# Cognitive functioning of prelingually deaf children

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Dawson, Elizabeth Helen (1979) *Cognitive functioning of prelingually deaf children*, Durham theses, Durham University. Available at Durham E-Theses Online: http://etheses.dur.ac.uk/7907/

# COGNITIVE FUNCTIONING OF PRELINGUALLY DEAF CHILDREN

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Thesis submitted for the degree of Ph.D. in the
Department of Psychology, University of Durham, 1979

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# GLOSSARY OF ABBREVIATIONS

| | |
|---|---|
| AI | Articulatory intelligibility |
| AS | Articulatory similarity |
| ASL | American sign language |
| BSL | British sign language |
| CNS | Central nervous system |
| CS | Comparison stimulus |
| CVC | Consonant vowel consonant |
| dB | Decibel |
| DE | "Deaf English" |
| DES | Department of Education and Science. |
| EMG | Electromyography |
| Hz | Hertz |
| IMS | Immediate memory span |
| ISI | Inter-stimulus-interval |
| L | Letter |
| LEA | Local education authority |
| M | Mode of articulation |
| MS | Memory stimulus |
| NW | Non-word |
| NCSD | Northern Counties School for the Deaf |
| P | Place of articulation |
| PGSS | Paget Gorman Sign System |
| RNID | Royal National Institute for the Deaf |
| RT | Reaction time |
| sd | Standard deviation |
| SE | Standard English |

| | |
|---|---|
| SL | Sign language |
| STM | Short-term memory |
| TTR | Type-token ratio |
| V | Voicing |
| VS | Visual similarity |
| W | Word |
| WISC | Wechsler Intelligence Scale for Children |

## DECLARATION

I hereby declare that the whole of the experimental work described in this thesis, and the collection of the data, are the results of my own studies. I also declare that this thesis has not already been accepted for any degree, nor is it concurrently submitted either in part, or as a whole, to any other University in candidature for any other degree.

Dawson

## ACKNOWLEDGEMENTS

Throughout the duration of this study a great many people have been most helpful to me. To list them individually would be impractical and I must, through necessity, thank them collectively. Vital assistance was given by head teachers, school administrators, school psychologists, teachers and residential child-care staff, and I was particularly appreciative of their willingness to co-operate with my work in addition to their own school activities.

I am, of course, also very grateful to all the children from the Northern Counties School for the Deaf and the West Jesmond Junior School in Newcastle-upon-Tyne, and the Marden Bridge Middle School, Whitley Bay, who so willingly took part in my experiments, and who were so pleasant to work with.

Finally, I would like to express my appreciation of the help and encouragement given by my supervisor, Dr. Robert Hockey, and by Professor Anthony Gale and by other members of the Psychology Departments of the Universities of Durham, Nottingham and Southampton whose constructive comments and ideas were often invaluable!

## ABSTRACT

The thought processes of profoundly and severely prelingually deaf children were studied in a field situation, to determine both general mechanisms and individual differences in information processing. The central concern was whether individuals who are largely deprived of normal means of verbal processing make particular use of visual, articulatory and kinaesthetic cues.

The perception and immediate recall of visually presented letters were investigated (Experiments 1-4). All the deaf subjects appeared to be relying heavily on visual cues, whilst articulatory coding was employed only by those most able to articulate intelligibly. The use of visual cues was also found in a lexical-decision task when graphemically similar word-pairs were processed significantly faster than either phonemically similar or control word-pairs (Experiment 5). When similarity of sign equivalent was manipulated (Experiment 6), the deaf subjects processed the word-pairs with sign equivalents significantly faster than those without sign equivalents. In a sentence-recall task, a written version of sign language (SL) was recalled significantly better than either "deaf English" or standard English (SE) (Experiment 7). The deaf subjects were also able to understand short stories written in SL significantly better than those written in SE (Experiment 8). In the final experiment (Experiment 9), kinaesthetic feedback provided by the active use of fingerspelling significantly improved the deaf children's retention of new spelling patterns.

The experimental evidence suggested that the cognitive system of the deaf children was structurally different from that of normally-hearing children, developing as it does primarily through visual input.

It was visually oriented, backed up by additional kinaesthetic, and, in some cases also by articulatory, information processing. In the light of the present findings, the implications for cognitive development of the use of standard English as the 'official' language of classroom instruction in deaf schools are discussed.

Throughout this study there was considerable evidence of marked individual differences in the communicative abilities of the deaf children. Since these differences clearly constituted important experimental variables, it is suggested that, in future studies, there should be greater awareness of the importance of such differences within experimental populations.

# CHAPTER 1

# GENERAL INTRODUCTION

## 1.1 Aspects of deafness.

1.1.1 Who are the deaf? The phrase 'the deaf', though linguistically convenient, is too comprehensive to have any functional meaning in education, and this limitation must be borne in mind. In practical terms, a hearing loss becomes a significant handicap as soon as it precludes normal auditory contact with the environment. A child is psychologically, educationally and socially deaf if he cannot hear and understand speech. By 'the deaf' are meant, in the course of this study, those people with defective hearing such that their "hearing loss prevents, for all practical purposes, auditory contact with the world around them" (Furth, 1966a,p.7), and who have been deaf from birth or early life. For educational purposes, however, the hearing impaired are categorised into 'deaf' and 'partially hearing', and it is the former with whom this study is concerned - viz. children "with impaired hearing who require education by methods suitable for pupils with little or no naturally acquired speech and language" (Department of Education and Science, 1962).

Furth (1966a,p.71) wrote:

> One would be guilty of gross overgeneralisation if one considered them [i.e. the deaf] as a homogeneous group. The same differences of ability, experience and personality no doubt exist among them that are found in any other group. For this reason there is, strictly speaking, no such thing as a 'psychology of the deaf'.

Yet those who are deaf seem to share common characteristics and common problems, but at the same time there are also marked individual differences - indeed the deaf are a very heterogeneous population.

Such variables as age at onset of deafness, type of deafness, degree of deafness, family history of deafness and social background all contribute to individuality, as well as all those sources of individuation which apply to the population at large.

1.1.2 The sense of hearing. In order to appreciate the effect of deafness on the individual, let us first consider the sense of hearing. Hearing is a multi-directional sense, unlike sight which is directional and can therefore monitor only the world that is facing one. One cannot close the ear as one can the eye, and the ear will continue to monitor the environment continuously whilst one remains conscious. But hearing not only operates in all directions, but also around corners, in the dark and whilst one is asleep - it is the basic contact sense with our environment.

It is hard to imagine what it must be like to be deaf - to put one's fingers in one's ears, or to watch the television with the sound turned down, might simulate to some extent what it is like to be adventitiously deaf. But in order to even begin to understand the enormity of the problem facing the child who is profoundly or severely congenitally or prelingually deaf, one has to try to imagine turning on the television, without sound, or with incomplete sound, in a foreign country in which one has no knowledge of the language, and with this very limited amount of information available, learn the new language, deprived also of the ability to hear, or monitor, the sound of one's own voice,i.e. with imperfect feedback. Such is the problem facing many deaf persons - the situation and environment of a prelingually deaf person in a hearing world and surrounded by hearing people.

1.1.3 The incidence and extent of deafness in the population. There are many estimates available of the number of deaf people in the world, and in our own country, and these provide a useful criterion by which to estimate the extent and magnitude of the problem. However, no reliable and meaningful estimate of the incidence of deafness exists, even on a smaller scale, such as a London borough, for deafness is not a notifiable handicap and no records are kept on a central basis. We do however know that it occurs sufficiently frequently for it to be considered a major problem for educationalists, psychologists, and social workers, and worthy of extensive research studies.

In the past there was a greater population of adventitiously deaf; it was estimated 50 years ago that about 40% of deaf pupils in school had acquired language before becoming deaf, possibly as a result of disease or injury. Thus the deaf population then was very different from that of today, when the majority (estimated at 95%) of deaf children are either congenitally or prelingually deaf, and have never heard speech and cannot acquire verbal language in the usual way. Today there is also an increasing number of multiply-handicapped deaf children i.e. children with at least one additional handicap besides hearing loss which is severe enough for the child to require special educational facilities even if he were not deaf. The additional handicap might be poor vision, or a heart defect such as is frequently associated with maternal Rubella during pregnancy, or a dysfunction of the C.N.S. associated with anoxia or birth injury - such children would probably not have survived until a few years ago.

1.1.4 Deafness in the individual. Hearing loss is on a continuum from the mild and insignificant to the severe and profound loss. There is no satisfactory and generally agreed upon classification of the various degrees of deafness and no two authorities agree as to where the divisions should occur. In this study four grades of deafness will be identified: mild (0-30dB loss)

moderate (30-60dB loss)
severe (60-90dB loss)
profound (>90dB loss)

(See Section 1.5 for a discussion of hearing loss measurement.) Children who have become deaf prelingually have very little advantage over those who were born deaf, as regards language acquisition and their subsequent psychological development. The concern in the present study is with the third and fourth of the above-mentioned categories, i.e. severe and profound deafness occurring early on in life when its impact on behaviour is greatest. These children even with amplification are largely unable to hear voices and speech sounds, and as a result their cognitive functioning is likely to be rather different from that of hearing and also less deaf individuals.

1.1.5 Changing attitudes towards deafness. In earlier times the archaic phrase 'deaf and dumb' was used, and the stigma of deafness was great. It was frequently believed that the affliction was a double one - that of loss of hearing and in addition to this, a dysfunction of the speech organs which caused dumbness. In reality this latter condition is a developmental consequence of deafness, and is not itself organic. Deafness was also regarded as part of a syndrome of deafness, dumbness and a general dullness of mind, and was even on occasions attributed to the works of the devil and witchcraft. Up until the 16th century, deaf people were treated virtually as sub-human and relegated to the category of the demented. Such ideas were born of ignorance and superstition and took centuries to overcome.

Before proceeding with a brief history of the education of deaf children, it is first necessary to discuss the various methods of communication which are used by and with the deaf, for as we shall see, these communication methods are very closely linked to developments in the educational field.

## 1.2 Methods of communication in current use.

A deaf child who is unable to hear speech, does not acquire verbal language naturally, and cannot therefore easily communicate orally. This lack of speech does not however necessarily imply a lack of language, or a lack of symbolic behaviour, but merely that verbal language is not acquired in the normal way: the deaf child is forced to rely predominantly on visual and manual methods of communication, rather than on the more usual auditory channel.

