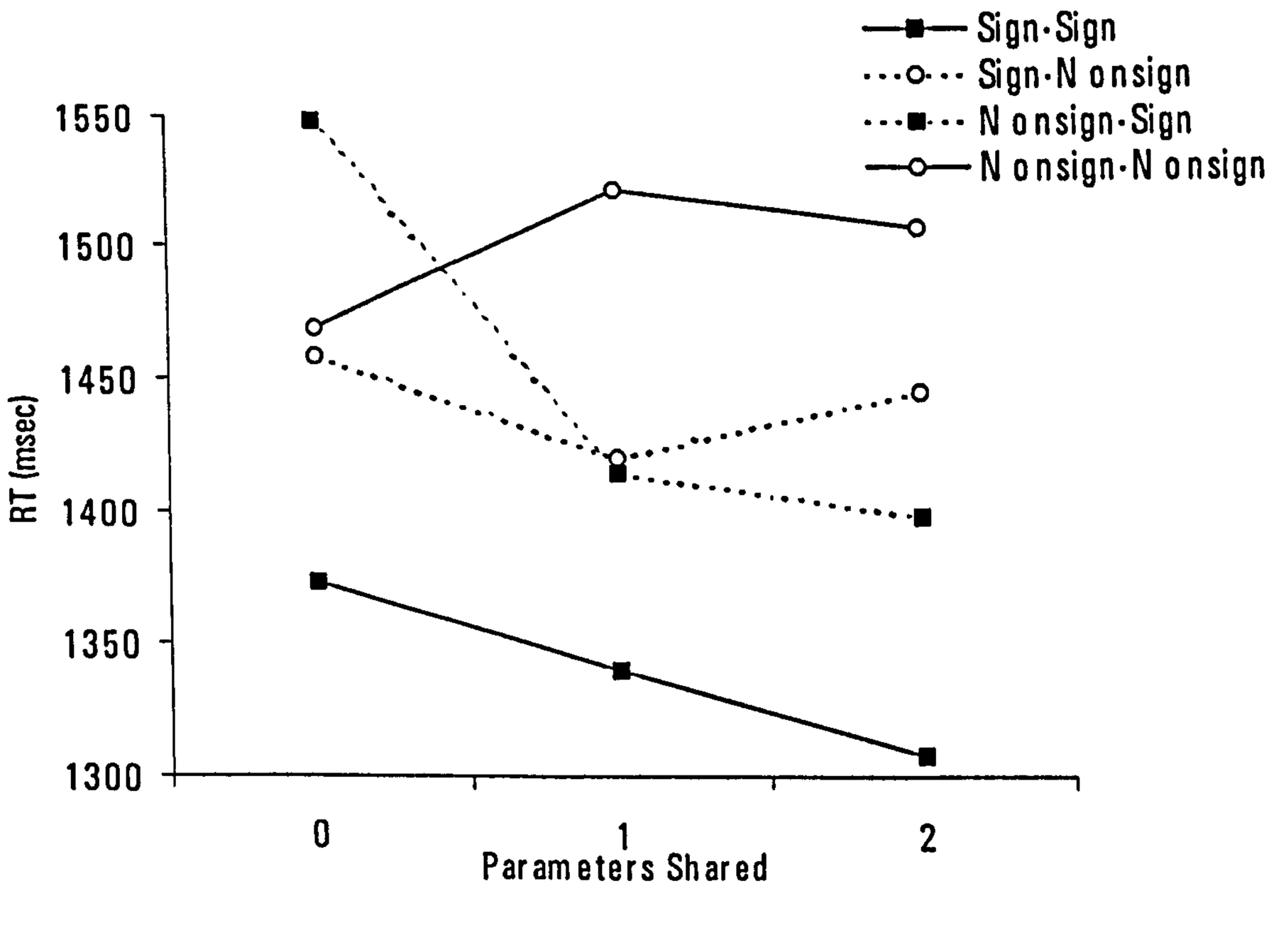

Figure 10.7: Estimated Effect of Number of Parameters Shared on Reaction Times, By Stimuli Analysis with Target Clip Duration as a Covariate, for Non-native Signers in Experiment 4.

Summary of By Stimuli Findings for Number of Parameters Shared

A. Without clip duration as a covariate, sign primes lead to faster target responses than nonsign primes
B. Without clip duration as a covariate, sign targets lead to faster target responses than nonsign targets
C. Without clip duration as a covariate, native signers were faster than non-native signers
D. Without clip duration as a covariate, there was no effect of the number of shared parameters
E. Either with or without clip duration as a covariate, there was no evidence of identity priming
F. With clip duration as a covariate, sign targets lead to faster responses than nonsign targets for native signers, but there was no significant effect of prime lexicality
G. With clip duration as a covariate, sign targets lead to faster responses than nonsign targets for non-native signers, and sign primes lead to faster responses than nonsign primes
H. With clip duration as a covariate, for non-native signers only, responses to targets were faster the more parameters they shared with their primes
I. With clip duration as a covariate, native and non-native signers did not significantly differ in the reaction times to targets

Effects of Specific Parameters

Reaction Time for Correct Responses

Analyses were performed initially for sign-sign pairs, and only extended to other pair types where this comparison was significant. Reported effects are for sign-sign pairs unless otherwise stated. Analyses were performed for native and non-native signers separately.

Table 10.22: Means (and Standard Errors) of Reaction Times (msec) for Each of the Conditions by Specific Parameters Shared in Experiment 4 by Stimuli, for native BSL signers (N = 12).

	Sign Prime		Nonsign Prime	
	Sign Target	**Nonsign Target**	**Sign Target**	**Nonsign Target**
hlm†	1300 (47)	1327 (43)	1335 (50)	1404 (41)
Hlm	1271 (49)	1330 (28)	1282 (31)	1346 (29)
hLm	1277 (39)	1358 (58)	1386 (38)	1404 (27)
hlM	1303 (34)	1437 (47)	1367 (63)	1451 (50)
HLm	1295 (38)	1392 (31)	1268 (39)	1487 (44)
HlM	1302 (47)	1400 (61)	1301 (57)	1395 (42)
hLM	1210 (30)	1418 (73)	1300 (41)	1463 (52)
HLM	1173 (26)	---	---	1397 (51)

† h/H indicate parameter handshape, l/L location, m/M: movement. An uppercase letter for a given parameter indicates that the prime and target are similar with respect of the given parameter, lowercase letter indicates that they are different. HLM pairs are identical.

Table 10.23: Means (and Standard Errors) of Reaction Times (msec) for Each of the Conditions by Specific Parameters Shared in Experiment 4 by Stimuli, for non-native BSL signers (N = 11).

	Sign Prime		Nonsign Prime	
	Sign Target	**Nonsign Target**	**Sign Target**	**Nonsign Target**
hlm†	1369 (64)	1454 (43)	1502 (52)	1496 (42)
Hlm	1318 (47)	1407 (31)	1406 (49)	1514 (45)
hLm	1335 (48)	1398 (58)	1514 (63)	1495 (45)
hlM	1331 (40)	1447 (53)	1426 (60)	1525 (47)
HLm	1385 (46)	1430 (31)	1414 (49)	1528 (50)
HlM	1317 (57)	1472 (51)	1356 (58)	1465 (56)
hLM	1269 (42)	1438 (59)	1375 (54)	1533 (49)
HLM	1265 (31)	---	---	1461 (26)

† h/H indicate parameter handshape, l/L location, m/M: movement. An uppercase letter for a given parameter indicates that the prime and target are similar with respect of the given parameter, lowercase letter indicates that they are different. HLM pairs are identical.

One Parameter Shared - Handshape

For both native and non-native signers, there was no significant main effect of shared handshape. This analysis compared all 'h' conditions with 'H' conditions. As in the by stimuli analyses for number of parameters shared, clip duration was entered as a covariate into the analyses. The effect of clip duration was significant for both native ($\underline{F}$ (1, 73) = 33.35, $p < .001$) and non-

native signers ($\underline{F}$ (1, 72) = 48.21, $p < .001$). However, the effect of shared handshape remained non-significant.

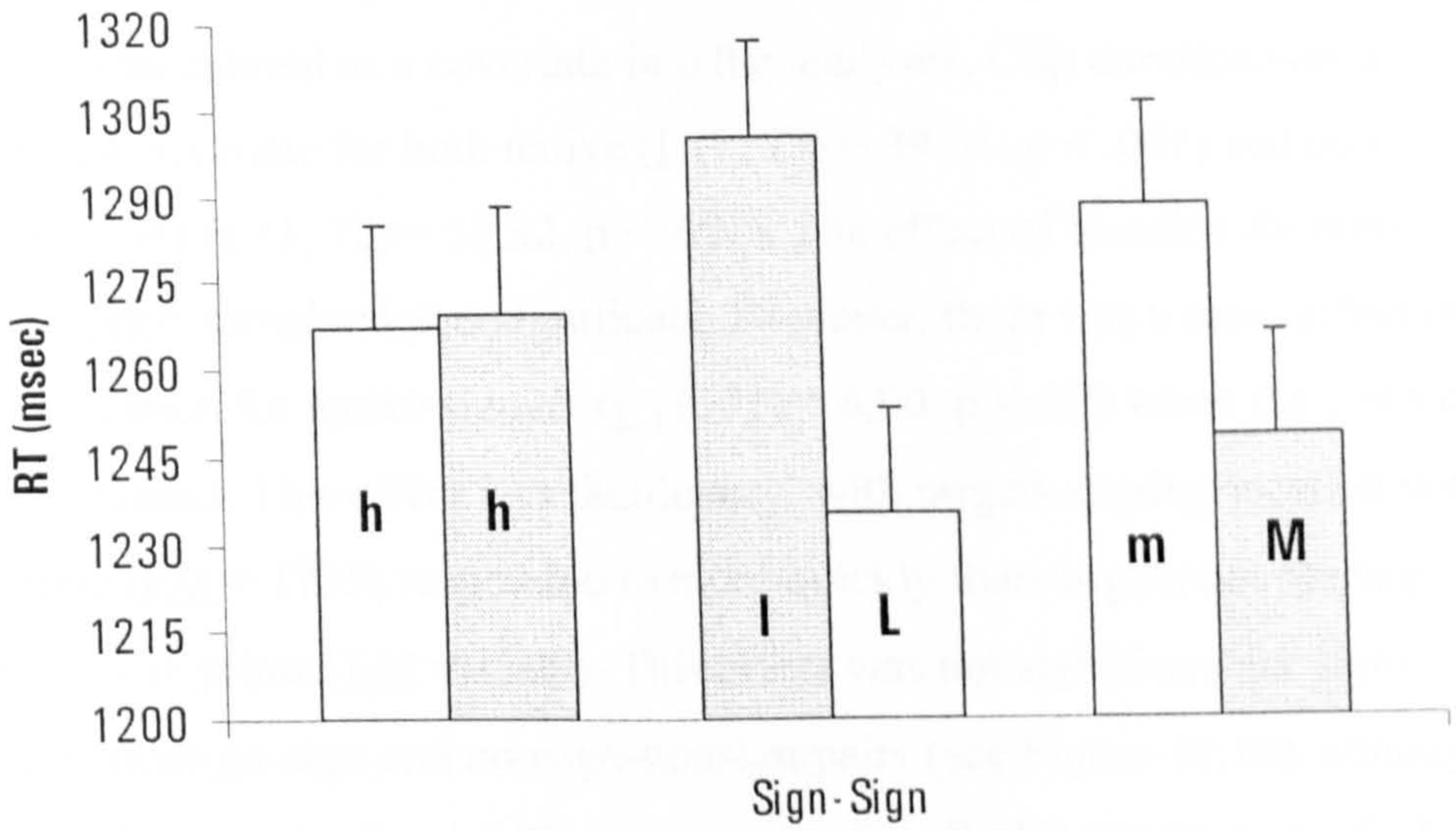

Figure 10.8: Estimated mean reaction times by handshape, location and movement for native signers in Experiment 4 (sign-sign pairs only).

