WRITING AND SIGNED LANGUAGES

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Bachelor of Arts
Western Washington University, 1998

Submitted in Partial Fulfillment of the

Requirements for the Degree of Master of Arts in the

Linguistics Program

College of Arts and Sciences

University of South Carolina

2007

Director of Thesis

2nd Reader

Dean of The Graduate School

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ABSTRACT

The idea of a written form for signed languages has been controversial, and this paper presents a series of experiments designed to provide answers. The findings:

- writing a signed language is in fact possible, using SignWriting, but not using another script. (experiments 1 and 2)
-
- a script for signed languages must be arranged in the nonlinear fashion employed by SignWriting and not in the linear manner of scripts for spoken language. (experiment three)
-
- our brains process SignWriting in the same manner they process scripts for spoken language. (experiments 4 and 5)
-

Conclusion: reading and writing is the same for both sign and speech, and SignWriting is just another writing system like any other.

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Writing and Signed Languages

Introduction. This paper explores the feasibility of a written form for signed languages. It demonstrates in a series of experiments that a properly designed script can reduce visual languages to writing and utilize the same reading process as that used with aural languages.

Of the hundreds of signed languages known, not one has developed its own written form. General acceptance of this lack of a written form has followed historically failed attempts to devise adequate writing systems for this class of language, coupled with debate over whether such a system is even possible. This project attempts to provide empirical data to a debate that has been fueled with much emotion but little experimental research.

The results argue that not only is literacy in a signed language possible, but that it is qualitatively identical to literacy in a spoken language: that despite superficial differences in form between the visual and aural media, the literacy process draws on the same cognitive resources and uses the same psychological capabilities in either medium.

The paper is organized as follows. The first few sections outline the controversy over writing visual language, why it is a problem, and arguments that have been advanced both for and against doing so. Experiments one and two comprise sections 6 and 7 and test whether it is possible to write ASL, a representative visual language, in two different proposed writing systems. Results are positive in one case and negative in the other. Section 8 then discusses reasons for why this might be, focusing on the roles of iconicity and linearity, and leading to the next experiment. Experiment three in section 9 demonstrates that the linearity of spoken language is not appropriate for writing visual languages. Section 10 discusses this, updating several traditional assumptions to capture generalities subsuming both aural and visual languages within the writing process. Section 11 turns to the reading process and applies it hypothetically to visual languages. Experiments four and five test and confirm this hypothesis using standard phonological priming and articulatory suppression tests. The conclusion is that reading and writing is the same for both sign and speech. A general discussion ends the paper by pointing out some ramifications of the findings for other fields.

1.0 Background. In his 1960 *Sign Language Structure,* William Stokoe was first to apply standard linguistic methods of analysis to a signed language. Five years later the *Dictionary of American Sign Language on Linguistic Principles* followed, now known as the DASL (Stokoe et al 1965). A key feature in both these texts was a newly created system of transcribing signs that came to be known as Stokoe Notation (SN). This notation was crucial to proving Stokoe's premise that the signs of American Sign Language (ASL) were not unanalyzable wholes, but combinations of a limited number of smaller units. Stokoe's insight was that signs have parts, and that each sign was composed of at least three: a place of articulation, a manner of movement, and a handshape. Each of these three parts allows only a limited number of possible choices. For his notation[1] Stokoe created a symbol for each choice, yielding three sets of symbols.

Combining one symbol from each of the three sets forms a single written character whose combination of three graphic symbols uniquely identifies a particular sign. For ASL ØV⊥ 'see', the place of articulation is the eye, the handshape is a two-fingered V, and the movement is outward. To write this sign, Stokoe wrote the location symbol Ø for the eye, a V for the handshape, and the arrow-like symbol ⊥ to show outward movement of the hand. DASL includes about three thousand signs, and the fact it can generate them all by recombining these few smaller units helped to convince linguists that ASL was structured like other languages (Miller 1994:192).

Although researchers began to use SN, no one adopted it as a regular script.[2] Those who used the notation typically modified it in various ways, so that today there is no standard version. An outstanding effort was the British Sign Language Dictionary Project that produced a comprehensive dictionary of BSL with around 6,000 entries and was first to include palm orientation as a fourth parameter, rendered in the notation by subscripts following the handshape symbol. This change was based on observation of proposed minimal pairs that differ only in orientation, for example $\mathrm{BB}_{ɒ}^{\vee > \vee}$, 'children', with the palm up, versus $\mathrm{BB}_{\alpha}^{\vee > \vee}$, 'things', with the palm down, as indicated by the subscripts. Representing a fourth parameter of orientation has since become standard practice in sign notation systems.

Several entirely new systems were proposed to replace SN, the best known of these being Signfont and Hamnosys (Supalla 1990:30). None of these proposals met

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[1] The basic system is outlined on Wikipedia, under Stokoe Notation. A reprint of Stokoe's classic 1960 *Sign Language Structure* can be accessed at http://jdsde.oxfordjournals.org/cgi/reprint/10/1/3.

[2] We use the term ***notation*** to include any system for writing things down: musical scores, mathematical formalisms, and graphic representations in linguistic research including the IPA. The term ***script*** we reserve for those notation systems that transcribe language for purposes of ordinary communication, for love letters and grocery lists.

much success outside the research lab even though they are all based on proven structuralist procedures. They all decompose the sign into parts, assign each a symbol and arrange the symbols in linear order on the page. They all identify the same linguistic parameters: handshape, location, movement, orientation, and now sometimes facial expressions.

Even though they represent all the necessary phonetic[3] information, these systems are very difficult to read. 'SN can be laboriously deciphered, but you can't really call it reading' according to one researcher (van Hoek 1999), while another describes using Hamnosys as '…absolutely excruciating… a whole new level of pain' (Parvaz 2004). Such sentiments have led to a consensus that signed languages cannot be written and must be recorded only on video. Stokoe himself has stated that theory 'suggests that signing cannot be written' (Stokoe 1987:118).

2.0 The problem. The general consensus that signed languages cannot be written is problematic on two counts. On one hand it seems to be contradicted by actual practice. For another it raises problems for linguistic theory.

2.1 Theory. The notion that signed languages must be unwritten contradicts an unspoken assumption in the field of linguistics that all languages can be written, and should be. Kenneth Pike's classic text *Phonemics*, for example was subtitled *a technique for*

[3] The term *phonetic* here refers to facts such as how to hold and move the hands, necessary sublexical details smaller than any word or morpheme. Use of the terms *phonetic, phonological*, etc are discussed in detail later in the paper.

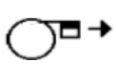
reducing languages to writing (Pike 1949). Paul Postal later elaborated on this definition:

> Given any utterance token in any language, all linguists assume in effect that it may be correctly represented, independently of any further knowledge about it, in a narrow phonetic transcription … every linguist recognizes that a discrete, segmented, correct phonetic representation is an absolute prerequisite to any work … (Postal 1968:6).

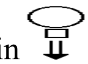
A huge body of research amassed over the past forty years concludes that human language is not limited to the medium of sound, and that signed and spoken languages share equivalent linguistic structure in every significant way (Valli & Lucas 1995). Written language mirrors this structure, which is the same for all language. 'The fact that all languages studied so far [*sic*] submit to an alphabetic representation … reflects this basic mode of linguistic organization' (Kenstowicz 1993:13). Inability to do so in the case of a specific language implies a difference at a basic structural level, and any such difference calls for an explanation in terms of fundamental structure or psycholinguistic processing. No such difference or explanation has been offered for ASL or any other signed language. To accept that ASL is a human language while maintaining that a writing system is not possible is an untenable theoretical position.

2.2 Evidence. The view that visual languages cannot be written is also challenged by the apparent success of the International Movement Writing Alphabet (IMA). In 1974, researchers in Denmark looking for a way to study Danish Sign Language approached dancer Valerie Sutton, who was skilled in the use of movement notations used to record dance. Unaware of Stokoe's work and with no background in linguistics, she adapted her dance notation specifically to record the movements of signed languages.

The resulting transcription system, SignWriting®, did not start from a linguistic analysis. It records movements in general, linguistic or otherwise, and consequently can record not just one, but any, signed language. The transcriber need not know the language being transcribed, or even if what she is transcribing is a language. SignWriting® itself is only one part of the more complete IMA system that records dance and other types of movement. The system has the flexibility to record sign with a deep phonetic transcription that includes every minute detail, or a more phonemic level that includes only the minimum contrasts, just as the International Phonetic Alphabet (IPA) does with spoken languages.[4]

Written characters of IMA can largely be treated as pictographs of the signer. The symbol , for example, represents a hand with index finger extended. More lines might show other fingers, and this example shows that the lighter-colored palm is clearly facing downward, with the finger pointing to the left. A circle represents the head, so the symbol  shows the fingertip touching the upper right forehead, an arrow indicating that it moves to the right. Different types of arrows and arrowheads show

[4] The entire system is explicated in great detail on the Deaf Action Committee's website, at http://www.SignWriting.org.

different movements, as the double line in  , 'old' for a fist moving vertically downward. There is a small set of non-iconic symbols, such as the dots that represent fingers bending in  , 'study'.

After Sutton's early experiments met with initial success she went on, with a group of deaf native signers, to form the nonprofit Deaf Action Committee (DAC) and under their guidance the writing system has evolved naturally into its present form. It has continually gained adherents, mostly among educators, to the point where it is now used in some forty countries.

Its most conspicuous success may be the Nicaraguan Sign Language Project in Bluefields, Nicaragua where it is fulfilling all the requirements of a typical literacy program (http://www.unet.maine.edu/courses/NSLP/). All textbooks and literature are printed and academic work done in the indigenous sign language ISN (Idioma de Signos Nicaragüense), and the curriculum even includes second language instruction in spoken Spanish (Emmorey 2002).

The empirical facts seem to contradict any argument that signing cannot be written. Abundant evidence indicates that the IMA works, that children especially take to it with great enthusiasm (Flood 2002), and even that it fosters L2 literacy in a spoken language (Kegl 2002). Its success at reducing these languages to writing however goes largely unnoticed, neither accepted nor rejected by the mainstream. Linguists have come, for example, to accept ASL as language, yet deny it a written form, yet assume all languages can have one, yet accept the view that ASL can't. This paper is an attempt to bring order to these conflicting claims.

3. Why it matters.

3.1 Linguistic issues. The discovery of an unrecorded language has typically set in motion a predictable chain of events. Scholars record the language, devise a script for it, write dictionaries and grammars and finally produce teaching aids, Bible translations, or other literature. These texts then serve as a basis for study of the language by linguists, missionaries, or educators. This is the standard operating procedure developed by American linguists in the early 20^{th} century, who under the direction of Leonard Bloomfield sought out and recorded scores Native American languages. The first step was to find a new and unrecorded language, an event that has again become commonplace amongst today's sign linguists. The next step is to record the phonetic details in a transcription which one then subjects to phonemic analysis. The results of the analysis enable one to create a script in which to compose texts. According to Bloch and Trager's 1942 *Outline of Linguistic Analysis*, one who fails to take this step not only 'is not a linguist but denies the very purpose of linguistic science' (1942:39). In the case if ASL and all the hundreds of other signed languages discovered to date, this normal chain of events halted at the second step, the transcription. The fact that standard procedure was abandoned creates a unique situation that suggests these languages are different and somehow deficient in crucial respects. Or, alternatively, that linguistic theory itself is.

The suggestion is reinforced when researchers on these languages do not follow standard linguistic practices when presenting examples for study. Researchers do not need to know every language on Earth because their standard way of presenting information enables a basic literacy that allows them to study and compare even languages they don't speak personally. An example of the standard layout is shown in

(1a). It consists of three lines, which for English speakers would be a translation to English on the bottom, a description in English—the gloss—above it, and at top an actual example from the source language, in this case Spanish (Tallerman 1998:13).

Only the actual example in the top line, preferably given in Postal's phonetic transcription, draws from the source language and enables one to identify what specific portion of the language stream is being discussed. The English gloss below it describes the transcription in terms of meanings of individual morphemes, but it does not identify the morpheme's actual form, nor does it enable one to reproduce the forms. All three lines of these examples are indispensable in guiding the reader from the form of the source language, through its meaning, to the form of the target language.

Figure 1. a) <u>Spanish Example</u> b) <u>ASL Example</u>

a) Spanish Example	b) ASL Example
Hola, esto es para ti.	___tp
hello this COP for 3PS.FAM	HELLO IX_R FOR-IX2.FAM
'Hi, this is for you.'	'Hi, this is for you.'

The literature on signed languages remains outside this tradition. Accepting that this class of language has no written form means that the standard three-line examples cannot be used. Published work instead uses only English translations and glosses, with special conventions that vary with each researcher. Comparing the signed and spoken examples in figure one illustrates a number of problems.

While there are many ways to say hello in either language, the Spanish example specifies an exact word, but which ASL sign is meant can only be guessed at. Both Spanish and ASL have a special familiar form of *you* (glossed as 3PS.FAM or IX2.FAM respectively), and the transcription shows that it is *ti* in Spanish, but to know what it is in ASL, one has to know ASL. Finally, highly descriptive glosses may be assigned to inflected forms for greater accuracy: COP could be described more accurately as THIRD PERSON PRESENT INDICATIVE SINGULAR COPULA. While such descriptions draw on established notions, it is still unclear how best to apply some of these notions to signing. Signed language structure is not only similar to polysynthetic tongues like Aleut where single words often contain a dozen or more morphemes, but is also highly inflected. The distinctions are unfamiliar, i.e. 'seriated external modulation' of verbs, and the number of inflected forms has been argued to be infinite. A large inventory of parts of signs that are not morphemes leads to 'insoluble glossing problems' (Liddell 2003:274), and 'there are good reasons for not even attempting to produce a gloss for each morpheme' (275).

Besides its recognized inadequacy as a research tool (Pizzuto & Pietrandrea 2001), this insular glossing practice limits the study of sign linguistics to those who know sign language, it isolates sign language researchers from the larger linguistics community, and it impedes efforts to disseminate research findings. It allows some to deny the very legitimacy of signed languages based on misleading glossed examples (deFrancis1989:17). A 'discrete, segmented, correct phonetic' transcription as demanded by Postal, such as the IPA, largely eliminates such barriers for the subset of human language that is spoken. A tool to do the same for the hundreds of visual languages would be of immense value, especially for those linguists whose stated goal is to uncover universals of all human language.

3.2 Educational issues. American Sign Language (ASL) has become one of the most popular foreign or second languages in United States schools and universities (Wilcox & Wilcox 2000: 115). Students in these classes though are offered only two of the normal 'four language abilities—listening, speaking, reading, and writing' (Baker 2001:4). The lack of a written form denies students the usual tools of second language study: vocabulary lists, written tests, graded readers, and so on. Textbooks and dictionaries are not written in the L2, as a text for teaching German or Russian would be. Worse, the pervasive use of English glosses seriously hampers teachers' efforts to move beyond word for word translation of the target language (Wilcox & Wilcox 2004: 120).

Much more serious is the plight of those who begin life with a visual first language. Even though it is considered the first language of deaf persons in North America, ASL is not used as the language of instruction in schools. In the belief that deaf children can acquire English through print, educators still routinely expect them to acquire their L1 by reading a language they have not yet learned (Johnson et al 1989).

In contrast to practices in Deaf Education, among ESL professionals second language teaching proceeds on the logical assumption that one first learns a language and only then achieves literacy in that first language. For at least fifty years it has been axiomatic that the best medium for initial literacy is the child's mother tongue (Baca & Cervantes 1992), yet those children whose mother tongue happens to be a visual language are denied this advantage.

By any account Deaf Education is a failure. It is widely documented that the average deaf school leaver reads at a fourth grade level (Allen 1994:1). The elusive bridge to spoken language has been a holy grail for educators of the deaf for centuries, and a workable script that would allow initial literacy in their mother tongue could form an important part of such a bridge.

3.3 Cultural issues. The theoretical positions of linguists have an enormous influence on deaf people, the main users of signed languages. Throughout history, deaf persons have struggled even to be recognized as fully human. Aristotle deemed them incapable of rational discourse and unable to learn (Beare 2004:2). Counterevidence was ignored, such as Peirre Desloges' book praising his own thriving deaf community and its sign language in 1779 Paris. (Lane 1992:107). Finally vindicated by Stokoe's use of modern linguistic science, they have begun a struggle for civil rights in the same manner as other cultural and linguistic minorities. It is an uphill struggle. Daniels & Bright (1996) state on page one that 'All humans speak', and Coulmas claims

> There is no society known which lacks speech. Should one be found, somewhere in the hills of New Guinea or in the rain forest of Brazil, we would be forced to alter our conception of humanity drastically or else to exclude that society from our species (1991:3).

Yet such societies exist in every major city, and worldwide wherever deaf people rally around a common signed language with its attendant cultural heritage. These communities struggle to be accepted as members of our species blessed with their own unique culture and language.

They struggle against yet another prejudice. In the sociological sense, those languages with a written literary tradition occupy the top tier of a hierarchy of language types (Fishman 1984). These so-called prestige languages are equated with culture, and with far more. According to Tzeng and Wang, 'without writing, human culture as we know it today is inconceivable' (1983:238). Or as Daniels & Bright put it, 'civilization is defined by writing' (1996:1). Because of this, 'otherwise intelligent persons may deny the legitimacy of sign language in part because it lacks a conventional writing system and the concomitant body of written literature' (Frishberg 1983:169).

Like any cultural group, ASL users maintain a rich and varied literature in a multiplicity of genres, some of which can only be appreciated in the original language. ABC stories, for example, relate a narrative with the restriction that each succeeding sign uses a specific hand shape, so that these spell out the letters of the alphabet or some relevant words or numbers. In translation they become simply stories, with the beauty and ingenuity of the art form entirely lost. Access to literature in the original is a major reason for study of any second language. While some argue that 'Deaf people have a perfectly good writing system: it's called written English' (Johnson 2001) they do not extend this argument to the Greeks or Chinese. Were Confucius to see his famous *Analects* written in glosses: STUDY WHEN CUSTOM NOT ALSO SAY … he might respond as one classmate did when shown a glossed ASL text, 'It looks like baby talk'! She was right of course, and the lack of a writing system robs the Deaf community of the standard time-honored way of transmitting their unique culture.

The question of sign language literacy is important for all these reasons— to free deaf people from oppression, to assist educators, and to help scientists understand language.

4. Theoretical Assumptions. Any discussion must share some set of theoretical assumptions, and this research program requires a perspective that may be foreign to some who have not worked with signed languages and/or are unfamiliar with linguistic sciences. It requires acceptance of the idea that visual languages, of which ASL is just one of many, are languages like any other languages. The ramifications of this one fact are many and significant and may not be immediately apparent. It means that these languages, invented by no one, evolve via natural processes of historical change and geographical and social distinctions that give rise to regional varieties, dialects and new signed languages and language families. Each has its own complex rules of grammar and word-formation that it imposes onto gesture, just as speech imposes them onto noise, to generate unique signs that represent unique concepts and are often difficult to translate into other languages, and that are commonly unrelated to words of any aural language with which they may be in contact.

Accepting this premise forces a change in perspective on nearly every aspect of things linguistic, and three points in particular are important enough to mention in detail: a universal model of language, an articulatory perspective on speech, and an abstract conception of phonology.

4.1 Language models. Our usual way of looking at language was systematized by Ferdinand de Saussure in the early twentieth century, and it provides a poor framework for investigating issues of literacy in signed languages. In the SAUSSUREAN MODEL language has two forms, a spoken aural form and a written visible form, and 'the sole reason for the existence of the latter is to represent the former' (Saussure 1916:45) Paradoxically, the term *visible language* in this model does not refer to languages whose form is visible, such as ASL. Instead it refers not to language at all, but to its written representation (Whitney 1998:ch 6). There is no provision in this model for either the written or the unwritten form of a language that is visible in its conversational form.

An alternative is a MULTIMEDIA MODEL that makes a distinction between natural language and artificial invented systems, rather than the medium used to convey either. This model acknowledges that language has at least two attested conversational forms, spoken/aural and signed/visual, respectively using sound or vision as a medium. It takes seriously the idea that signed languages are languages like any other, and the corollary that they can be represented by written codes. These codes are artificial inventions rather than natural languages, in keeping with Bloomfield's dictum[5] that 'writing is not language at all, but merely a way of recording language' (1933:21). Artificial invented codes have many attested forms including electronic bits and bytes, written symbols, manual gestures, the dots and dashes of Morse, and so on. The multimedia model views our Roman alphabet as a visual code for aural language, and uses the term *visual*

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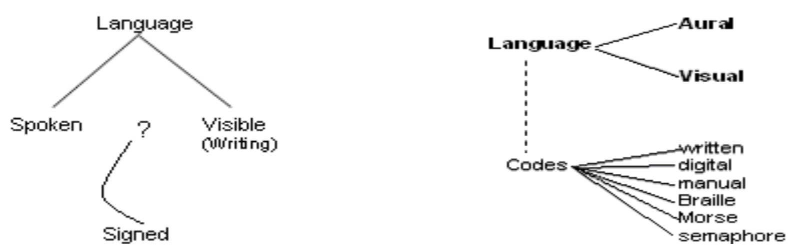
[5] A useful generalization only. Written language has many characteristics not shared by spoken language, and vice-versa, so that they are two interdependent systems in a symbiotic relationship. For an overview see Jahandarie 1999: ch 8-9. Harris 1986 gives an opposing viewpoint.

language for actual languages whose conversational form is visual, such as ASL, British Sign Language, Langue des Signes Québécoise, Auslan and others.

Figure 2. Language models

a) Saussurean Model b) Multimedia Model



Linguistics is by definition the scientific study of language. 'The central goal of linguistic theory is to shed light on the core of grammatical principles that is common to all languages' (Kager 1999:1), not some sanctioned subset. The discovery of vision-based language revealed that for thousands of years we had not been studying human language after all but only that subset of human language that uses sound. 'A science begins with the identification and definition of its object of study (Daniels 1996:3), and this new discovery is causing a change reminiscent of Alchemy becoming Chemistry or Astrology becoming Astronomy. Now that the very object of study has changed it is past time to update our terminology to reflect the new reality. Traditional terminology developed for spoken language in a time when language without speech was literally inconceivable. 'Linguists have long been fond of asserting the existence of properties universal to all languages when what they meant was "universal to all spoken languages" (Tabak 2006:147). For example, Kager claims that 'all languages have unrounded front vowels such as [i] and [e]' (1999:3). Such claims, long assumed to be true, are now easily seen as factually inaccurate.