1.2.1 Speech. The Ewings (1950, p.159) wrote that the goal of the deaf child is to "achieve fluent, audible, rhythmic and intelligible speech in order that other people may understand it". This is a noble aim that few would dispute on theoretical grounds. However, even after many years of training the speech of many deaf persons generally remains very difficult to understand and can easily be recognised as 'deaf speech'. Few profoundly or severely prelingually deaf articulate clearly enough to be understood by a total stranger; some are not always comprehended by their teachers and family and those with whom they have most contact, and who are familiar with their speech. Conrad (1976b) in a recent survey of 360 deaf school-leavers recorded that nearly 50% of his sample had speech that was considered either 'very hard to understand' or 'effectively unintelligible'. Of those deaf children with a hearing loss greater than 85dB, this percentage was increased to 70%, and only 10% had speech that was rated as 'fairly easy to understand' or 'wholly intelligible'. Yet the Ewings, two of the most eminent and influential of British educators of the deaf, wrote a 'text book' entitled "Teaching deaf children to talk" (1964). In this book they rarely refer to the existence of manual communication systems, reducing their discussion to a foot-note, and dismissing them as a weak alternative to verbal language.

Under 'normal' conditions speech is an audio-vocal system of communication, the ear receives speech messages and the vocal tract produces them. The spoken language of the deaf child however, is primarily a visual-vocal system - the eye (rather than the ear) receives the messages from the mouth/lips of the speaker, and the kinaesthetic sense (rather than hearing) monitors the deaf person's vocal message to others.

1.2.2 Lip-reading. Lip-reading (also known as speech-reading) enables speech to be seen on the lips of another person, rather than heard. Words and speech movements are not always very easy to see on the lips, and therefore, as a means of receiving speech, it is far less accurate than hearing speech. There is no one-to-one association between a particular phoneme and its corresponding visual shape, and some speech sounds are invisible since they are articulated actually inside the mouth (e.g. 'girl'), and some are identical to others (e.g. 'pit' looks identical on the lips to 'bit'). Of the 44 phonemes used in the English language, it has been estimated that only 16 are visible (Fisher, 1968). In short, one is dependent on ambiguous lip movements. Very few profoundly or severely prelingually deaf people are good lip-readers, and as yet we do not know what makes a person a 'good' or a 'poor' lip-reader. Even at best, and for those who know the language well and can make use of contextual cues (lip-reading assumes a basic familiarity with verbal language), lip-reading is a very 'hit and miss' affair. Many deaf people can only lip-read very simple words and phrases, and beyond 10 feet the use of lip-reading cues is very limited and impractical.

Conrad (1977a) reported a study in which he compared the lip-reading ability of profoundly deaf 15-year-old children with no other handicap and of average non-verbal intelligence, with a comparable group of hearing children, untrained and inexperienced, who were 'deafened' by white noise masking. He assumed that after 10 years of education, a deaf child ought to be able to lip-read better than children with no such experience. Conrad however, found no significant difference between the performance of the two groups on an amended version of the Donaldson Lip-reading Test (Montgomery, 1966) - a face to face test using short sentences. He also found that both groups performed significantly better when the test items were read from print, suggesting that the relatively poor lip-reading ability of the deaf children, which was no better than that of unpractised hearing controls, was not due to linguistic impairment or the particular materials used. Lip-reading did not enable the deaf children to extract meaning that was within their competence and otherwise available through reading. Vernon (1974, p.5) also reported similarly gloomy evidence that "In practice the best lip-readers only get 25% of what is said under ideal circumstances and these lip-readers are hearing, not deaf. The average deaf child lip-reads 5% of what is said to him". In the light of these findings,lip-reading should not be considered as a major compensation for deafness, and cannot be regarded as a magic and easy route to the learning of verbal language.

1.2.3 Fingerspelling. Fingerspelling is a visual-manual system of hand configurations that correspond to the letters of the alphabet.

Individual words are spelled out letter by letter on the fingers; there is a one-to-one correspondence with the orthography of written language, as in Morse Code, and the system presupposes a working knowledge of verbal language. It is a direct method of encoding verbal language visually. For example, the word 'hello' is spelled out h-e-l-l-o in rapid sequence and, like spoken languages, fingerspelling relies on the dimension of time and the temporal ordering of letters and morphemes to convey a message. If fluently presented, words appear as a continuous movement of the hands and fingers; the hands are in motion and the letters are not presented discretely as printed letters but as a rapid, transient trace. Fingerspelling is frequently used when no conventional sign symbol is available and for proper names. Fingerspelling reinforces reading and writing and may act as a 'bridge' between the written and the spoken word. In the United States, the method of communication involving fingerspelling and simultaneous speech is known as the Rochester Method.

All the methods of communication discussed so far rely on, and presuppose,a working knowledge of English. However, communication systems such as these which are based on verbal language, are rarely used by the deaf themselves for casual 'conversation'. Instead, sign language is used and appears to be the primary language of most deaf people and of deaf communities. Furth (1973, p.34) quoted what a deaf adult had once related to him to illustrate how difficult it is to suppress the spontaneous way in which most of the prelingually deaf population communicate: "You can cut off the fingers of deaf people and they will sign with their arms, and you can cut off their arms and they will sign with their shoulders".

1.2.4 Signs and sign languages. When considering sign language it is important to point out that it is not merely a gestural pantomime re-enacting incidents and situations, but is based on a visual-conceptual system of communication, not a verbal one. Gestures, as opposed to signs, are an integral part of our everyday communication - we may point, shake our head, beckon, and shrug our shoulders. These natural gestures are a means of communicating information, but this does not imply that they form a language in the sense of a formal linguistic system. An important distinction therefore has to be made between gestures and sign language. Each sign corresponds to a particular word, phrase or concept. There are few signs that are so obviously iconic or representational that a non-signer could guess the meaning without some additional cues, yet few signs are totally arbitrary - there is some degree of internal structure and some iconic associations, frequently historical.

In Britain there are regional variations in sign language, known as dialects, which are associated with the various deaf communities on a geographical basis. However, the British Deaf Association are currently involved in the production of a single dictionary of British signs in an attempt to improve the situation and provide a more unified base to British Sign Language. In the United States on the other hand, the sign language is more general and widespread, and is known as American Sign Language (ASL). ASL is very different from any form of English, written or spoken, it offers no help in the mastery of English and has its own syntax. Many of the 'grammatical' features of English, such as articles, plurals, verb tenses and prepositions are omitted.

Stokoe (1960) was the first person to begin a detailed study of ASL. The dictionary of signs produced by Stokoe, Casterline and Croneberg (1965) was the earliest attempt to catalogue signs according to the characteristics that differentiate one sign from another. It has enabled ASL to be studied in more detail and more widely by hearing people. Stokoe devised a set of elements, which he called 'cheremes', to describe the formation of individual signs. The three main types of element he labelled 'tab' (based on location), 'dez' (based on handshape), and 'sig' (based on movement). Stokoe identified 55 different cheremes in ASL, and suggested that their role was roughly analogous to that of phonemes in vocal languages. A vital distinction should be made, however, between sequentially ordered phonemes of speech, and sign cheremes which occur in synchrony, rather than linearly over time. A sign then is characterised not by successive and distinct cheremes, but by spatial events which coexist within a unit of time (Bonvillian, Nelson & Charrow, 1976; Lane, Boyes-Braem & Bellugi, 1976), and this as we shall see later (in Chapter 3) may influence the perception of temporal order by deaf people.

A question that is frequently asked is whether or not ASL is a language 'in its own right'?- language in the full sense of a linguistic system as opposed to a secondary language code, i.e. a manual-visual system for encoding English. There has been a tendency for many linguists, particularly those heavily influenced by Bloomfield (1933), to assume that all languages are primarily spoken and that other means of communication, such as written communication, have developed from the basic spoken system and are secondary to it. Hockett (1960, p.4) for example, outlined a set of 13 design-features shared by "all languages of the world" ...."The first design-feature -

the 'vocal-auditory channel' - is perhaps the most obvious". He then went on to write: "They become worthy of mention only when it is realised that certain systems other than language lack them". He would not, therefore, agree that ASL is a true language.

In fact there have been many strange, uninformed statements about sign language in the general literature. For example Lewis (1968) (the chairman of the Commission appointed, in 1963, to investigate the possible place of, besides other things, signing in the education of deaf children) described sign language as "lacking the systematic structures of a language" (p.37), and he is certainly not alone in this belief. It has been repeatedly suggested that sign language is limited to expressing concrete ideas, is a collection of gestures and lacks a grammar of its own (e.g. Van Uden, 1970). Van Uden has also claimed that sign language is primitive - an argument very similar to that made about the 'primitive' and 'inadequate' nature of Black Vernacular English (cf. Labov, 1972). It is perhaps significant however, that no such statement has ever been expressed by a linguist who has studied sign language, nor by an educated deaf person who uses sign language.

The work by Stokoe (1974, 1976) and Bellugi and colleagues (Klima, Siple, Fischer, Battison and Gough) at the Salk Institute for Biological Studies represents a detailed linguistic study of ASL, a direct contrast to the allegations made by some uninformed non-linguists from within the field of deaf educators. Sign language is said to be 'concrete' and 'pictorial'. This was one of the arguments that has been cited to demonstrate that it is not a 'real' language, i.e. not like a spoken language which is described by linguists as arbitrary. Bellugi (1976) pointed out that if signs were really as transparent in meaning as suggested, then hearing people who do not know sign language should be able to understand conversations between deaf people without an interpreter. Yet those who have tried this know that it is not possible, and my own initial experience supports this. Bellugi carried out a simple experiment as a further demonstration. She asked hearing people to guess the meaning of 90 different signs; very few guessed any of the meanings correctly. Bellugi (1976) also states that any deaf person would be able to tell you the signs for many non-concrete concepts such as 'government', 'law', 'character', 'idea', 'wisdom' etc. She concluded:"In sum,signs are in general somewhat less arbitrary than words simply because sign language evolved in a visual-gestural channel, but this does not in any way limit signs to concrete meanings ..... moreover, there is no intrinsic limit on what can be expressed in sign language" (p.334).

Lewis's characterisation of sign language as 'lacking systematic structures' implies that it has no system, no grammar, yet Bellugi et al. are finding that there is a very rich grammar based on principles suited to visual language. They have observed regular, predictable changes associated with regular changes in meaning. Bellugi (1976) concluded that "ASL does have a full set of grammatical processes of its own" (p.336). They are not the same grammatical rules as English, but this does not therefore imply that sign language lacks a grammar of its own. Stokoe (1976, p.7) wrote:

> Sign language has its own rules as well as its own lexicon, or vocabulary of signs; and rules and lexicon of Sign differ from the rules and lexicon of English. Seen as a whole system, then, Sign is quite like English or any other language.

It must be remembered that these statements regarding sign language have been written by linguists and researchers, including individuals who are themselves deaf, who have actually studied sign language in depth.

Their statements and findings are quite different from the allegations concerning the inferiority of sign language.