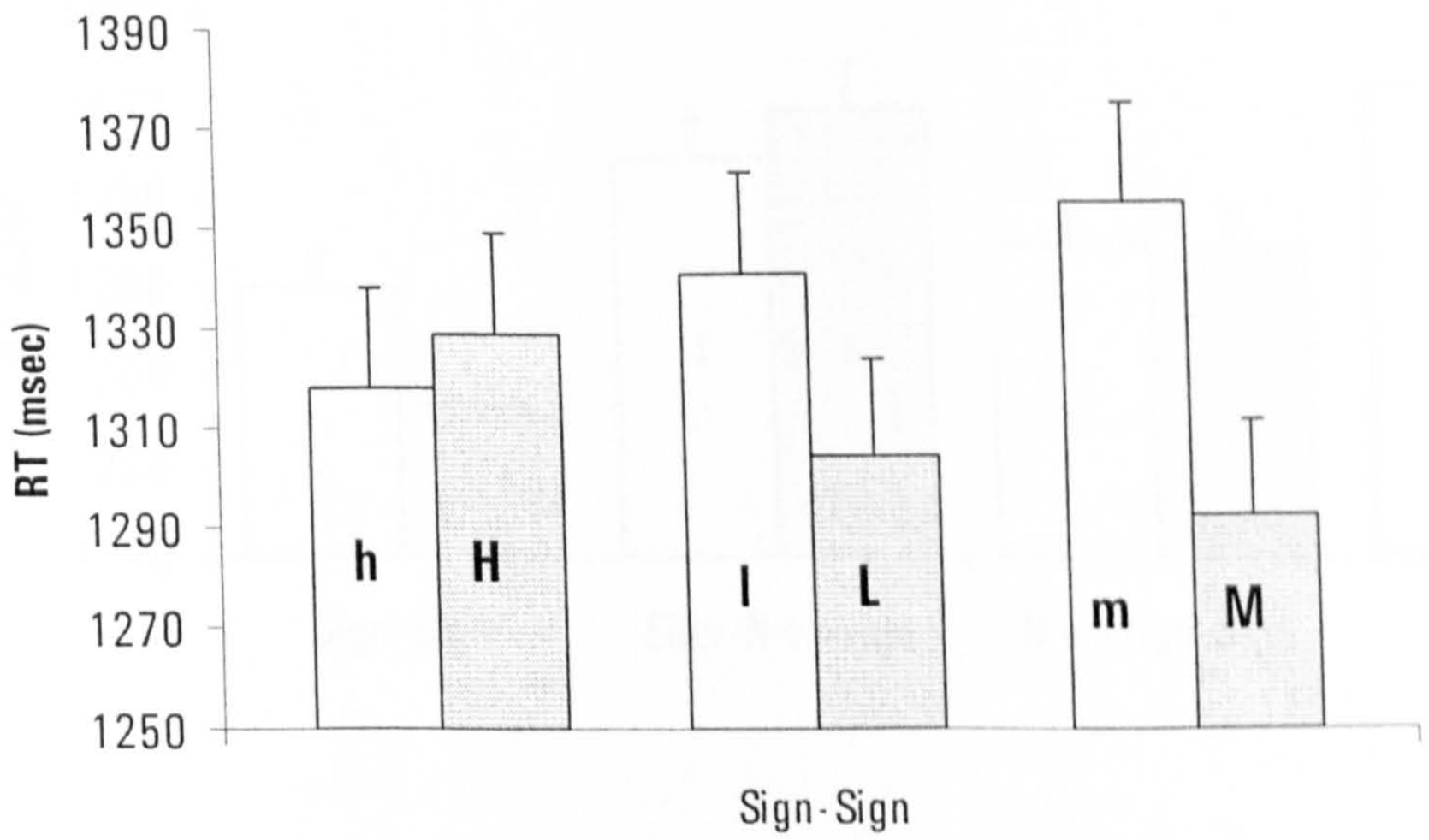

Figure 10.9: Estimated mean reaction times by handshape, location and movement for non-native signers in Experiment 4 (sign-sign pairs only).

One Parameter Shared - Location

For both native and non-native signers, there was no significant main effect of shared location. This analysis compared all 'I' conditions with 'L' conditions. As in the by stimuli analyses for number of parameters shared, clip duration was entered as a covariate into the analyses. Clip duration was a significant covariate for both native ($\underline{F}$ (1, 73) = 39.31, $p < .001$) and non-native signers ($\underline{F}$ (1, 72) = 50.32, $p < .001$). The effect of location for non-native signers remained non-significant. However, there was a main effect of shared location for native signers ($\underline{F}$ (1, 73) = 6.90, $p < .02$) when the covariate was introduced. This effect was facilitatory, with targets sharing location with the prime ($\underline{EM}$ = 1235) responded to more quickly than targets not sharing location with prime ($\underline{EM}$ = 1300). This effect was not significant for sign-nonsign, nonsign-sign and nonsign-nonsign pairs (see Figure 10.10), although clip duration remained a significant covariate for all of these analyses: $\underline{F}$ (1, 61) = 37.24, $p < .001$, $\underline{F}$ (1, 59) = 62.63, $p < .001$ and $\underline{F}$ (1, 73) = 18.5, $p < .001$ respectively.

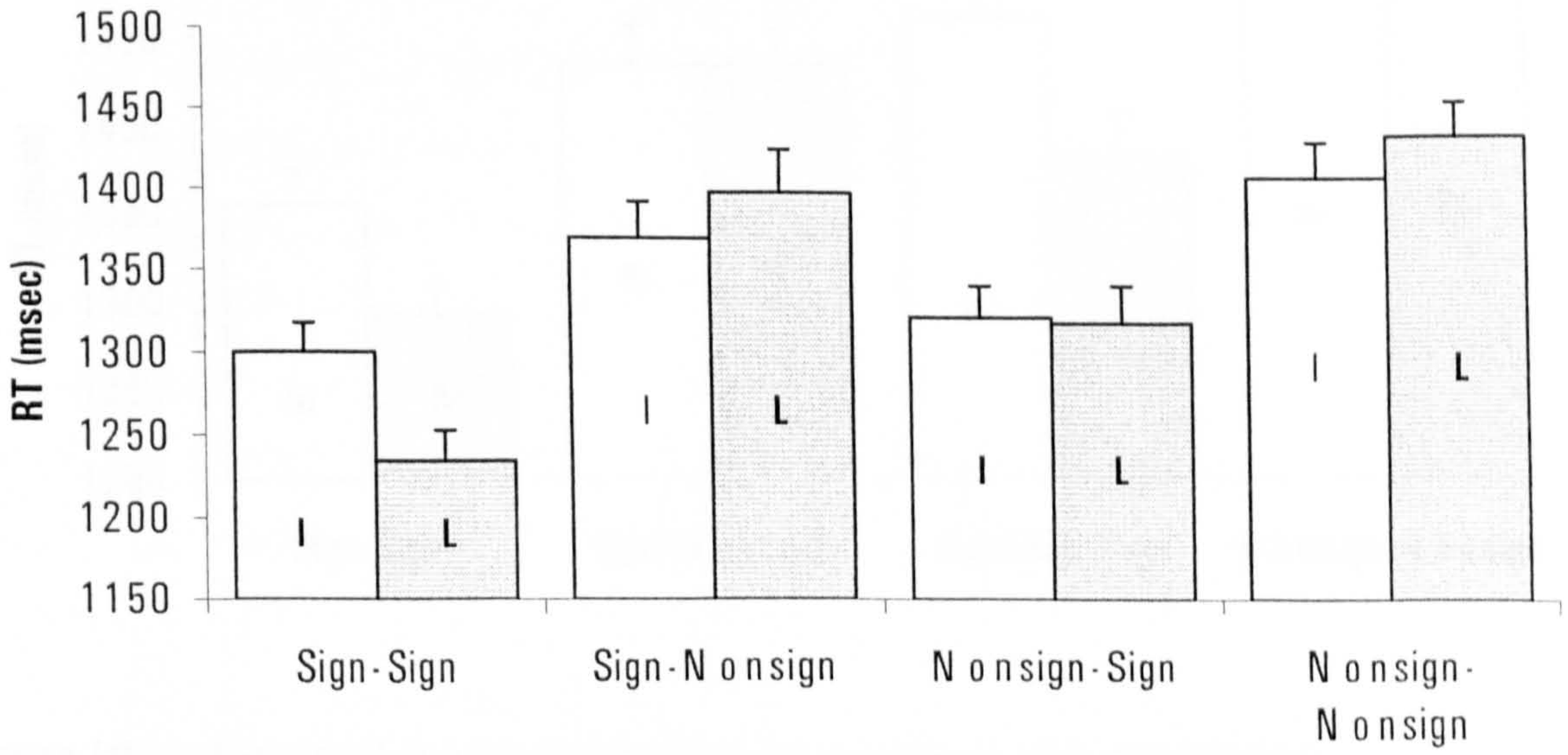

Figure 10.10: Estimated mean reaction times by location and prime-target lexicality for native signers in Experiment 4.