To avoid making such inaccurate claims, we need to update the traditional terminology, starting with an expanded definition of the word *language* that accurately describes our field of study. Mainstream linguistics has only begun to do this. Over the past decade, most textbooks have changed from saying language is a system of arbitrary 'oral symbols' (Azevedo 1992:3), to describing it as a system 'composed of meaningful elements' (Borden et al 1994:2).

Once language is redefined in that way, it no longer makes sense to insist that writing must encode speech (DeFrancis 1989) or limit reading to a speech-based code (Underwood & Batt 1996:12). Adopting the Multimedia model resolves these inconsistencies by reframing other terms, as we have *language*, in more abstract ways that apply to both aural and visual media. Taking this step also provides us with the necessary tools to pursue the present investigation.

4.2 Articulatory perspective. If ASL is just another language, our investigations of ASL and literacy are investigations into the human language faculty. If we frame our inquiry and give our results in a restricted vocabulary that applies only to visual language, we contribute little to our understanding of language overall. On the other hand, we add to the discussion if we frame our inquiry and give our results in general terms normally used to describe facts about all human languages.

Two major traditions exist for describing facts about human language. One views language as acoustic phenomena, the other treats it as movements and postures of articulators acting in three dimensional space. Since the acoustic perspective on language is impossible to apply to the visual medium[6], the only view possible for the visual languages treated in this series of studies is the articulatory perspective. It would be unsatisfactory to provide a set of facts about signing, given in articulatory terms, alongside another set of facts about spoken language given in acoustic terms. This would obscure the underlying similarity and make it difficult to produce a unified treatment for all language.

Since the discovery that not all languages make use of sound, descriptions given in acoustic terms can no longer be taken as facts about language, but only about speech. Statements such as 'all languages have oral vowels' (O'Grady et al 1997:349) or 'all languages use outgoing air in all words' (Ladefoged 2005:4) cannot be facts about human language, but only that subset of languages that make use of sound. Any statement about language generally, independent of a specific medium, must necessarily be given in articulatory terms.

Fortunately, even though some articulators are not visible, an articulatory perspective is valid for describing spoken language. The approach is most thoroughly formalized as Articulatory Phonology (Browman & Goldstein 1986), and through ongoing research at Haskins Laboratories, New Haven, Connecticut (Haskins). Recasting traditional constructs into articulatory terms allows us to build on existing knowledge in our studies of visual language and enables us to produce a unified treatment

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[6] It is also problematic for some aspects of the aural medium, such as vowel harmony and tone. This weakness has led to a proliferation of non-linear models, including dependency and autosegmental phonology, metrical theory, and feature geometry. As these evolve they approach congruity with models of visual language, as well as to the more visually-oriented perspective formalized as Articulatory Phonology (Browman & Goldstein 1992).

valid for language in any media. 'Theoretical constructs serve to describe speech. But those that also describe signing really do describe . . . language' (Sandler & Lillo-Martin 2006:114).

4.3 Visual phonology. One cannot long discuss signed language without hearing the inevitable objection that signed languages cannot have phonology because *phonology* refers to sound. Actually this shouldn't be an issue, but since it is so often raised, addressing it before going further becomes necessary.

The fact that the name *phon-* is Latin for sound shouldn't bother us any more than the fact that *phony* originally referred to a gold-plated ring; or that Greenland is mostly ice. This is the basic and unavoidable linguistic process of semantic shift, 'when a word moves from one set of circumstances to another' (Crystal 1987:330). When early Norsemen spotted solid land looming out of the ice-spattered North Atlantic, they named it for what most impressed them at the time, green-land, the land (of green). Later, when it snowed, they discovered that this land can be all white, but they didn't rename it the land (of white), because languages don't work that way. Likewise, when linguists studied the smallest units of language they named them for what most impressed them, phons, the smallest units (of sound). Later, they discovered that these smallest units can be visual images, but they didn't need to rename these smallest units. Just as the Norsemen, whether it was green or white, were talking about the body of land, linguists, whether languages are aural or visual, are still talking about the smallest units. What they named was a level of language structure.

By definition, human language is composed of several levels: phonetic, phonological, morphological, syntactic, and discourse levels. All of these are necessary, as communication is not recognized as full human language if any of these are missing. Every level supports a logical argument, as here for phonology:

(1) All languages have phonology

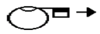
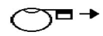
(2) ASL is a language

∴ ASL has phonology

When we say that a language has phonology we are not referring to sound, we are saying that the language has

> 'a finite set of meaningless contrastive units that combine in constrained ways to form meaningful morphemes and words, and that the mental representations of these lexical items may differ predictably and discretely from their actual realization'. Sandler & Lillo-Martin (2006:xv)

One cannot evade the issue by saying the term is only metaphorical or that visual language has the 'functional equivalent of phonology' as Perfetti & Sandak attempt. Without mentioning any medium they say 'the function of the phonological level is to organize smaller meaningless elements into larger structures the morphology assigns meaning to' (2000:33). Their perspective on phonology and morphology as structure-building processes rather than levels of completed structure is a valid alternative, but there is no reason the two media, aural and visual, should require different processes.

Using the IMA to illustrate, one would have to claim that the feature [– bent finger], a meaningless element, is one of several in the handshape . ASL's (functional equivalent of) phonology organizes these smaller meaningless elements into the larger structure  . Then ASL's (functional equivalent of)? morphology assigns the meaning 'black' to this larger structure  , ASL's (functional equivalent of)? syntax then uses that structure to build a sentence, and its (functional equivalent of)? discourse builds narratives out of that.

It is not parsimonious to distinguish between aural and visual instances by claiming the same processes or structures in different media are actually different processes or structures, and no one makes that claim of other levels where the Greenland problem doesn't arise. No research findings support the notion that visual languages have other than a level of phonological structure, and abundant research by now corroborates just the opposite view, namely that the same processes operate in either medium (Sandler & Lillo-Martin 2006:114).

It may be tempting to create whole new terms for a process when it occurs in a new or novel way, and William Stokoe did this when he coined the term *cherology* for the phonology of ASL. However this terminology has been abandoned as it draws attention away from the underlying process, misses the generalization that the same process is occurring, and gives the appearance of difference where none exists. This study will use the traditional terms where they apply, with modifying terms when needed to specify additional information, such as in *visual phonetics.*

Note that the terms *aural phonology* and *visual phonology* may be self-contradictory. Phonology takes place in the brain, where there are neither sounds nor pictures, only electrochemical patterns in a neural medium. The linguistic patterns manipulated there are encryptions of other patterns received via the optical or auditory nerves—themselves encryptions of the raw sensory input—that may be organized phonologically, or optically, or acoustically, or may be articulatory motor programs. How these encryptions operate, and any correlations amongst these various neural patterns, remains speculative. Only one kind of phonology exists, and it is neither aural nor visual. These adjectives can only be applied meaningfully when used in the same sense as references to Indo-European phonology or Japanese phonology.

Also note that acoustics have little relation to literacy. Even though we speak of linking letter to sound, or grapheme to phoneme, these sounds or phonemes are actually neural patterns occurring in our brains. Our eyes send optical patterns of written glyphs, which lack phonological organization, to the language centers of the brain which create mental representations that do have phonological organization. If these mental representations have any connection at all to external stimuli, in the present investigation it is to visual patterns, not sounds. The reading process is intimately connected with phonology but only indirectly related to sound.

5. The Debate. Skepticism regarding the writing of visual language persists in the lack of any empirical studies. The literature includes little published research that argues against writing sign, only anecdotal evidence showing that SN and similar scripts have not been adopted. On the other hand, there is no published research in favor of writing

sign, only anecdotal evidence regarding the success of IMA. Arguments boil down to those against any writing at all, versus those in favor of writing with the IMA.

5.1 Arguments in favor. Scholars use SN, Hamnosys and other systems as notations for research purposes, but the fact that only IMA is in actual use as a script narrows our discussion to this one system. Numerous published sources exist describing its use.

Steve and Diane Parkhurst, who study Spain's two indigenous signed languages, have published a complete textbook on the use of the IMA. It is written bilingually in both Spanish and the Spanish sign language known as LSE, for Lengua de Signos Española (Parkhurst & Parkhurst 1999).

Researchers in one study successfully used the IMA to produce a phonetic transcription of French Sign Language dialogue even though the transcribers themselves had no knowledge of the language. Their transcription is available online at http://gmc.ucpel.tche.br/TALS2005 (Boiera et al 2005: 3).

For over a decade at Bluefields, Nicaragua, teachers literate in the indigenous signed language have used the IMA script to develop literacy in the indigenous signed language via daily lessons, reading instruction, children's literature such as Aesop's Fables, and all typical uses of written language. They now provide instruction as well in Spanish as a Second Language, using texts written primarily in sign language using the IMA script (Kegl 2005).

It is even possible now to send email messages written in a signed language. All this is documented in detail on the very extensive website of the Deaf Action Committee at Signwriting.org. We are well past the point where one can simply argue that visual languages cannot be written. More sophisticated arguments must be offered, and these are considered in the next section.

5.2 Arguments against. Since so much information is packaged simultaneously in the visual signal, some object that no writing system could possibly capture it all. In this they may be right. No writing system captures all the intonation, stress, rhythm and pauses of speech, but neither should they try. The less detail a script includes the better so long as it enables a reader to reproduce the message. Regardless of what a script includes or omits, it succeeds if the reader can reproduce the message.

Another potential objection concerns how to represent a three dimensional spatial language on two-dimensional paper. This is less a problem than it seems. Authors invariably resort to schematic drawings of signs, and numerous books are filled with these, all on two-dimensional paper, yet they clearly show the three dimensions involved. Both drawings and photographs show the third dimension by the use of perspective; objects further away are smaller than those in the foreground. The IMA makes use of this familiar technique by having movement arrows taper, giving the appearance of receding into the distance, when they indicate movement toward or away from the reader. This all assumes that it is desirable to show the visual image of the signing, which may be an unwarranted assumption. Scripts for aural language depict neither the movements of the articulators nor the acoustic images they create. What they encode are the phonological contrasts of the language, which occur in two dimensions, that of temporal sequence and co-occurrence. This issue is explored in more detail in section 10.2.

Signing makes movements with both the right and left hands, with the eyebrows, and with other articulators, and some see this as a problem (Miller 1994: 197). They argue that it forces us to use awkward multiple lines of text: one line for the right hand, one for the left hand, one for the face, and maybe more. Gloss based transcriptions use this technique, for example writing indicators for facial expressions above the text. A notation such as ____*tp*__ , written above the English glosses with the line extending over a word or clause, indicates that at the same time the hands are making these words, the eyebrows are raised to mark them as a sentential topic. It is not unusual for several of these non-manual grammatical markers to be happening at the same time, as well as both hands moving, and this can require an awkward transcript partitioned out over four or five lines of text.

Movement writing systems take a different approach to this problem, one that is similar in some respects to the writing system used in Korea. Although Korean writing is actually an alphabet, its visual appearance is similar to Chinese characters because its letters are not in linear order. Instead, the letters of each syllable fill in an imaginary square to form a single character. These square characters are written in linear order from left to right, but within the character the letters are above, below, left or right of each other so as to fill in the square. Similarly, IMA arranges its symbols into syllabic characters. Within each character are symbols representing the left hand, right hand, brows, etc, arranged in a schematic diagram of the actual sign. These schematic images are snapshots of the sign stream at particular instants, and these are arranged in linear order. Instead of a separate line for each articulator, IMA uses one line to show a series of grabs of the total visual image. Each sequential picture-character includes all the articulators and their spatial relationships just as they occur in the actual signing, all in one line of text.

One might complain that writing systems that do not use the standard keyboard characters make typing more difficult. This creates problems for technology, but they are problems that can be and are being solved. 'Every kind of language and document processing (storage and retrieval, analysis and generation, translation, spell-checking, search, animation, dictionary automation, etc.) can be applied to sign language texts' when using the IMA (da Rocha Costa 2002). The SignNet Project in Pelotas, Brazil maintains several websites relevant to ongoing work in this area. These can be accessed at <http://sign-net.ucpel.tche.br>. A crude but simple way around this whole problem is to use the brush function included in every graphics program, like Microsoft Paint, which allows one to write just as if using a real pencil.

How to implement a writing system on a keyboard is an entirely separate discussion from the internal mechanism of that writing system, and only the latter topic will be dealt with here. The relevance of the former is questionable in my view considering that so many users of signed languages are deaf, poor, and live without access to technology in underdeveloped countries that lack any modern infrastructure. When asked in 1998 whether the rapid pace of technology wouldn't soon render writing signs obsolete, James Kegl replied from rural Nicaragua,

> ‘Rapid pace of technology? Where are you? We have electricity, some places have phones, I met someone once with a flush toilet — didn’t work though’ (Kegl 1998).

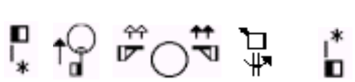
My personal feeling is that a system that depended on expensive or complicated equipment would be basically ill-conceived, and I happily leave high-tech details for others to pursue in other projects. None of the foregoing seems to offer solid objection to writing visual languages, but one substantive argument does exist, in regard to manual codes for visual languages.

5.3 Signed English. The fact that one can write signs with the IMA does not necessarily mean that one can use it to write a natural signed language. It is important to distinguish between ASL and signed English, and more generally between native sign languages and manual codes for spoken languages. Natural processes within a community inevitably use the medium of sound or of vision to construct indigenous languages—spoken in the former case, signed in the latter. Natural spoken languages include English, Japanese and Portuguese. Natural signed languages include ASL, Shuwa, and Libras. These are found in the same three countries as the spoken examples—the US, Japan, and Brazil respectively—but are entirely unrelated to their spoken neighbors. The spoken languages already have written forms: at issue is how to represent the natural signed languages in the same manner.

Natural languages, whether signed or spoken, are entirely distinct from codes invented later to represent them after they arise. Just as there are codes using the dots and dashes of Morse and the flags of semaphore, there are codes using manual signs. One of these is signed English, and there are also signed Japanese, signed Portuguese and so on. Even though they use signs as code symbols, these manual codes represent natural spoken languages and have little to do with natural signed language. Though sharing the same geographical area, the unrelated languages Shuwa and Japanese are radically different in their grammar, morphology, and syntax. The same is true of Libras and Portuguese, or ASL and English. In fact, English probably has more in common with Japanese, another spoken language, than it does with ASL.

Along with ASL, nearly the entire signing community in North America is bilingual in English. Communication takes place along a continuum from grammatically pure ASL at one end to purely signed English at the other. People often communicate using signed English, and some may not even know ASL. Accordingly, much of what one sees in writing is not ASL but is actually English. The fact that people are communicating by using the IMA to write signs does not necessarily mean they are writing a signed language, and it does not refute an argument that natural signed languages cannot be written.

Figure 3. Signed Codes and Natural Languages

	a) Signed English	b) American Sign Language
Signs		
Lx gloss	1PS true teach PROG 2PS	2PS-TOP 1PS-teach-2PS-DUR 1PS
Eng gloss	I AM TEACH –ING YOU	YOU TEACH I
Translation	'I am teaching you.'	'I am teaching you.'

When the IMA is used to write signed English, it is just a written code for a manual code for English: another method, along with digital and Morse codes, of representing speech. It might be that IMA can only write Signed English, and is not adequate to represent the radically different structure of a natural signed language. Example (3) illustrates the difference between natural sign language and manual codes by using IMA characters to write the same sentence in both ASL and signed English. The signed English sentence merely gives a signed gloss for each English morpheme. The first, third, and last are borrowed ASL signs. Since ASL is like Russian in not using copular verbs, a sign usually translated as TRUE replaces the English verb *am*. And since ASL is like Chinese in not using suffixes, a sign for the ending *-ing* is simply invented. These made-up manual symbols can stand for English words just as well as any other symbols could, but this has little to do with ASL, which bears no relationship to English and operates very differently. Besides making no use of copulas, tenses, or suffixes, the ASL sentence has different word order, a null subject, overt topicalization, a verb that shows continuous aspect (but not tense) and incorporates agreement morphemes for both subject and object similarly to nonconfigurational languages like Mohawk (Baker 2003:407-38).

This simple example shows how manual codes differ from signed language, and also show how any written form must reflect this difference. The first sign in the ASL sentence is enclosed in brackets, , with the raised eyebrows that mark topics.[7] This is the same feature indicated by $\overline{IX_R}^{tp}$ in the glossing used in figure (3). It is one of the

[7] The brackets here show when to start and stop the [+raised] brows feature, which marks the object pronoun as a topic and licenses NP movement. Non-manual grammatical markers like this one co-occur obligatorily with the head of a phrase, and optionally spread across larger structures.

most common constructions in ASL, and makes the important distinction between the subject and object of a sentence. With no way to write facial expressions, Stokoe Notation is unable to include this crucial aspect of ASL grammar, whereas the IMA is able to do so. The question is whether or not the IMA can encode all the grammatical constructions of naturally occurring visual conversation, to provide a 'discrete, segmented, correct phonetic transcription' of a natural signed language such as ASL. This is the goal of experiment one.

6. Experiment One: reading IMA. How can we prove that signed language can be written? We can find a precedent in the experience of the Cherokee genius Sequoia, who after inventing a writing system for his language had to convince his people that these new talking leaves were useful. At a famous meeting, Sequoia wrote down a message dictated by the chiefs, who then carried his markings to the other side of the village, to Sequoia's daughter who also understood the talking leaves. When she accurately reproduced the written message the tribe was convinced (Foreman 1938:3987). Experiment one follows the precedent by replicating this famous experiment, substituting the IMA script for the talking leaves and replacing the Cherokee language with ASL.

6.1 Method. We transcribed an IMA narrative in grammatically complex ASL and presented it to literate ASL signers. If these participants are able to read and reproduce the message in ASL, this confirms empirically that it is possible to read and write the conversational form of a natural sign language. As a test of comprehension they also translated the message into English. This was a simple way to confirm understanding, given that all participants were bilingual in English as well as ASL. If participants are able to read, write, and understand a visual language transcribed in the IMA script, this proves that there is no technical barrier to writing this class of languages. The hypothesis to be tested is that it is possible to write the normal conversational form of a natural signed language, using the International Movement Writing Alphabet (IMA), in such a way that users of that language can retrieve both the form and the meaning of the original utterance.

6.1.1 Participants. Five participants took part as readers in the experiment. All were adult undergraduates at a major university, who had learned ASL at university and taught themselves to read both SN and IMA through their own efforts. None were deaf. Three were males and two females, and two of the former and one of the latter were certified ASL interpreters. Of the non-interpreters, one was a native signer with moderately high English skills, and the two others signed at a second year level.

6.1.2 Design. The study tested the reader's ability to decode, focusing on characteristics of ASL signing that are structurally different from English. The following list was drawn up of constructions that are well represented in the literature and that take significantly different form, or do not exist, in English.

1) Role shifts
2) Fingerspelling
3) Spatial Comparisons
4) Classifiers and classifier predicates

5) Spatial deixis and loci

6) Facial adverbs, and their spread over clauses

7) Inflections for temporal aspect and the spatial modulation known as distributional aspect, and hierarchal embedding of each within the other

8) Simultaneous use of lexical items, both as simultaneous production of signs on both hands and as morphemes incorporated into root words

9) Nonmanual grammatical markers (NMGS) for yes-no questions, wh-questions, rhetorical questions, negation, relative clauses, and topicalization; and overlapping use of more than one of these at the same time

A text narrative was composed that included at least two examples of each of the above constructions (Appendix A). This was checked for acceptability by a native user of ASL and judged to be grammatical. Vocabulary items were restricted to those in common use. Individual signs were taken from Sutton's American Sign Language Dictionary (Deaf Action Committee 1999) as much as the inflectional system permitted. Conventions for marking grammatical structure mostly followed Parkhurst (1999).

The text was written in vertical columns. Like Chinese, ASL can be written horizontally or vertically. The consensus amongst deaf readers over the past decades has been that the latter is preferable as it more clearly shows spatial relationships that are important in ASL grammar (Sutton 2003).

6.1.3. Tools. The text narrative was written out by hand, although it can be typed on a computer rather easily. The finished text occupied five sheets of 8½ x 11 paper, written in vertical columns with 4 columns per page. Counting the number of words was problematic. Signs made simultaneously with both hands were counted here as one sign, even when they were two separate morphemes or words. In fingerspelling, each handshape made to spell out a foreign (English) word should be counted as a separate word, because technically it is: the name of a letter in the Roman alphabet, analogous to saying *pee-aye-zee-zee-ey* instead of *pizza*. Even so, all the fingerspelled words in the text were short enough to easily take in with a single glance, and so were counted as just one word. Many of the non-manual grammatical markers in the text were also counted as one word. Some of them contain as many glyphs as some of the signs, so these were also counted as words on the reasoning that they require as much visual processing as any other set of glyphs. With these stipulations, there were 150 ASL words in the narrative. An English rendition of the same narrative contained 387 words (Appendix B).

As there are as yet no standardized spellings for ASL, writers largely decide for themselves[8] how a word should be spelled and at what level of detail. To the extent possible given the infinitude of inflected forms, spellings were taken from the dictionary, and written at a level that included more phonetic detail than might ordinarily be included.

6.1.4 Procedure. Each participant sat at a desk while I sat next to them at such an angle that I could observe both the text and the reader's signing. The readers uncovered and read the text, signing as they read. They also gave a running translation into English. I

[8] Each writer is free to choose the spelling they deem most appropriate. Sutton and the DAC have always resisted imposing rules for standardization, as their policy has always been to let the system develop naturally at the hands of its users. IMA today is at the stage of written English during the 15th century, before the printing press and standard dictionaries froze the spelling of words in their present form.

watched their signing and made note of any signs produced that did not match what was written on the page, and the process was recorded on video for later reference and verification.

In order to quantify the results the misread signs can be expressed as a percentage of the total number of signs. To develop a scoring procedure for comprehension, the essential details of each proposition were listed. These included identification of the actors involved, their relative locations and their semantic roles, and which actions preceded or followed others: that is, who did what to whom, and when. Listening to the English translation, any essential details that were misinterpreted were noted as errors. Any errors made subtracted from the total yielded a percentage of error score that could be used to rate the subjects' comprehension.

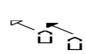
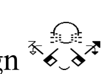
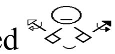
6.2 Results. None of the participants had any trouble reading the IMA narrative. They sometimes attributed the wrong meaning or form to a sign at the first reading, but then looked more closely and produced the correct sign. Temporary production of the wrong sign appeared to result from attempting to read too fast. The only difficulty that arose was when the readers were unfamiliar with the sign portrayed in writing. In that case they reproduced it accurately but just didn't know what it meant at first, but in every case the context made the correct meaning clear. Some took longer than others to read the narrative, but every participant correctly reproduced all the signs and accurately translated all essential details of the meanings, with two minor exceptions. One was to read an inflected version of the sign  'bring' as 'walked', which had no particular effect on overall meaning. The other error was to mistake the ASL sign  'finally' for the very similar phonologically and easily confused  'succeed', which caused a small puzzlement over possession in one clause. The scoring procedures proved virtually superfluous, with a comprehension score of 99.6 per cent.