Bellugi (1971) has also studied the acquisition of ASL by a deaf child of deaf parents, and found a similar sequence of events as in the acquisition of any first language in hearing children (McNeill, 1970; Brown, 1973). Schlesinger and Meadow (1972) wrote several case-histories including that of Ann, who, it is reported, has by the age of 18 months a sign vocabulary that compares very favourably with the spoken vocabulary of many hearing children of a similar age. A parallel would seem to exist between speech acquisition and the acquisition of sign language, in terms of time of onset, the sequencing and size of vocabulary. A detailed analysis of several individuals has suggested that the milestones are similar. Signs are learned easily and naturally by deaf children given access to meaningful sign language input, a vivid contrast to the difficulties frequently encountered in the learning of verbal language. Even if deaf children are prohibited (as a result of the resolution passed in 1880 at the International Congress of teachers of the deaf that oral methods should be exclusively used with deaf children) from learning and using sign language in school, then they will usually acquire it surreptitiously from other deaf individuals outside of school in the deaf community, or even in the playground.

A deaf child of deaf parents shares the same linguistic system - the world is coded into a series of signs which the child learns to manipulate in much the same way as the hearing child learns to use speech to encode the world around him. For these children there is language and meaningful communication from the very beginning. The majority of hearing parents on the other hand do not know any sign language, and apart from a few crude gestures there may be very little communication with the child until he or she enters school. Parents who are able to communicate with their children by whatever means (and a deaf household may be a very non-oral environment) will naturally provide a significant part of the early educational, emotional and social support that is needed by every individual. Perhaps this is the reason why deaf children of deaf parent(s) or with close relatives who are deaf, appear to be brighter and to cope more adequately in school, which has been demonstrated repeatedly. For example, Meadow (1968) reported that deaf children of deaf parents scored higher on a self-image test than those with hearing parents. The discrepancies in self-image scores however, decreased with increasing age. Data from the Stanford Achievement Tests showed an average advantage of 1.25 years achievement in arithmetic, 2.1 years achievement in reading and 1.28 years in overall grade achievement for the deaf children of deaf parents, and she found that the gap in achievement scores increased with age. Vernon and Koh (1970) also reported similar findings in favour of deaf children of deaf parents, giving overall an average gain of 1.44 years - the reading average was 1.39 years better, paragraph meaning 1.57 years, and vocabulary 1.19 years better. These results were also based upon Stanford Achievement test scores. Using a matched-pairs design, Vernon and Koh were able to effectively control for possible differences due to the aetiological basis of deafness by only including deaf children of hearing parents with presumptive evidence of hereditary deafness.

Besides ASL and the various sign dialects that are used in this country, a number of other sign language systems have been developed which approximate to English word order, morphology, and syntax. One such example is the system which is known as 'Signed English' which was developed by Bornstein (1974). The late Sir Richard Paget also saw that the natural signing tendency of the deaf could be put to good use, rather than stifled, in order to develop a more structured, grammatical basis to English language in the form of a systematic sign language. Thus the Paget Gorman Sign System (P.G.S.S.) was created, which after Sir Richard's death has been further developed by O'Gorman, and studied by Craig (1973). This system of signs enables grammatical English to be encoded manually and visually. It was intended to provide a clear, systematic, complete and accurate visible pattern of spoken language, simultaneously with speech, and has been adopted in several schools throughout Britain.

1.2.5 Total communication. Total communication is a manual, auditory, oral system of communication. It includes the full spectrum of language modes - child devised gestures, sign language, speech, lip-reading, fingerspelling, reading and writing; the use of residual hearing is encouraged in order to develop speech and lip-reading skills. It is often erroneously referred to as a communication technique per se, but strictly speaking, total communication is a philosophy of educating deaf children (Denton, 1976). Since it was introduced into deaf education in the United States in 1968, it has received widespread recognition and acceptance.

### 1.2.6 A summary table of the different methods of communication used by and with deaf children.

| | |
|---|---|
| Lip-reading*: | speech is read on the lips of other people. A visual means of receptive communication. Relies on a good knowledge of the language being spoken. Lip movements tend to be ambiguous and difficult to interpret even under ideal viewing conditions. |

| | |
|---|---|
| Fingerspelling*: | words are spelled out letter by letter using either a one-handed or a two-handed manual alphabet. Requires good knowledge of verbal language, particularly spelling skills. A clear, unambiguous visual-manual method of receptive and expressive communication. Tends to be slower than normal speech or signing. |
| Rochester method*: | simultaneous one-handed fingerspelling and speech. If not sufficiently skilled the rhythm of speech can be lost. A visual-manual receptive and expressive means of communication. |
| Systematic sign language*: | a manual method of encoding English visually. Requires good knowledge of verbal language and is used for both receptive and expressive communication (e.g. P.G.S.S., Signed English). |
| Sign language: | a manual language which is not based on the syntax of the English language, but has its own lexicon and syntax. Used for both receptive and expressive communication within deaf communities and by the majority of prelingually deaf people (e.g. ASL and the dialects of native sign language used in Britain). |
| Total communication*: | use of visual, manual and auditory means of communication - residual hearing, amplification, lip-reading, fingerspelling, signs, gesture, reading and writing are all used to communicate both receptively and expressively. |

Note: * indicates a form of verbal language.

The use of different methods of communication are of obvious educational interest, but psychological issues are also raised. The psychologist recognises that all the above methods, with the exception of sign language, are visual means of encoding and transmitting verbal language, and will therefore reinforce the learning of verbal language. Verbal language is not however easily learned by deaf children and it has to be formally taught in the classroom rather than incidentally learned. Native sign language on the other hand is relatively easily acquired by young deaf children in the presence of others using sign language, but it is a different language, and may therefore interfere with, rather than supplement verbal learning. Underlying knowledge of the linguistic principles of sign language may interfere and be reflected in the deaf children's production of verbal language - this possibility is investigated in Chapter 6.

## 1.3 A brief history of the education of deaf children.

For many centuries the deaf were not recognised as being educable, and only slowly did they gain their rights in society as a human being. One of the earliest attempts on record at teaching deaf children, was the Benedictine monk, Pedro Ponce de Léon (1520-1584), in Spain. He taught a few carefully selected pupils for money. Not until the mid 18th century however, did the deaf person's right to education become established, and their education become more systematised.

Samuel Heinicke (1729-1790), an early teacher of the deaf in Germany, adopted a philosophical position inspired by Locke who claimed that thought was not possible without spoken language. Heinicke believed therefore, that speech was the necessary fore-runner of clear thinking, and that a person who had not learned to talk would be prevented from thinking in abstract terms. He opposed manual communication as being harmful to the intellectual development of the deaf. Speech at that time was also regarded as a necessary qualification for being a 'legal' person with rights to property, and without it a deaf person was forbidden to manage his own affairs. Heinicke is regarded as the 'founder' of oralism, with his staunch belief that the deaf had to be able to speak and lip-read in order to take their place in society.

In France meanwhile, Abbé de l'Epée (1712-1789), a contemporary of Heinicke, began to teach the deaf. He believed that the priority in deaf education was the teaching of language, compared to the narrower goal of speech. It was he who introduced manual communication and a sign language for the deaf into France.De l'Epée believed that sign language was the natural language of the deaf and should therefore be the medium for their instruction; Furth's suggestion (1966) that sign language is the 'true' language of the deaf is not, therefore, a new one.

Also at a similar period in time, Thomas Braidwood taught using oral methods in Scotland. For him the education of deaf children was a private and commercial business, and therefore he considered the methods he used to be his 'trade secret'. Thus, when Thomas Hopkins Gallaudet travelled from the United States to Scotland, to learn about methods used in the education of deaf children, no information was forthcoming. So Gallaudet proceeded to France where he learned the manual methods of de l'Epée from his successor, Abbé Sicard, and took them back to America in 1817. It is therefore, almost a historical accident that Gallaudet College is today the centre of manual communication in North America, and well-known throughout the world.

At the International Congress of teachers of the deaf held in Milan in 1880, it was resolved that in future oral methods were to be used exclusively in the teaching of deaf children:

> The Congress considering the incontestable superiority of speech over signing in restoring the deaf-mute to society, and in giving him a more perfect knowledge of language, declares that the oral method ought to be preferred to that of signs for the education and instruction of the deaf and dumb.

This resolution, passed nearly 100 years ago, gave a great impetus to oral methods, and was reflected in the subsequent expansion of oral practices all over the world. Since then Britain has been officially recognised as a country supporting the oral tradition. Thus, the official policy of the National College of Teachers of the Deaf is oral. A further impetus was provided by Dr. Kerr Love, who in 1890, claimed that only 10% of the deaf were in fact totally deaf and introduced an awareness of residual hearing. He emphasised the vital role of auditory training in oral teaching methods.

In 1893, the Elementary Education (Blind and Deaf Children) Act was passed and provided for the compulsory attendance at school of all deaf children aged between 7 and 16 years. In 1937 the lower age limit was reduced to 5, and in 1946 was further reduced to 2, but remains optional until the age of 5 when school attendance becomes compulsory for all children. But should the parents desire it, education must be provided by the L.E.A. from the child's second birthday.

In 1919, a University department was founded in Manchester to train teachers of the deaf, and until 1965 it had the monopoly of the field and was therefore very influential. This department, under the late Professor Ewing, is, and always has been, committed to oral methods of teaching the deaf.

## 1.4 The oral-manual controversy.

In the mid 18th century a controversy developed over the type of communication that should be used to teach deaf children, between those who advocated, like Heinicke, that oral methods (speech and lip-reading) should be used exclusively and that manual methods should never be resorted to, and those who believed, like de l'Epée, that manual methods (signs and fingerspelling) are necessary to teach deaf children adequately, since they are less ambiguous and easier to perceive. The controversy was never resolved and is still a major issue. One cannot be concerned with deaf children for very long without becoming involved in the bitter debate between the two schools of thought and practice.

The dispute concerns the best way of achieving agreed aims, and involves a choice of priorities - whether one aims at speech at all costs because our society is a hearing society and relies heavily on communication by speech, or whether one should concentrate on other efficient means of communication, not necessarily speech, which allow deaf people to communicate between themselves, but at the same time segregates the deaf community into their own sub-culture to a large extent. The controversy disregards the probability that different deaf children have differing needs and do not necessarily respond in the same way, or benefit to the same extent from the same approach. As Furth (1973, p.34) wrote:

> It is difficult to convey adequately the issues that are implied by the phrase the oral-manual controversy. This controversy which is as old as deaf education colours all educational considerations; any major decision or change concerning educational practices implies some stand on the controversy. It is much more than a difference in teaching methods; it touches the very core of deaf people's existence. Indeed, in its extreme form oralism is nothing less than a denial of deafness.