One Parameter Shared - Movement

For both native and non-native signers, there was no significant main effect of shared movement. This analysis compared all 'm' conditions with 'M' conditions. As in the by stimuli analyses for number of parameters shared, clip duration was entered as a covariate into the analyses. Clip duration was a significant covariate for both native ($F(1, 73) = 35.21$, $p < .001$) and non-native signers ($F(1, 72) = 53.43$, $p < .001$). Introducing the covariate revealed a significant effect of shared movement for non-native signers only: $F(1, 72) = 5.24$, $p < .05$. R=The effect was facilitatory, with targets sharing movement with their prime (EM = 1292) responded to more quickly than targets not sharing movement with their prime (EM = 1355). However, the same facilitatory effect was found for nonsign-sign pairs (see Figure 10.11): $F(1, 62) = 5.63$, $p < .05$, EM (m) = 1461 and EM (M) = 1383.

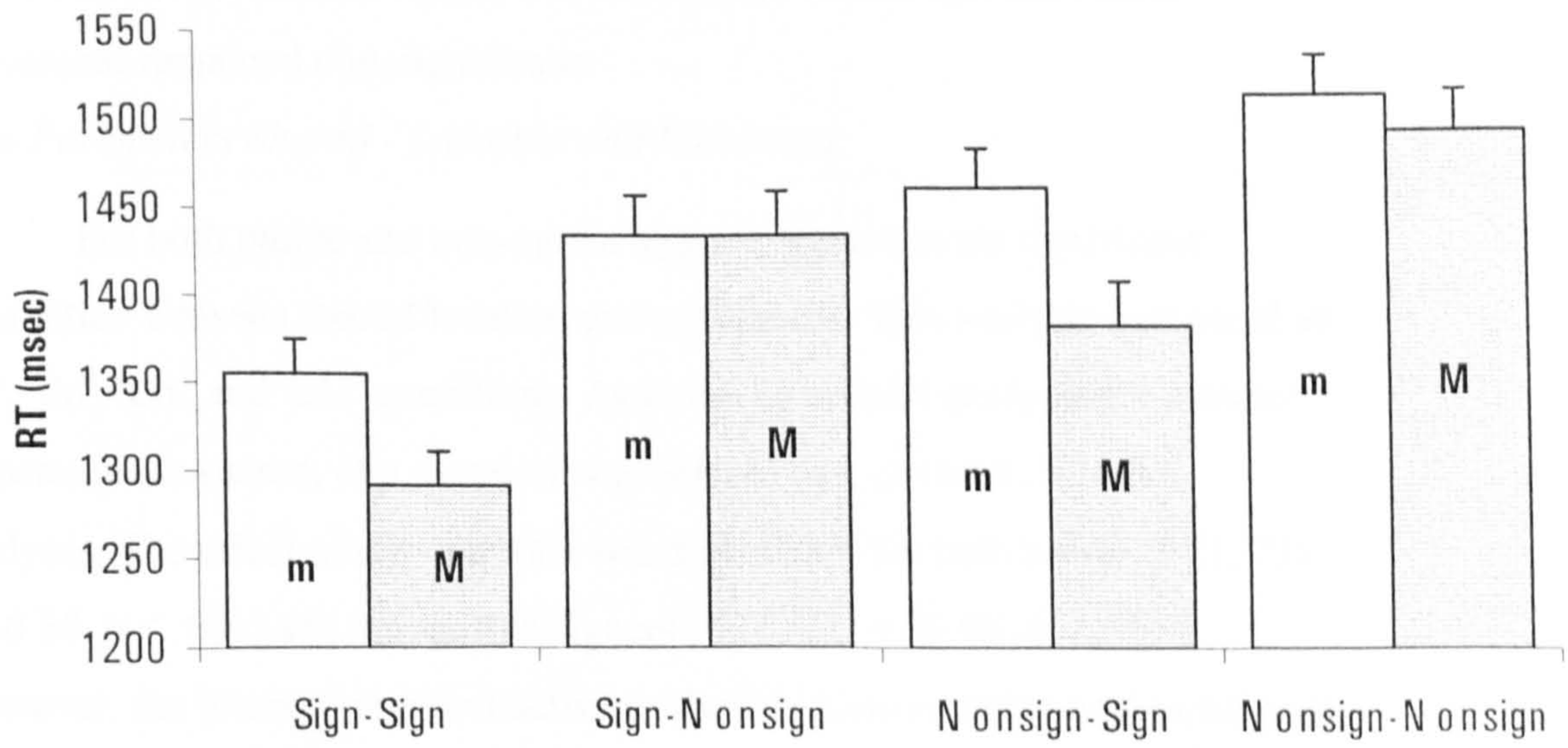

Figure 10.11: Estimated mean reaction times by movement and prime-target lexicality for non-native signers in Experiment 4.

Two Parameters Shared - Handshape and Location

For both native and non-native signers, there was no significant interaction between shared handshape and location. This analysis compared all

'hl', 'hL', 'Hl' and 'HL' conditions. As in the by stimuli analyses for number of parameters shared, clip duration was entered as a covariate into the analyses. The effect of clip duration was significant for both native ($F(1, 73) = 37.97$, $p < .001$) and non-native signers ($F(1, 72) = 48.73$, $p < .001$). However, the interaction effects between shared handshape and shared location remained non-significant.

Two Parameters Shared - Handshape and Movement

For both native and non-native signers, there was no significant interaction between shared handshape and movement. This analysis compared all 'hm', 'hM', 'Hm' and 'HM' conditions. As in the by stimuli analyses for number of parameters shared, clip duration was entered as a covariate into the analyses. The effect of clip duration was significant for both native ($F(1, 73) = 34.05$, $p < .001$) and non-native signers ($F(1, 72) = 52.18$, $p < .001$). However, the interaction effects between shared handshape and shared movement remained non-significant.

Two Parameters Shared - Location and Movement

For both native and non-native signers, there was no significant interaction between shared location and movement. This analysis compared all 'lm', 'lM', 'Lm' and 'LM' conditions. As in the by stimuli analyses for number of parameters shared, clip duration was entered as a covariate into the analyses. The effect of clip duration was significant for both native ($F(1, 73) = 40.89$, $p < .001$) and non-native signers ($F(1, 72) = 55.08$, $p < .001$). However, the interaction effect between shared location and shared movement remained non-significant for non-native signers. For native signers, the interaction between location and movement was marginally significant: $F(1, 73) = 3.54$, $p = 0.064$. Pairwise comparisons were used to locate the source of the interaction for the sign-sign pairs. The effect was due to significantly quicker reaction times when prime and target shared both location and movement (see Table 10.24 and Figure 10.12).

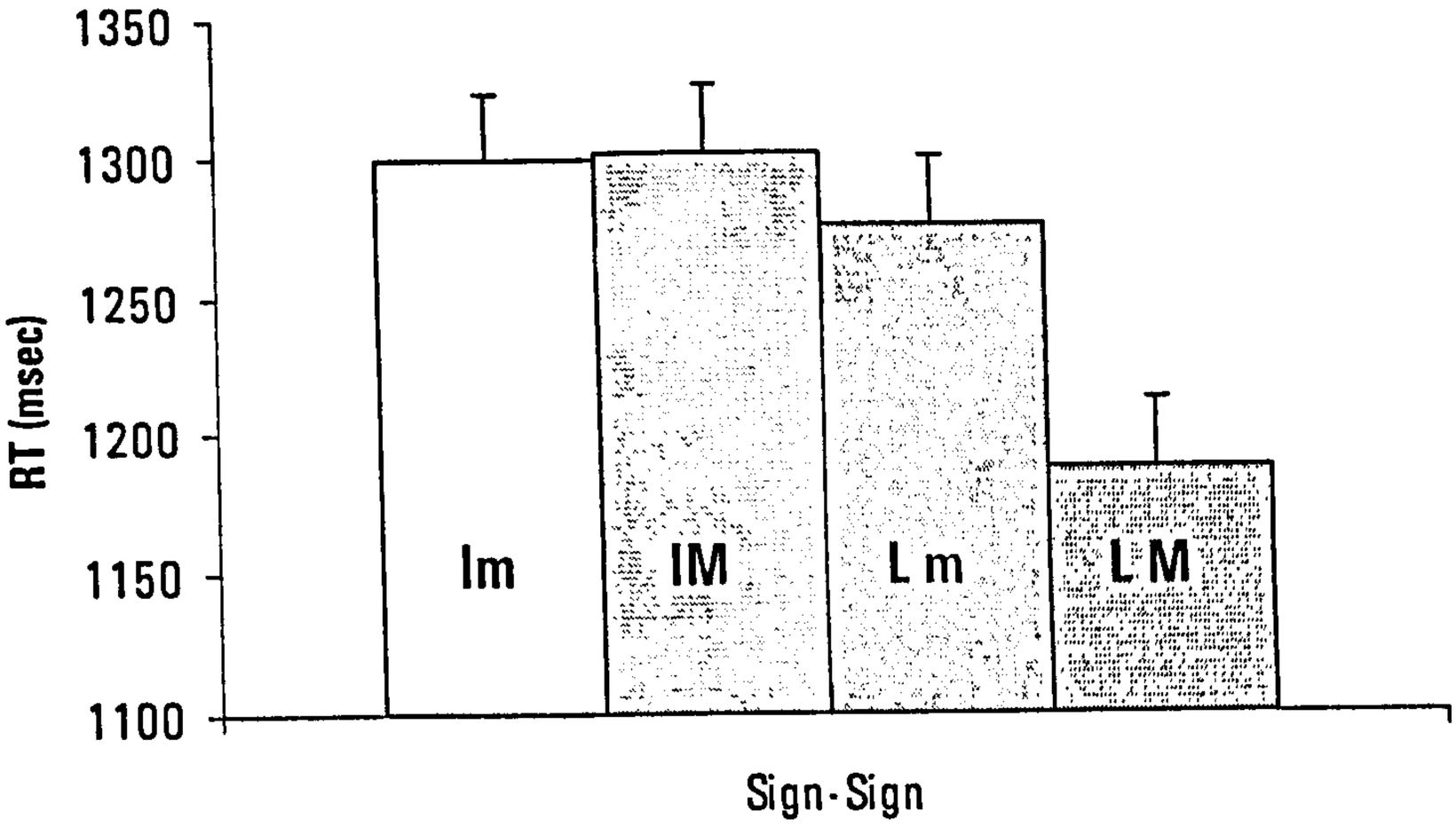

Figure 10.12: Estimated mean reaction times by location and movement for sign-sign pairs for native signers in Experiment 4.

Table 10.24: One-way ANOVAs examining Location by Movement Interaction for Sign-Sign Pairs, By Stimuli Analysis (with Clip Time as a Covariate), Native Signers, Experiment 4.