Figure 4. Experiment One Results: Comprehension of ASL/IMA text.

Reader	A	B	C	D	E
Comprehension: %	100	100	100	99	99

Results confirm the hypothesis: it is possible to write the normal conversational form of a natural signed language, using the International Movement Writing Alphabet (IMA), in such a way that users of that language can retrieve both the form and the meaning of the original utterance. Leaving social factors aside, there is no technical barrier to writing and reading a visual language.

6.3 Discussion, experiment one. The lack of errors in reading the IMA transcription was something of a surprise. It is consistent however with anecdotal reports that even young children can easily read the IMA script. The large amount of rereading can be attributed to two factors. First, participants were not just reading the texts but giving simultaneous translations. They often held up reading while they searched for words to explain a more exact meaning for a word they had just signed. During periods when they weren't talking, their signing became faster and more fluid, and more like normal signing. Second, all these participants were reading in a second language, so that very likely they were still translating to their L1 in order to understand the text. There can be no comparison with reading written English in which participants averaged nearly two decades of daily practice.

Predictably, reading times were slower for ASL/IMA than for English/Roman Alphabet. Average reading times were three and a quarter minutes, compared to one minute for reading the English translation of the same text. Interestingly, the English translation of the narrative required over twice as many words as the number of signs in the original: 387 versus 150. For several of the signs written in the narrative, readers used a dozen or so words to translate to English. It is well known that signing takes longer than speaking, and that attempting to do both at once almost inevitably results in worse performance in at least one medium (Emmorey 2002). Although this should not affect the validity of the present results, this sort of simultaneous translation is probably not the best methodology for this task.

The signs the readers hesitated on were often classifier constructions. These tend to be quite complex, with a number of morphemes joined together in often unique ways. These signs are unlikely to have ever been seen before, unlike lexical signs that they may have read before and could recognize on sight. All the participants in this study were acquainted with one another and shared a familiar reading vocabulary. Testing readers from different areas or with different backgrounds would be a good follow-up to this study, if it could avoid testing the amount of standardization rather than the actual script itself.

It is noticeable that the English version of the narrative requires only one page, while the IMA text filled up five pages. Another variable to investigate would be text size, which was purposely made rather large in this case for legibility, as is typical with written ASL. Especially when typed on a computer the characters can be made as small as 12 point type and still be legible, although difficult to read. Along with standard spellings, this is another aspect of the new script that is currently in the process of being negotiated by its users.

Such details aside, the results of this experiment stands as clear proof that it is possible to write sign language. The results demonstrate that a visual language can be reduced to writing such that others who know the language can accurately reproduce both the pronunciation and meaning encoded in the text.

7. Experiment two: reading SN. Given the results of Experiment one, it seems likely that problems with writing signed languages stem not from any aspects of the languages themselves but from the scripts used to represent them. With this in mind, we repeated the same experiment as above using Stokoe Notation.

7.1 Method. As in the previous test, an ASL text was written out, this time using Stokoe Notation as a script. Participants read this and it was scored in the same manner as the previous experiment. Within limitations imposed by the nature of the writing system the same methods were followed in both tests.

7.1.1 Participants. Participants in this test were the same group of persons who took part in Experiment One.

7.1.2 Design. SN was designed to be a scientific notation rather than a script, so it is not surprising that it can encode only four of the nine ASL grammatical features compiled for the IMA reading test: numbers 2, 4, 6, and 7. Also, since SN has no means of showing the facial expressions that serve as function words in ASL, relationships among words and clauses can only be guesswork, yielding at best a sort of pidgin. Even so a short paragraph was drawn up for purposes of comparison.

7.1.3 Tools. The test narrative for the SN reading test was a short text of only 19 characters, written out in SN in standard linear order to tell the beginning of the story of Goldilocks. This was typed out on a computer and occupied about a half page. A copy is attached as Appendix C,[9] with a rough translation into English.

7.1.4 Procedure. Participants read the SN paragraph in the same manner as the IMA text. It was scored in the same manner as the IMA text as far as was possible.

7.2 Results. Participants had little success with deciphering the SN text. Three readers gave up altogether, one after translating only six of the nineteen words, another after getting all but three, neither being able to actually piece together a coherent storyline. They managed to figure out that it was the story of Goldilocks, but that's about all. One reader persevered through to the end, figuring out all but one sign, although it took nearly ten minutes to do so. Even though all the readers were familiar with the symbols and even used the script in their own work, they had extreme difficulty piecing together

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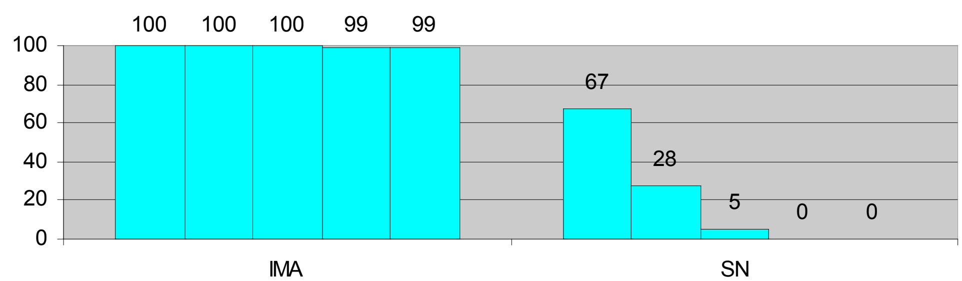
[9] Since the time of the testing, this text has since been posted on the web at <http://www.signwriting.org/forums/linguistics/ling006.html>.

unfamiliar signs. Even then, faced with a lack of function words, readers relied on context to guess at interclausal relationships, getting them wrong as often as right. Scoring the SN according to the criteria above gave an accuracy of only twenty-two per cent. Apparently the script serves mainly as a mnemonic rather a phonological coding device. Since Stokoe designed his notation only for transcribing single words, this finding came as no surprise.

Figure 5. Results: Reading Comprehension, Experiment One and Two



Results of this experiment make it clear that even though SN is capable of representing individual words it is not adequate as a script for signed language. Taken together with the results of experiment one, it demonstrates that problems with writing signed languages are best attributed to characteristics of the scripts used to represent them, rather than to any aspects of the languages themselves.

8. Discussion, experiments one and two. Although experiments one and two have established that visual languages can be reduced to a written form, it is with the caveat that a certain type of graphic representation must be used. The nature of this representation is radically different from what we normally accept as writing, and some

might argue that these new graphics are only diagrams or pictorial depiction and are not writing at all.

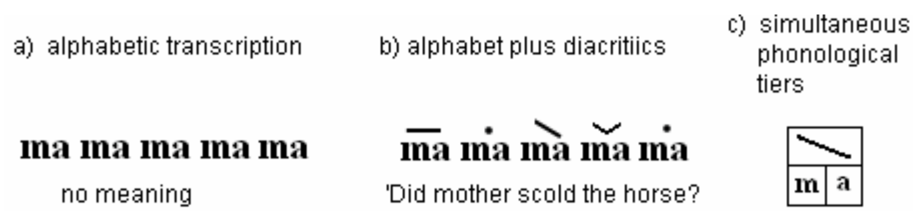
8.1 Writing Systems. Identifying how these new scripts fit into our existing typology of writing systems is not a straightforward task. Even though 'what writing is must count as a question which lies at the heart of linguistics' (Harris 1986:47), the study of writing systems has 'absorbed the attention of very few linguists' (Daniels & Bright 1996:1). One of the first was I. J. Gelb (1963), who produced a three-part typology of writing systems in which 'there are three ways that we can symbolize words in writing' (Whitney 1998: 173). The symbols of an ALPHABET approximate the phonemes, or speech sounds, of a language, a SYLLABARY links each symbol to a unique syllable, and a LOGOGRAPHY links a symbol to a whole word or morpheme. This three way classification has since become standard (O'Grady 1997: 554) even though 'Gelb's tripartite classification of writing systems is only one of many' (Daniels 1996:8), and the meaning of the term LOGOGRAPH is rarely made clear. Some writers use it as a synonym for IDEOGRAPH, a symbol that stands for an idea and 'has nothing to do with the sounds involved' (Saussure 1916:47). The typology perpetuates a persistent myth that scripts like this exist and that 'the classic example of this system is Chinese' (Saussure 1916:47). Actually, Chinese characters, like all scripts, represent the sounds of the spoken language (Perfetti & Liu 2005). DeFrancis describes Chinese writing as an outsized syllabary (1989:107). While individual ideographs such as the ampersand are in use, no script represents meaning only (Unger 2004).

Since language is a pairing of meaning and form, the only other option is to represent some aspect of form, and all scripts represent the phonological form of a particular language (Tzeng & Wang:242). This is such a basic characteristic of all writing systems that it has been titled the Universal Phonological Principle (UPP) and designated the underlying principle of all writing (Perfetti et al 1992). 'Purely logographic writing is not possible' (Daniels 1996:4). It would require the average high school student to memorize over 60,000 symbols for the words in their vocabulary (O'Grady 1997:117), instead of the five or six thousand characters even skilled Chinese readers actually know (Norman 1998:73). Even then 'no writing system is purely logographic…nor can it be' (O'Grady 1997: 554), because 'a strict logography would not be productive' (Mattingly 1985: 22), meaning its users could not write new words or names, whether made up or borrowed from other languages.

The UPP entails that the phonological structure of a language dictates what type of script is appropriate. The simplest phonological structure consists of only consonant-vowel (CV) syllables, and a syllabary can adequately represent languages with this structure, such as Japanese or Cherokee. The more complex syllable structure of languages like English generates far too many syllables for this to be practical, and an alphabet can represent them, however 'there are languages for which an alphabet is not the ideal writing system' (Daniels 1996:27). For tone languages like Chinese 'alphabetic writing could be no improvement and to use only an alphabet…would be disastrous for readers' (Mattingly 1985:23). Languages of this type are very difficult to read when written in alphabetic script unless diacritics are added to indicate the tones. Without them, the famous poem about a lion-eating poet consists of the same syllable *shi* repeated

92 times! These languages effectively have two tiers of structure occurring simultaneously: the tones themselves, and the other phonological material that the alphabet is able to encode. The amount of simultaneous structure, or co-articulation, in their phonology dictates that something more than an alphabet is required to represent them in writing. Visual languages such as ASL[10] are known for having far more co-articulation than any spoken language.

Figure 6. Alphabets are inadequate for some languages.



The UPP applies to visual languages as well. Optical patterns in the case of signed languages, and acoustic patterns in the case of spoken languages, make up the phonological forms that any script must encode. We can describe these phonological forms in terms of contrastive features, such as [+/– bent finger] or [+/– rounded lips], that combine with one another in sets. The three sets Stokoe used for his notation symbols represent the same parameters linguists traditionally use for phonological description: location—where the articulator is held; shape—of the tongue, finger or vocal fold; and manner—of the articulator's movement. A shape or movement can't exist without a location, so these always co-occur, and other features occur before, with, or after them to

[10] Since all known signed languages share so much basic structure, it will be safe to assume that whatever is asserted about ASL can be taken as generally true of all of visual languages, at least for purposes of this paper.

make a two-dimensional array of simultaneous and sequential features that define any syllable or part of any syllable.

Both visual and aural languages can be described as combinations of features, but the medium affects the number of possible values for each feature. With speech the number of possible values is small. Voicing basically only gives the two choices of voiced and voiceless, nasality does the same, and there are only about a half dozen choices for place or for manner, so the same combinations keep repeating. Japanese speakers can pick out some 48 combinations that keep repeating as syllables in their language, and English has its 40 or so repeating phonemes. The small number of possible values for each feature makes syllabaries and alphabets possible. Rene Kager (1999:7) calculates that using all the sounds of all the world's languages and every possible combination of features, an array with two features in sequence would produce about 6400 possible combinations. This is far fewer than the 100,000 or so words a natural language needs, so our speech has to repeat the same combinations of features to make arrays with longer sequential combinations.

The articulators used for sign are much more complicated. There are far more than six or eight locations on the human body, and we can make far more hand shapes than tongue shapes. ASL has about a hundred contrastive values for each of these two parameters, location (Johnson & Liddell 1996:5) and hand shape (Liddell & Johnson 1989:268), and then there are movements, hand orientations and facial expressions. Performing Kager's calculations with ASL, an array with only two features in sequence produces over 178 trillion possible combinations. Unlike speech, visual languages have no need for long sequences. Of course we don't use all of the possibilities, but the number of feature combinations that occur is far too many to write a unique symbol for each one as is done to create an alphabet or a syllabary. There is no small, listable set of phonemes or syllables and this means that neither an alphabet nor a syllabary can be used to reduce visual languages to writing.

Otto Jesperson in 1889 described a fourth type of script he called an ANTALPHABETIC system[11]. The idea is to use, not arbitrary symbols, but symbols that show the phonetic features. Any written character is composed of smaller elements like dots and lines: Jesperson's antalphabet linked the phonetic features with these dots and lines. The glyphs in such a script don't stand for sounds but for these smaller elements within the sounds. It takes several of these feature-glyphs, that can't appear alone, to make up one larger independent character that represents a language segment. That defines an antalphabet (Harris 1995), and though Jesperson knew nothing of visual languages, it also defines the type of script used for transcribing them, such as SN and IMA. The characters in these scripts represent visual language segments, but the characters themselves are made up of smaller glyphs that represent phonetic features like [bent finger] or [palm up].

Sampson has also discussed this type of writing based on phonetic features, describing it as a hypothetical type he called a FEATURAL SCRIPT. He cites the feature arrays used by linguists, shown in figure 7, as a purely feature-based notation (1985:40), but 'it is nearly impossible to read words written solely in distinctive features' (Kim 1997: 151).

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[11] He originally called it an analphabetic system. Since analphabetic already had a meaning, basically the same as illiterate, Jesperson later added a /t/, changing it to antalphabetic.

Figure 7. The word *cat* in a phonological feature notation.

	[k	æ	t]
consonantal	+	–	+
vocalic	–	+	–
sonorant	–	+	–
anterior	–	–	+
coronal	–	–	+
close	–	–	–
open	+	–	–
back	–	–	–
round	–	–	–
voiced	+	–	–

Sampson offers Pitman Shorthand[12] as a usable script that indicates some phonetic features, and his other example is Han'gul, the alphabet used to write Korean. The letters of Han'gul indicate not only the sounds of Korean speech but also many of the smaller features of which they are composed. It 'makes more systematic use of the phonetic features of the spoken language than any other orthography' (Tzeng & Wang 1983:239), and is often called the world's best writing system (Kim-Renaud 1997:ix)

However, both the Korean script and Pitman Shorthand are only partly and incidentally featural, whereas this is a fundamental design element of both SN and IMA. Until now the world has not seen a real antalphabetic, or featural, script in common use, but they are clearly a recognized and even highly regarded type of writing system. They may be even better than an alphabet or a syllabary, because an alphabet lacks the 'precise and expandable repertoire of classificatory subtleties that are available' in an antalphabet (Daniels & Bright 1996:843). Unfortunately, both the IMA and SN share another characteristic that is not so highly regarded.

12 Pitman uses a dark line for voiced sounds and a light line for unvoiced sounds, which way the line slants shows where the sound is made, and the straightness of the line shows how it is made.

8.2 Iconicity. New scripts must overcome deeply entrenched traditional attitudes, and much of the IMA's slow acceptance over the past decades is surely due to its highly iconic nature. This characteristic generally meets disfavor flowing from two main sources: an evolutionary view of writing, and Saussure's principle of arbitrariness. Both these are at best oversimplifications and in some respects not supported by currently available data.

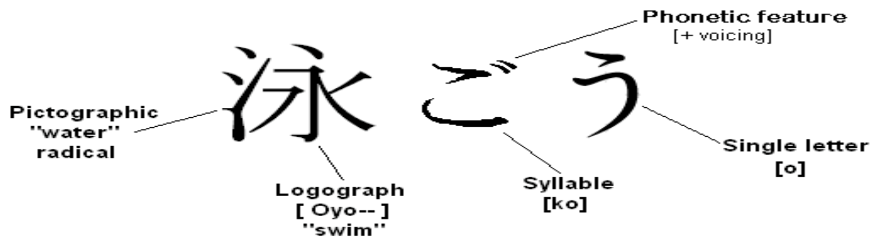
8.2.1 Evolution. Uninformed persons, revealing the bias that delayed recognition of the linguistic nature of visual language for several thousand years, invariably describe signing as pictures in the air, more primitive than language. They likewise see any pictorial representation as akin to drawings left by cave dwellers in contrast to our modern, sophisticated alphabet. Even some linguists scoff at the IMA as mere 'cartoon characters' (Johnson 2001), dismissing any kind of pictorial representation as 'prewriting' (O'Grady et al.1997:555), a 'precursor' (Coulmas 1991:17) that precedes 'true writing'.

> It is generally believed by linguists, psychologists, psycholinguists, and educators that writing has "evolved." According to this view, first there was picture writing, then logographies, then syllabaries, and finally, the alphabet. At each of these stages of development, writing became more efficient because a smaller inventory of signs was required to do the job. The alphabet is the culmination of this evolutionary process.
> (Mattingly 1985:18)

This view has been debunked in recent years (Daniels 1996:5). The alphabet is not the 'final perfection of writing' that most Westerners consider it (Harris 2000:128) and 'what surveys of different writing systems have made clear is that there is no one "best" way to go from a spoken language to a visual pattern' (Whitney 1998:175). Evolution requires progressive stages, but 'one of the puzzles of Egyptian documents is that what in the abstract model appear to be subsequent steps are all present in the earliest records. Documents dating from the beginning of the dynastic era (about 3000 BC) exhibit all' three types of writing (Coulmas 1991:60). In Sumerian and Chinese as well 'there appears to be no historical period during which the writing is strictly logographic; the consonantal signs are there from the first (Gelb 1963:p. 74)'. 'Gelb himself makes it quite clear that there is no period in any of these traditions during which the writing was strictly logographic; syllabic signs occur in the earliest specimens' (Mattingly 1985:20), and the same is true of Mayan writing (Coe 1992).

Thus 'Gelb's widely accepted theory of orthographic evolution must be rejected. Orthography has no relation to picture language, and there is no sequential development' (Mattingly 1985:23. New techniques were simply added on to older methods, with the result that 'there are no pure systems of writing' (Gelb 1963:99). Korean writing is well noted for being both an alphabet and a syllabary, and the IMA is organized similarly. Our alphabetic writing includes logographic characters like the ampersand, and characters for individual vowels are included in most syllabaries, including Japanese. The Japanese word *oyogō,* which can be translated as 'Let's go swimming', uses a logograph for the word stem, and a syllabary to write the inflectional ending -*gou.* It also uses a diacritic for the phonetic feature VOICE, changing the pronunciation from [ko] to [go]. The final symbol serves the alphabetic function of representing a single vowel [o]. Within this single word we find elements from all three types of scripts.

Figure 8. All writing systems are a mixture of script types: Japanese *Oyogō.*



We also find picture writing. The leftmost portion of the logographic character 泳 is a semantic determinative, or radical, traditionally described as an image of three drops of water, and the rightmost phonetic element is also considered a pictograph, of streams flowing together. Far from being replaced, pictographs are still in use as instructions and warning signs, and the dashboard of any modern car invariably features at least one telling you to wear your seatbelt. They co-exist peaceably both alongside and within writing proper, notably including emoticons like ;-) and (^_^).

Since no scripts include only one type of character, calling a script a syllabary or other type only means that a high proportion of its characters function a certain way. This simply relocates the problem to classifying the individual symbols. The English symbol < a >[13] represents at one time a word, a syllable and a letter. The symbol 泳 is pronounced in some cases as a syllabic [ei], and in others as the logographic [oyo-].

[13] Following standard practice in the literature, we use square brackets [ ] to enclose phonetic material, slashes / / to enclose phonology, and angle brackets < > for orthography.

The volitional inflection [gō] is added onto the root [oyo–] by two members of a syllabary, ご and う, acting here as alphabetic letters to represent the two sounds [g] and [ō]. More technically, the character う adds a mora, changing the short vowel of ご, [go], to a long vowel in ごう, [gō], which describes the type of writing system known as an ABUGIDA, neither an alphabet nor a syllabary (Daniels 1996:4). Gelb's evolutionary model hinges on the similar 'distinction without a difference' (Mattingly 1985:20) of whether the West Semitic script was an alphabet that wrote only consonants, or a syllabary that wrote syllables with unspecified vowels. One person's syllabary is another person's alphabet, one's pictogram is another's inkblot, and all these categories are 'artifacts produced by the imaginative eye of the beholder' (Harris 2000:160). As the characters are ambiguous and subjective, so too are the systems, leaving us with only the fact that people drew pictures before writing was invented.

Writing introduces a new, symbolic, relationship in addition to the iconic relationship the picture has to its referent. The inventor of writing assigned a symbolic function to the picture, saying 'let X = Y, where X is the picture and Y is something else'. One might let X stand for any letter of the alphabet, including the letter X, and in this case when X stands for X it is no less a symbol in spite of the fact that it is also an exact pictorial duplicate. The iconic relationship is irrelevant to the symbolic function that defines writing. One can choose the perspective that the glyph  is a picture of someone's hand, or the perspective that  is a symbol that stands for an element of ASL. Mayan writing, which prominently contains many kinds of stylized pictures of heads, illustrates the importance of this choice of perspective. Decipherment was held up for centuries by the perspective that the heads were only pictures. Scholars changed their perspective in the 1960's to see those heads as symbols for phonetic elements of the Mayan language, and soon they were able to read Mayan writing (Coe 1992). To go from pictures to writing requires only one step, that of adding the symbolic function.

Gelb presupposed that the abstract symbols must have gradually evolved through many stages of ever more sophistication. Supposedly the Sumerian picture of an arrow, , evolved into a logograph that stood for the word for arrow, [ti], and then evolved further into phonographic writing that stood for the sound [ti], and then further into syllabic writing when it stood for the syllable [ti] (O'grady et al 1997:559). Unless one is trying to justify an evolutionary account it is hard to see the need for all these different stages beyond the first. Since a word is the indivisible 'combination of a concept and a sound pattern' (Saussure 1916:99), it is difficult to explain how the symbol can represent only half of it. Modern psycholinguistics makes it very clear that activating the phonologic, syllabic, sound [ti] also activates not only the associated concept but an entire network of related sounds and concepts. This point is developed further in section eleven.