Viewed historically, oralism would probably never have gained such status in the early years of deaf education if the majority of the children at that time had been prelingually deaf as the majority are today. Oral methods of communication are particularly successful with the postlingually deaf (who have previously heard and acquired verbal language), and were therefore ideal with the small, private classes of postlingually deaf children of the 19th and early 20th centuries.Today oral methods are still being used, but with a very different population of deaf children - the prelingually deaf who have no prior knowledge of verbal language. One persuasive argument used by 'oralists' in favour of their methods is that the world is a hearing world and that speech is the basic means of communication used by our society. They argue for the necessity of living in such a world and of having to communicate with hearing persons, and they hold the philosophical view that speech alone separates man from animal. They assume that all deaf children can be taught to speak and lip-read, and that manual communication destroys the chances of oral success.

The 'manualists' on the other hand, have recognised that despite the ideal of every deaf person being able to speak intelligibly, the majority of the prelingually deaf cannot produce speech sounds sufficiently clearly to be able to communicate intelligibly. Their speech is not therefore of functional use in the world of hearing people. Many deaf individuals appear to need the manual supplements of signs and finger-spelling to learn language, and so that they can communicate with other deaf people.

It may seem very surprising to outsiders that such a debate over methodologies has continued for so many decades. For years this polemic has largely been confined to those directly concerned with deaf education. There seems to have been very little attempt to consult other disciplines, such as psychology, to help analyse the important problems. In fact, only very recently in this country have psychologists,such as Dr. Conrad and Dr. Montgomery,been invited to present their ideas at major conferences. Until the 1960's there was virtually no objective research; most of the abundant literature on the subject consisted of 'position' papers in favour of one or other of the methodologies. Such subjective evidence is difficult to evaluate and has tended to further obscure, rather than enlighten, the whole issue, and continues to do so. The socio-cultural context of linguistic communication within the deaf community has also largely been ignored. Viewed in this light, it is perhaps less surprising that the controversy has continued for so long. The proceedings of the R.N.I.D. conference on 'Methods of communication currently being used in the education of deaf children' (1976) is an excellent source of information, and the divergent views are clearly and typically reflected.

Today, the debate over methods of communication continues in the modified form - oralism versus total communication. No-one is now advocating the exclusive use of manual, silent methods of communication with deaf children, but rather the use of signs, fingerspelling and speech,i.e. a combination of methods - total communication. This change may be largely attributable, it seems, to a lead from the United States, where a series of research studies have contradicted that which had been commonly assumed, namely that manual communication hindered the development of verbal language and oral skills. Studies by Stuckless and Birch (1966), Meadow (1968) and Vernon and Koh (1970, 1971) have all shown that exactly the opposite is true - that early use of manual communication with young deaf children results in lasting gains in educational achievement, for example their reading, vocabulary, written language, paragraph meaning and arithmetic were reported to be superior to that of deaf children receiving early oral communication or oral pre-school education. This may possibly be a result of the difficulties encountered in teaching oral language unambiguously to very young prelingually deaf children using visual methods. Even more surprisingly, Stuckless and Birch (1966) found no difference in the intelligibility of speech, and better lip-reading skills in the group of deaf children using early manual communication compared to a similar group who had not used early manual communication ('early' here referred to the introduction of manual methods of communication before the age of 2). There is however an important confounding variable which cannot be ignored, the children receiving early manual communication were mostly, though not exclusively,the deaf children of deaf parents, and those brought up in an early oral environment tended to be the children of hearing parents, though again not exclusively. There may well be other important factors besides the early use of different methods of communication, such as differences in parental acceptance of the child who is deaf, and the very likely advantage of parents who are deaf using and sharing the same linguistic code as their deaf children. It is an untested idea that deaf children are accepted more readily by parents who are themselves also deaf (Vernon, 1971) and that they are better adjusted to their handicap of deafness than many deaf children of hearing parents, for whom the birth of a handicapped child may be traumatic. Furthermore, there are the additional problems of diagnosis which may be slow and uncertain, and there is also the possibility of parental rejection.

In a comprehensive review of the literature on the use of manual communication, Moores (1971) concluded that the results suggested that early manual communication facilitated the development of language and academic achievement generally and that speech and lip-reading skills were not impaired as previously assumed. This being the case it is surprising then, that every educator of the deaf who has heard of these research studies, does not regard the matter as clear-cut - the major argument against the use of manual communication, namely that it hindered the development of oral skills, has been shown empirically to be untrue.

The situation is obviously not as straight-forward as it might at first appear - the experimental evidence supporting early use of manual methods is counterbalanced by equally convincing studies demonstrating the success of oral methods. One such recent example is that of Lane (1976) who studied 731 orally educated deaf adults. She does not in any way contradict the above findings, nor does she attempt to do so, for no reference is made to any of the above studies, but presents, as a psychologist, an account of the success of oral education, leaving the reader in very little doubt that oral methods are essential for a proper education of deaf children. There is no mention of, nor discussion of, alternatives - it is a totally one-sided presentation. She defines 'success' as the achievement of academic success - "a favourable result or a wished-for ending" (p.329). She states that her large sample are not less deaf, and that this, therefore, is not the reason for their success. She also reports subjective evidence of the success of oral education by the deaf people themselves. This is one example of a study that does not examine achievement levels per se, but implies unequivocally that the academic achievement of the group was excellent. The reader is given no information about whether the individuals included in the sample had deaf or hearing parents nor about their early communication history, factors which other studies have shown to be very important. Given this sort of evidence how can the educators of deaf children attempt to reconcile the findings? Experimental evidence does not appear to have helped to clarify the situation. There is no longer a lack of evidence, and proponents of both the oral and the combined methods can select isolated studies and generalise beyond the particular samples, to support their case. These then are the problems facing teachers of the deaf, who were perhaps hoping for a definite lead from research studies and outside investigators.

Speaking as a psychologist, it is clear that no adequate control studies have been carried out, nor indeed can they be undertaken when there are so many confounding variables. Home background, parental and teacher differences, and differences in educational techniques and philosophies, cannot ever be adequately controlled for when one is working in a real-life situation, with real people and the ethical problems associated with such a study. It is clear that the results from any single study cannot be generalised beyond the particular group under study, and are only relevant for that particular period of time; a small change in either personnel or teaching techniques can quite easily radically alter the outcome.

Perhaps then, the concept of the best method of communication is unrealistic. Certain deaf children seem to respond better to oral methods of communication and others to the use of both oral and manual methods and the factors which determine this remain unclear at present. Individual differences are certainly very important. What is significant however, is that the achievements in verbal language of neither orally nor manually communicating deaf children are outstanding, nor do they approach the linguistic abilities of hearing children of a similar age.

In Britain the need for research was realised in the early years of the 1960's. In 1964, the then Secretary of State for Education and Science set up a committee under the chairmanship of the late Professor Lewis to investigate "the possible place, if any, of fingerspelling and signing in the education of deaf children". In 1968 the results of the investigation were published - 14 recommendations were put forward including the suggestion that research "should be undertaken to determine whether or not and in what circumstances the introduction of manual media of communication would lead to improvement in the education of deaf children" (p.106). The Lewis Report and its endorsement by the Department of Education and Science, gave deaf schools in Britain licence to use manual methods. This step represents the first official recognition of the possible need for alternative methods since the resolution passed in 1880 at the Milan Congress that speech and lip-reading should be exclusively used in all schools for the deaf. One of the other recommendations however, was that steps should also be taken to secure the conditions in which every deaf child can have the fullest opportunities of oral education. The new and important difference being the word 'can', rather than 'must' which at least implies a choice. This then, is a move towards the present situation in the United States.

As a result of the above recommendations for research into the use of manual methods of communication in the education of deaf children, a 5-year (1973-1978) D.E.S. project was set up in the Northern Counties School for the deaf, Newcastle-upon-Tyne, to study the use of one-handed fingerspelling. It was in this deaf school in Newcastle that the present study was carried out between 1973 and 1976. In Britain the two-handed manual alphabet is most widely used, whilst in the United States the one-handed system is employed, and it was the American system that was introduced experimentally into the Newcastle school. (See Appendix A for the one-handed and two-handed manual alphabets.)

Relating to my earlier discussion of some of the problems that are associated with research concerned with the evaluation of communication methods, it is interesting to note that the research project mentioned above studying one-handed fingerspelling was fraught with all kinds of difficulties such as teacher cooperation, the problems of how one assesses adequately possible benefits of using a particular method of communication, and, perhaps most important of all, actually getting the children to use the system of fingerspelling under study when they have previously used the two-handed system, and while some of their parents and the deaf community at large continued to do so. This particular problem was reflected by the continued persistence on the part of some of the deaf children to use two-handed fingerspelling outside of the classroom. Consequently, financial support from the D.E.S. was cut short after only three years of the study - not a fair reflection one feels of any shortcomings of the actual communication system which was being studied, but of the more general problems associated with undertaking any study of this kind.

In this section the 'oral-manual' controversy has been introduced at length - within the field of deaf education it is regarded as the most important issue. Conference after conference has been devoted to discussing the relative merits, and arguments have been repeatedly presented both 'for' and 'against' the use of oral and manual methods of communication. As DiCarlo (1966, p.269) so rightly remarked:

> Of the many controversies in the education of the deaf none has generated more volcanic cinder, less illumination; precipitated more vitriolic diatribe, less dispassionate survey; promoted more vested interest, less freedom from bias; and completely confounded fact and fiction, than the issue of methodology.

Having discussed the main methods of communication in current use and the resulting controversy, as viewed from within the field, and presented my own formal analysis of the situation as a psychologist and someone who is not first and foremost concerned with the education of deaf children, I shall now leave this subject and for the rest of the study concentrate on the system of communication that was used in the particular school in which the present study was carried out. Here, the main teaching method was fingerspelling, mainly one-handed, in conjunction with speech and lip-reading. Some classes however, were taught by exclusively oral means, and others, where there were children with additional learning problems, were taught using some sign language as well as speech, lip-reading and fingerspelling, i.e. total communication. Fingerspelling was used with the older children as a means of rapidly and unambiguously transmitting verbal language for teaching purposes, and with the younger children (those in the Lower

School), it was used as an aid to the acquisition and development of verbal language.

## 1.5 Hearing loss and audiometry.

Hearing loss, which may range from a mild to a profound loss, is measured by audiometric techniques. The hearing loss is measured in relation to the normal threshold of hearing which is found empirically and referred to as 0 dB. (The decibel (dB) is a logarithmic measurement of intensity; it is not based on a fixed unit but a ratio, it is therefore necessary to have a fixed frame of reference - .0002dynes/cm² at 1000 cycle frequency). The intensity tolerance of the human ear is about 1-120 dB; ordinary level of conversation is about 60 dB. With a hearing loss of 75 dB or over in the better ear, even with the aid of amplification, an individual will have little awareness of different speech sounds. The sensitivity of the ear is not the same for all frequencies in the audible spectrum and so a threshold determination is necessary at a number of different frequencies. Each ear is tested separately.