Pair Type	F	df	Sig.
Effect of location for dissimilar movement	0.35	1, 37	n.s.
Effect of location for similar movement	15.82	1, 35	< 0.001
Effect of movement for dissimilar location	0.00	1, 37	n.s.
Effect of movement for similar location	8.15	1, 35	< 0.01

The interaction between location and movement was non-significant for sign-nonsign pairs ($\underline{F}$ (1, 61) = 0.75, p > .05) and nonsign-sign pairs ($\underline{F}$ (1, 59) = 0.41, p > .05). For nonsign-sign pairs there was a marginally significant interaction: F (1, 73) = 3.48, p = 0.066. The interaction was due to slower reaction times for targets sharing location with their prime, only when they did not share movement (see Table 10.25 and Figure 10.13).

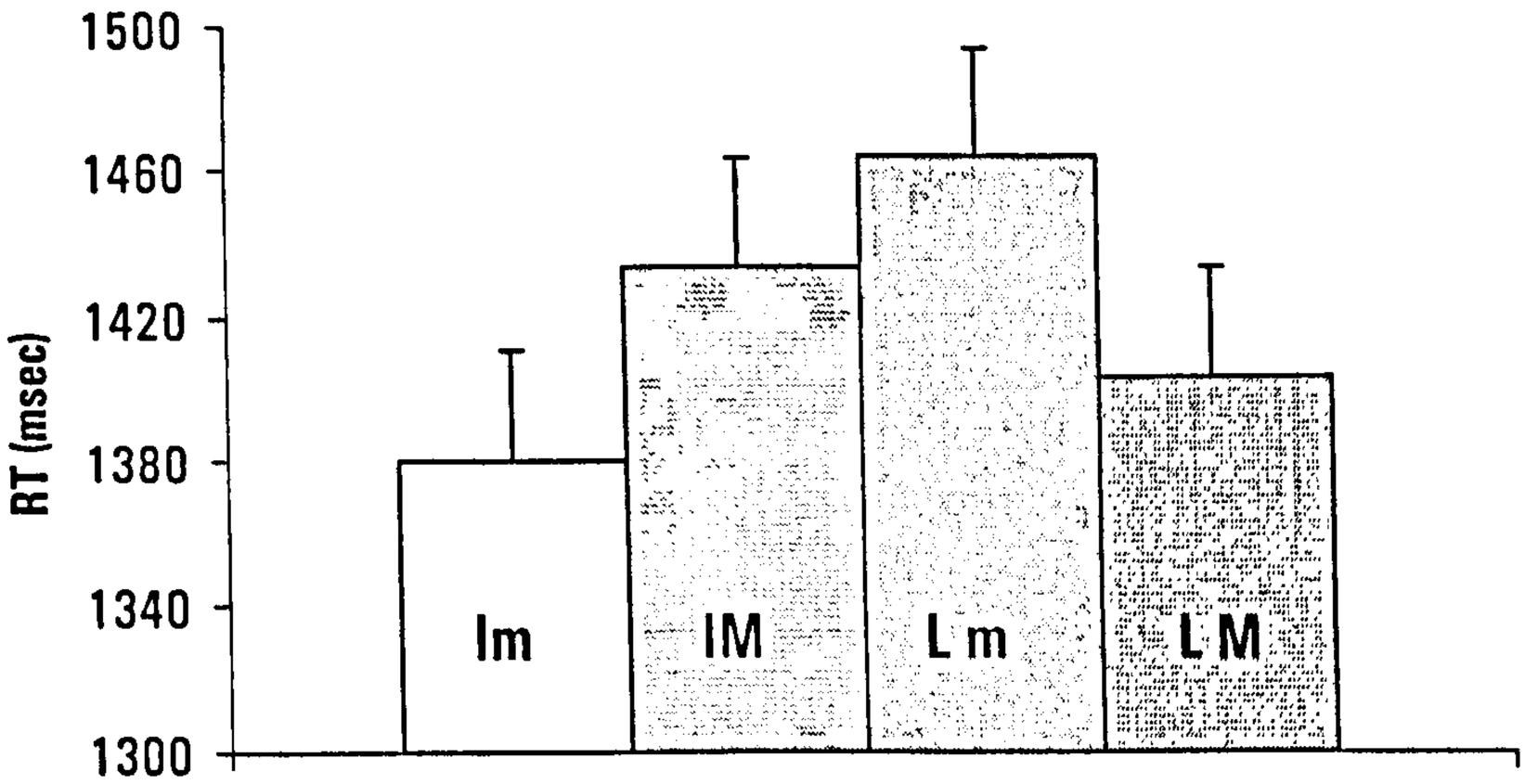

Figure 10.13: Estimated mean reaction times by location and movement for nonsign-nonsign pairs for native signers in Experiment 4.

Table 10.25: One-way ANOVAs examining Location by Movement Interaction for Nonsign-Nonsign Pairs, By Stimuli Analysis(with Clip Time as a Covariate), Native Signers, Experiment 4.

Pair Type	F	df	Sig.
Effect of location for dissimilar movement	4.38	1, 34	< 0.05
Effect of location for similar movement	0.52	1, 38	n.s.
Effect of movement for dissimilar location	1.31	1, 35	n.s.
Effect of movement for similar location	2.85	1, 37	n.s.

Pairwise comparisons were used to check that the effect of LM sign-sign pairs was not solely due to HLM pairs (i.e. attributable to repetition priming). Significantly faster reaction times to targets sharing both location and movement was evident for both hLM (non-identical) and HLM (identical) pairs (see Table 10.26). The effect cannot be attributed solely to repetition priming.

Table 10.26: One-way ANOVAs examining Effect of Location combined with Movement for Handshape Similar and Handshape Dissimilar Pairs, By Stimuli Analysis (with Clip Time as a Covariate), Native Signers, Experiment 4.

Pair Type	Comparison	F	df	Sig.
Sign-Sign	hlm-HLM	3.96	1, 16	0.066
Sign-Sign	hlm-hLM	4.80	1, 17	0.045
Nonsign-Nonsign	hlm-HLM	0.74	1, 18	0.402
Nonsign-Nonsign	hlm-hLM	1.26	1, 18	0.278

Summary of By Stimuli Findings for Specific Parameters Shared

A. There was some (marginal) evidence for repetition priming for native signers, for sign-sign pairs only, when clip duration was used as a covariate
B. For native signers, targets were responded to faster when they shared both location and movement with their prime. This effect was found only for sign-sign pairs when clip duration was used as a covariate
C. For non-native signers, targets were responded to faster when they shared movement with their prime. This effect was found only when clip duration was used as a covariate, and for nonsign-sign pairs

10.4 Discussion

Twelve native and 12 non-native signers of BSL participated in a primed lexical decision task. Participants were required to indicate whether a target sign was an actual BSL sign or a nonsign. The target was preceded by a prime that was related to the target in terms of handshape, location and/or movement parameters. In order to encourage attention to the prime, a block of primed lexical decision trials was always followed by a block of prime recognition trials.

Signal detection analysis of the prime recognition test data revealed only one participant (a non-native signer) who performed poorly (at chance level). This participant was removed from all further analyses as either (a)

they had paid no attention to the primes, or (b) they had misunderstood the instructions given by the experimenter.

For the primed lexical decision data the two dependent measures were (1) accuracy of response and (2) reaction time for correct responses. There were 5 independent variables: (1) group (native or non-native signers of BSL), (2) lexicality of the prime (sign or nonsign), (3) lexicality of the target (sign or nonsign), and either (4) number of parameters shared (0, 1 or 2) or (5) specific parameters shared (no parameters, handshape only, location only, movement only, handshape and location, handshape and movement, or location and movement). The priming data were analysed in three ways: (1) by subjects, (2) by stimuli, and (3) by stimuli with target clip duration as a covariate in the model. The analysis with target clip duration as a covariate focused only upon analyses with reaction time as a dependent measure.

10.4.1 Effects of Group

Native and non-native signers did not differ on any accuracy or bias measures associated with the recognition test. For the primed lexical decision task, non-native signers were more accurate than native signers in the by stimuli analysis, but no significant difference was found for the by subjects analysis. For both by subjects and by stimuli analyses, native signers reacted more quickly on correct trials than non-native signers. However, when target clip duration was introduced as a covariate in the by stimuli analysis the group effect failed to reach significance. The actual means and the estimated means (with target clip duration as a covariate) are the same, suggesting that the effect fails to reach significance in the latter model because of larger standard errors when target clip duration is covaried.

10.4.2 Lexicality of Signs

Prime and target lexicality had no effect on accuracy of responses in any analysis. Participants do not seem to be prone to making more mistakes when either accepting signs or rejecting nonsigns. Neither does the preceding sign's lexicality appear to influence lexical decision accuracy.

For both the by subjects and by stimuli analyses, sign primes led to faster responses to targets than did nonsign primes. The same was found for targets, with sign targets responded to more quickly than nonsign targets (the classic lexicality effect). In the by subjects analysis, the effects of prime and target lexicality interacted. Sign-sign pairs lead to faster reaction times than either sign-nonsign or nonsign-sign pairs, which in turn lead to faster reaction times than nonsign-nonsign pairs. However, when target clip duration was introduced as a covariate the effect of prime lexicality disappeared for native signers, as did the interaction between prime and target lexicality.

10.4.3 Number of Parameters Shared

In the by subjects analysis, prime-target overlap of 2 parameters led to faster rejection of nonsign targets by native signers. For non-native signers, nonsign primes sharing 2 parameters led to faster responses to targets, and sign primes sharing 2 parameters led to slower rejection of nonsign targets. In the by stimuli analysis there were no significant effects of the number of parameters shared by prime and target for either native or non-native signers. When target clip duration was introduced as a covariate, increasing prime-target overlap led to faster reaction times for non-native signers only, regardless of prime and target lexicality.

10.4.4 Specific Parameters Shared

For native signers, both the by subjects and by stimuli analyses revealed no significant effects of specific parameters. For non-native signers, the by subjects analysis revealed facilitation due to location overlap for sign-sign pairs only, and facilitation due to handshape combined with movement overlap for sign-sign, nonsign-sign and nonsign-nonsign pairs.

Introducing target clip duration as a covariate changed this pattern of results substantially. For native signers, location with movement overlap resulted in facilitation of response to the target for the sign-sign pairs only. This effect was not attributable to the effect of identity primes. For non-native

signers, movement overlap led to facilitation for sign-sign and nonsign-sign pairs.

10.4.5 Repetition/Identity Priming

In the by subjects analysis, facilitative repetition/identity priming was found for sign-sign pairs, but not for nonsign-nonsign pairs. This was true for both native and non-native signers. However, in the by stimuli analysis (even with target clip duration as a covariate) there was only marginally significant evidence of repetition/identity priming for sign-sign pairs for native signers only.