Coulmas reasons that 'the relation between sign and meaning is more obvious and hence stronger than that between sign and sound image' because 'the written sign continues to have iconic features with respect to the represented object while the relation to the word is totally arbitrary' (1991:21). Over time, 'to the extent that visual iconicity was reduced, the relation of the sign to its linguistic form attained equal weight. Gradually the graphical sign thus came to stand for a linguistic sound unit', because 'the meanings were *no longer self-evident by the icon'* [emphasis added] (1991:21).

Written signs like IMA , for an ASL word meaning 'black', refute this reasoning. The iconic relationship is to the phonology, and it is the relationship to the abstract referent that is only arbitrary. If iconic relations were somehow stronger, one could only argue that this script is more fully evolved than even Gelb's final stage where the relations have 'attained equal weight'. The IMA symbol for ASL 'tree', , includes an icon for a real tree yet it is also an iconic picture of the ASL word. Since these relationships are both iconic and thus of equal weight, we have no basis to claim either is more natural or stronger than the other. Nor can we say this doubly iconic word is any more linguistically evolved than regular spoken, non-iconic words.

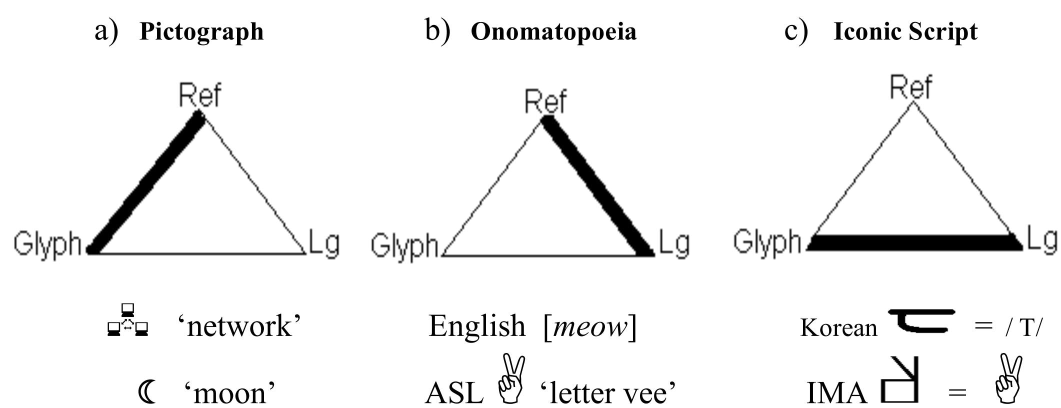
8.2.2 Arbitrariness. For Saussure too the difference between pictures and language hinged on iconicity. His first principle was that: 'the linguistic sign is arbitrary' (Saussure 1916:100), and he made clear that what he meant by this was more accurately not-iconic, meaning the sign was not motivated by any 'natural connection in reality' to a real world referent (101). The case of onomatopoeia, 'words that imitate the sounds of the world' (Crystal 1987:426), provide a clear counterexample but he dismissed this exception as 'rather marginal phenomena' (Saussure 1916:102) that are 'never organic elements of a linguistic system' (101).

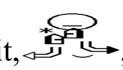
However, Saussure knew nothing of signed languages. Since so many words in visual language are obviously motivated by an iconic relationship with their referents, and are clearly organic elements of the systems, the issue of iconicity was very much a focus of early research on sign language. Early experiments showed that a sign can possess the requisite arbitrariness while possessing aspects that are extremely iconic, both at the same time. Klima & Bellugi cite the classic example with signs for 'tree' in various languages. Danish Sign Language draws the overall shape, ASL mimics the overall form, and Chinese Sign Language outlines the vertical trunk (1979:21). Like the blind men and the elephant, all select arbitrarily different elements to portray iconically. The same applies to spoken language. Mimicking the sound of a barking dog gives us *woof, arf*, and *bowwow,* and Saussure himself pointed out the French dog's *ouaoua* and German dog's *wauwau* (Harris 1983:69), all iconic links to some arbitrarily selected characteristics of the referent. Saussure was not entirely wrong about arbitrariness, but the two attributes of arbitrariness and iconicity are not mutually exclusive as is often assumed.

The research shows that although iconicity is important in word formation, it does not play a role in acquisition, is not used in coding signs into short term memory, and with time and usage it often fades out of the language altogether, as is well known from spoken languages (Klima & Bellugi 1979). Klima & Bellugi established experimentally that when non-signers look at ASL signs, 'meaning *is not self-evident* from form alone' [emphasis added] (1979:22). When shown ASL signs, subjects who had not studied the language were able to identify the correct meanings for less than one percent of the signs. It would seem that people are fooling themselves when they believe, like Coulmas, that the meanings of icons are self-evident.

Saussure proscribed a motivated relationship between a real world referent and a word, not the written symbol that stands for the word. His linguistics was almost exclusively concerned with the spoken word and had little to say about writing. Written pictographs exploit a completely different relationship, that between a referent and a written symbol. A pictograph of a tree is a picture of a tree, not a picture of the word for tree.

Figure 9. Iconic scripts.



IMA characters, on the other hand are pictures of words and do not involve the referent at all. Such iconic script symbols exploit a separate, third, relationship between the written symbol and the phonologic unit of language. The ASL word for 'silence' looks very much like the written symbol that represents it, , but neither of them look very much like actual silence. Even though it is a picture of the tongue touching the roof of the mouth, the Korean letter  does not have the meaning 'tongue touching the roof of the mouth', it means the sound /t/. These glyphs associate a written symbol with a unit of the articulatory phonology of language.

The three relationships involved in representing language graphically, shown as (a), (b), and (c) in the figure above, occur in different conditions depending on the medium. A referent may be an abstract concept only, or it may offer some visual or acoustic image. Since it is not possible to draw a picture of an abstract concept or a sound, the glyph-referent relationship (a) can only be visually iconic when the referent shares the same visual condition as the written glyph.

The limited data available in Saussure's time allowed only a few possible conditions. Then as now, a written glyph was always a visual image. The linguistic sign, the word, was always an acoustic image, and since one cannot draw a picture of an acoustic pattern, in Saussure's data the glyph-word relationship (c) could only be unmotivated. The right side of the triangle, relationship (b) between a referent and a spoken word, was also normally unmotivated, in contrast to the left side, the glyph-referent link (a), which generally is iconic for visual images. Given these conditions, Saussure's observation was not so much that (b) was arbitrary, as any link is partly arbitrary, but that it was 'unmotivated' by a 'natural connection in reality', and stood in contrast with relationship (a), except in the rare exception of onomatopoeic words.

In the post-Stokoe era we have new and more complete data. Words that are visual introduce a new condition for (c), visual glyphs for visual words, allowing an iconic link between the word and the written glyph and making it easy and natural to draw a picture of a word, something impossible for Saussure. The new data also introduces a new condition for relationship (b), the right side of the triangle, that is opposite to what Saussure observed. Visual words for visual referents show a motivated link between the linguistic sign and its referent and constitute a second counterexample to Saussure's principle, along with onomatopoeia.

Words for sounds are an exception to both counterexamples. In visual language words tend to be iconic, and in spoken language most are not, but in the case of words for sounds the reverse is true in either media. Visual words for visual referents, together with spoken words for sounds, utilize only one medium and so can be and usually are iconic. The general rule is that iconicity appears when both the referent and the linguistic sign share the same medium. Saussure based his observations on one special case, spoken words for visual images, which are cross-modal and cannot be iconic. His principle of arbitrariness is merely a special case of Liddell's observation that language will be iconic whenever it can be (Liddell 1992).

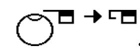
Figure 10. Words are iconic when they are not cross-modal.

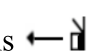
(arbitrariness present in all cases)		WORD[14]	
		visual	acoustic
REFERENT	visual	**PICTOGRAM**	**non-iconic**
	acoustic	**non-iconic**	**ONOMATOPOEIA**

With writing systems too, 'natural connections in reality' do not bridge the gap between different media, and cross-modal code symbols are non-iconic. Written glyphs for spoken words cannot be icons, but visual glyphs for visual words easily can be and most scripts for signed languages naturally take advantage of this.

Written glyphs are always arbitrary, and are iconic within the same medium, but in any case function as symbols to encode the phonology of a language. The reason 'pictography is not writing' (Daniels 1996:3) is that it is not linked to phonology, in contrast to systems that are considered writing precisely because they do encode

[14] Including pictograms under words is a result of the debatable status of iconic visual words. One can include them with onomatopoeia if one extends the definition to include the visual medium, or one could classify them with pictographs in that both mimic the visual form of their referents. The latter course is followed here to avoid making a three dimensional diagram.

phonological structure. An acoustic view of phonology obscures any connection with vision, but an articulatory view makes it easy to see a link between visual phonologic units and visual images of the articulators that create them. Words in visual languages are optical images, and the iconic symbols used in scripts like SN and IMA represent parts of these words. The IMA glyph  and the SN glyph **V** represent the two-finger V-hand, a morpheme that is part of many words. Each finger is an articulator expressing the phonetic feature [+/– straight], and the script represents this with a straight line for [+ straight], the IMA using a bent line for [– straight], as in the sign . It is these links to phonology that differentiate these scripts from pictography and make them full writing systems.

Coulmas explains that 'the decisive step in the development of writing is PHONETIZATION: that is, the transition from pictorial icon to phonetic symbol' (Coulmas 1991:33). It is not clear what other steps would be necessary. Because anything can act as a symbol, there is no continuum of written shapes with opposing poles of pictorial icons and arbitrary symbols. One can use pictorial icons as symbols or not, and the same for arbitrary shapes, but a continuum of symbols that are less and less iconic bears no relation to the mental process of phonetization. This process occurs when the reader associates a graphic image with a linguistic sign instead of with its referent (26). IMA symbols undergo phonetization when we stop viewing the written IMA symbol  as two fingers, and see it as the ASL word for 'two', , as a morpheme in the signs  'two people travel leftward together', and  'twelve', or simply a feature combination in the signs  'study', and  'doubt'. 'Phonetization is generally considered a critical criterion for recognizing a system as writing proper' (Coulmas 1991:35), and by this criterion these iconic writing systems are indeed actual writing.

In fact iconic writing systems are not only feasible, but many have been attested over the years. Alexander Graham Bell's Visible Speech, whose glyphs act as modified schematic images of the vocal apparatus, enjoyed widespread support during the nineteenth century (MacMahon 1996:838). Of writing systems currently in wide use, the Korean Han'gul alphabet is the poster child for iconic scripts. A number of Han'gul letters form schematic diagrams of the body parts that make their sounds. Some use a horizontal line for the roof of the mouth with a second line contacting it to show where the tongue makes contact, as in the letter ㄷ above. The shape of the tongue line depicts how the sound is made. Others use iconic diagrams of the mouth to indicate sounds made with the lips, similarly to Plato's O. Korean writing is 'simultaneously phonetic and pictographic' (Harris 2000:124), as is the IMA.

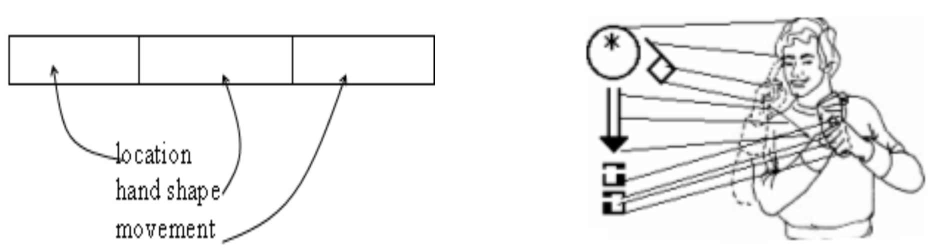
Ironically though, iconicity is a trait that endears the Korean alphabet to linguists. Coulmas calls it 'an extraordinary feature' (1991:119) that is 'consistent and systematically beautiful' (123). However iconic the symbols of Han'gul may be though, they are far less so than scripts for visual languages, particularly the IMA, yet the former is praised while the latter is scorned. An objective reading can only conclude that iconicity, while it may be a characteristic of any script, has no bearing on whether a particular writing system is appropriate for a particular class of languages.

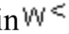
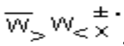
The phonological structure of visual language mandates that they be written with featural antalphabets, with varying amounts of iconicity, but none of this affects their ability to perform the functions of writing. We need to look elsewhere for an explanation of our findings in experiments one and two which showed that visual languages require a script organized like the IMA and unlike SN. One candidate is the relative importance of linearity. IMA differs from SN and other scripts in not arranging its individual glyphs in linear order. Since the phonologic structures of visual and aural languages also differ in the relative importance of linearity, this factor might account for the difference in legibility found in experiment one.

8.3 Ordering conventions. Both IMA and SN are antalphabets with many glyphs making up one syllabic character, however the ways the two scripts arrange the individual glyphs follow totally different principles. SN retains the tradition of writing systems for spoken language by arranging its symbols in linear order. As an ORDERING CONVENTION it uses a template that consists of a linear grid with a number of empty cells, each to be filled with a particular kind of symbol. In its simplest form the template has three cells. Going from left to right the first is filled by a location, the second by a handshape, and the third by a movement symbol.

Figure 11. Ordering conventions

a) Linear template b) Spatial mapping



If palm orientation is included as a parameter, the first and second cells split, with the resulting new cells filled by subscripts for orientation. Somewhat confusingly the number of filled cells is not consistent, ranging from two in , 'west', to six in , 'math'.

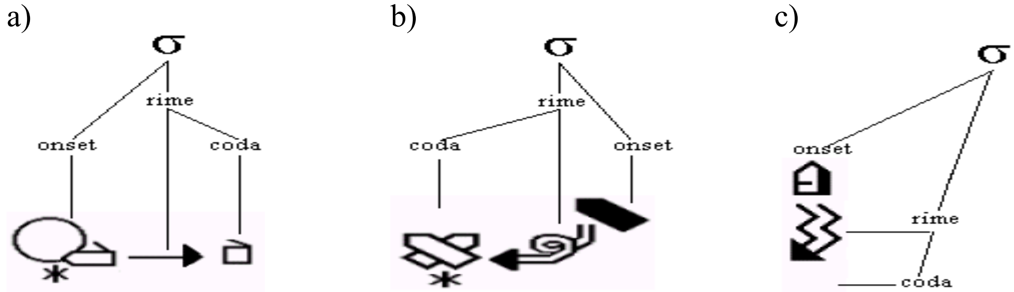
At the syllable level the IMA uses the same ordering convention as any script, with each syllabic character following another. However for the sun-syllabic level it uses a completely different ordering convention, that of SPATIAL MAPPING. This is natural for signed languages where the movements of the articulators are already visible images. To represent a visual image on paper one simply draws a picture of it. Or a map. We use the term mapping in the mathematical sense of correspondence between two coordinate structures, one including points in space occupied by the marks on paper and the other including points in space occupied by the articulators. Since one cannot map the articulators unless they hold still, the array of features that make up the map image capture the articulators at a given instant in time, yielding an instantaneous snapshot of the language stream.

When conversing in ASL one perceives language segments with all their phonetic detail and phonologic organization, as visual images. The script records those visual images and leaves it to the reader to analyze their significance just the same as they do when seeing actual signing. Unlike linking the Chinese character 五 to [labiovelar glide followed by rounded high back vowel with dipping tone], or [*wǔ*], 'five', it is easy to see the ASL word for five, , in the IMA character . The spatially mapped character is a schematic diagram of the sign in that it omits visual details that lack phonologic value (hair, jewelry, non-contrastive details of handshape or location…), but retains those features with phonologic value (bent/extended finger, +/– raised eyebrows…)

Every sign obligatorily includes movement, whose glyph in the IMA generally is some kind of arrow. The movements these arrows represent have beginning and end points in space as well as in time. This gives a temporal dimension to the entire character, which is read from the beginning to the end of its movement arrow. The bundle of glyphs that compose the beginning segment of the sign is located at the beginning of the arrow. The glyphs located at the beginning of the arrow show the initial posture of the articulators and those at the end show the final posture. If an articulator shows no change between initial and final states, its feature glyphs may be written at both ends of the arrow, although this is usually omitted as being redundant as in figure12c.

Figure 12. IMA characters showing ASL syllables.

a) b) c)



a) ‘Better’ b) ‘All’ c) ‘Brazil’

The reading direction within each individual character may be completely different, but the arrow convention tells the order in which to read the glyphs. It segments each IMA syllabic character into a beginning, middle and end, corresponding to the parts of the syllable, the onset, rime, and coda.[15] This meets Postal's requirement that a script be a discrete*, segmented*, correct phonetic representation.

To summarize, visual languages with their multitudinous simultaneous contrasts require a featural antalphabet. The two such scripts under investigation use entirely different ordering conventions at the sub-syllabic level: SN retains the linear ordering of spoken language scripts, whereas IMA uses a completely different spatial ordering convention. Since the latter seems to be quite readable, it is possible that Stokoe Notation's poor legibility results from use of an inappropriate ordering convention. Testing this hypothesis will be our next experiment.

9. Experiment three: Scripts. If the linear ordering used for speech is inapplicable to transcribing visual language, this would offer an explanation for the inconsistent success of the various transcription systems for these languages. By arranging the glyphs of each script according to the ordering convention of the other script, it is possible to isolate the effects of the ordering conventions. The reasoning is that if linearity is the source of problems with reading SN, the problems should correlate with the ordering conventions rather than the symbols of the scripts.

9.1 Method. To determine the effects of linearity, this experiment switches the ordering conventions between the two scripts. Keeping the symbols and other conventions of the IMA otherwise unchanged, they were arranged according to the linear template of SN,

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[15] The analysis shown here was chosen to highlight similarities rather than for strict accuracy. Visual syllable structure remains an area of active research, and a general treatment reconciling the PMP analysis of sign and the segmental analysis of speech, if one exists, must refer to autosegments and feature geometry. For a discussion see Brentari 2002.

and conversely, the symbols of SN were arranged according to the spatial mapping of IMA. The normal arrangements of the two scripts provided controls. The prediction was that amongst writing systems for visual language, less legibility would result from use of a linear, compared to spatial, ordering convention. Experiment three poses as a research question the null hypothesis that the choice between linear or spatial arrangement of the glyphs has no effect on the script's readability.

9.1.1 Participants. Participants were selected based on the following criteria: a) fluent signers of ASL; b) literate in both reading and writing the IMA. c) at least a working familiarity with Stokoe Notation.[16] Seven subjects, four female and three male, agreed to participate. All were adult hearing bilinguals with English L1 and fluent although non-native signers of ASL. Of the seven, two were students currently enrolled in graduate linguistics programs who had worked with the scripts over the past two to three years. Other participants were all researchers and/or teachers whose experience with the two scripts spans periods of six years to nearly two decades. Four were teachers who regularly used the IMA in classes. Four were researchers who use the IMA, SN, or both in the normal course of their work.

9.1.2 Design. The goal was to measure legibility as a function of script organization. Samples of each script were manipulated by changing the sublexical arrangement of the glyphs to reflect one of two script conditions. In the linear condition the glyphs were arranged using the linear template of SN and other such scripts. This is the normal

[16] We accept as unavoidable at this point in history that all participants were more familiar with the IMA than with SN, due to the diverging trends in popularity.

condition for SN. In the spatial condition the glyphs were arranged using spatial mapping as their ordering convention. This is the normal arrangement used by the IMA. The procedure yields four script conditions in total. To isolate the effects of ordering, the same glyphic units of each script were used with no other changes. Participants read sentences of ASL transcribed in each script condition. Their task was to reproduce the sentences as quickly as possible by physically signing them. The unit of measure was reading speed. To avoid comprehension presenting a confound, only common words familiar to the participants were used. Complex inflections and signs judged difficult to read were avoided, with nearly all signs taken from the dictionary in their citation form. Reading times were recorded and used as indications of relative difficulty, according to standard practice in psycholinguistic research.

9.1.3 Tools. Participants were presented with stimuli consisting of written sentences of ASL presented in four different script conditions:

a) linear SN, in its normal form
b) spatial IMA, in its normal form
c) spatial SN, with glyphs rearranged to fit a template
d) linear IMA, with glyphs rearranged to fit a template

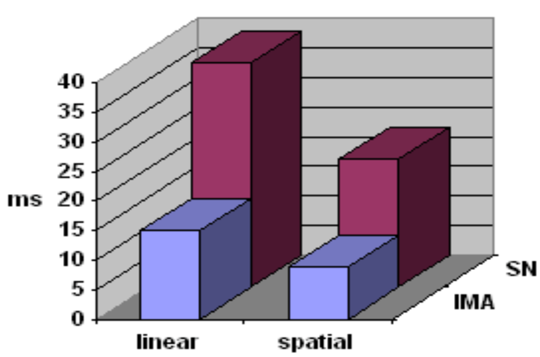
In each of the four script conditions there were six sentences, 24 sentences in all, with an average length of 4.6 ASL signs. All were unique sentences, not duplicating the wording of any other. All were of comparable grammatical complexity. ASL is rife with phenomena that have no counterpart in either signed or spoken English, including classifier constructions, incorporation, overt topicalization, and spatial anaphora. Although the IMA allows one to write these constructions, the original form of SN used here is mostly incapable of doing so. Therefore, in the interests of comparability none of the stimulus sentences included such constructions. Each sentence consisted of a simple clause without embedding. This may not be apparent from the English translations, which may require complex constructions to express the same content as the original sentences that are written entirely in ASL. The test sentences are shown with glosses and translations as Appendix D.

All the 24 stimulus sentences were arranged in random order with the same script conditions following each other no more than twice. To control for effects of familiarity, the same sentences were presented in the same order to each participant. Since standard spellings have yet to evolve with either script, characters are written as given in dictionary entries. SN characters were copied from Stokoe's Dictionary of American Sign Language, and IMA characters from Sutton's American Sign Language Dictionary.

9.1.4 Procedure. The test sentences were entered into slides in the form of a slideshow in a standard format with which all the participants were familiar. The participants did not see the slides until the actual trial. For the trial the participant sat facing the computer screen at a distance comfortable for signing. A video camera faced the participant in such a way as to record his or her signing and was left to run continuously throughout the experiment. An assistant sat to one side controlling the slides. Timing began when a new slide appeared on the screen. The participant then read the sentence and physically signed it while reading it. If unable to read a given passage, they stated that they were giving up on that sentence. The assistant allowed a short pause and then presented the next slide. The same procedure was repeated through all twenty-four sentences. Each sentence was shown only once. The reader and assistant ran through the slides once, and at the end of the trial the camcorder was shut down, and the video record retrieved for data analysis. Reading times were computed from an onscreen running record of time elapsed. Timing started with the first frame and ended when the participant finished signing the sentence. As with any discourse, an ASL sentence ends with clearly perceptible signals marking the end of a conversational turn. The video frame that includes this indication of finality marks the end of the elapsed reading time.