In pure-tone audiometry pure tones are presented at various frequencies, usually over the range 250-4000 Hz, which are known to be particularly important for hearing and understanding speech sounds. The sensation of pitch depends on the frequency of the tone, and the loudness depends on the intensity (dB level). At each frequency tested, the intensity is reduced in 10 dB steps until the sound is no longer audible and then raised in 5 dB steps until it can be heard once again. This procedure is repeated until a reliable measure of the threshold of hearing is obtained at a particular intensity at a given frequency. The threshold readings are plotted on an audiogram, frequency against hearing level (see Appendix B for a typical example of an audiogram). An average hearing loss in dB is frequently quoted

for the better ear over the frequencies 250, 500, 1000, 2000 and 4000 Hz, but this conceals important information concerning the high and low frequency ranges relevant to the discrimination of speech sounds. Lewis (1968) overcame this problem by devising a system whereby the hearing loss over the frequencies 250, 500 and 1000 Hz were averaged - the low frequency loss, and over the range 1000, 2000 and 4000 Hz for the high frequency loss. He used four categories: 0< 30 dB - a
30< 60 dB - b
60< 90 dB - c
90+ dB - d

For example, the deaf individual whose audiogram is presented in Appendix B has an average hearing loss of 52 dB over the low frequency range (250, 500, and 1000 Hz), and an average loss of 77 dB over the high frequency range (1000, 2000, and 4000 Hz). Following Lewis (1968) the hearing loss of such an individual would be represented as 'bc'. This system provides more useful information, and is used in the present study in Chapter 3, in an attempt to relate individual differences in immediate memory performance with hearing loss and other factors.

The majority of deaf individuals do not have an overall loss of say 60 dB over the frequencies of sound tested, but may have either a significant high or low frequency loss. Speech consists of complex sound waves, the frequency range of which is defined for most purposes at between 250 and 4000 Hz. Generally speaking, vowel sounds occur at low frequencies (around 500 Hz) and consonant sounds at higher frequencies (2000-3000 Hz). The perception of speech depends largely on the ability to discriminate between consonants which are the least predictable and which carry the most information. High frequency deafness is therefore a greater handicap to accurate speech perception than low frequency deafness, for the understanding of speech on the basis of vowel sounds only is practically impossible, whereas it is more feasible with consonant sounds only. The ability of a deaf person to perceive speech can only be roughly assessed from a pure-tone audiogram, for the relationship between pure-tone thresholds and speech perception is not a simple one. Speech audiometry, using speech sounds instead of pure tones, gives a more accurate assessment of the ability to perceive speech.

In the following chapter the effects of deafness on language development will be considered, and some of the problems that were encountered whilst working with deaf children in a field situation discussed.

# CHAPTER 2

# RESEARCH WITH THE DEAF

## 2.1 The effect of deafness on the development of language and intellect.

2.1.1 Speech and language. Early deafness has far-reaching effects on many aspects of development the most noticeable of which is lack of speech. Perhaps more basic and important however, is the lack of verbal language of the majority of prelingually deaf people, with consequent retardation of all those intellectual and cognitive skills which are dependent on verbal language. The actual role of verbal language in cognitive development is a question that is currently being discussed. Piaget and his followers minimise the influence of verbal language in children's intellectual development. They suggest that logical operations are not dependent on language behaviour, but are rather reflected by it. Following this line of reasoning, one would predict that deaf children with deficient verbal language would not be very different from hearing children with regard to their attainment of 'logical operations'. Several attempts have been made to test this within the framework of Piaget's theoretical model. Furth (1964) published a paper in which he reviewed a series of empirical studies of deaf people's performance on non-verbal cognitive tasks. He concluded that deaf subjects performed similarly to hearing persons on a wide range of tasks where verbal knowledge could be assumed to benefit the hearing. He wrote: "The ability for intellective behaviour is seen as largely independent of language and mainly subject to the general experience of living" (p. 162). Blank (1965) attacked Furth's conclusions that studies of the deaf indicated that intellectual development proceeded independently of the acquisition of language, on the grounds that the deaf often do possess a verbal language and may not therefore, be considered as language deficient, and that his choice of task assumed that symbolic activity was necessary, an assumption that she believed was open to question. The type of debate which Blank opened regarding Furth's ideas, is not easily resolved. Certainly Furth has not publicly replied to Blank's criticisms or attempted to justify his position, but has continued to publish both books (1966a,1973) and journal articles (e.g. 1971) along the same line of reasoning. One additional criticism, which has not I believe been made elsewhere, is that Furth appears to neglect the possible contribution of sign language in the development of logical thought, and yet he himself refers to sign language as the 'true' language of the deaf (1966a).

Children with normal hearing begin to talk around the age of 18 months to 2 years. When hearing is substantially impaired from an early age, verbal language is only learned with a great deal of difficulty. As Furth (1964, p. 147) wrote about deaf children: "They are apparently normal children growing up in a society and culture which is intimately bound up with language despite the fact that they themselves have had minimal direct exposure to the all-pervading linguistic environment."

Normal hearing is a necessary pre-condition of learning to speak normally, and until around the age of 6, hearing children develop their verbal language from an oral input, the visual aspects are very much a secondary feature. Broadbent (1958, p.3) wrote:"It is the ear which is primary in the development of language, and written alphabets are secondary." If the auditory system is impaired then the natural communication system is disrupted and one might expect to find fundamental differences in areas of cognition involving language. The language problems of deaf children and adults have received a considerable amount of attention (e.g. Alterman, 1970; Brown & Mecham, 1961; Furth, 1964; McNeill, 1966a) probably more than any other single problem associated with deafness, but then language is a critical feature of human behaviour.

Speech, the actual articulation of sounds and words, is in fact not a reliable indicator of linguistic competence. A deaf child with good speech does not necessarily have good language, and conversely, a deaf child with good language does not necessarily have good speech. In most cases the prelingually deaf child however, is not only without intelligible speech, but lacks also an extensive vocabulary and knowledge of the syntax and morphology of English. A serious linguistic retardation is generally found in the profoundly and severely prelingually deaf irrespective of how they are taught - whether by 'oral', 'manual' or 'combined' methods. This fact is emphasised time and time again by Furth (1966a) who wrote: "The fact is that under present educational systems the vast majority of persons born deaf do not acquire functional language competence even after undergoing many years of intensive training" (p.13), and "For all practical purposes, however, the typical deaf person, whether child or adult, is a language deficient person both in his present functioning and in past experience" (p. 15). Furth was using a satisfactory command of 'correct' English as his criterion.

This view however, is not shared by all, as illustrated by Ivimey (1973) in an article entitled 'Teach your child to be deaf and dumb'. This was included in the influential magazine 'Talk', which is published by the National Deaf Children's Society and circulated widely among parents of deaf children. Without any data or research to support his argument, he wrote: "The fact that many deaf children do acquire normal language shows that it can be done. Deafness is not a total barrier - it just makes the path of learning a bit rougher" (p. 23). Ivimey, a lecturer in the education of deaf children at the London University Institute of Education, certainly minimises the language difficulties of the deaf. He seems to have generalised from particular children and assumed this to be true for all categories of deafness. Furth (1966a) on the other hand, appears to have been more aware of individual differences and the factors that are vitally important in any practical assessment (such as was made by Ivimey), when he wrote:

> The occasional deaf adult who is thoroughly at home in English has either lost his hearing after the establishment of language or does not have so serious a hearing loss as to be justifiably classified among the deaf, or finally, he may be an exception. (p. 15)

There is then at present no general agreement in the current literature on the effects of deafness on language and cognitive development, an area that requires further research. Most people however, do agree that the profoundly and severely prelingually deaf are clearly deficient in their verbal language ability and that this, as we shall see, is reflected in other ways besides their oral language - in their reading and ability to express themselves correctly in written language. It must however be remembered that this lack of verbal language does not mean that the deaf are deprived of all symbolic behaviour. The deaf are not only linguistically retarded but linguistically different.

2.1.2 Written language. Written language is the product of language experience. The hearing individual makes use of accumulated experience and may encounter phrases innumerable times through hearing and reading, whilst the deaf child frequently lacks sufficient experience of the correct form, and is therefore, retarded in verbal language generally. The deaf frequently do not manage to master the basic structures of verbal language, which is clearly reflected in their written expression - countless grammatical errors are made- a striking departure from standard English. This is a problem to which we will be returning in Chapter 6.

2.1.3 Reading. Reading involves the perception and reception of verbal language in print, and is a very complex serial skill involving both visual and phonological patterns. Usually a child learns to read words and language with which he has already had extensive oral experience and with which he is therefore already familiar. A hearing person learns to associate the visual pattern with the auditory speech sound of the spoken word; a number of psychologists, like Gibson and Downing, are in fact trying to produce an adequate, working model of this process of learning to read, but as yet there is no simple, generally accepted model.

A deaf child however, must learn to read without the benefit of a wealth of previous auditory verbal experience. The deaf child may learn to associate the written word with the 'feel' of the articulated word, or the sight of the word on the lips of another person, or the object itself, or an image of the object, or the sign, or the finger-spelled representation of the word. Some people believe that after a deaf child has learned to read, all his/her problems are solved. For example Fowler (1974, p. 2) wrote: "Those who are deaf or severely hard of hearing learn to speak only with great difficulty; but as soon as they can be taught to read and write they pick up a knowledge of language which may be perfect except in its phonetic manifestation". This statement could not be further from the actual situation and is in direct contrast to the repeated emphases made by Furth (1966a) and quoted in section 2.1.1, of the lack of verbal language in deaf children and adults.

A child with a language deficit owing to severe or profound prelingual deafness will have great difficulty learning to read. Low reading attainments are nearly universal in the deaf, and provide some indication of the difficulties encountered by children who have not learned language through hearing. Furth (1966b) undertook a comprehensive survey of the reading ability of about 5,000 deaf children in the United States, aged between 10½ and 16½. He reported that by the age of 16½, only 12% scored at Grade 4.9 or better (a reading age of about 11 years) based on hearing norms, and he suggested that this level "was arbitrarily chosen as a reasonable cut-off point between those pupils who appear to have reached a functionally useful ability to read, versus those who may know some vocabulary and do some intelligent guessing but can hardly be said to know the language as expressed in written English". (Furth, 1966b, p.461).