10.4.6 Evidence for Phonological Priming

Duration of target clip was a highly significant covariate, accounting for over 30% of reaction time variance (adjusted R^2) in most analyses. Using the minimum F statistic for 'by subjects' and 'by stimuli' analyses results in three significant effects: (1) native signers correctly respond quicker than non-native signers in a primed lexical decision task, (2) sign targets are correctly reacted to more quickly than nonsign targets (lexicality effect), and (3) sign primes result in quicker correct reactions to their targets than do nonsign primes. However, focusing upon the by stimuli analyses that take into account the effect of target clip duration provides a more interesting set of findings.

10.4.6.1 Effect of Group

Native and non-native signers do not differ significantly in their accuracy or reaction times. This matches the findings reported by Corina and Emmorey (1993), who found no native/non-native group differences in a lexical decision task looking at phonological priming.

10.4.6.2 Lexicality of Signs

For all signers, sign targets are correctly reacted to more quickly than nonsign targets. For non-native signers, sign primes result in quicker correct decisions about targets. The effect of target status is the classic lexicality effect, also reported by Corina and Emmorey (1993). Lexical items are reacted

to more quickly than non-lexical items, i.e. 'yes' responses are elicited more quickly than 'no' responses. The effect of sign primes for non-native signers only is a different issue. The presence of a sign prime appears to facilitate both 'yes' and 'no' responses to its target.

10.4.6.3 Number of Parameters and Specific Parameters Shared

For non-native signers, the degree of overlap (number of parameters shared by prime and target) influences reaction time — the greater the overlap, the quicker the reaction time. For native signers, degree of overlap has no measurable effect on reaction time.

For native signers, the nature of the overlap (the specific phonological parameters shared by prime and target) influences reaction time — when prime and target share the same location and movement, reaction is facilitated. This is found for sign-sign pairs only, suggesting that the effect is a lexical one. Simply sharing parameters seems to not influence the processing of signs for native signers, rather it is a combination of specific parameters, in this case location and movement, that influences the time required for a correct lexical decision. Interestingly, this study has found that shared location/movement has a facilitatory effect on lexical decision times. Corina and Emmorey (1993) report an inhibitory effect of location for both native and non-native signers.

For non-native signers, parameter-specific effects appear to be prelexical — when prime and target share the same movement, reaction time is facilitated for both sign-sign and nonsign-sign pairs. Emmorey and Corina (1993) reported facilitation due to movement for both native and non-native signers. However, their design did not employ nonsign-sign or nonsign-nonsign pairs, so it is not possible to assess whether the effects they report were lexical or prelexical.

There was some (marginal) evidence for repetition/identity priming. Signs preceded by an identical sign were reacted to more quickly for non-native signers only. The same effect for nonsign-nonsign pairs did not approach significance.

10.4.7 Towards a Model

The cohort and NAM models of lexical access provided the theoretical framework within which this experiment was conducted. These models share certain characteristics: (1) lexical items are represented by units, (2) these units accumulate evidence for the lexical item they represent on the basis of incoming stimuli, (3) increasing evidence is instantiated as increasing activation in the unit, and (4) the level of activation of the unit and its competitors/neighbourhood is used as input to a decision stage. A tentative model is put forward in Figure 10.14.

In this model, visual information from the visual system is processed and evidence for specific phonological parameters is extracted. This information is first used to activate prelexical units at the level of individual parameters — location, and then handshape and movement. Location and movement information is further combined, activating units representing specific combinations of location and movement. This can tentatively be termed the 'syllabic' level. Parameter and syllabic units, in turn, are linked to lexical units (circles in Figure 10.14) — a prelexical unit (representing a 'parameter' or 'syllable') is connected to, and activates, each lexical unit representing a sign containing that parameter or combination of parameters. The lexical unit that receives the most activation is the 'winner', and has been accessed. Once a lexical unit is accessed, a 'yes' decision can be made at the decision stage; if after a period of time no unit 'wins', then a 'no' decision can be made at the decision stage. In this model, location is used to define the initial cohort (following the data provided by Emmorey and Corina, 1990). In addition to parameter-based influences of handshape and movement, at a later stage, a combination of location and movement ('syllabic' input) further reduces the set of potential competitors. Can this model account for the results reported in Experiment 4?

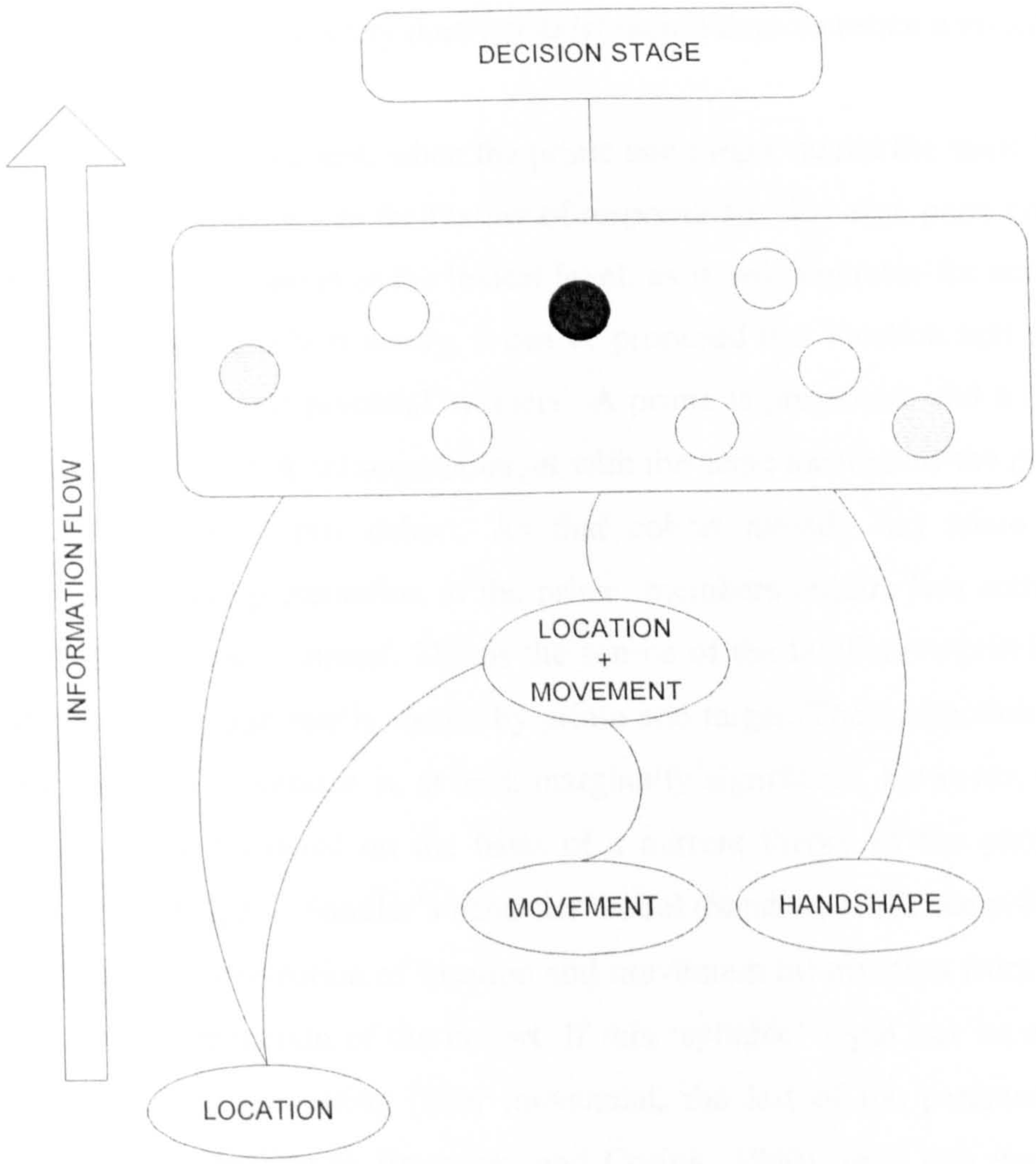

Figure 10.14: A model of lexical access for signed languages.

10.4.7.1 Native Signers

First of all, let us consider the results for native signers. The model can account for the lexicality effect (quicker reaction to actual sign targets) at the decision stage. A 'yes' response can be made once a lexical item has been accessed — this will happen when an actual sign has been presented, and the most similar representation in the lexicon has accumulated enough activation to 'win'. When a nonsign is presented, prelexical 'parameter' units still accumulate activation and pass it on to lexical units. However, there will be no 'winner' after resolution of competition between lexical units. The lack of a 'winner' means that nonsign presentations will normally be resolved in a

longer time than it takes to resolve nonsign presentations. It takes longer to establish that a lexical entry does not exist then it does to locate a matching entry.

For native signers, when the prime and target shared the same location and movement there was facilitation of response for sign-sign pairs only. This requires an explanation at the lexical level, as it only operates for actual BSL signs. Following cohort theory, it can be proposed that location acts to define the initial cohort of potential 'winners'. A prime is presented, and a cohort of signs is activated. A subsequent target with the same location as the prime will be a member of this cohort. As that cohort already has some residual activation from presentation of the prime, members require less activation in order to become 'winners'. This is the source of the facilitative priming when the location parameter is shared by prime and target. The interaction between location and movement is, at best, marginally significant. However, the trend follows that predicted on the basis of a current theory of the phonological structure of signs – Sandler's hand-tier model (Sandler, 1989, see p.48). In this model, the combination of location and movement information from the input also drives reduction of the cohort. If this 'syllabic' input has its effect at a later stage in processing (after movement, the last of the parameters to be extracted according to Emmorey and Corina, 1990), then this may explain why the effect is smaller and did not achieve significance in Experiment 4. It remains to explain why handshape and movement do not (independently) result in significant form priming (as would be predicted on the basis of Emmorey and Corina's data), if their effect in reducing the cohort occurs prior to that of location and movement combined. It is at this point that data from Emmorey and Corina and those resulting from Experiment 4 are difficult to reconcile. Whilst the effect of movement can be postulated to be indirect, acting through the 'syllabic' combination with movement, the role of handshape in the process remains unclear. More research is required to elaborate the function of handshape, and the timing of 'parameter' and 'syllabic' influences in lexical access for signed languages. This may require a

replication of Emmorey and Corina's gating study, and a re-evaluation of such data in terms of what it tells us about the process of lexical access.

10.4.7.2 Non-native Signers

The pattern of results for non-native signers is different to that for native signers. The effect of target lexicality can be explained as for native signers, but there is also an effect of prime lexicality.