9.2 Results. Experiment three refutes the null hypothesis that the choice between linear or spatial arrangement of the glyphs has no effect on the script's readability. Linear ordering resulted in slower reading times in all cases and for all participants. Average reading times for the two ordering conventions were: for SN, linear 38 seconds versus spatial 22; for IMA, linear 15 seconds versus spatial 9. Average times for each of the four conditions, in seconds, averaged out over all sentences and all readers, were as shown in figure 13.

Figure 13. Experiment Three: Effect of Ordering Conventions on Reading Times



Reading Times, in seconds				
	IMA		SN	
Reader	Spatial	Linear	Spatial	Linear
A	3.26	6.68	6.99	17.31
B	5.23	14.98	29.19	39.35
C	22.08	26.43	36.56	51.46
D	5.25	***13.58***	***9.81***	22.63
E	5.12	***9.82***	***7.44***	24.85
F	11.26	21.24	37.06	39.20
G	8.91	12.69	24.39	70.90
Avg	**8.73**	**15.06**	**37.95**	**37.95**

For the two scripts in their normal conditions IMA was much faster than SN, confirming reports that IMA is easier to read. All readers found spatial ordering easier than linear for both scripts. Most (5 out of 7 or 71%) exhibited a clear continuum of reading speed, from fastest to slowest: spatial IMA > linear IMA > spatial SN > linear SN. All readers read normal IMA fastest and SN slowest. However things were less clear for the middle two arrangements, the manipulated conditions, as two of the seven readers showed faster times for spatialized SN than for linear IMA.

Mistakes were quite rare in any of the four conditions, indicating that we were successful in eliminating variable comprehension as a confounding factor. In three instances readers produced a sign that differed in one phonological feature, as when one reader produced ASL *'nice'* for *'new'*, by misreading the direction of the movement arrow. All these errors were with SN, two with linear, and one with spatial, ordering. Readers typically gave up if unable to decipher the sentence for much more than a minute. This occurred twice with normal linear SN, and twice with spatial SN: three of these four were the same reader. Another reader gave up on one sentence in linear IMA, but no one did so with IMA in its normal spatial condition. These findings confirm the hypothesis that the ordering convention of the script affects legibility, and quantify impressions that SN is harder to read than IMA.

For either script linear order hinders readability. Within the same linear ordering, the iconic IMA glyphs are a little more than twice as easy to read as the less iconic SN, at 38 vs. 15 seconds average reading time. Using spatial mapping for both scripts, the IMA characters are over four times easier to read, at 38 seconds vs. 9 seconds average reading times. With SN, which was designed to use the linear template, getting rid of it improves legibility 37%. Imposing a linear template on the IMA, which was not designed for it, nearly doubles reading times.

It seems safe to conclude that a linear template ordering convention is not compatible with the phonological structure of ASL, and by extension other signed languages. Any language needs a script compatible with its phonology, and processing difficulties seem to arise when a script such as SN imposes a linear organization appropriate for speech onto the more simultaneously organized phonological structure of sign. This provides an explanation for the success of spatially organized IMA as a script, and why the linearly ordered Stokoe Notation and others like it have met success only as specialized notations for scientific purposes.

10. Discussion. The foregoing interprets the results of experiment three as following from general principles governing human language and literacy independent of medium. An alternative view, following the Saussurean model of language, might interpret the results as a modality effect stemming from a fundamental difference between spoken and signed languages, the former being linear and the latter simultaneous in organization. On this view it would be unsurprising to find different strategies required for graphically encoding radically different structures, one linear and one not.

However the Saussurean model can neither explain the results of experiment three nor even provide an adequate framework for the discussion. Aside from its failure to assimilate visual languages, it says nothing about antalphabetic scripts, fails to distinguish speech from phonology, and clings to an outdated model of the alphabet as a standard against which to judge other writing systems. The model rests upon several assumptions that need to be updated in light of more recent findings from modern instruments and research. Four of these assumptions are: the linguistic sign is linear; writing makes language visible; writing depends on the alphabetic principle; and reading reproduces inner speech. The next four sections address each of these points in turn.

10.1 The linear sign. The notion that aural and visual languages are fundamentally different in organization owes much to the linguistics of de Saussure, for whom linearity was the second fundamental principle. For him, the linguistic signal 'is measured in just one dimension: it is a line' (Saussure 1983:103), and 'the whole mechanism of linguistic structure depends upon…the linear character of the signal' (Saussure1983:103). This traditional view treated the continuous language stream as segments that were independent units strung together like beads on a string. Today, however we know that 'this is a profound error: the writing is linear but that which it represents is not' (Herrero & Alfaro 1999:94). Written glyphs typically follow each other in a linear order that is said to reflect the linear nature of the segments of speech. This is only a metaphor, however, as there is nothing linear about compression and rarefaction of air molecules in a sound wave. The 'notion that in speaking we select the individual consonants and vowels which somehow emerge from our mouths threaded in the right order like beads on a string' (Harris 1986:41) was disproved upon the invention of modern electronic measuring instruments. When researchers in the 1940s attempted the first electronic synthesis of speech by stringing recorded phonemes together in correct orders, 'their machine produced only an unintelligible jumble' (Whitney 1998:149) because there is no acoustically identifiable segmentation into individual speech sounds. There aren't any beads. Laboratory 'phonetics has shown the stream of speech not to be segmentable into units corresponding to letters—that is, into phonemes' (Daniels 1996:12).

What actually occurs is speech are overlapping actions by multiple articulators moving in parallel, and neither the movements nor the acoustic patterns they create are linear. The sound waves of speech consist of simultaneous vibrations at many different frequencies with measurable differences in amplitude at each frequency. Like chords on a piano, areas of high amplitude, called formants, occur simultaneously with other frequencies at lower amplitudes, and all together these create the complex wave form that makes up a single speech sound[17]. High amplitudes at 800, 1000, and 2500 Hertz we identify as the vowel /a/, which contrasts with the vowel /u/, consisting of high amplitudes at 300, 900, and 2500 Hertz (Borden et al 1994:111).

These acoustic phenomena all have articulatory origins. For the English /u/ five separate muscles act to close the vocal folds and create a periodic waveform, the styloglossus muscle pulls the tongue body back and up to create the lower formants, and the lips round to lower the second formant (F_2). In contrast, relaxed lip muscles, closed vocal chords, and a tongue body held in a lower position results in the speech sound /a/ (Borden et al 1994:ch 5). When the tongue body rises up, the pharyngeal resonance cavity changes shape and shifts the lower formants from the 300 and 900 Hz combination characteristic of /a/, to the 800 and 1000 Hz combination characteristic of /u/. However, all the while this is happening the upper resonance chamber in the mouth remains unchanged, leaving unaffected the third formant (F_3) at 2500 Hz that both these sounds share (Borden et al 1994:108). Additionally, the vocal folds remain in the closed

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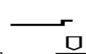
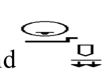
[17] The examples given are representative rather than definitive. No one-to-one relationship exists between acoustics and articulation, and the whole subject is so complex as to render any simple description inaccurate. For detailed description see any textbook on phonetics.

position, and for unrounded vowels like those in Korean the lips remain unchanged. The important point is that even though some features change, most remain the same, so the patterns bear no resemblance to beads on a string.

Whether described in acoustic or articulatory terms, any single speech sound is a combination of many simultaneous events, and the same is true of the segments of visual language. Tongue shape is a combination of three mostly independent positions of the tip, blade, and root of the tongue, each formed by many muscles acting simultaneously. Hand shape is a combination of five separate events caused by many different muscles acting on each joint of the finger or thumb. The resulting hand shape, or tongue shape, combines simultaneously with actions of other articulators, including for ASL the brows and the tilt of the shoulders. Sign and speech both make use of the lips and the tongue. [18]

Cross-linguistically, we can describe any utterance as co-occurring movements of language-specific articulators. By its movement each individual articulator assumes a series of positions, and an utterance is a combination of many such sequences occurring simultaneously. We can describe this combination of simultaneous and sequential positions as an ARRAY in the mathematical sense of data arranged into rows and columns. The two dimensions of the array are co-occurrence and succession. Articulatory positions that co-occur simultaneously form the vertical columns, and positions that succeed one another sequentially form horizontal rows. Rather than being linear only, the linguistic sign is an array of simultaneous and sequential articulatory positions. Writing may well

[18] For example the difference between the ASL signs  'late' and  'not yet' lies solely in the presence of an extended tongue in the latter.

be linear, but the common misperception that this reflects some fundamental principle of language puts the cart before the horse.

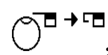
10.2 Making language visible. In the Saussurean model "a script is only a device for making examples of a language visible' (Sampson 1985:21). However, signing makes language visible without the use of writing at all, and writing a natural sign language like ASL certainly accomplishes something other than making the language visible, since it was visible to begin with.

The multimedia model takes the primary function of writing to be that of making language static or relatively permanent so that it can be recovered at a later time, following Daniel's definition of writing as 'a system of visible marks used to represent an utterance in such a way that it can be recovered more or less exactly without the intervention of the utterer' (Daniels 1996:3).[19]

An utterance is easily given permanence by recording it on tape, however recordings include far more information than is necessary. The same is true of scientific notations that faithfully record every phonetic detail but are virtually unreadable. Examples are Jesperson's writing of the [n] sound, α,,β0fλ,,δ2εIζ3, or the Hamnosys version of *Goldilocks*, . Unlike these notations, a workable script is an analysis that sorts the essential from the superfluous, and records only enough phonological detail to recover the message while omitting the rest (Pizzuto & Pietralandea 2001:30). The earliest versions of IMA

[19] Modern technology enables one to animate the written symbols of the IMA. Whatever this unique new form of graphic art may be, I would not call it writing. You can see examples at http://www.movementwriting.org/animation/sgn-DE/ .

resembled stick figures, but experience has shown this to be too much detail, and today a single line for example adequately represents the shoulders. The goal of a script for visual language is not to transfer three-dimensional language onto two-dimensional paper by showing all the articulatory movements. The exact acoustic or optical patterns are not what a script must make permanent. What matters is the phonological organization in the linguistic array.

Specifically a script must record phonological contrasts. The tongue body is higher or lower for every person, and acoustically one person's /o/ could be virtually identical to another person's /a/. What remains consistent is that with each person their /a/ position is lower than their /o/ position. The important fact to record is the feature [+/– low] for the tongue shape. Similarly in the sign , we can actually see an infinite number of finger positions between totally straight and a 90° bend, but we interpret it as either bent or not, the phonological feature [+ / – straight]. Accordingly the script must record not articulatory movements, but an array of phonological contrasts. Each language selects certain articulators and in which positions they contrast, and distinguishes different words by differences within the array.

The constant movement of the articulators creates sequential, or linear, contrasts, as when the lips close and then open in *bad*, or the palm changes location from left to right in . This observation underlies Saussure's model of linear beads on a string, but it chooses to ignore the equally valid observation that one cannot have sequential contrasts without also having simultaneous contrasts.

The word *uh* is a different word from *ey* because of a simultaneous contrast. The positions of the lips, velum, vocal folds, and other English articulators co-occur with a [+

front] versus [– front] position of the tongue body. We say the word *they* [ðe] differs from *the* [ðʌ] in having a sequential contrast, meaning the second vertical column of the phonological array differs from the first column. However what makes them different words is precisely the simultaneous contrast [+/– front] of *ey* and *uh* in the second column. What's more, the tongue body does not wait till the second segment before assuming the vowel position, it occurs simultaneously with the tongue tip actions that create the [ð] in the first column. This gives the array an entire row with the same value for the feature [+/– front] for the tongue, a simultaneous contrast that persists continuously throughout the word and distinguishes between *they* and *the*. Throughout the ASL sign  'things', the palm orientation [+up] co-occurs with other features to distinguish it from  'children', where the palm orientation, is [– up] throughout the sign. A lowered velum co-occurs with other features throughout the English word *man* to distinguish it from the word *bad*. The resulting feature, [+ nasal] in traditional acoustic terms, is the only difference that distinguishes these two words.

Figure 14. Feature array for English *man* and *bad*

	b	**a**	**d**		**m**	**a**	**n**
Lips closed……………	+	–	–	……	+	–	–
Tongue tip up…………	–	–	+	……	–	–	+
Tongue blade low……	+			……	+		
Tongue root back……	+			……	+		
Vocal folds closed……	+			……	+		
Velum…………………	**raised**			……	**lowered**		
[nasal]	–				+		

These examples show differences along the dimension of simultaneous co-occurence. Whether to describe the *man/bad* distinction as a [+ / - nasal] difference in one row, or as differences in several vertical columns is merely a theoretical choice. The task for a writing system is to encode the phonological array, in both its simultaneous and sequential dimensions, so that it can be reconstructed later by the reader. A script is not ‘a device for making examples of a language visible’; it is a device for extracting the phonological structure of language and making it permanent.

10.3 The alphabetic principle. The Saussurean model takes as ‘its central paradigm example of a writing system’ (Harris 1986:37) an idealized alphabet in which ‘each sound unit is represented by one symbol, and conversely each symbol invariably corresponds to a single sound’ (Saussure 1983:64).

Things are not that simple in the real world. Instead of only 26 sound-symbol correspondences, for example, English spelling uses over 7000 (Underwood & Batt 1996:77). It is difficult to see how a 1 sound-1 symbol correspondence could be possible anyway, because the alphabetic principle ‘enshrines a fundamental misconception about the nature of sound. There is no question of using a separate symbol for each sound because sounds are not discrete segmental units’ (Harris 1986:114).

The alphabet is not any ultimate system that should be used as a yardstick for measuring other scripts. Referring to other writing systems with such terms as *consonantal alphabet* or *semi-syllabary* (Crystal 1987:120), or even to say that a syllabic character corresponds to a consonant-vowel pair, frames all writing in terms of alphabets and ‘makes it extremely difficult to resist the implication that’ other writing systems are mere imperfect alphabets (Harris 1986:ch2), when in fact the ‘half dozen fundamentally different types of writing systems' used throughout the world (Daniels 1996:4) are equally workable solutions to the problem of making language permanent.

Finally, framing things in terms of a sound-symbol link disallows any possibility of writing soundless languages like ASL or Shuwa. A more useful approach is Perfetti's Universal Phonological Principle, which 'states that encounters with printed words activate multiple levels of phonology in all writing systems, which control only the details of activation' (Perfetti 1998:16). The writing system consists of glyphs, plus mapping rules to link the glyphs to language units (Perfetti 2003:4). The language units are arrays of movements, with the two dimensions of simultaneous co-occurance and temporal sequencing. The mapping rules link these to a writing surface that also has essentially two dimensions.

The first mapping task is to encode the temporal dimension of time onto the spatial dimensions of a durable surface. The only way humans seem able to think about time is by using the metaphor [TIME AS SPACE] (Langacker 2000). We assign temporal events to a dimension of 3D space and imagine it as a line, illustrated nicely by the so-called timeline signed languages use to locate the future in front of the signer and the past behind. Users of a script agree to assign this timeline to some spatial dimension on a writing surface. English readers assign it to the horizontal dimension, left to right. Arabic readers view time as right to left, Chinese and ASL often put it top to bottom. Boustrophedon writing reversed directions with each line, and the popular game Boggle® allows the timeline to go in any direction at all.

Once the temporal dimension has been encoded, the writing must map the continuous and overlapping movements of the linguistic array onto the timeline.

Fortunately there are syllables. 'Sound in all spoken languages consists of an alternation between louder and quieter levels of sound, with a period not far from 150-200ms' (Mairal & Gil 2006:92). In a signed language such as ASL, syllables parallel those of spoken language in terms of perception, acquisition, morphophonology and grammar (Brentari 2002: 49). In sign or speech the syllable is the basic perceptual unit in language, the smallest segment we are physically capable of perceiving (van der Hulst 2000:237), and awareness of syllables and even their onsets and rimes emerges as a natural consequence of language acquisition (Goswami 2006:492). Developmentally too, a child's first attempts at writing often assign one letter to each syllable, as the Italian child who guessed <ICAO> for *elefante* (Rego 1999:73).

This makes it natural that writing originated independently in three places on earth, Mesopotamia, China, and Mesoamerica, where languages feature simple CV syllables (Daniels & Bright 1996:585). Cherokee also has this structure, and demonstrates how surprisingly easy it is to learn syllable-based writing. After the tribe accepted Sequoia's syllabary, essentially the entire Cherokee Nation became literate within a matter of months, without the benefit of schools, teachers or textbooks (Bender 2002: 25). The same thing happened in Canada with the Cree Syllabary. These scripts do not require the special metalinguistic knowledge demanded by scripts based on other units. One simply assigns a written symbol to what one hears, the way the alphabetic principle is supposed to work. It may be significant that IMA characters mainly represent syllables, and that most users are self-taught.

Syllabries are an option for languages in which the speech stream can be analyzed as a limited number of movements in the manner of martial arts forms or dance steps. In those cases the movements can be assigned names, like Brush Knee or Play Lute, or with writing systems, names like タ or た or *ta*. Mapping these into their proper order on the timeline encodes the sequential contrasts of the phonological array.

Which name or symbol is on the timeline at any point records the simultaneous dimension. This avoids the fact that syllables are complicated actions involving many articulators. If there were just one articulator making one movement, it could be encoded with a string of ones and zeros as with a computer. Four articulators, each with four movements, would need 256 name-symbols. As the syllabic array gets more complex, there are soon too many symbols to be practical. Writing systems solve this problem by dividing the syllable up into parts.

The parts that make up a syllable are individual movements of each single articulator, including the tongue body, tongue tip, lips, vocal folds, etc. These all have particular contributions to the acoustic image they produce, but not all of them are equal. Whether in speech or sign, a phonologic unit contains two qualitatively different components. There is a portion that creates the maximum disturbance of the medium and is thus highly perceptible, or sonorant, and acts as a sort of carrier wave, and other less perceptible portions that effectively modulate the carrier portion. The primary component acts as the nucleus of the syllable, the secondary component contributes most of the phonological contrasts.

In speech the primary components are vowels. The only articulator moving is the diaphragm, rising and pushing air out and creating a speech wave whose acoustic image is shaped by the configuration of the vocal tract. The wave is created by pushing air through two resonance chambers, in the pharynx and the oral cavity, whose shapes depend on the position of the tongue. The tongue root adjusts the size of the pharyngeal cavity and the position of the tongue body adjusts the oral cavity. Their combined actions create a specific tongue shape that determines the shape of the resonance chambers, and produces a specific acoustic pattern consisting primarily of the first and second formants (F_1 and F_2) that we hear as vowels. Secondary movements of other articulators create consonants as further restrictions in the air flow through the two vocalic resonance chambers. These superimpose their own acoustic signatures onto the basic speech stream. Movement of the tongue tip for example affects mostly the third formant (F_3).

It is not possible to attribute a single speech sound to any single articulator. 'Research into these relationships has led to general agreement that the frequencies of formants cannot be attributed solely to a particular resonating cavity within the vocal tract' (Borden et al 1994:106), however general correlations can be made. An especially strong correlation exists between the position of the tongue body and the first and second formants that define vowels. 'Speech scientists have found it impossible to ignore the well-established correlations' between tongue shape and the first two formants (Borden et al 1994:107). Creators of writing systems have also found this impossible to ignore, and have incorporated into virtually every script a distinction between vowels and consonants.

For visual language, the primary, highly perceptible component is the optical image created by path movement of the hand. The moving articulator is the hand, creating a perceivable optical image that is customized by the configuration of the individual fingers and thumb. Secondary movement such as finger bending co-occurs with and modulates the resulting mobile image.

For both media, the primary components of syllables are high on a sonority scale, most easily perceivable, act as a carrier wave, form the nucleus of the syllable, may occur alone, and consist of only one moving articulator—the diaphragm for speech, the hand for sign. Secondary components are less sonorant, less perceptible, modulate the carrier wave, form syllable margins, co-occur with the primary component, do not occur on their own, and provide most of the phonological contrast of the language (Brentari 2002).

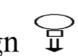
While all scripts for spoken language recognize these facts and distinguish between consonants and vowels, the same is not true of proposed scripts for visual languages. SN and other linguistically based writing systems proposed for sign do not distinguish between path and secondary movement, in fact treat any movement as only one of several parameters, including location and hand shape, that all act equally in defining the sign. Only the IMA singles out path movement for special treatment.

Viewing writing systems as linguistic analysis, the IMA anticipates much later work[20] in phonology. It has much in common with the Movement-Hold model (Liddell and Johnson 1989) and the Hand Tier model (Sandler 1989) of sign phonology. These usefully describe the language stream as a series of movements (M) and postures (P), in the manner of a Tai Chi form or dance routine. Postures are imaginary snapshots that include all the positions of all the articulators at a given instant: Movements are

[20] From its inception in the 1970's this script has recognized many aspects of signing that were only later discovered by scientists studying signed languages: sequentiality within the sign, orientation as a separate parameter, the importance of facial expression, internal syllable structure, separate path and secondary movement, and the former as syllabic nuclei. Some of these insights were not rediscovered by phonologists for some twenty years.

obligatory transitions from one posture to the next. One cannot perform only part of a posture. Like the Tai Chi player whose legs must be in some stance while punching, one cannot move the tongue tip without holding the tongue body in some position. A new posture is formed whenever one or more articulators move from one to another phonologically relevant position, i.e. make a change that affects meaning.

The IMA uses a separate set of symbols for path movement, and gives them a special role in the written character. Analogously to the way other scripts treat spoken vowels, the IMA glyphs for path movement locate the nucleus of the written syllable. Mapping these movements and postures onto the timeline records the sequential contrasts of the phonological array, and the parts of the syllable.

These models of phonology, in common with the IMA, treat the basic syllable as a PMP sequence. Simple CV syllables generally consist of one movement, and IMA characters typically include a single path movement. In the monosyllabic sign  ‘old’, the initial posture has the clenched fist in contact with the chin: the movement is downward: the final posture has the fist lower but is otherwise identical to the initial posture. In the spoken monosyllable /ta/ the initial posture has the tongue tip in contact with the roof of the mouth, tongue body low and back: the movement is downward: the final posture has the tongue tip lower but is otherwise identical to the initial posture. The analysis works for either medium.