The concept of 'functional literacy', which Furth (1966b) has suggested is reached at the end of the 4th Grade in the United States, i.e. a reading age of about 11 years, is one that is currently being discussed. There has been general concern about the reading standards of our own nation, which is reflected in the recent publication of the most significant document on reading to appear for many years (Bullock, 1975). Bullock summarises a number of viewpoints on the issue of 'functional literacy', including that of Moyle (1973) who regards a reading age of 13 as necessary to read the simplest of the daily newspapers with 'a reasonable level of comprehension'. Bullock also refers to the 1950 Ministry of Education booklet in which an illiterate person is defined as someone with a reading age of less than 7, and a semi-literate with a reading age of between 7 and 9 years on the Watts-Vernon test. It is clear therefore, that a single criterion of literacy has not been agreed upon, but is more a matter of opinion at the present time, and the opinions differ widely. Whatever the criterion, deaf children are not able to read as well as their hearing peers, and their reading ages are indicative of their competence with verbal language. As Furth (1966b) wrote: "The measurement of reading disability presupposes a linguistic competence which is not present in the deaf. The low reading level of the deaf does not constitute a reading deficiency but linguistic incompetence" (p.462).

Conrad (1977b) reported equally gloomy findings from the results of a recent survey of the reading achievements of 355 profoundly deaf children of school-leaving age (15-16½ years old) throughout this country. He found that over half of the population sample with a hearing loss of at least 85dB, had a reading age of less than 7.6, that is their reading achievement is less than that of the average 7½-year-old child with normal hearing,based on standardised measures of reading ability. Both these research studies pin-point and agree upon the very specific and substantial reading deficiency of profoundly and severely prelingually deaf children.

The problem is not however straightforward, for the average 9-year old deaf child has a reading age of 7, and yet when he or she leaves school, his or her reading ability will have improved very little in spite of the intervening years of schooling. This particularly striking finding has been reported by several independent researchers. For example, Wrightstone, Aronow and Moskowitz (1963) found in their study of over 5,000 deaf students that the mean Grade equivalent scores only increased from 2.8 to 3.5 years in the 6 years between the ages of 10½ and 16½.

Similarly, Vernon (1969) also reported that the average gain in reading ability was less than one year between the ages of 10 and 16 years. For some reason the relatively good start to learning to read is not consolidated; this is one of the problems that is currently being investigated by the deaf research group in the Psychology Department of Nottingham University (1976-1981).

Thus teaching a deaf child to read is not the easy solution to language problems that it might at first appear to be. The input of written language may be visual, and therefore, theoretically easily perceived by deaf children, but it is the more basic underlying linguistic incompetence that causes the learning difficulties and creates the reading deficiency.

2.1.4 Intellectual functioning and studies of the intelligence of deaf children. The traditional way of assessing intellectual development is by evaluation of performance on standardised tests which purport to measure intellectual ability. Tests of so-called 'intelligence' have been administered to deaf children for over 60 years - Pintner and Paterson (1915, 1916, 1917) were probably the pioneers in this field. Since these early days some 50 or more comparative studies of the intelligence of deaf children have been carried out, and there has been much discussion concerning the relationship between deafness and intelligence. The reference made by Pintner and Paterson (1918, p. 10) to the "mental inferiority of the deaf" typifies the rather unfortunate, but nonetheless common, misconception that deafness is associated with lack of intelligence and general stupidity; a misconception that has arisen through ignorance and also as a result of the use of inappropriate tests. In deaf children verbal language ability is not a reliable index of their mental/intellectual capacity, and one needs therefore, to distinguish between measures of mental ability as judged by 'performance' (or non-verbal) tests, and measures of language ability reflected by their scores on 'verbal' tests. Profoundly and severely prelingually deaf children will obviously appear very retarded on verbal tests as is also reflected by their reading achievements.

Vernon (1968) reviewed 50 years of research on the intelligence of deaf and hard-of-hearing children (his term for the partially hearing) and concluded that the range of intelligence among those with a profound hearing loss was as great as the range among 'normal' hearing people on tests which do not require specific verbal proficiency. It is only when researchers draw their conclusions about the general intelligence and the intellectual ability of deaf children from the results of tests which rely heavily on verbal instructions, and the comprehension of verbal material, that a general inferiority is reported. Such findings are not contradictory, but merely reflect the different nature of the test and the poor verbal abilities of deaf people.

No direct relationship has been found between the degree of hearing loss and I.Q., or age of onset of deafness and I.Q. However, it seems that there may be a relationship between slight mental retardation and deafness in a few individuals which is not causal, but due to common aetiology bringing about both the deafness and the retardation.

### 2.1.5 Current research studies of the thinking processes of deaf people.

The influence of verbal and non-verbal language on cognitive and intellectual development is one of the most intriguing problems in psychology. Psychologists have realised the opportunity offered by the presence of linguistically abnormal people, to test their theories concerning the influence of verbal language on various cognitive activities subsumed under the more general heading 'thinking'.

Today, the major challenge is to discover more about the cognitive functioning of profoundly and severely prelingually deaf people. Research into the thinking processes of deaf individuals was begun in earnest by Furth (1964, 1966a) and later taken up by Conrad (1970), but is still in its early stages. As Conrad (1970, p.179) wrote:

> It is an elegant and deceptively simple question that Furth (1964) asks: what do deaf people think in? ... whilst Furth and his collaborators continue their trenchant studies of thinking in the deaf, the question of what they think in remains elusive.

He concluded: "That the deaf with little overt speech, learn to think is self-evident, what they do it in remains a challenge with perhaps far-reaching implications" (p. 194). Statements such as these are quite as true in 1979 as they were at the beginning of the decade. But certainly there is a very real need to study, and to understand more fully, the medium of thought of deaf children (which may differ according to the individual), and apply the findings to future educational programmes. Levine (1976), in her recent evaluation of possible contributions of psychology to our understanding of deafness, has also pinpointed the need for research which aims to discover some of the basic processes involved in deaf information processing, so that we might begin to understand the reasons for the relatively poor learning achievement of the deaf generally.

The whole question concerning the relationship between language and internal language, speech and internal speech, is being studied in hearing as well as in deaf persons. Most 'normal' hearing people appear to make substantial use of silent speech as their internal language, particularly in verbal tasks. Conrad (1976a) recently spoke on this important question at a conference, and is worth quoting at length for his clear statement of the major issues. He said:

> One thing we know is that internal speech is helpful over a wide range of cognitive operations. What we don't know is whether any internalised language will do equally well. In particular we don't begin to know what happens when a child is concurrently learning two modes of the same language - like speech and a sign mode. Crucially, does he develop internal language in both modes - and do they facilitate or interfere with each other? Or does he develop just one - and which one, because that's the one he'll think in. (p. 151).

The problem has certainly been very lucidly formulated for us here by Conrad. It is a very difficult field within which to operate, with many problems, many questions to be asked, and as yet,few answers, but it is a challenging area into which some researchers are moving, including the present writer.

## 2.2 The problems encountered whilst working with deaf children.

Deafness is a very heterogeneous condition and so one should not take all deaf persons and place them in a single category, for there are great differences according to the degree of hearing loss, the time of onset of deafness - whether prelingual or postlingual with the cut-off defined as two years of age, the family background of deafness, and the different methods of communication used at home and in the schools. There is therefore, no such thing as a typical deaf child, or group of deaf people, and any findings obtained from studying a small sample of deaf children intensively cannot be generalised to other groups of deaf children from different schools.

Working with deaf children means that one has a built-in communication problem. It is, I believe, very important to communicate directly with the deaf child being tested, rather than via an interpreter. One needs therefore, to have experience and knowledge of the various methods of communication used by the particular group being tested.

In the test situation, the experimenter needs to be able to interpret and understand the children, without continual repetition and explanation on their part, and whatever mode of communication they choose to employ. It may easily take up to a year before one can cope adequately with this type of situation. Effective communication is therefore a basic necessity, and is a very demanding requirement.

In spite of the above, the understanding of deaf children can still present a major problem, and misunderstandings may all too easily arise. Furth (1966a) quoted a typical example of such a situation which concerned the use, and understanding, of the word 'more'. The young deaf child in question had only come across this word at meal times, to indicate the desire for a bigger, or a second-helping. Therefore, when faced with two piles of dried beans, one pile obviously much larger than the other, and asked by the experimenter which pile had more beans, the child replied that it was the smaller of the two piles. This response seemed surprising until it was realised that the child had understood and responded to the question 'which <u>needs</u> more?' instead of answering the actual question 'which pile <u>has</u> more?'. One needs therefore to be continually aware of possible sources of misunderstanding, such as the one quoted above, in order to begin to understand the logic and reasoning of the children, and interpret results in a more meaningful way. To work as a complete 'stranger' to the system and to the deaf community is, in my view, totally inadequate, and can all too easily lead to false or superficial conclusions being drawn.

The satisfactory matching of a sample of hearing and deaf children is another major problem. It is very difficult to make meaningful comparisons between different groups. For example, as already mentioned, most deaf children have significantly lower reading ages compared to hearing children of a similar age. It is therefore, virtually impossible to control for reading ages and chronological ages. At best, the matching of control groups for the relevant factors can only be an approximation of limited validity. Frequently, little, or no provision is made, or can be made, to control the countless variables that are likely to contribute to test performance.

Probably the greatest problem of all is gaining access to a deaf school for a long period of say,three years. It is not always easy to obtain the cooperation from all the teachers concerned, or have the necessary freedom to mix freely within the school. To achieve the desired level of integration requires persistence and patience, and a certain commitment, for it can be a very time-consuming and absorbing activity. General familiarisation with the teaching methods and day-to-day running of the school, and also the extra-curricular activities, were all deemed to be very important for a realistic and competent assessment of the school environment and the children within it.

The participant-observer approach, combining insight and detailed knowledge of the deaf children with whom one is working,with the skills of an objective experimental psychologist, can itself create problems. One risks immersion in the problems and local politics, and becoming as involved as the personnel within the field. This can make it difficult to maintain the primary scientific goal objectivity, absolutely essential if the research is to carry any general validity.

### 2.2.1 <u>Working with deaf children - some special testing requirements.</u>

The problems of working with children and using them as experimental subjects are accentuated when working with deaf children. They are frequently very anxious and lacking in confidence in an unfamiliar situation faced with an unfamiliar task. It may take longer, and require greater ingenuity to establish the vital rapport that is necessary before one begins each test session.