Actual sign primes facilitate correct lexical decisions (relative to nonsign primes), whether the correct decision is a 'yes' or a 'no'. When examining the effects of specific primes, only primes that share movement with the target appear to facilitate decisions. However, this is true for sign-sign and nonsign-sign pairs. General similarity (as defined by the number of parameters shared by prime and target) facilitates lexical decision for non-native signers, yet this effect does not interact with the lexicality of prime and target. Thus, the prime lexicality effect may represent facilitation due to a general rise in the level of activity in the lexicon after presentation of a prime, independent of sign parameter considerations.

Turning to the effect of the movement parameter, this appears to be a prelexical phenomenon. Nonsign-sign pairs that share movement also result in facilitation of response, yet nonsign primes cannot produce a 'winner' in the lexicon. Nonsign primes can, however, activate prelexical units such as those representing parameters (triangles in Figure 10.14). It may be that residual activation in these prelexical units results in evidence for the same movement parameter in the target being passed to the lexicon more quickly, hence facilitating response to that target.

The effect of increasing the number of shared parameters is to decrease the decision time for the target. This effect is found when the actual overlapping parameters are unspecified. When actual parameters are examined (e.g. the effect of sharing handshape and location) there are no significant differences. Only taken as a whole do these parameters give rise to a significant facilitative effect. This suggests that although lexical decision can be primed as a result of phonological similarity, for non-native signers that

similarity is not a function of specific parameters. This is difficult to account for in terms of the model reported in Figure 10.14.

10.4.8 Heterogeneity of Non-native Signers

It is difficult to reconcile the findings for non-native signers within one model of lexical access. The finding related to the number of parameters suggests that a formational similarity metric that is not parameter-based influences lexical access. Yet there is also evidence that the movement parameter is involved at a prelexical stage. One explanation may lie in the heterogeneity of the non-native signing sample. Although all of the sample acquired BSL after the age of 6 years, their actual linguistic experiences will almost certainly differ widely. They will have attended different kinds of school, interacted with other deaf people in different ways, and started to learn BSL at different ages. All of these factors may influence the degree to which they became fluent BSL users, and the way in which they process the language.

10.4.9 Other Factors Influencing Reaction Times

In addition to the heterogeneity of non-native signers, there are five other factors that need to be considered when interpreting the findings of Experiment 4: (1) regional variation, (2) non-manual features and mouthing, (3) nonsigns in signed languages, (4) fluency of nonsign production, and (5) frequency of sign occurrence. These factors need to be taken into account when planning future lexical decision studies.

10.4.9.1 Regional Variation

The signs used in Experiment 4 were all lexical signs. They all occur in BSL, can be produced in isolation, and have meaning in the absence of context. The signers who produced the stimuli are all native to or live in the South West of England. BSL exhibits a relatively large degree of regional variation, and some of the signs produced for the experiment may not have been recognised by participants from other regions in the UK. Even if recognised, the recognition process may have been slower as the signs were

'rare' or seldom experienced forms to the participants (see Frequency of Sign Occurrence, below).

10.4.9.2 Non-manual Features and Mouthing

Experiment 4 manipulated three formational parameters of BSL: handshape, location and movement. Two other parameters were not considered: (1) orientation (considered to a less salient parameter by most sign linguists) and (2) non-manual features. Many BSL signs have a non-manual component, such as a shift in eye-gaze, change in body posture or movement of the lips/cheeks/eyebrows. The role of these two parameters was not assessed in Experiment 4. The lack of non-manual features in the nonsigns produced for Experiment 4 may also be an important factor. The signers who produced the signs were instructed to: (1) produce non-manual features for lexical signs where they were normally produced, and (2) insert non-manual features into some of the nonsigns they produced. However, one participant (a non-native signer) reported that they used lack of non-manual features as a cue for nonsigns and a 'no' response in the lexical decision task. To what extent other participants used this strategy, and its effectiveness, is unclear.

The same issue arises with 'mouthing'. The signers producing the stimuli were explicitly asked not to mouth the English equivalents of signs. However, review of the materials made it clear that in some cases this instruction was ignored. Clearly, nonsigns will have no English equivalent and mouthing of English words for nonsigns was not evident. Again, this could have been used as a cue by participants, aiding their lexical decisions.

10.4.9.3 Nonsigns in Signed Languages

The sign models were asked to produce nonsigns that were phonotactically legal in BSL. That is, nonsigns which were not lexical BSL signs, but could be 'possible' BSL signs. Again, review of the materials suggested that this instruction was not followed for some nonsigns, which clearly violated dominance and symmetry constraints in BSL.

There is also a fundamental difference between nonsigns and nonwords: nonsigns are more likely to be meaningful in BSL than nonwords are in a language like English. This goes beyond merely looking like an actual sign or an actual word. A nonsign may not look like a lexical sign in BSL, but it may be meaningful at the same time. This is because individual formational parameters in BSL can carry meaning (see Section 5.2.1 in Chapter 5). Johnston and Schembri (1999), in a discussion on defining lexemes in signed languages, state that:

> *"A potential sign in Auslan is thus not as meaningless as potential words in English because the combination of component aspects of a sign usually results in some minimally meaningful visual-gestural act."* (p. 123).

The authors state that these signs can *"... take on ... 'local lexicalisation' for the duration of the text"* (p. 123) although they are not lexemes within the language. Any model of sign recognition will have to explain how signers can process and understand these non-lexical signs. In Experiment 4, it is feasible that some of the nonsigns used may be meaningful in certain contexts. Whether this factor influences lexical decision when such nonsigns are presented in isolation is also unclear.

10.4.9.4 Fluency of Nonsign Production

The duration of nonsigns was significantly longer than the duration of actual BSL signs in Experiment 4. Target clip duration was shown to be a highly significant covariate, although the lexicality effect was still evident when the effect of clip duration was covaried. The longer duration of nonsigns, although accounted for within the analysis, still suggests that nonsign production may be less fluent than sign production. The nonsigns were created in a collaboration between the experimenter and the sign models, and only practised one or two times before being committed to film. This contrasts with the lexical BSL signs which will have been produced many

times by the sign models prior to the filming session. As well as influencing the duration of the target clips, the dysfluency of nonsign production may have offered additional cues to participants. The kinematics of production may be significantly different for signs and nonsigns, with differences in parameters such as articulator velocity. To what extent signers can pick up on such dysfluency is another unknown. The use of actual signs (non-lexical in BSL) from other signed languages may help circumnavigate this, but would impose heavy constraints in terms of matching nonsigns to signs in terms of specific formational parameters making such a strategy untenable for studies involving large numbers of sign pairs.

10.4.9.5 Frequency of Sign Occurrence

Finally, as mentioned in Chapter 6, there was no measurement of sign frequency available for the BSL signs employed in Experiment 4. The only frequency data available for signed languages is for a corpus of 1000 New Zealand Sign Language signs reported by McKee and Kennedy (1999). Frequency has been shown to be a significant factor in lexical access for spoken languages, and one would hypothesise that this would also be the case for signed languages. Experimental tests of this hypothesis have not been published to date. The use of a large corpus of BSL signs in this study may mediate any imbalance in 'common' and 'rare' sign forms for larger comparisons, i.e. group or target lexicality comparisons. For comparisons with 10 signs in one group and 30 in another, however, may be open to the influence of frequency effects doe to a greater proportion of relatively 'rare' signs in one group.

10.4.10Conclusions

The aim of Experiment 4 was to assess the applicability of models of lexical access (such as cohort theory) to signed languages. At the same time, it was hoped that the design would encourage sign-based encoding of the stimuli and reveal effects of formational parameters such as handshape, location and movement. Data from Experiment 2 suggested that deaf signers encoded the

formational parameters of BSL in an ordered recall task, yet in Experiment 3 there was no observable effect of formational parameters for either native or non-native signers. The lexical decision task used in Experiment 4 did reveal effects of formational parameters for native BSL signers. The data are best accounted for within the cohort model of lexical access, where a combination of the location and movement parameters is used to determine a cohort of potential signs in the lexicon. For non-native signers, the evidence for the involvement of formational parameters at a lexical level was less clear-cut. There was evidence that the lexical access system of non-native signers utilised the movement parameter, but this may have been a prelexical effect. There was also evidence for encoding based upon a formational metric that was not allied to handshape, location and movement. This encoding may also have been at a prelexical level.

Using a lexical decision task, evidence was obtained that native BSL signers encode signs in terms of at least two of their formational parameters (location and movement) and use these parameters to access the mental lexicon. Specifically, it seems that a combination of sign location and movement is used to determine an initial cohort of competitors, analogous to the role of word onset in the cohort model of lexical access. For non-native signers the evidence is less clear. Although similarity of prime and target had an effect, this did not appear to be tied to specific parameters.

Future work needs to take into account limitations within the design of Experiment 4. It would be useful to include sign pairs which shared three parameters but which were not identical. This would allow a full factorial analysis of the data, and more adequately explore interactions between the parameters. Care must be taken in the construction of nonsign pairs, as they are typically longer in duration, and may exhibit a degree of dysfluency in their production. Along with the absence of non-manual features and English-based mouthing, these factors may act as cues for participants and influence both accuracy and reaction times. One area of interest for future work is the 'productive vocabulary' of signed languages such as BSL. Signed discourse frequently reveals sign forms which are neither lexical nor the result of

grammatical processes upon existing lexical forms. This 'productive vocabulary' relies upon the association between individual parameters and meaning. How such signs are processed and understood 'on-line' is an unexplored question.

11 Thesis Summary and Implications

Can Deaf people think in sign language? Research starting in the 1970's and continuing to this today has suggested an affirmative answer to this question. It has been proposed, and supported by several studies, that Deaf people can use sign language as an internal code. Chapter 2 of this thesis outlines linguistic theory and research into the phonetics and phonology of sign languages. Sign linguists have claimed that sign languages display phonological properties analogous to those of spoken languages, termed in this thesis *formational* properties. As should be clear from Chapter 2, there is still much debate as to the nature of these formational properties, although the majority of theories focus upon the three parameters first identified by William Stokoe: *handshape*, *location* and *movement*. Recently, however, some linguists (and anthropologists studying the origins of language) have proposed that sign languages are qualitatively distinct from spoken languages in terms of their phonological structure. In particular, William Stokoe and his colleagues in the USA have proposed that the structure of sign languages are intimately linked to what it is they represent. They argue that the phonological level of structure cannot be separated from the morphological level in sign languages: sign parameters act as morphemes, in that they convey meaning individually as well as when combined to form a sign. This thesis aimed to explore how signs are internalised and used as a mental code by sign language users. It asked the question: is the internal sign code formational or morphological in nature?