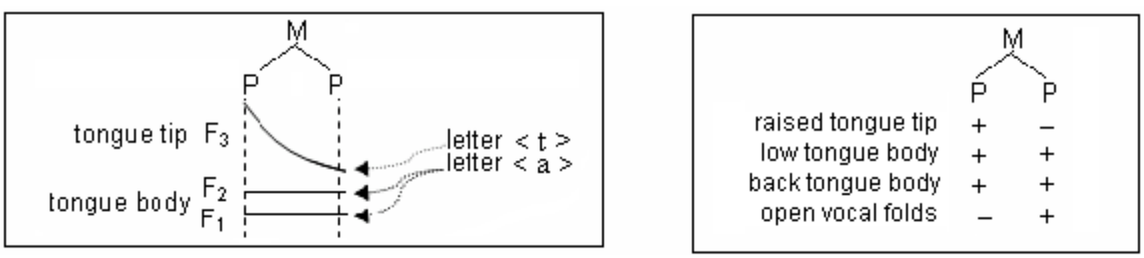
Scripts that map onto units smaller than the entire syllable use a part-to-part mapping. They not only separate certain articulators out of the syllabic structure, they divide the glyph itself into multiple parts. The two Ethiopic letters ሙ, [mū] and ማ, [mā] illustrate how this script divides its glyphs into a major and minor component. The minor part, in this example the little extension on the right, represents the shape of the tongue body, i.e. the vowel, while the major component, resembling the Roman M, encodes the rest of the syllable. The Cree syllabary cleverly lets the shape of the symbols represent consonants, and treats the glyphs's orientation as the separate component that indicates vowels. The glyphs ∨, ∧, >, and < respectively encode [*pe, pi, po, pa*] in Cree. Other options are to ignore the vowels altogether, or to separate the minor part from the rest of the glyph. Arabic and Hebrew are examples of both these latter strategies. The basic alphabets map consonants onto the timeline from right to left, omitting the vowels, that is without mentioning tongue shape. If such is desired, there is an option of adding smaller marks that represent vowels/tongue shapes at the appropriate points along the timeline, effectively adding a second tier to the phonological array as Chinese does with tones.

Such part to part mappings are ubiquitous in the writing systems of the world, with diacritics marking not only tongue shape and Chinese tones, but also Japanese voicing, which shows the position of the vocal folds, and any number of other distinctions. These include umlaut in German, rhotics in Hindi, reduplication in Thai, and all these and more in IPA phonetic transcriptions. Since all these use more than one symbol to represent a single language segment, they do not quite fit the one symbol-one sound mapping prescribed for an alphabet, so by a strict definition these could perhaps all be called antalphabetic. A full antalphabet carries this trend to its logical conclusion by assigning each individual articulator its own symbol. The IMA falls only a little short of this. The square block that symbolizes a closed fist hand shape for example, conflates all the ten [+/– bent] features for each joint of the hand into one glyph, instead of using a separate line for each finger as the script sometimes does.

Supposedly an alphabet is an exception to this part to part mapping, having one glyph for each sound. That would be the case if Cs and Vs actually did occur in sequence rather than being co-articulated, but 'the concept of a [t] followed by an [a] is, strictly speaking, erroneous' (MacMahon 1996:842). The syllable that Japanese writes as タ and English as < *ta* > uses two mostly independent articulators, the tongue tip and the tongue body. The tip of the tongue moves away from contact with the roof of the mouth at the same time that the body of the tongue is held low and back in the throat. The resonance chamber created by the low-back tongue shape produces the F_1 and F_2 of the vowel /a/, while the lowering tongue tip generates a steadily falling F_3.

Figure 15. The syllable タ, or /ta/…

a) …as articulatory movements, b) …as feature array.



Written out in alphabetic script, the letter < *t* > represents the movement of the tongue tip while the letter < *a* > captures the shape of the tongue body. This is not a /t/ segment followed by an /a/ segment even though the alphabetic principle treats it as such. The /t/ is technically a stop, defined as complete interruption of the airflow, whose acoustic signature is silence and can't be heard. What we actually hear is the changing F_3

caused by the moving tongue tip, which can't exist by itself without a tongue body in some position, in this case producing the formants of the vowel /a/ at the same time as the falling F_3 of the /t/. The English < *t* > encodes the tip movement (and also informs about the state of the vocal chords—it is not a *d*) but leaves underspecified the features for the tongue body. The reader has to hold the tip movement in memory and get the position of the tongue body from the next letter.

Alphabets use one symbol for only some features, and leave the rest unspecified. The [t] made with the [a] tongue shape is different from the [t] made with the [i] tongue shape, and the alphabetic < t > encodes the tongue tip gesture made with any one of the {a, e, i, o, u, æ, ə, ε, α …} tongue shapes. Worse yet, the alphabet writes the same letter for initial and final /t/ even though these are actually mirror images of each other. The movements are opposite, and postures exactly contradictory: in one the tongue starts low and moves up to contact the palate, in the other it starts up in contact with the palate and moves down. Both in articulatory terms and acoustically these are perceivably opposites, yet the alphabet manages to treat them as if they are the same thing. One cannot help but be amazed at the ingenuity of this analysis, and it is no wonder it took thousands of years to invent it.

Unlike learning a syllabary, learning an alphabetic script is difficult, and is nearly impossible without explicit instruction (Bryne 1998). The segments it encodes are only imaginary or theoretical, not real as are syllables, and it requires complicated rules to reassemble them. Also, alphabets do not keep the temporal and simultaneous dimensions separate by assigning them to horizontal and vertical dimensions respectively, and such mixing of dimensions is always hard to read. One method for writing Chinese tones affixes numbers to the end of the syllable, as in *bu4 hao3.* Although Chinese speakers are forced to use it in email, the method has been mostly abandoned. What has become customary after much trial and error is the use of superscripted tone marks, as in *bù hăo.* Soviet experiments with the Korean alphabet provide another historical instance of this phenomenon. Instead of grouping the letters into square blocks separated by spaces, with each square block representing a syllable, as in 안 녕 하 십 니 까 , they tried writing out the letters in linear order, as 아ㄴ ㄴㅕㅇ ㅡ아 ㅅㅣㅂ ㄴㅣ ㄲㅏ . This was found to be impractical (King 1997:219-261), with the linear version 2½ times slower to read (Chin 1997:151). All these phenomena are consistent with the results of our experiment three.

The alphabetic principle itself is a blatant oversimplification, and an alphabet is only one of several methods to map glyphs onto phonological arrays. A continuum exists with *1 glyph—1 syllable* at one end and *1 glyph—1 feature* at the other. Our alphabet is near the former and the IMA is near the latter.

10.4 Inner speech. The Saussurean model defines reading as ‘the translation of visual images on a page into a speech-based code in order to access a stored vocabulary of sound-meaning units’ (Underwood & Batt 1996:12). The traditional view sees the reading process as using Grapheme-Phoneme Correspondence (GPC) rules to transform graphemes into the linear string of phonemes which is inner speech. This is matched with linear strings of phonemes stored in the lexicon as words. This description of the reading process in terms of letter-sound correspondences is inadequate for either syllabaries or antalphabets, which do not have letters. It also makes an assumption that the reading process crucially depends on sound, obviously not true in the case of reading

ASL. Its unquestioned reliance on speech and sound precludes any attempt to investigate reading any signed language.

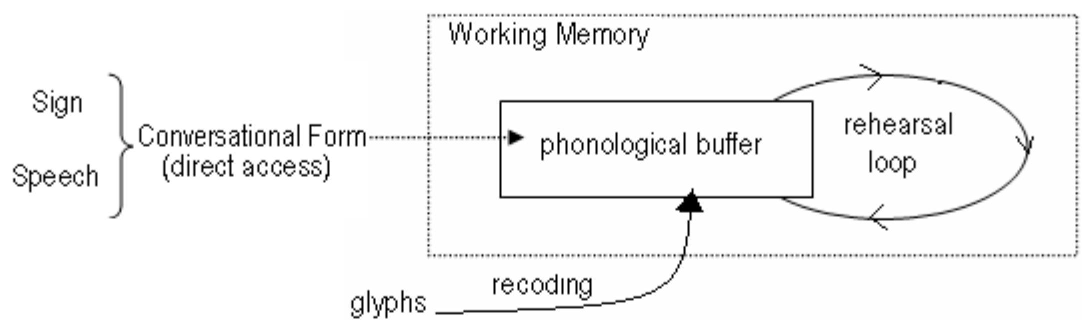
In the multimedia view the reading process recodes glyphs of any sort into articulatory movements, and reconstructs the phonological array that makes up syllables of the language stream. A reader may create inner speech or inner sign, but in every case she creates and processes inner phonology—phonologically patterned mental representations that can be encryptions of either optical or acoustic patterns. Unlike the traditional model which is specific to spoken language, the multimedia model describes the reading process in articulatory terms, and can be generalized to all language. On this view, there is no reason to assume that well-established phenomena connected with literacy can not also apply in other media, so that reading could use the same resources and processes for visual languages as for aural languages. This reflects the new data and new realities in regard to visible language and inner speech, the linear sign and the alphabetic principle. It allows us to proceed with our current investigation by building on the existing body of scientific knowledge, and superficial though quite obvious differences in form can be seen to follow from general principles governing human language and literacy independent of medium.

11. The reading process. Researchers today accept a dual route model of reading that uses both a direct and an assembled route to word identification (Coltheart et al 1993:589). The assembled route uses the phonological recoding that was first formalized by Rubenstein et al. (1971), and has been overwhelmingly confirmed since (Smith 1996). In this model a reader converts the orthographic code of the text into a phonological code

that we know as inner speech, and enters this mental representation into working memory. They then perform a search for a matching mental representation in the stored mental lexicon, while maintaining the phonological code in working memory (Underwood & Batt 1996:105).

The generally accepted model of working memory, developed by Baddeley and colleagues, includes two separate components, one for speech-based phonological information and another for visual-spatial information (Baddeley 1986). The phonological component consists of two sub-components: a short term storage buffer and an articulatory rehearsal mechanism. The buffer stores incoming data in a phonological code that decays rapidly if it is not constantly refreshed by the rehearsal loop.

Figure 16. Baddeley's model of working memory.



The phonological buffer and the articulatory loop are separate components, and reveal their presence by generating different experimental effects. The articulatory loop occupies a certain amount of capacity in working memory, leaving it unavailable for other tasks. This gives rise to the ARTICULATORY SUPPRESSION EFFECT, in which task performance is degraded when irrelevant articulatory movements are performed during the task. The effects of ARTICULATORY SUPPRESSION TASKS, such as repeating an unrelated word, demonstrate activity of the articulatory loop during reading. Since the loop is needed for the reading process and disabling the loop with a suppression task hinders reading, we conclude that some of the available working memory capacity is being used by the suppression task and is not available for processing. If reading were not hindered by the articulatory suppression task, we would conclude that the articulatory loop was not in use.

The phonological buffer organizes and stores incoming data according to phonological patterns that are held in common with stored lexical items. This gives rise to a PHONOLOGICAL PRIMING EFFECT in which processing tasks show reduced latencies for phonologically similar words. Stored lexical items contain orthographic, semantic and phonological information, and prior exposure can result in any one of these parameters becoming activated to a greater degree than the others. When the parameter activated is the same as that used by the phonological buffer to organize incoming data, lexical access is easier and word naming tasks take less time.

11.1 Visual Language. These two experimental paradigms, phonological priming and articulatory suppression, are among those that have established the presence of a phonological buffer and an articulatory loop in the conversational forms of spoken language, confirming the accuracy of current models of working memory and the reading process. Relying as they do on a well-established division between linguistic and visuospatial processing, the original form of these models faced a challenge in the existence of signed languages that are both visuospatial and linguistic. Research over the past three decades has demonstrated unequivocally that these effects and cognitive processes are not limited to the aural medium, but that users of signed languages make use of a visual phonological code based on the formational parameters of visual-gestural languages. Summarizing this work, Emmorey concludes that 'the structural properties of working memory are the same for both signed and spoken languages' and include 'a working memory system for sign language that includes a phonological buffer and an articulatory rehearsal loop' (2002:232).

Working with scripts for spoken languages, reading research has shown a basic and crucial part of the reading process to be the phonological recoding of orthographic information for its subsequent processing in working memory (Smith 1996). We know that the two components of working memory are actively involved in processing the conversational form of aural languages, the conversational form of visual languages, and the written forms of aural languages. However the written form of a visual language has not been investigated to date. Published studies have presented visual language as actual or videotaped signing, pictures of signs, or various written forms of spoken language (Emmorey 2002: ch 7). In the only study presenting IMA script, Gangel-Vasquez studied recognition of individual words (1997). The processing of a written form of signed discourse has not been investigated as of this writing.

It is logical to ask if readers of IMA script utilize the same working memory systems to perform the same process of phonological recoding as other readers even though the medium of their language is optical rather than acoustic. Acoustics need play no part in this. What is processed in working memory is not sound but phonological patterns which any media can express. For example ASL makes a phonologically contrastive distinction between a straight or bent finger that allows us to distinguish the two words shown[21] in figure 17, whose final segments differ in this one feature.

Figure 17. Proposed Minimal Pair[22] in ASL

black summer

The symbols of the script identify these phonologically significant features by stripping away irrelevant details, leaving only those features that are linguistically relevant. The straight or hooked line in the IMA character indicates the value of the [+/– bent] feature for the index finger, the square box indicates a [+ bent] value for the other four digits, half-shading of the box indicates an orientation value of [palm down], and the juxtaposition of the hand shape symbol with the circle representing the head gives the value of the location feature.

More is needed to form a pattern than a mere list of features, and the script must also indicate the relationships that hold amongst features to organize them into a pattern. The patterns shown by IMA characters are generally syllables that the script encodes as a PmP sequence, an initial and final posture linked by a movement arrow.

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[21] The second hand shape in 'black' is entirely redundant and thus not normally written. It is included here for purposes of comparison.

[22] The view that the two signs, , 'children', with the palm up, versus ,'things', with the palm down, formed a minimal pair was based on the earliest analysis of ASL sign as a simultaneous event. These signs differ only in the palm orientation feature [+/- up], but they do so throughout the entire sign rather than only one segment as required for a minimal pair. It is also arguable whether the two signs in (1) should be called a minimal pair, since it is likely impossible for identical movements to result in different final postures. Speech avoids the problem by not writing separate movement segments. There is as yet no consensus on applying the notion of minimal pairs to visual languages.

All the features listed in the example above occur simultaneously, to comprise a single articulatory posture, a complete unit that can be rehearsed in the articulatory rehearsal loop of working memory. This is no different from the speech based recoding of Rubenstein's model: a process of converting glyphs into a mental, phonological, representation that is maintained in working memory until matched with a similar one stored in the lexicon. Upon seeing a previously unknown string of glyphs, a reader applies GPC rules to the first glyph to link it with a phonological unit such as /s/. She stores this in working memory while she tackles the next glyph and so on, building a phonological string…/s/…/st/…/str/…/stri/…/string/...until it finally matches another mental representation she has stored in her mind as one of the words of her language.

In this example it is not until the fourth letter that she has all the features needed to create a complete, pronounceable, posture that can be repeated in the rehearsal loop. In a typical IMA character, the bundle of glyphs at the start of the movement arrow includes all the features needed to create a posture that can be rehearsed in working memory. The reader follows the timeline indicated by the arrow, and the script notes any sequential contrasts, as here the change from [– bent] to [+ bent] in the index finger. This new detail can be added to the phonological array being constructed in working memory, and rehearsed, exactly as in the spoken example…/stri/...until a match is found in the lexicon.

In either medium, the optical pattern of a written glyph is converted to a phonologically organized mental pattern, entered into working memory, and stored while the lexicon is searched for a matching pattern that identifies the word and completes the reading process. This is precisely Rubenstein's description of phonological recoding. Whether the medium is vision or sound, the psychological reconstruction and storage in working memory of phonologically contrastive segments is the phonological coding that underlies reading.

By hypothesis, the same tests of priming and suppression, when applied to the reading of ASL, should yield results consistent with the phonological buffer and articulatory loop, just as they do with scripts for spoken language. To test this hypothesis, two experiments follow. The first is a priming experiment which seeks to confirm the presence of a phonological buffer when reading ASL characters. The second applies an articulatory suppression task to the reading of an ASL narrative to determine if an articulatory loop is utilized by readers.

12. Experiment four: Priming. Working with scripts for aural languages, evidence from priming experiments have produced results which 'can only be explained by assuming phonological coding' (Perfetti 1999:2). Researchers accept various kinds of priming tasks as reliable indicators of the use of a phonological coding process by readers (Whitney 1998:180). In these priming studies, a subject is briefly shown a word, the prime, before being shown a target word. Seeing a word in some sense activates whatever we store in our brains as that word, and since our memories are not simply random lists, it activates related words as well. If the prime is related in some way, the target will already be activated to a certain extent when we first see it, and it will take us less time to read it. Primes can be related to targets either phonologically or semantically. A semantic prime would have a meaning similar to the target. In other words you can read *dog* faster if you have just seen *wolf*. A phonological prime has a similar phonological shape to its target, normally meaning that it sounds similar, for example *shows* as a prime for *chose.* For

ASL a phonological prime has a similar visual appearance to its target, by virtue of having similar hand shapes, movements and so on.

If we process the words we read on the basis of phonological information, entering phonological features into a phonological buffer, the phonological form of the word is there even before word identification, so that one can reproduce the word's pronunciation before knowing what the word is. Thus, words that follow phonological primes will be read faster. On the other hand, if a reader is using a direct route they will have access to the word before they are able to pronounce it, and a semantic prime will not speed up naming times. The presence of a phonological code will give itself away by reducing latencies for phonologic primes but not semantic primes.

Phonological recoding 'has been implicated in the processing of every usable writing system investigated to date' (Goswami 2006:494), including Chinese, 'the one writing system viewed as providing maximal contrast with alphabetic systems' (Perfetti 1999:1). However such tests have yet to be performed with any script used to represent a signed language.

This experiment applies the well-established research paradigm of priming tasks to the reading of ASL, to test the null hypothesis that reading ASL will generate no phonological priming effects. If the null hypothesis is confirmed and phonological priming effects are not found, this will demonstrate that the script is not being recoded into a sign-based phonological code and entered into the phonological buffer of working memory, and thus no phonological recoding is taking place. If the null hypothesis is disconfirmed by finding phonological priming effects, it will be taken to mean that this recoding is taking place.

12.1 Methods. A standard three-screen priming procedure was utilized in an attempt to verify the presence of a phonological buffer in reading ASL. In this paradigm subjects name a target word after briefly viewing another word which is called the prime. The eponymous three screens are viewed sequentially, the first being neutral, the second displaying the prime, and the third showing the target. The prime is the independent variable, manipulated by being presented in one of three conditions; phonological or semantic prime, or an unrelated control. The measurements recorded are naming latencies for the target words.

12.1.1 Participants. Participants were selected based on the following criteria: a) fluent signers of ASL, b) literate in both reading and writing ASL written with the International Movement Writing Alphabet. Five subjects, four female and one male, agreed to participate. All were hearing bilinguals with English L1 and fluent although non-native signers of ASL. Four were students currently attending university and one a housewife. All were actively involved with writing ASL as part of home schooling activities with their children and had worked with the IMA for at least a year.

12.1.2 Design. Participants were shown pairs of ASL signs written in the IMA script. Each pair either consisted of a prime followed by a target, or was a control pair. Controls were pairs of unrelated words that had no obvious semantic or phonological relationships. Primes were either semantic or phonological. Semantic primes shared some characteristic of meaning with the target but had no obvious physical resemblance.

Phonological primes had unrelated meanings but resembled the target word by virtue of having a similar phonological structure. Phonological similarity was considered as having the same hand shape, location, type of movement, or just general overall visual appearance as judged by fluent users of ASL. The phonological pairs had similar forms but different meanings.

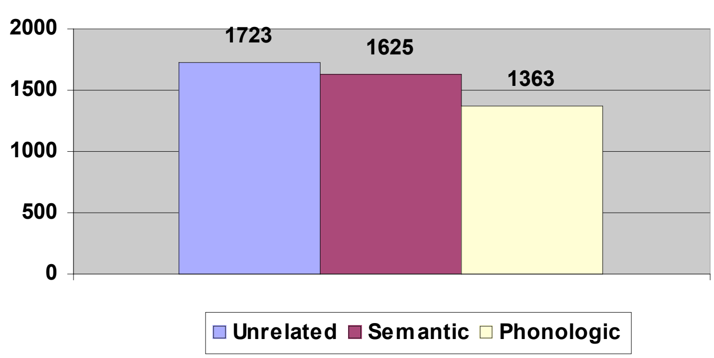
Upon seeing the target word, participants signed the word, and their response time was recorded. After completing the sign they spoke aloud an English translation in order to confirm that they understood the word they had just read and signed. Extra time taken to perform this task was not included in the measured response time. Although this introduced an extra step of translation, it should not adversely affect the results as it affected all participants equally. It was felt that since all participants were bilingual in both ASL and English this was a simple way to test for comprehension. Test items were chosen that have simple English equivalents as much as possible. Test pairs were presented randomly, scores collected, sorted by priming type and analyzed.

12.1.3 Tools. A list of 90 words was taken from Sutton's English-ASL SignWriting Dictionary. The words were separated into three groups of fifteen pairs each on the basis of the relationship between the words in each pair. The test items are shown as Appendix E. The test words were formed into 45 prime-target pairs, grouped into three lists, each in one of the three conditions: semantic prime, phonological prime, unrelated control. The entire corpus was entered into the computer to display one pair after another in random order.

12.1.4 Procedure. The entire corpus was presented in random order, one pair at a time, to each subject in the standard three-screen priming paradigm. First, a large cross was shown on the computer screen for 500 milliseconds (ms). A prime or control word then appeared and was shown for 40 ms. After an interstimulus interval (ISI) of 100 ms this was replaced by the target word. The target word remained on screen until the reader named it by performing the sign. The assistant was seated next to the reader, situated for accurate viewing of the signing as well as the text, and recorded the time on completion by pressing a button on the keyboard. After the reader gave an English translation, the assistant advanced the display to the next test pair. All 45 trials were presented in sequence in this manner

12.2 Results. The null hypothesis, that reading ASL will generate no phonological priming effects, was disconfirmed. Phonological priming effects were present, with phonological primes reducing latencies by an average of 360 ms, a twenty per cent reduction.

Figure 18. Priming Results: Latencies in ms.



A small semantic priming effect was also found. Semantic primes decreased reading speed by 98 ms on average, a reduction of only six per cent, and less than one third the effect of semantic priming. There was clearly phonologic processing going on here to be interfered with.