Great care needs to be taken over the instructions, the important points need to be stressed repeatedly. No set or standard form of instructions is practical and many practice trials are helpful to ensure adequate understanding. It is however very difficult to be certain that the apparent understanding of deaf children is in fact real understanding. Many deaf individuals have developed a set for compliance with hearing people, and this can be very misleading for a researcher. An experimenter is only interested in the incorrect responses that occur as a result of the operating characteristics of the subject's information processing system, and not those due to failure to understand the task. If a task contains a strong linguistic component, particularly in its instructions, then the results will merely reflect the poor linguistic ability of the child who is deaf, rather than his ability to perform the task. It is similar to judging the performance of a hearing child using a test, the instructions of which are delivered in a language that the child is unable to understand, say Japanese! Obviously it is not always possible to create situations in which all linguistic behaviour is suspended, but it is possible to contrive circumstances in which spoken language is not an essential part of the experimental situation, and overt verbalisations are not a necessary part of the proceedings. For a deaf person 'verbal' thinking may be the image of a written word, or the word seen on the lips of another person, a fingerspelled word, or a sign. It is therefore important to sort out difficulties of test administration and language competence from the problems of information processing.

The tasks chosen for the test sessions should ideally allow individual children to approach the task and process the relevant information as they choose. If the experimental conditions are manipulated too closely then one may also be manipulating the coding strategies and the whole approach to the task. For example, a situation could be designed in which only visual coding was applicable and no verbal coding was possible, and as a result one might conclude that the subjects could only code information visually - an unfortunate conclusion reflecting the flaw in the original design rather than processing ability of the experimental subjects.

Serious consideration of the ideas originally raised by Labov working in the United States with coloured children is also helpful. He makes it clear that different approaches to methodology and testing are demanded, and these apply equally to those who are working with congenitally deaf children and help to focus our ideas on some of the crucial problems that present themselves. When working with a deaf child one should not, I think, necessarily inflict one's own norms and one's own language. Labov (1972) in his book describing the "Language in the Inner City", namely Black English Vernacular, shows that this dialect is based on a grammar that is as rich as, but also different from, standard English. He argues that ordinary methods of testing the language abilities of Negro children are inadequate, when the child is given a standard test in a school setting by a white tester, and he believes that this was responsible for the subsequent inadequate verbal expression of the Negro child. An obvious analogy is the psychologist who can hear, who is a stranger to the deaf school, unfamiliar with deaf children, and who carries out the test procedure via an interpreter.

Labov assumes that cognitive competence in areas such as memory and language are manifest in the child's interaction with his or her natural environment, whereas standard tests, or a formal test setting, may fail to elicit true abilities in these areas. This might explain possible discrepancies between everyday life observations and test results. The researcher therefore, needs to be familiar with the abilities of the deaf children both inside and outside the classroom, so that realistic demands and expectations can be made during individual test sessions. One should ideally evaluate all 'test' measures of cognitive skills by reference to cognitive abilities in the natural setting, and, as Labov reminds us, one must always be careful to distinguish between a child's potential ability and his performance in a given situation, especially when under test conditions.

The importance of some of the points discussed in this section is clearly illustrated by Goda's (1959 p. 375) post hoc realisation that:

> The oral speaking test may have been fear provoking to the subjects since it demanded a form of response which was somewhat foreign to them and one which they did not feel adequate in handling. A further element in creating fear was the presence of the experimenter, who was not only a normal hearing person and a stranger but also one who could not communicate with or understand sign language.

These then were some of the more important problems which were encountered when working with deaf children, and which needed to be borne in mind when actually planning, designing and undertaking the present experimental investigation. On no account should these factors ever be overlooked or dismissed as unimportant.

## 2.3 The deaf school in which the study was conducted.

### 2.3.1 A description of the school.

Northern Counties School for the Deaf is a non-maintained special school; it is residential (mainly on a weekly-boarding basis) and is large by deaf school standards, and long established (1880's). There were around 200 pupils between the ages of 2 and 17 during the period of testing (1973-1976), of whom 120 were boarders. It is a non-selective school, in as much as there are no clearly defined selection criteria used for admission to the school. The children are referred by the L.E.A. and are from a regional catchment area. The school is divided into three separate departments, each of which is run independently under its own Head of Department:Lower School (2-8 years); Middle School (8-12 years); Upper School (12-17 years).

2.3.2 The sample of deaf children tested. Testing was carried out in the Middle and Upper Schools only. There was no precise minimum hearing-loss cut-off level for inclusion in the study; all the children tested were however either severely or profoundly deaf (hearing loss of at least 60 dB in the better ear), and all had lost their hearing before the age of 2, i.e. they were all prelingually deaf. The children were sampled randomly with the constraint that none of the children tested had any other known major physical or intellectual disability or obvious emotional or behavioural disturbance that would interfere in any way with performance on a particular test. All the children were classified as educationally deaf. Each child was tested individually. The majority of the children came from city homes of lower socio-economic status as judged by parental occupation.

All the children tested had either 'normal' vision, or vision corrected to within 'normal' limits. Each child wore a hearing aid individually suited to the loss of hearing in each ear. I.Q. scores from non-verbal tests of intelligence were taken from existing school records, and represented therefore, results from a variety of tests administered over time by several different testers. These scores were probably not very meaningful in view of this, but they did however indicate that the level of intellectual functioning was within the 'normal' range (i.e. 80-120). The children were classified as 'manual', not on the basis of their failure to develop speech, but as a result of the modes of communication and instruction emphasised within the school. Manual methods of communication are traditionally associated with low intellectual functioning (see 'Talk' Autumn 1970, No. 57, p. 11) yet it is 'natural' for the profoundly prelingually deaf child of deaf parents to sign and to fingerspell; the child may be highly intelligent (W.I.S.C. Performance Score $\geqslant 120$), but may never be able to speak intelligibly. Other children within the sample had intelligible speech and articulation, relative to the total population and to the deaf population at large.

From what is already known, deafness seems to force children to use different strategies to think and to solve problems. The question that was asked throughout this experimental study did not concern the way in which the overall deaf population at large remembered and processed information, but how a particular sample, who preferred and chose to communicate manually, using sign language and fingerspelling, and who differed widely in the intelligibility of their speech, how these individuals processed information. The present study was directly concerned with the inner language and the thinking activities that mediate cognitive functioning - the imagery that was used and preferred - and the individual differences within the sample of deaf children studied.

## 2.4 An outline of the present investigation.

2.4.1 The aims and limits. The aim of the present study was to investigate and further our understanding of the cognitive functioning of a particular group of severely and profoundly prelingually deaf children, aged between 8 and 16 years, who use 'manual' as well as 'oral' methods of communication. The study was designed to have intrinsic interest and value, and to be of both practical and theoretical importance. Since there are so many possible factors which may influence performance, in particular the educational techniques and method(s) of communication in use, which differ from school to school, and also within a single school over time, it was necessary to limit the scope of study. The findings cannot, therefore, be generalised to different groups of deaf children.

2.4.2 The scope of the study. The cognitive functions with which this study is most concerned include the perceptual processes which provide the input into the memory system, immediate memory coding, word processing, and the use and understanding of different forms of written language by the deaf children. Perception and memory are vitally important interacting processes in any learning activity and are essential to learning, as well as being involved in some way in thinking.

2.4.3 The background. The present work grew partly out of a study (Dawson, 1973) in which memory recognition performance of profoundly deaf and hearing school children (12 to 14 years of age) was compared using a probe-recall technique. The recognition performance of the deaf children suggested that they might be relying on visual or shape cues for memorisation, since they made significantly more errors in the sequences of visually similar letters, and were superior in their ability to recognise abstract shapes compared to the hearing controls.

The aim throughout this study was to employ already established experimental paradigms that have, for the most part, been tried and found to be useful and informative with hearing people,in an attempt to discover how a particular sample of deaf children differ from 'normal' in the ways in which they process information.

2.4.4 An outline of the techniques used. Between the perception and recall of any information it must be held in memory. Internal speech and speech coding is an almost universal feature in hearing persons over the age of 5 (e.g. Conrad, 1972c) and helps maintain information in memory, as does visual imagery (e.g. Paivio, 1971) which may be used to recall certain scenes, places and faces. The aim of the present study was to investigate how the processes employed by deaf children were similar to, or differed from, those that we know are used by hearing children.

In the course of this investigation, the immediate memory coding of deaf children was studied using a task developed and used by Conrad (1971). This was then followed by a name- and shape-matching experiment, using a technique developed by Posner and Mitchell (1967). In both of these experiments alphabet letters were used. After these early experiments, a pilot study was carried out to look at the effects of shape, phonemic and sign similarity on recognition of word-pairs, using a lexical-decision type task as previously employed by Meyer and Schvaneveldt (1971), and which has subsequently been employed by several researchers interested in visual word recognition. As a follow-up the effect of the form of written language was investigated, comparing standard English, 'deaf English' and sign language structures and their effects on memory recall and recognition of simple sentences. In a further experiment the comprehension of two stories written according to the grammatical rules of sign language and standard English was compared for both deaf and hearing children. The final experiment concerned the optimal use of fingerspelling for teaching spelling in a classroom-type situation where fingerspelling is normally employed.

In the following chapter, experimental studies of memory, memory processes, and memory coding in both deaf and hearing subjects will be presented and discussed, and Experiment 1 will be described.

# CHAPTER 3

# INDIVIDUAL DIFFERENCES IN IMMEDIATE MEMORY CODING

## 3.1 The basis of memory coding.

3.1.1 S.T.M. coding in hearing subjects. The rationale of an information processing approach to S.T.M. requires the input of information, some internal means of processing/storing the information, and its subsequent retrieval and output. Recently, an increasing amount of attention has been paid to the manner in which information is encoded for storage, and much research has been carried out into the nature of coding in S.T.M. The experimenter controls the input and the subject's report represents the output. A comparison of the discrepancy between the two, and a detailed analysis of the consistency of error patterns provides an indirect clue to the internal processes, and a short-cut to a better understanding of the structures involved. Conrad (1962) was the first to adopt such a technique and examine error confusions as indicators of coding.

Let us assume that when an item is stored in memory 'something' is laid down, and this we shall call a memory trace. When the memory trace is strong the item will be correctly recalled, but when it has completely decayed the item will be forgotten, and a guess, or random error, will occur. Frequently however, it is not an 'all-or-none' matter, as Goodnow (1972, p.85) has shown with her comment that "not quite right" should not be interpreted as meaning "all wrong". A partially decayed memory trace may give rise to a systematic error, that is an error that is not totally unrelated to the original stimulus input. Errors are not as random as one might suppose, and it is wrong to assume that when the correct item cannot be recalled, other choices are equally probable.