Chapters 3 and 4 reviewed the literature (for spoken and signed languages) on long-term and short-term internal representations of language. Chapter 3 covered the literature on long-term representations in the mental lexicon. In particular, it focused upon phonological representations and the relationship between entries in the lexicon. Here we find research evidence supporting the notion that lexical entries are linked to each other in terms of their phonological properties. This evidence comes from studies of lexical

access, conducted within the framework of lexical access models such as *cohort theory* and the *neighbourhood activation model.* Whilst these models disagree on aspects of the micro- and macro-structure of the lexical access process, they demonstrate agreement on at least two key principles: (1) lexical entries are accessed within a *lexical node activation* framework - entries accumulate bottom-up evidence, instantiated as increasing activation for those entries that best match that input, and (2) lexical entries are *connected where they share phonological properties*, and these connections can be used to explain lexical access behaviours. Long-term representations are intimately related to short-term representations, such as those involved in working memory. Chapter 4 examined the literature on phonological representations in working memory. Again, the literature demonstrates the internalisation of language as an internal code, with that code being phonological in nature for spoken languages and formational for signed languages. Indeed, recent research at the Salk Institute for Biological Studies in the USA has provided evidence that the structure of working memory is very similar for signed and spoken language users. It appears that signers can internalise language in a visual-gestural modality, and that internal code is formational in that signs are represented in terms of parameters such as handshape, location and movement.

Deaf people present an unusual case, in that lack of exposure to spoken languages is extremely rare in humans. Most Deaf people have, however, received some form of speech-reading and articulation training at home and in school. Indeed, most are born to hearing families, and access to a signed language is often delayed until adolescence. The mixed linguistic environment within which Deaf children find themselves, and the heterogeneity of family, cultural and educational experiences means that Deaf children can display a potential range of possible internal linguistic codes. In Chapter 5 these were considered, with a discussion of phonological, visual and gestural coding. Chapter 5 proposes that the actual code used by Deaf signers will depend upon two key variables: (1) their early linguistic exposure, and (2) the nature of the experimental task used to tap the nature of that code. The discussion in Chapter 5 led into a discussion of methodology. Given the conclusions of

Chapter 5, the selection of participants and the choice of experimental paradigm take on key importance. Chapter 6 therefore discussed the experimental paradigms used within this thesis – ordered recall and form priming - as well as covering issues related to participant selection and problems faced by researchers when conducting such research within the Deaf community.

Experiment 1 used an ordered recall task to assess whether the internal code in the working memory of deaf signers and hearing sign language learners was formational or morphological. The findings in Experiment 1 did not support either type of internal code. For Deaf signers there were no effects of formational or morphological similarity on list recall, either in terms of the number of list items recalled or the ordering of those items. For the hearing learners, more items were recalled from formationally similar lists, suggesting that shared formational parameters between signs in a list were identified and used to provide evidence for the identity of decaying traces in working memory. The lack of an item order effect means that the traces may not have been sign-based representations, but possible speech-based. Interestingly, formational similarity was not used as a cue by the Deaf signers. This may be due to Deaf signers employing a different internal coding system, or using different strategies. The fact that these strategies did *not* help them to recall more items suggests a possible lack of cognitive complexity when faced with such tasks (Jim Kyle, personal communication, December 2000), although this may be a feature of the novelty of the task rather than of a delayed cognitive development.

Experiment 2 was a partial replication of Experiment 1, with an oral articulatory suppression task used to discourage speech-based coding by both Deaf signers and hearing learners. This significantly altered the pattern of results. In Experiment 1, there was evidence that hearing learners used formational similarity as a cue for recall; in Experiment 2, it was morphological similarity that led to enhanced recall of items for hearing learners. Informal post-test interviews suggested that hearing learners found it difficult to internalise the stimuli in a speech-based code. Many reported a

marked preference for imagining themselves engaging in a series of actions related to the stimulus items. For the sequence BAR-SAW-CANOE, one hearing learner reported "walking up to a bar, and then using a saw to saw it up and get wood to make a canoe". This grounding in actions performed with the stimulus objects may have brought the morphological properties of those objects to the fore when replaying the series of events at recall. Deaf signers in Experiment 1 displayed no results consistent with either formational or morphological coding. However, in Experiment 2, signs from morphologically similar lists were recalled with more order errors (as a proportion of the number of items recalled). This suggests that an internal code based upon the morphological properties of the signs was employed, supporting the notion of *semantic phonology* as a possible internal code for Deaf sign language users. However, the design was changed once again, and the study repeated as Experiment 3.

In Experiment 3, the number of stimuli was expanded to decrease familiarity with the stimulus set and to introduce new stimulus items in order to improve the generalisability of the findings. A condition was also removed: the formationally dissimilar but morphologically similar condition. Items within this condition were problematic for two related reasons: (1) given the close relationship between formational and morphological similarity, the validity of the condition was questionable, and (2) the morphological 'similarity' of items in that condition was argued to be lower than the morphological 'similarity' of items in the formationally similar and morphologically similar condition. To avoid ceiling effects, the items were edited using computer-based video editing software, and presented at a faster rate, making the task harder. Hearing learners were excluded from the study, and Deaf signers divided into two groups: native and non-native signers. It was hypothesised that effects of formational similarity were more likely for native signers, and effects of morphological similarity more likely for non-native signers. For native signers, there was some evidence for an internal code based upon the formational properties of the signs: there was a greater number of order errors for signs in formationally similar lists. However, when

the number of items recalled was controlled for, this effect disappeared. This is an important finding because previously reported studies did not include this control. It suggests that order effects found in previous studies may also be attributable to a greater number of items being recalled in formationally similar list conditions, and thus a greater opportunity for order errors to occur. For non-native signers there was no evidence for either formational or morphological coding of stimulus items.

Overall, the results from Experiments 1 to 3 were inconclusive. Experiment 1 suggested that hearing signers used formational aspects of signs as a cue to recall, but that Deaf signers did not. The cognitive load imposed by an oral articulatory suppression task (Experiment 2) changed the pattern of the data, revealing evidence for morphological encoding of the sign lists by Deaf signers. This finding is based upon a small sample size and a restricted corpus of signs, however. Replication in Experiment 3, using alternative methods of increasing cognitive load, failed to find evidence for formational or morphological encoding. How then do these studies relate to the proposals of semantic phonology theorists? As previously discussed, semantic phonology does not account for a range of signs that have no clear motivation or agent-action-patient interpretation. Evidence for encoding in morphological terms would therefore apply only to a subset of signs, such as those included in Experiments 1 to 3. Even here, however, the evidence is not strong and findings are hard to replicate. In addition, alternative proposals may account for the findings. Signs may have been processed at a semantic level in terms of their visual affordances. Saint-Aubin and Poirier (1999) have demonstrated that semantic similarity can lead to greater order confusions in short-term memory tasks. In conclusion, the Experiments reported here do not allow firm conclusions about the psychological validity of semantic morphological parameters to be drawn. These semantic parameters may prove to be of greater validity in understanding the processing of polymorphemic signs, although semantic phonology can then be interpreted as superfluous in light of alternative proposals for such signs (c.f. Wallin, 1996). Interestingly, Experiments 1 to 3 do not support formational theories of sign language

encoding either, despite a series of papers in the literature that do provide such evidence (see Section 4.2). This appears to be due to controlling for the number of items recalled when interpreting the magnitude of order error measures (following Saint-Aubin and Poirier, 1999). It would be interesting to see whether reported findings yield the same interpretation when such data processing controls are put in place.

The final study, Experiment 4, marks a deviation in the thesis from the use of ordered recall paradigms. Experiment 4 focuses upon lexical access, rather than short-term retention. However, it is still examining the internal code used by Deaf signers when processing a sign language. Experiment 4 used a form priming procedure. Participants were presented with pairs of signs, and required to make a decision about the lexicality of the second (target) sign: 'BSL' or 'not BSL'. The influence of the first (prime) sign on decision accuracy and response latency was measured. The relationship between the prime and target was recorded as a formational one: the degree to which they shared formational parameters. The sharing of morphological parameters was not investigated for three main reasons: (1) there was no compelling evidence for morphological coding across Experiments 1 to 3, (2) semantic phonology is not theoretically applicable to a wide range of signs within a signed language, and (3) it proved too difficult to generate a sufficient number of sign pairs sharing such parameters. The results suggested that, for non-native signers, prime-target similarity did affect recall. The more parameters shared by prime and target, the faster the lexical decision with regard to the target. This was true only for BSL-BSL pairs, and the actual parameters shared (handshape, location or movement) did not play a role. For native signers, the identity of the parameters was crucial. Facilitation of response to the target only occurred for BSL-BSL pairs where the signs shared location and movement. These data suggest that a 'holistic' similarity is important for non-native signers. That is, coding is visual and not formational. For native signers, long-term representations are formational. Finally, Experiment 4 proposed a model for lexical access in native signers based upon cohort theory.

Overall, the results of this thesis contribute to our understanding of internal coding of sign languages in two key ways: (1) care must be taken when concluding formational coding occurs, if those conclusions are based upon order errors only and do not take into account the number of items recalled, and (2) native and non-native signers differ in terms of how they encode sign language: for native signers it is formational and, crucially, based upon the relationships between formational parameters, whereas for non-native signers the encoding may be visual in nature and not parameter-based.

The thesis also raises issues to be addressed in future work.

Experiment 4 resulted in a proposed model for lexical access. For native signers, it proved to be important to consider location and movement together as aspects of a single entity. We may tentatively term this a sign language "rhyme". This is an analogy drawn with the joining of a nucleus and coda to form a spoken language rhyme, and no linguistic claim about syllable structure is being put forward. It does, however, relate to a point made earlier in the thesis that accurate measures of in what way signs are and are not similar are lacking within the psychological literature. Most psycholinguistic research has been conducted within the parameter framework first proposed by William Stokoe. It may be time for psychologists to pay more attention to the latest theories of sign language formational structure proposed by sign language phonologists. Future studies would benefit, in that measures of formational similarity may be more valid, and results easier to replicate with larger effect sizes, Such research may be better focused towards longer-term representations, especially within designs that encourage sign-based coding and do not allow for a reliance upon speech-based codes. The model proposed in Experiment 4 will serve as basis for future research using form priming studies to examine the content and structure of the sign language lexicon.