The results are consistent with those of the same tests when used for reading in scripts that represent spoken language, namely that significant phonological priming effects would be found, but little or no semantic priming effects. Such findings argue that reading ASL draws on the same resources and makes use of the same processes as reading the written form of a spoken language, namely the recoding of orthographic information into a phonological buffer in working memory.

12.3 Discussion. Scripts are classified as deep or transparent, the latter being those that come closer to a 1:1 mapping between symbols and sound, as for example Spanish spelling as compared to English. The size of priming effects varies with transparency, as a more transparent script makes it easier for readers to use phonological coding (Whitney 1998:179). Replacing the term *sound* with the more appropriate *phonological unit,* it is hard to imagine a more transparent script than the IMA, so reading ASL written with this script one would expect phonological but not semantic priming effect, and that is what was found. The six per cent semantic priming effect is most likely due to the script's iconicity, and a good follow-up study would be to control for this aspect of the stimuli.

The reasoning behind the experiment was that phonological priming effects are traditionally assumed to reveal the presence of phonological recoding into a phonological buffer in working memory, a fundamental part of the reading process (Goswami

2006:495). If these tests yielding these results are interpreted in this way when applied to aural language, then the same tests giving the same results should be interpreted in the same way when applied to visual language. Since these same effects were shown to be present when reading ASL, we can assume that written ASL is processed in the same manner as other writing. The conclusion is that readers of ASL recode orthographic information into a phonological code for processing in working memory.

13. Experiment five: Articulatory suppression. Working with scripts for aural languages, evidence from articulatory suppression experiments have produced results that are traditionally interpreted as demonstrating that the articulatory loop exists and is used in reading. The reasoning is that

> ‘Reading should be hindered if the articulatory loop is disabled in some way. The common technique for disabling the loop is to use articulatory suppression, whereby a subject has to recite a number, word, or phrase over and over whilst performing a task. If performance of the task is not hindered by articulatory suppression, then it can be concluded that the articulatory loop is not required for this task (Underwood & Batt 1996:105)

For any language, reciting a word consists of articulators moving from one phonologically significant posture to another. For visual languages these articulators include the hands, and a suppression task might require changing from one hand shape to another. In previous experiments,

> ‘the manual suppression task . . . consisted of the subjects opening and closing their hands in an alternating fashion (roughly from an ASL “5” handshape to an ASL “S” handshape) throughout the stimulus presentation. This particular task was chosen because it had been demonstrated to be effective in the published literature and was a good analog to the types of interference tasks used in spoken language research in terms of obeying phonological and phonotactic constraints of the language. (Hall 2003:32).

This experiment applies the suppression task described above to the reading of ASL, to investigate whether reading a signed language utilizes the same process of phonological recoding and articulatory rehearsal that is fundamental to the reading process used with spoken languages. The hypothesis tested is that reading a visual language written with the IMA gives rise to an articulatory suppression effect.

13.1 Methods. Following standard practice, participants read a running text in a normal condition and also while performing a manual suppression activity. Overall reading times were recorded in each case and compared. Under investigation was whether suppression would degrade performance as is usual in reading, due to interference with the articulatory loop. If reading times are shown to be slower under the suppressed condition, this is taken as evidence that a phonological loop is present and being utilized in working memory. If there is no difference in reading times between the normal and the suppressed conditions, this will indicate that a phonological loop is not involved in working memory during this reading process.

13.1.1 Participants. Participants were the same as those who participated in the priming experiment. The suppression test was performed later on in the same day as the priming tests, following a break of several hours.

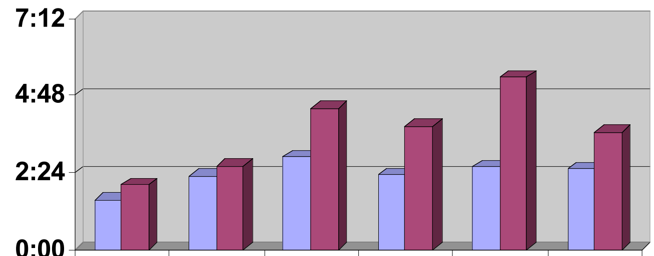
13.1.2 Design. Subjects read a narrative written in ASL using the IMA script, alternately with and without performing an articulatory suppression task. This task consisted of opening and closing the hand from a five hand shape to a closed fist as described above. Reading times were collected and analyzed for comparison between the suppressed and normal conditions. All participants read the same text for both the normal and the suppressed conditions. Reading in the normal condition was recorded on one day and reading in the suppressed condition was done on the following day, shortly after performing the priming experiments.

13.1.3 Tools. The task used the same prepared text as experiment one: handwritten in grammatically correct ASL, specially designed to include most of the characteristics of ASL signing that take significantly different form or do not exist in signed or spoken English. The complete text consists of some 150 IMA characters arranged in the preferred format of vertical columns (Sutton 2003). This was checked for acceptability by a native user of ASL and judged to be grammatical. Vocabulary items were restricted to those in common use. Individual signs were taken from Sutton's American Sign Language Dictionary as much as the inflectional system permitted. Conventions for marking grammatical structure mostly followed Parkhurst (1999). The complete text is reproduced as appendix A. An English translation, containing 387 words, is included as appendix B.

13.1.4 Procedure. Readers sat at a desk with a printed hard copy of the written test narrative lying in front of them covered by a blank page. This cover was removed and the reader began, signing what they were reading to the assistant who sat across from them at a distance normal for signed conversation. Readers also kept up a running translation, describing the story in English as they signed it in ASL. The purpose of this was to monitor understanding of the semantics of the text, ensuring that readers were not merely reproducing the phonetic form of the signs without understanding. The entire performance was recorded on videotape, and this translation was reviewed for accuracy at a later time.

13.2 Results. The hypothesis that reading a visual language written with the IMA results in articulatory suppression effects was confirmed. Suppression degraded performance, as is usual in reading due to interference with short-term memory, and this interference showed up as suppression effects in the form of longer reading times. The suppression task slowed reading by an average of 29%, a clear indicator that an articulatory loop is being utilized in working memory.

Figure19. Suppression results: reading times in minutes for each participant.



	A	B	C	D	E	Avg
Normal	1:33	2:19	2:53	2:20	2:34	2:32
Suppressed	2:01	2:37	4:24	3:50	5:22	3:39

These results support the premise that reading text written in the IMA includes the usual assembled route to the lexicon, by recoding orthographic information into a phonological code and rehearsing it in an articulatory loop in working memory.

13.3 Discussion. The reasoning behind this experiment was that suppression effects are traditionally assumed to reveal the presence of an articulatory rehearsal loop, a crucial element of the phonological recoding fundamental to the reading process (Goswami 2006:495). If these tests yielding these results are interpreted in this way when applied to aural language, then the same tests giving the same results should be interpreted in the same way when applied to visual language. Since these same suppression effects were shown to be present when reading ASL, we can assume that the same phonological recoding, utilizing an articulatory loop that maintains phonological information in working memory, is a fundamental part of the reading process for sign language.

A criticism of this experiment is that in the suppressed condition readers were reading the same text they had already read once before. Obviously this would shorten reading times. The overall effect was that reading times in the suppressed condition were subject to two conflicting variables: shortened due to familiarity, but made longer due to suppression. Fortunately the familiarity effect did not overwhelm the suppression effects, and with novel texts the suppression effects should be even more pronounced. Ideally one would establish reading times for each subject with one text in the normal condition, then establish reading times for the suppressed conditions using different texts. This was not possible given time constraints and the limited number of test subjects available. Perhaps later researchers will work to clarify this matter.

The slow reading speeds overall were surprising. Average reading speed in English is something over 200 words per minute (wpm), yet in this population ASL was read at an average of only 37 wpm. This may be due partly to differences between the visual and aural media. It takes longer to produce words with the larger and slower articulators of a visual language, so the rate of sign production is less that that of speech. In normal conversation the average rate of production is 2-3 signs per second or 4-5 spoken words per second. However where speech typically produces one morpheme at a time, signing typically packs many morphemes into each single sign, with the result that speech and sign both produce propositions at the same rate, about 1½ per second, and it takes the same amount of time to say something in either medium (Emmorey 2002:118). In fact, the capacity of the articulatory loop is limited to what can be articulated in about two seconds for either sign-based or speech-based rehearsal (Emmorey 2002:223). This universal constraint on natural language dictates that on average three signed words carry the same amount of information as five spoken words. Adjusting for this, the average reading speed for ASL was equivalent to a speed of 111 wpm, and my own work has shown reading speeds equivalent to 150 wpm, much more comparable. As of this writing I know of no other studies that measure reading of connected text in signed languages. We need more studies in this area so that at least we know what to compare with.

Reading was undoubtedly slowed in this experiment by the fact that the participants were not only reading in an L2, ASL, but were also doing translations into another language and another medium. The translation to English was included to ensure participants read with understanding, but in future research a way can surely be found to eliminate the confounds of translating. This would also open a door for reading studies that entirely separate the reading process from any acoustic phenomena, a desirable goal for research.

14. General discussion. Results of both experiments support the premise that processing the written form of a signed language is qualitatively no different from processing the written form of a spoken language. The priming experiment confirms that readers recode the orthographic information in the script into a representation based on phonological features, and enter this into the phonological buffer of working memory. The suppression experiment confirms the presence of an articulatory loop to maintain information held in the phonological buffer. Taken together, these two experiments provide the same evidence for visual languages as previous studies have provided for spoken languages, and which are interpreted as indicators of phonological recoding. We can conclude that the reading process is independent of the language medium.

Admittedly there are some methodological issues, most of which are unavoidable in such an unplowed field of study. The results must be interpreted with extreme caution as there is no equivalent data for comparison. Direct contrasts with other such data in the literature are likely to be misleading as they all deal with spoken languages. Compared to reading studies in for example English, this is a different language, different language typology, different medium, different script, different type of script, and probably other factors.

Also, the number of participants was far smaller than desirable. At this point in time signers who are literate in the language they sign are still few and far between. Should the use of IMA continue to spread, this will become less of a problem and hopefully these studies will be replicated and improved upon.

As already addressed, participants were not only reading in an L2 but also doing simultaneous crossmodal translations. Crossmodal bilingualism, in which a person uses two languages in different media, provides a valuable window into the representation and processing of language, but presents a serious problem. Traditional studies have long compared the written word with the spoken, and now with the signed, word. A typical study might test short term memory by having a native signer either sign or write down what they remembered after either reading a written list or seeing a video of a person signing. Not surprisingly, best recall is always the sign in-sign out condition. All the others not only involve changing between sign and writing, they also involve a change between two different languages, an L1 and an L2. Few have addressed this situation even though it 'is counterintuitive to the goals of their research' (Dufour 1997: 124). The IMA offers a potential way out of this trap by distinguishing the conversational from the written form within the same visual medium in just the manner it is done within the auditory medium, thus making the two directly comparable.

Taken all together, the results of this study permit reasonable speculation on the question raised at the beginning: what is it that causes other attempts to write visual languages to fail, yet allows the IMA to succeed? The answer is apparently that scripts organized like SN fail to encode syllable structure. They encode phonetic details, but not how those details are structured into a language segment that can be used in phonological recoding. The reading process requires a means for converting the written orthographic code into a phonological code that consists of rehearsable segments of the language stream, at minimum complete postures and not merely unorganized phonetic details. SN characters give details that we possibly can enter into the phonological buffer, but we cannot enter them into the rehearsal loop until they are assembled into a complete phonological array that constitutes a segment of signing. We know that working memory has a storage capacity for visual material of 5 ± 1 items (Boutla et al 2004), and our alphabet requires that only two symbols, or a maximum of four, be processed to create a syllabic phonological array. Presumably the iconicity and spatial mapping of the IMA requires little or no cognitive processing to convert its orthographic code into segments of inner language.

On the other hand a typical, a typical SN character includes at least four items, one each for location, hand shape, orientation, and movement, that are only descriptive facts about phonetics. They are not segments of the language stream that can be rehearsed in the articulatory loop as inner language and matched against stored items in the lexicon. All those unconnected phonetic details must be held in WM while assembling them into a phonologically organized posture, and this puts WM at or near capacity, leaving little cognitive resources for other aspects of the reading process. In this way SN apparently overloads working memory and this makes it unusable as a script.

The hypothesis tested in experiments four and five was that that reading a visual language written with the International Movement Writing Alphabet results in articulatory suppression and phonologic priming effects. Both sets of results supported the hypothesis, lending strong support to the premise that reading a visual language draws on the same resources and makes use of the same processes as reading the written form of a spoken language. The conclusion is that despite superficial differences in form between the visual and aural media, reading a signed language is not qualitatively different from reading a spoken language. This establishes that there is no theoretical barrier to a written form for visual languages, a finding with implications for educational practice as well as linguistics and psychology.

14.1 Implications. The introduction to this paper introduced a litany of problems that result from lack of a writing system for visual languages—problems relating to linguistic theory, ESL pedagogy and Deaf emancipation. Implicit in this is the suggestion that adopting a successful writing system, and the present studies indicate that the IMA is such a system, would help solve many of those problems. Rather than rehashing these issues here, I would like to focus on just two areas where this line of research has the most significant ramifications: Education and Psychology.

14.2 Education. One out of a thousand children born in the US is deaf, and on average these children graduate high school with a fourth grade reading level (Goldin-Meadow & Mayberry 2001: 224). An effective pedagogical approach to this population is desperately needed. With the recognition of ASL as a natural language the idea began to gain currency of bilingual education using a native signed language as the child's L1, and the most current model of Deaf Education, in theory if not in practice, espouses such a bilingual approach (Johnson et al 1989). The rationale for this is based largely on Cummins' Linguistic Interdependence Model that states proficiency in an L1 will transfer to an L2 (Singleton et al 1998). Mayer and Wells (1996) challenged the appropriateness of this model for deaf students on grounds that there is no written form of ASL and therefore no skills to transfer:

> 'Here the applicability of the linguistic interdependence model breaks down. Since their first language (ASL) has no written form, profoundly deaf students cannot acquire literacy skill in their first language, consequently they do not have literacy skills to transfer to the written form of a second, spoken, language such as English' (Mayer & Wells 1996:94).

Mayer & Wells themselves cite research confirming that literacy in a first language does transfer to literacy in an L2. Recent research makes it abundantly clear that we only learn to read once, and thereby gain a long list of low-level coding and functional skills that are applicable to other orthographies and need not be relearned

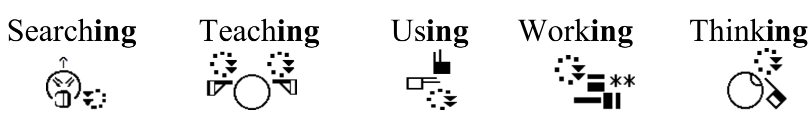
(Cook & Benedetta 2005). It is the unwritten conversational form of ASL that is questionable as a bridge to English literacy.

Normally the conversational form of English, for those who are able to hear it, provides the bridge to literacy in English. The deaf child is denied this bridge, and is provided no literacy skills in their signed L1 to replace the bridge. Given any literacy skills in the L1 at least some of these skills would transfer to the L2, as we know from experience with such disparate scripts and languages as English and Chinese (Harris & Hatano 1999). Utilizing the IMA to create literacy skills in the L1 ASL could provide a bridge to literacy in the L2 English. L1 literacy is extremely important, as primary literacy in the mother tongue is axiomatically a goal of literacy instruction (Bialystok 1991), and is the preferred avenue of literacy teachers everywhere (Baca & Cervantes 1992). Besides promoting both phonologic and morphological awareness, literacy in an L1 allows the learner to organize the conversational form of their native tongue into a more abstract written form, thereby fostering metalinguistic knowledge. Becoming literate develops familiarity with phonological awareness, the organizing principles of writing, and metalinguistic skills—knowledge about how to segment the language stream into parts, how to identify morphemes amongst those parts, and how to map them onto the written inscription. These are the tools the child needs for the task facing them.

For the deaf child this task is less like that of a hearing child learning to read and more like that of an archeologist who deciphers an inscription in an unknown tongue. Metalinguistic knowledge gained from their own language provides the tools to decipher, and later read, the inscription. The job begins with matching known morphemes that are familiar from one's own language onto specific segments of the L2. This is much easier in print than in a language one has never heard, and it begins with concrete nouns like  'food',  'elephant' and  'horse', then other content words and simple verbs like  'think', and  'teach'. Knowing how these words fit together in ones own language, one deduces how they must do so in the inscription.

The child, or the archeologist, creates and tests rules in order to construct an internal grammar for the new language, working up to more and more complex constructions. In both ASL and English, present progressive[23] of a verb is expressed by very abstract phonological and morphological rules that the reader knows only subconsciously. ASL expresses progressive by reduplicating the movement portion of the syllable, something that never occurs in English. English expresses it by not only preceding the verb with an auxiliary but also adding a final suffix, something unknown in ASL. The written forms are much simpler, less abstract and easier to grasp. They are respectively a particular kind of arrow, , and a letter sequence, *–ing*.

Figure 20. Progressive Aspect in ASL and English



Even for items as abstract as these, mapping between the two written forms seems like a natural bridge to English literacy. The experience of the Nicaraguan Sign Language Project (Kegl 2005) and research by Gangel-Vasquez (1997) and Flood (2002) all support

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[23] Actually, ASL makes much finer distinctions in its tense/aspect system than English, so this statement is somewhat misleading, but accurate enough for the purpose at hand.

this premise. Educators owe it to their students to investigate the possibility that this written form offers positive benefits for their charges.

14.3 Psychology. The articulatory perspective taken here necessarily treats phonological units as being made up of movements rather than acoustic events and treats the sound-symbol relationship as an articulation-glyph relationship. These relationships exist for aural as well as visual language, and it may be that this is a more accurate viewpoint in neurological terms. The nature of working memory is very much an active area of research. Evidence seems to indicate that our brains store linguistic information in terms of the motor impulses that govern articulation, instead of the more traditional assumption that this is auditory information. However it is extremely difficult to separate the sounds of a word from the articulations that create the sounds. Gupta & McWhinney asked the central question in the title of their article: 'Is the phonological loop articulatory or auditory?' (1995). Musselman states 'It has not yet been possible to empirically disentangle articulatory from sound-based encoding in order to provide a direct demonstration of its use in reading-related tasks' (2000:16). These present studies seem to do exactly that, dealing with articulatory encoding in the complete absence of any sound. The question remains of what relationships exist between articulation and phonological encoding within the same medium. Phonological patterns seem to come in four forms: optical and acoustic patterns, the motor programs used to produce them, and the electo-neuro-chemical patterns used to store and process them. The relationships amongst these remain mysterious, but reading in visual languages where nothing acoustic is involved would seem to provide a new and useful tool for investigating such issues.

Reading research and the study of literacy is a complete field of study in its own right, with a vast field of literature relevant to spoken languages all of which could, but has yet to be, duplicated with visual languages. Deeper study of these scripts and their psychological processing should add much to our understanding of both the reading process and mental functions in general.