12 References

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Appendix A: Linguistic Background Questionnaire

1. Participant No. _____

Gender: Male ◘ Female ◘

2. Date of Birth:

3. You became deaf, when?

At birth ◘ Before 3 years ◘ Before 6 years ◘ After 6 years ◘

4. Your family:

Family Member	How many?	Deaf or hearing?	Sign to you?
Father	1	Deaf ◘ Hearing ◘	Yes ◘ No ◘
Mother	1	Deaf ◘ Hearing ◘	Yes ◘ No ◘
Deaf Brothers	—	Deaf	Yes ◘ No ◘
Deaf Sisters	—	Deaf	Yes ◘ No ◘
Hearing Brothers	—	Hearing	Yes ◘ No ◘
Hearing Sisters	—	Hearing	Yes ◘ No ◘

5. Did you have other deaf family? Yes ◘ No ◘

If YES, what relation and did they sign to you?

_____ Yes ◘ No ◘

_____ Yes ◘ No ◘

_____ Yes ◘ No ◘

6. What age where you when you first saw sign language?

Younger than 5 years ◘ 6-10 years ◘ 11-18 years ◘ Older than 18 years ◘

7. Where did you first see sign language?

At home ◘ At school ◘ At a club ◘ Other place _____

8. At what age do you think you learned sign language?

Younger than 5 years ◘ 6-10 years ◘ 11-18 years ◘ Older than 18 years ◘

9. Are you:

A very good signer ◘ A good signer ◘ An average signer ◘

A poor signer ◘ A very poor signer ◘

10. Which language do you prefer to communicate in with other deaf people?

BSL ◘ SSE ◘ Speech ◘ Mix of BSL and SSE ◘

Mix of BSL and speech ◘ Mix of SSE and speech ◘

11. Which language do you prefer to communicate in with hearing people?

BSL ◘ SSE ◘ Speech ◘ Mix of BSL and SSE ◘

Mix of BSL and speech ◘ Mix of SSE and speech ◘

12. Which do you feel is your native language?

BSL ◘ English ◘ Bilingual BSL/English ◘ Other _____

13. Which schools did you attend?

School Name	School Type	Boarding?	How many deaf children?	Age started
1.	Deaf ◘ Hearing ◘ PHU ◘	Yes ◘ No ◘		
2.	Deaf ◘ Hearing ◘ PHU ◘	Yes ◘ No ◘		
3.	Deaf ◘ Hearing ◘ PHU ◘	Yes ◘ No ◘		

14. In your first school, did your teachers sign to you?

Yes, all the time ◘ Yes, outside the classroom ◘ Only rarely ◘ Never ◘

15. Did you sign to other children?

Yes, all the time ◘ Yes, outside the classroom ◘ Only rarely ◘ Never ◘

Date: ____ / _____ / _____ Interviewer: _____

Appendix B: Experimental Conditions in Experiment Four

Condition	Prime	Target	Handshape	Location	Movement
SS-hlm	S	S	N	N	N
SS-Hlm	S	S	Y	N	N
SS-hLm	S	S	N	Y	N
SS-hlM	S	S	N	N	Y
SS-HLm	S	S	Y	Y	N
SS-HlM	S	S	Y	N	Y
SS-hLM	S	S	N	Y	Y
SN-hlm	S	N	N	N	N
SN-Hlm	S	N	Y	N	N
SN-hLm	S	N	N	Y	N
SN-hlM	S	N	N	N	Y
SN-HLm	S	N	Y	Y	N
SN-HlM	S	N	Y	N	Y
SN-hLM	S	N	N	Y	Y
NS-hlm	N	S	N	N	N
NS-Hlm	N	S	Y	N	N
NS-hLm	N	S	N	Y	N
NS-hlM	N	S	N	N	Y
NS-HLm	N	S	Y	Y	N
NS-HlM	N	S	Y	N	Y
NS-hLM	N	S	N	Y	Y
NN-hlm	N	N	N	N	N
NN-Hlm	N	N	Y	N	N
NN-hLm	N	N	N	Y	N
NN-hlM	N	N	N	N	Y
NN-HLm	N	N	Y	Y	N
NN-HlM	N	N	Y	N	Y
NN-hLM	N	N	N	Y	Y
SS-HLM	S	S	signs identical		
NN-HLM	N	N	signs identical		

For Prime and Target, S indicates the stimulus is a sign, and N that it is a nonsign. For Handshape, Location and Movement, Y indicates that the pairs in that condition share that parameter; N indicates that they differ in terms of that parameter.

Appendix C: Signs Used in Experiment Four

Condition	Prime	Target	Condition	Prime	Target
SS-hlm	CAR	GIRL	SN-hlm	BOOKING	001
	CHAIR	OLD		DRUM	002
	COMMUNITY	SUN		GAME	074
	DOG	TREE		HORSE	075
	EVENING	ELEPHANT		MOTORBIKE	147
	PARK	ICE		PRIEST	148
	SHIRT	BOOK		SAW	220
	VASE	BULL		STORY	221
	VIDEO	GERMAN		STRANGE	293
	WHITE	CANDLE		UNIVERSITY	294
SS-Hlm	BINOCULARS	GROUP	SN-Hlm	AIM	003
	BITTER	DEVIL		BONE	004
	BLIND	BUS		DAY	076
	CAREFUL	CONSIDER		DRY	077
	CLASS	CONFIDENCE		JAIL	149
	COUGH	TRAIN		RAIN	150
	KARATE	PART		SYSTEM	222
	KNOW	PROBLEM		TEAM	223
	TOILET(a)	MAD		THIEF	295
	WORK	HOTEL		WIND	296
SS-hLm	DISAPPOINT	HANG	SN-hLm	BATHROOM	005
	EASTER	THEATRE		DIRT	006
	GARAGE	CLEAR		EAT	078
	WALK	MEANING		NURSE	079
	KNIFE	ENGLISH		PLUG	151
	POSITIVE	TEASE		SAINT	152
	PUNK	COW		SOCKS	224
	SISTER	MOUSE		STAGE	225
	SWEET	TOILET(b)		TATTOO	297
	TOOTHBRUSH	SWEAR		THEME	298
SS-hlM	AWARE	IRISH	SN-hlM	BABY	007
	CENTRE	EASY		BEE	008
	DON'T-WANT	APPLE		DRINK	080
	LIE	SLOW		FAST	081

	MOUSTACHE	SAUSAGES		PEACE	153
	PROPELLOR	SHEEP		SALT	154
	RICH	BLACK		SPADE	226
	SATISFIED	USEFUL		VOTE	227
	UNCLE	EGG		WALK	299
	WASHING-MACHINE	LONDON		WALL	300
SS-HLm	WORST	LAST	SN-HLm	BUTTER	009
	REPEAT	DEAD		CABLE	010
	NUMBER	MAN		FERRY	082
	BIRTHDAY	COMMITTEE		FIRE	083
	HALL	INTERPRETER		LANGUAGE	155
	POLITICIAN	EXPERIMENT		MEET	156
	COMPANY	SUPPORT		PRINT	228
	SHOE	FAX		RABBIT	229
	MEMORY	BALD		RED	301
	INDIAN	PROFILE		REGION	302
SS-HIM	AFTERNOON	NAME	SN-HIM	BLUE	011
	CLOWN	EYE		MACHINE	012
	THIRSTY	HANKERCHIEF		MINICOM	084
	FLOWER	MEDICINE		MUSIC	085
	SORRY	DELICIOUS		OIL	157
	EAR-RING	DYE		PIG	158
	HOW-MANY	THEORY		RIVER	230
	SEE	SAY		SCISSORS	231
	INCENSED	STRIKE		SUBTITLES	303
	CATHOLIC	PROMISE		WATER	304
SS-hLM	HEAVY	ILL	SN-hLM	ARRANGE	013
	NUISANCE	CAKE		BISCUIT	014
	LET'S-SEE	GLASSES		KITE	086
	TOMORROW	TELEPHONE		MAYBE	087
	CAN	WOLF		MILK	159
	ART	SCHOOL		REST	160
	FIGHT	AGREE		SIGN	232
	MOCK	ATTITUDE		SURPRISE	233
	SPEECH	ORANGE		TEDDY-BEAR	305
	VARIABLE	STATISTICS		WAR	306
SS-HLM	PIANO	PIANO			
	BOY	BOY			

		TALK			
		TRAVEL			
		BANK			
		HARE			
		LIST			
		MATCH			
		BOTTLE			
		POSTER			
NS-hlm	015	EAR	NN-hlm	031	032
	016	PILL		033	034
	088	REJECT		104	105
	089	RENT		106	107
	161	SNAKE		177	178
	162	STONE		179	180
	234	TICK		250	251
	235	TIMETABLE		252	253
	307	WALES		323	324
	308	WHIP		325	326
NS-Hlm	017	AMERICA	NN-Hlm	035	036
	018	BICYCLE		037	038
	090	BREAD		108	109
	091	CARROT		110	111
	163	CONFERENCE		181	182
	164	DOOR		183	184
	236	GOLD		254	255
	237	NEW		256	257
	309	PROFESSOR		327	328
	310	TOWER		329	330
NS-hLm	019	AVERAGE	NN-hLm	039	040
	020	BANANA		041	042
	092	BEGGAR		112	113
	093	ELECTRICITY		114	115
	165	FLAG		185	186
	166	FRANCE		187	188
	238	MORNING		258	259
	239	QUESTION		260	261
	311	TUBE-TRAIN		331	332
	312	WINDOW		333	334

NS-hlM	021	CARPENTER	NN-hlM	043	044
	022	CHAIN		045	046
	094	CRISPS		116	117
	095	DEGREE		118	119
	167	FROG		189	190
	168	POTATO		191	192
	240	SHIP		262	263
	241	SOLDIER		264	265
	313	TEACHER		335	336
	314	VALUE		337	338
NS-HLm	023	AUSTRALIA	NN-HLm	047	048
	024	DRUNK		049	050
	096	HELP		120	121
	097	LATE		122	123
	169	MONKEY		193	194
	170	PEA		195	196
	242	POLAND		266	267
	243	SECRETARY		268	269
	315	TASTE		339	340
	316	WEDDING		341	342
NS-HlM	025	BUY	NN-HlM	051	052
	026	CLEVER		053	054
	098	FISH		124	125
	099	ILLEGAL		126	127
	171	LEEK		197	198
	172	OPTION		199	200
	244	PINK		270	271
	245	PLUMBER		272	273
	317	SIDEBURNS		343	344
	318	SPAIN		345	346
NS-hLM	027	AEROPLANE	NN-hLM	055	056
	028	BROWN		057	058
	100	DEFENCE		128	129
	101	GRIN-AND-BEAR-IT		130	131
	173	HOLLAND		201	202
	174	KEY		203	204
	246	LAWYER		274	275

247	POLISH		276	277
319	START		347	348
320	WORRY		349	350
		NN-HLM	029	029
			030	030
			102	102
			103	103
			175	175
			176	176
			248	248
			249	249
			321	321
			322	322