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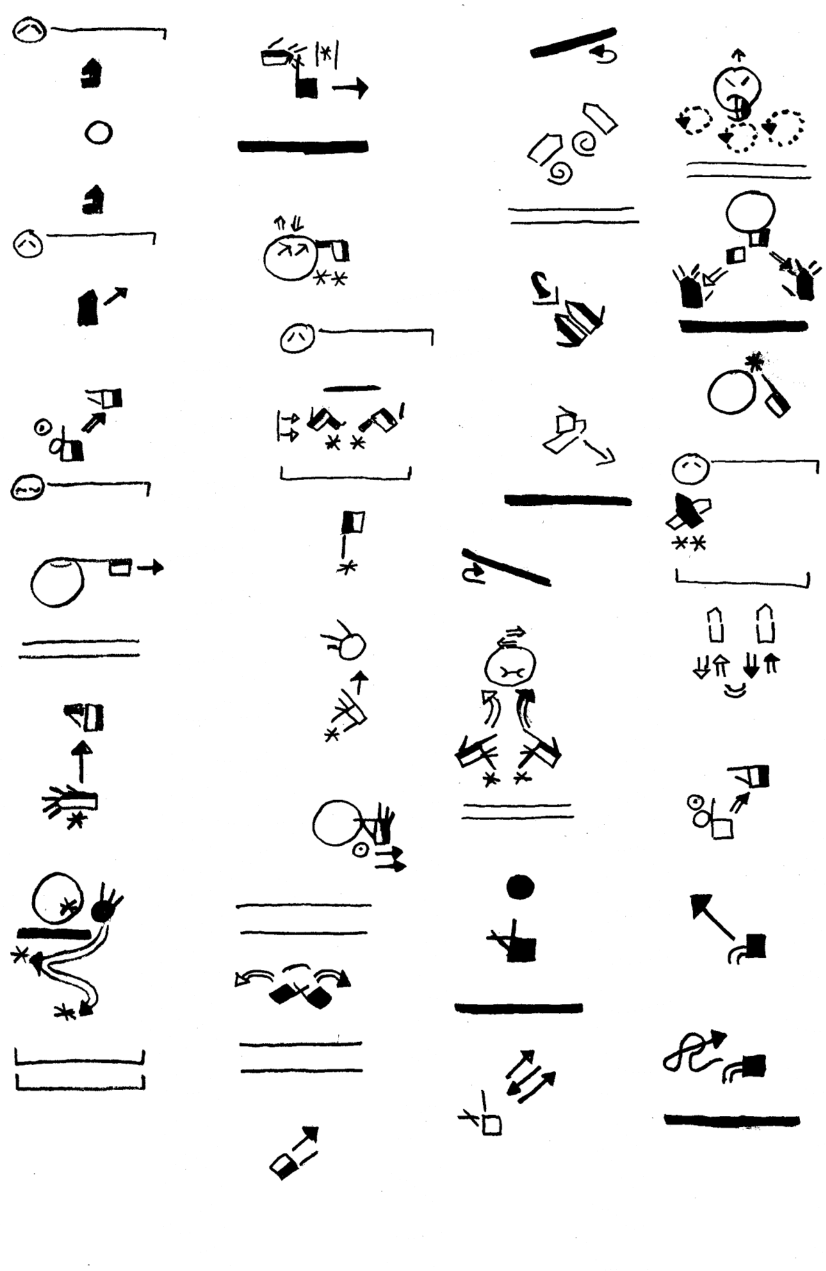
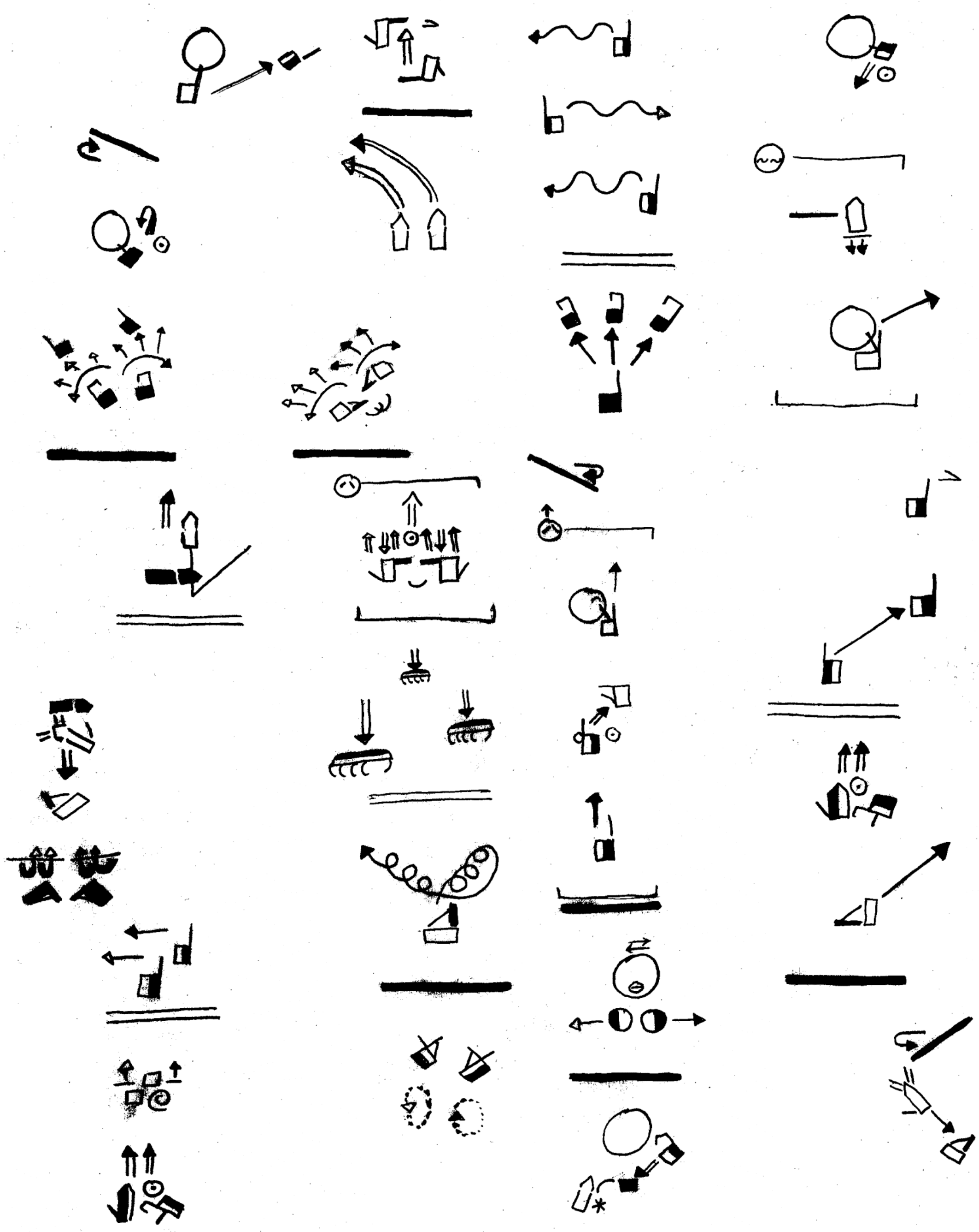
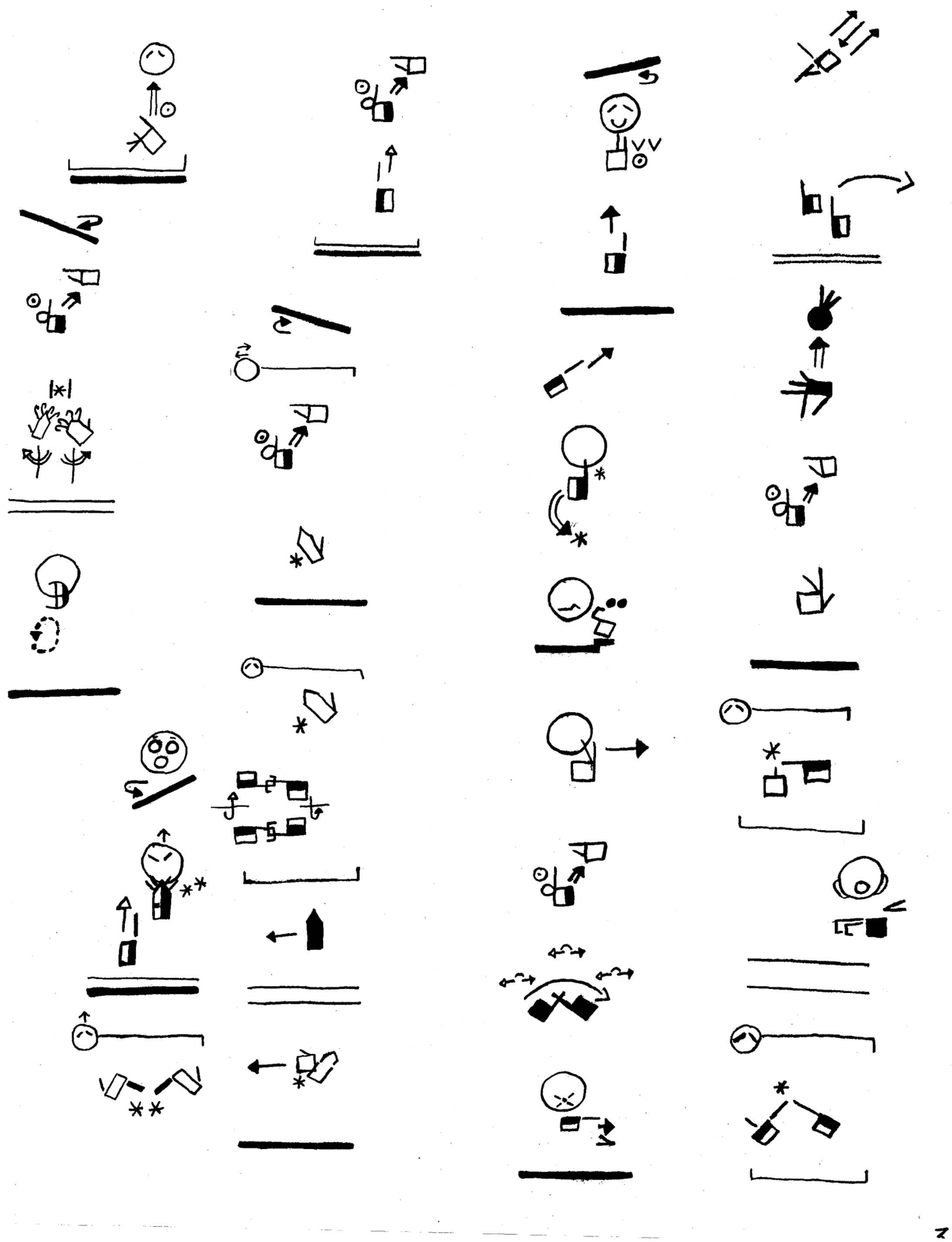
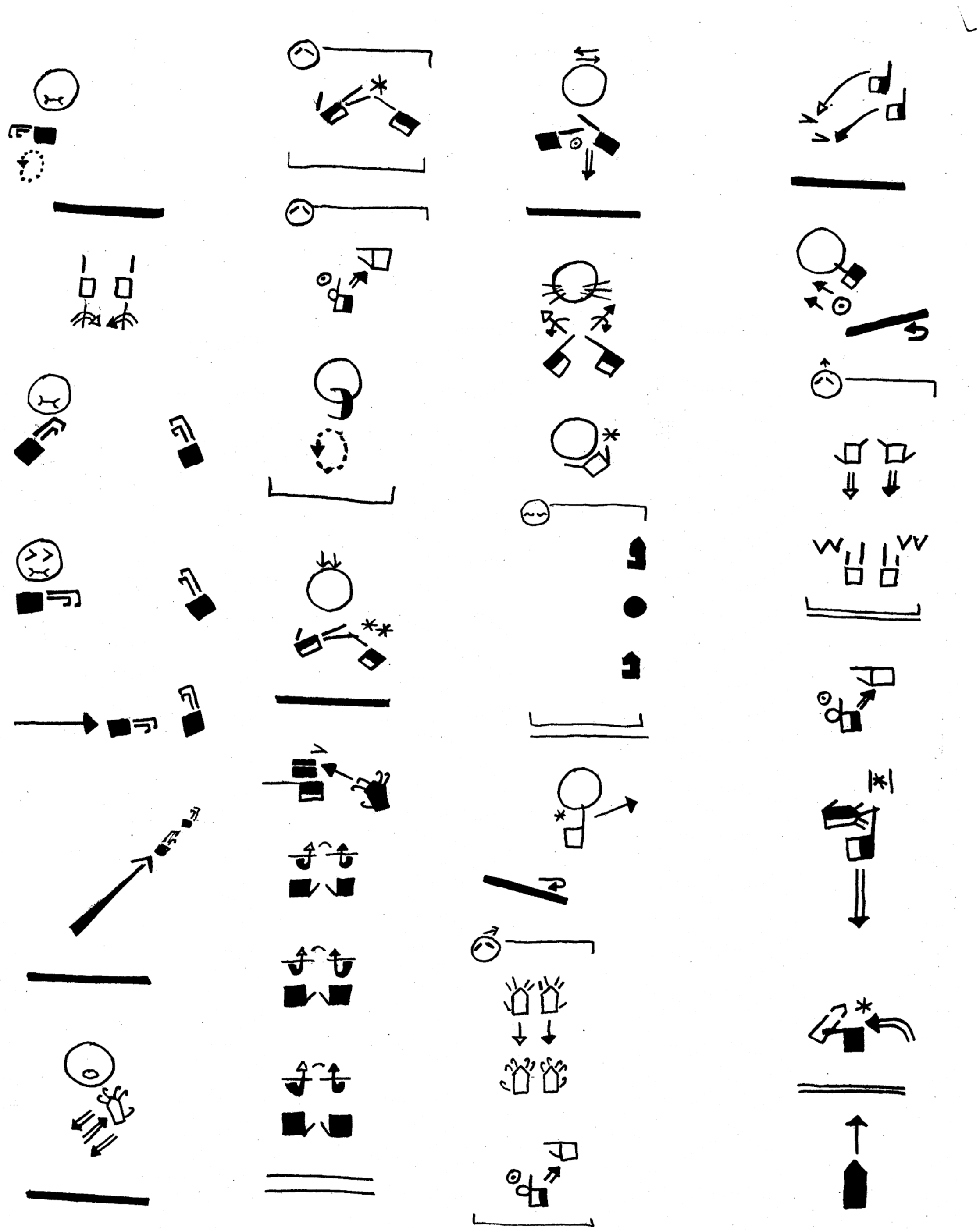
Appendix A

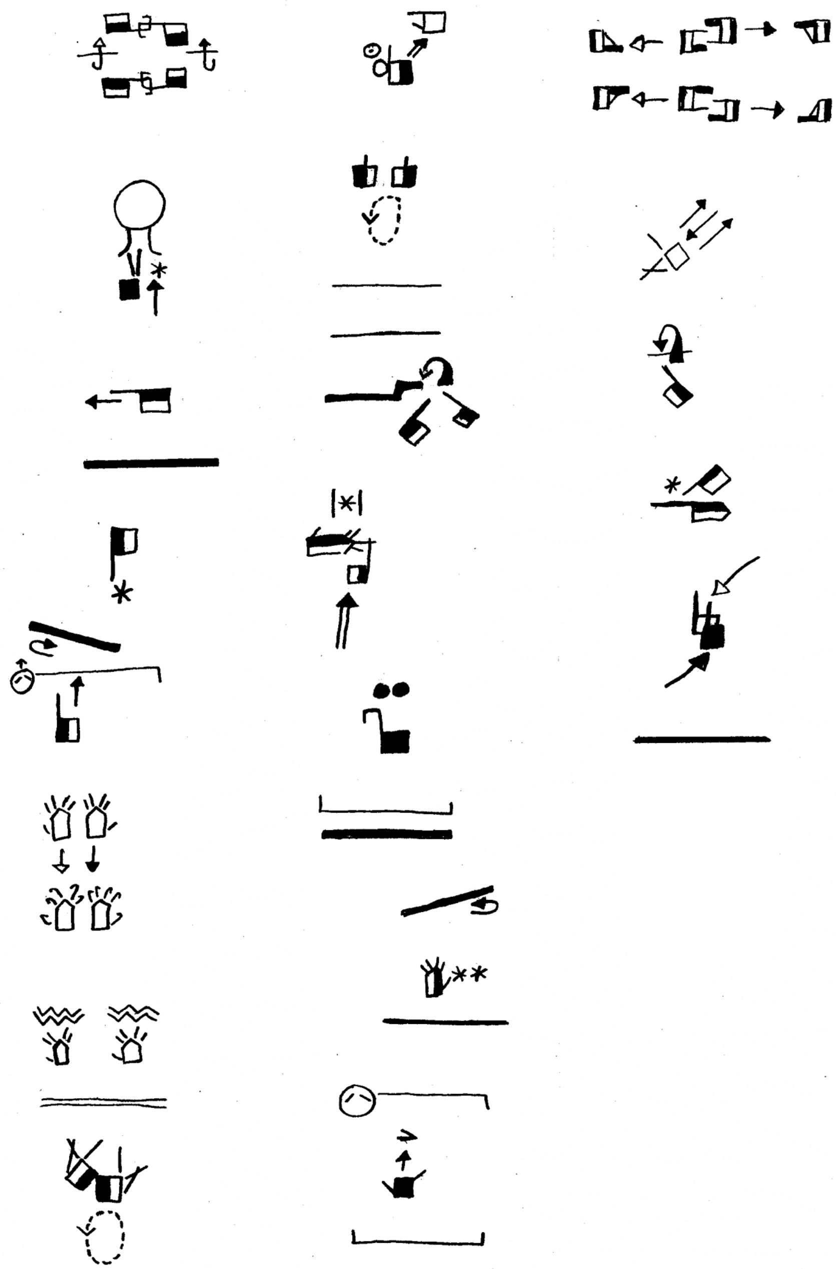
ASL Narrative Text











Appendix B

English translation of ASL narrative, experiments one and four.

Bob's dog, the black one with white spots all over her face and chest, ran away. He knows I'm a cat person, but he still begged me to help him. I told him 'I'm not too thrilled, but ok'. The two of us looked and looked all over the place, but we finally gave up. I thought maybe the dog had gone to school and was running around the campus, so I told him I would go tomorrow and ask around over there. Next morning I went to the copy store, made a bunch of flyers, took them to school and passed them out to everybody. There are three building there, two close and one far away; I kept giving them out at the two close buildings but didn't give any to the far away building. People kept walking by, and I would ask them if they'd seen a dog, but nobody saw anything.

I noticed a girl that I had seen before, and I went up to her, said hi, and gave her a flyer. She took the flyer and said 'Hi, what's up?' I said 'This dog got lost and I'm looking for it'. She looked really surprised and said, "What are you saying? You have a dog? I told her, It's not my dog, it's my friend's. I'm helping him.' She said, "Aw, you're sweet." She told me she had just recently seen some dogs. The two of us went together to where she was talking about, and we found three dogs. There was a big fat one, who was just loafing around enjoying himself, and a little teeny one. The little teeny one saw the big one, went after him and chased him away! That was weird. Anyway, the third dog was the one we were looking for. We tried to grab the dog, and kept trying and trying but we couldn't. Finally, I called Bob and told him "If you want your dog you better get over here fast!"

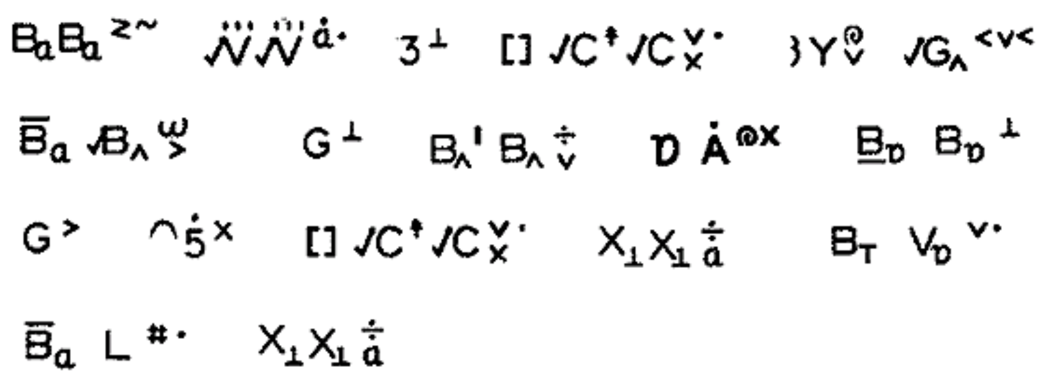
Then the girl asked, “What do we do now? Your friend will be stuck if the dog disappears again.” I asked her, "Do you want to wait here with me and keep tabs on the dog until he gets here? She said “fine”. And that’s the story of how she and I met!

English translation; 387 words

Appendix C

Experiment One, Test Item

Stokoe Notation paragraph



English translation.

This is the story of Goldilocks and the Three Bears.

Somewhere in the forest, you will find a house.

Inside, there is Papa Bear, reading a newspaper.

Appendix D

Experiment Three Test Items

Test sentences in four conditions

International Movement Writing Alphabet, linearized condition

girl DEM:LOC$_R$ boy DEM:LOC$_L$ 3PS$_R$-height$_L$-height$_{R:}$more

‘The girl is taller than the boy.’

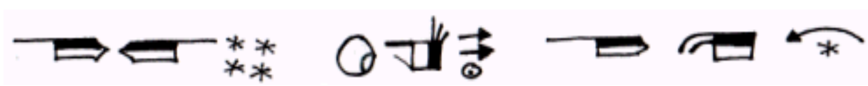


table cat $_i$on$_j$.CL:flat object$_j$.CL:small-animal$_i$

‘The cat is on the table.’

International Movement Writing Alphabet, spatial condition

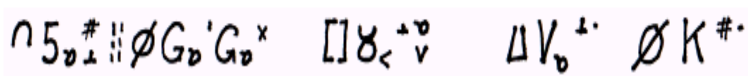
horse die RHET-why eat nothing

‘The horse died because it didn’t eat anything.’

suppose wrong teach-AGT help-3PS.SUBJ-2PS.OBJ

‘If it’s wrong the teacher will help you.’

Stokoe Notation, linear condition



Brother like-NEG look-at television

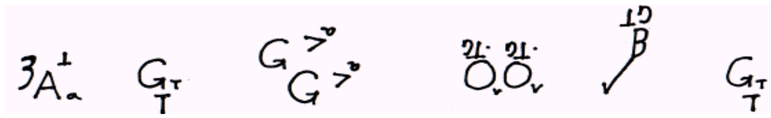
‘My brother doesn’t like to watch TV.’

Stokoe Notation, linear condition

remember week-one-PAST 2P-DUAL discuss girl DEM:LOC$_R$

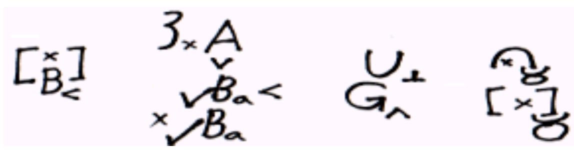
‘Remember last week we talked about that girl.’

Stokoe Notation, spatial condition



tomorrow 1PS go store will 1PS

‘I’ll go to the store tomorrow.’



1PS daughter true sick

‘My daughter is really sick.’

Appendix E

Priming Stimuli

Unrelated pairs

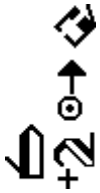
1.   basic meet

2.   never history

3.   grandfather feelings

4.   million president

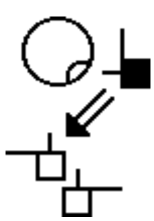
5.   see silence’

6.   think-same skill

7.   French fries home

8.   think book

9.   magazine game

10.   sister often

11.   ugly again

12.   no more look

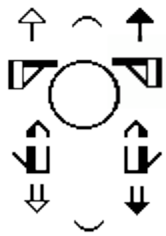
13.   eat again and again

14.   me future’

15.   deaf school husband

Semantic primes

1.   study analyze

2.   teacher student

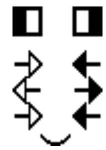
3.   happy sad

4.   angel devil

5.   short long

6.   more than more

7.   listen talk

8.   hot cold

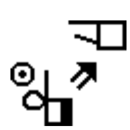
9.   fifteen sixteen

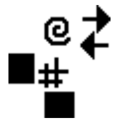
10.   twenty-one twenty five

11.   deaf blind

12.   believe doubt

13.   always never

14.   cat dog

15.   airplane train

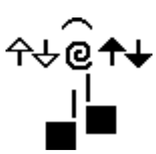
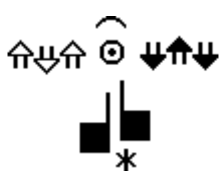
16.   alone together

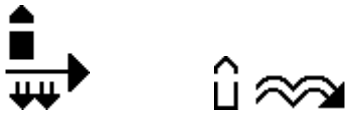
phonological primes

  sour true

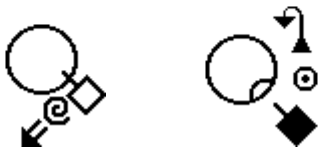
  twenty no

  feel twenty five

  socks star



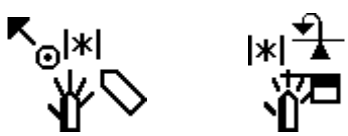
children things



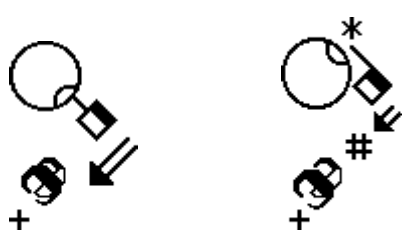
girl tomorrow

Alaska lion

understand eleven

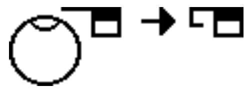


through start’



wife believe

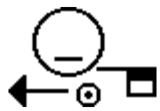
furniture French’

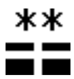
black summer

disbelief twelve

dry lie

shoes coffee