In a series of experiments Conrad (1962, 1964 and 1965) suggested that simple verbal material, such as random sequences of alphabet letters, drawn from a restricted vocabulary, is stored in S.T.M. using acoustic coding, even when the items were presented visually. He found that the errors in immediate recall of visually presented consonants correlated with the errors made during the perception of spoken letters presented against a background of white noise (Conrad, 1959). The so-called 'acoustic confusions' in recall were similar sounding letters e.g. 'b' and 'c'; 's' and 'x'. Conrad and Hull (1964) demonstrated that the difficulty of recalling a string of letters depends more on the potential confusability (i.e. similarity) between letters, than on the size of the vocabulary from which they were originally drawn, contrary to the predictions of information theory. Having shown the importance of acoustic associations in memory over time intervals ranging from immediate recall to 2.4 seconds delay, Conrad (1967) proceeded to demonstrate that this relationship breaks down at longer intervals, 7 seconds, during which time letters lose more of their identifying characteristics, and the randomness of errors increases. However, more recent evidence has suggested that both phonetic and semantic features can be encoded in S.T.M. When verbal items are read rapidly without meaning (either because they are meaningless or insufficient time is allowed) only phonemic coding is possible, whilst over longer retention intervals phonemic coding fades and only semantic coding of the items remains available (Schulman, 1971).

3.1.2 <u>Electrophysiological evidence</u>. A more direct method of investigating the possible existence of covert speech coding, involves electromyographic recordings (E.M.G.). Several studies (Jacobson, 1932; Locke & Fehr, 1970; McGuigan, 1967; Novikova, 1961) have reported that covert oral activity does increase, relative to the resting baseline, during many language-related activities, such as learning, memorising and recalling verbal material, and silent reading. Faarborg-Anderson (1957) and Faarborg-Anderson and Edfeldt (1958) localised the area of increased electrical activity more specifically to the intrinsic laryngeal muscles in the vocal muscles and the mylohyoid muscle. McGuigan (1970), in an extensive review of many of the studies undertaken during the past 80 years, wrote that the results lead to the "... firm conclusion that covert oral behaviour increases over base-line during the covert performance of a wide variety of language tasks" (p.321).

Such research however, is not without its problems, and the possible sources of interference are many and varied, including activities such as swallowing and breathing. Also, one cannot be certain whether sub-vocal activity is an integral part of the processing activity, or merely an accompaniment. On the basis of introspective evidence, Locke (1970a) suggested that sub-vocal speech accompanies language-related activities, and Underwood (1964) has reported experimental evidence that articulatory movements during verbal learning were not associated with rate of learning. More recent data of Cole and Young (1975) also strongly suggest that encoding of speech sounds in S.T.M. is not dependent on concurrent sub-vocalisation. All these various sources of evidence would seem to suggest fairly conclusively that some kind of verbal representational system is crucial in certain tasks, including S.T.M. performance involving verbal material.

3.1.3 Coding - acoustic or articulatory? - the continuing debate. Since Conrad's early studies (1962; 1963; 1964) it has become accepted practice to use intrusion errors to investigate the nature of S.T.M. coding.

Agreement however, has not been reached on the exact nature of coding used in this verbal representational system, despite the fact that Conrad's findings have been replicated by several different experimenters (e.g. Baddeley, 1966;Cole, Haber and Sales, 1968; Murray, 1968; Wickelgren, 1965). Although it is generally recognised that acoustic factors are important in S.T.M., it is difficult to identify the precise encoding mechanisms, since the relevant items frequently have both acoustic and articulatory features in common, and the complex relationship existing between them is still not clear.

Perceptual confusions between English consonants such as were analysed by Miller and Nicely (1955) are a possible source of confusion in S.T.M. coding experiments, producing systematic bias, and need therefore, to be eradicated in order to obtain a valid qualitative analysis. Two methods have generally been adopted:

(1) Slow presentation - approximately one item per second - a speed at which the likelihood of a perceptual error is known to be negligible.

(2) Subjects copy the items as they are presented, and only those correctly copied (perceived) are scored for recall (Wickelgren, 1965; 1966). In this way one can be fairly confident that the errors do result from memory processing rather than the earlier perceptual stage.

Linguists classify sounds by features such as place of articulation, mode of production and the presence/absence of voice, terms that have been adopted by experimental psychologists, in their attempts to discover whether acoustic or articulatory features play a more critical role in the encoding of information in S.T.M. Both Wickelgren (1966) and Hintzman (1967) have suggested that voicing and place of articulation are 'critical' features. Hintzman argued that the so-called "auditory confusions" were really kinaesthetic, and were based on similar kinaesthetic feedback patterns resulting from sub-vocal rehearsal. Similarly, Thomassen (1970) concluded that articulation plays a role in S.T.M. He differentiated between the sources of confusion in auditory perception and in S.T.M., and found that the 'place of articulation' dimension most affected the likelihood of confusion in S.T.M., whilst that of 'voicing' most affected the probability of confusion in auditory perception. Murray (1968) manipulated the articulation variable; when articulation was allowed the effects of acoustic confusability were more moderate than when items were retrieved from auditory storage. The addition of motor articulatory cues seemed to enhance the discrimination of individual items. Coles, Sales & Haber (1969) have suggested that even when articulation is prevented, feedback may persist from the blocked movement, and that it is possible that normal impulses representing articulatory movements are so overlearned that actual articulation of the sounds is not necessary to instigate the impulses.

Others have suggested that both articulatory and acoustic cues can be utilised in short-term retention. Pinkus and Laughery (1967) refer to an auditory-motor memory code, with the utilisation of one or other of the cues dependent on the relative salience of the features in the task, whilst Peterson and Johnson (1971) believe that subjects will use whichever is the most convenient at the time. Levy (1971) attempted to separate the acoustic and articulatory effects by studying the effect of variations of overt acoustic and articulatory activity on performance. She reports that both types of information appear to be used and stored in S.T.M., and may be used in a compensatory manner. Loss/absence of one type can be compensated for by use of the other. She concludes:

> Both acoustic and articulatory information are acceptable to the system and both types of information can be used with equal facility. It seems unnecessary to assume that all inputs are coded identically. It seems equally plausible to assume that at least two codes, acoustic and articulatory, are available in S.T.M. (p.131)

To avoid prejudging the acoustic/articulatory issue, Schulman (1971) prefers to use the more neutral term 'phonemic similarity', and Atkinson and Shiffrin (1968) refer to the auditory-verbal-linguistic (a-v-l) short-term store, because of the difficulty of distinguishing between these aspects. Wickelgren (1969) discussed the possibility of an abstract verbal system that was neither purely auditory, nor purely articulatory, but concluded that present error data could not establish whether the S.T.M. trace was auditory, articulatory or abstract-verbal. The debate regarding the role of articulatory and acoustic cues in memory no longer occupies the central position that it did in the late 1960's and early 1970's. This is typically illustrated in a recent book by Baddeley (1976, p.115), who uses the term 'acoustic similarity' and then immediately afterwards qualifies his operational usage of the term to refer to "items which would be judged similar if presented acoustically". It does not, he assures the reader, imply that basic encoding is acoustic rather than articulatory. No recent attempt has been made to distinguish between articulatory and acoustic coding, and it is possible that it is not useful to do so.

However, it would appear that when hearing subjects memorise verbal material that is either heard or read, they do use some kind of phonological coding, whether it be based on acoustic or articulatory features, or both, or even on some set of abstract features related in a complex, and as yet, not fully understood way to speech (Wickelgren, 1966). As long as no conclusive experimental method is available to distinguish between these alternatives then the matter cannot be easily settled, and no possibility should be excluded. However, working with profoundly prelingually deaf subjects there is no possibility of acoustic imagery, and therefore one can study the effect of articulatory imagery isolated from acoustic imagery, in those deaf individuals who are able to articulate intelligibly.

### 3.1.4 The possibility of multidimensional representation in S.T.M.

Much work has been done on visual S.T.M. using verbal material, particularly letters. This over-emphasis on verbal materials in all S.T.M. tasks has coincided with a tendency to favour an interpretation of the data in terms of auditory (verbal) coding, even when other forms are possible. Most would assert, as does the linguistic-coding hypothesis, that the primary code for verbal materials is phonemic, rather than visual or some other form (Laughery, Weltor & Spector, 1973), but at the same time would not deny that some S.T.M. is visual. Laughery and Harris (1970) reported a significant level of visual similarity between intrusions and correct items, although not as strong as acoustic similarity.

It is clear therefore that short-term retention is not solely verbal, and there is an increasing weight of evidence against the single code conception of S.T.M. (e.g. Baddeley, 1966; Cohen, 1972; Kroll, Parks Parkinson, Bieber and Johnson, 1970; Neisser, 1967; Paivio, 1971; Posner, 1974). Models of S.T.M. based solely on verbal codes need modification to incorporate the effects of type of coding on subsequent memory and the possible relationships between systems of coding. Craik and Lockhart (1972) suggest that the memory trace is a by-product of perceptual analysis, and that the memory system "can accept a variety of physical codes" (p.674), i.e. memory coding appears to be flexible. Conrad (1971a) has also supported these ideas, adding that the concept of a multi-code system that is hierarchically organised is intuitively attractive as being biologically adaptive.

Shallice and Warrington (1970) reported the case-study of a patient, known as KF, who suffered from a deficient auditory-verbal S.T.M., so that his immediate memory span for visually presented information was not subject to acoustic confusions. In 'normal' individuals the function of the visual S.T.M. system is frequently masked by the superior capacity of the auditory S.T.M., whereas for KF this was not the case. In this example the imperfectly behaving system provides us with additional insight into the functioning of immediate memory.

Conrad (1971a,1972a) studied the development of the use of memory codes, and has shown that the visual code is the more 'primitive' in that it is present long before verbal coding is utilised in memory. Children appear to code pictures pictorially until they are about 5 years old, and then seem to spontaneously abandon this strategy in favour of speech-based memory coding.

Finally, the multidimensional nature of S.T.M. trace is further endorsed by Craik and Lockhart's summary formula (1972) concerning the format of information in S.T.M. which they describe as "phonemic, probably visual, possibly semantic" (taken from Table 1, p.672).

3.1.5 The role of task variables in the use of coding strategies. The importance of task demands as a variable in determining the subjects' processing strategies has recently be recognised. Garner (1970) suggests that we need to pay greater attention to experimental variables, and that "for too long we have considered that a stimulus is a stimulus" (p.357). All stimuli cannot be processed in the same manner, and errors in memory do not occur as the result of fixed coding characteristics.

Craik and Lockhart (1972, p.674) argue that:

> The coding question is more appropriately formulated in terms of the processing demands imposed by the experimental paradigm and the material to be remembered. In some paradigms and with certain material, acoustic coding may be either adequate or all that is possible. In other circumstances processing to a semantic level may be both possible and advantageous.

Thus, if subjects are merely required to recall verbal items very shortly after presentation, coding on the basis of sound may indeed be 'all that is possible'. Similarly, Schulman (1971) makes the point that whenever the encoding of semantic features is not a task-demand, or not even possible, encoding in S.T.M. will be primarily phonemic, but that this is not the same as claiming that the memory trace in the short-term store is by nature phonemic.

The ability to vary encoding strategies in accordance with instructions and task demands has been clearly demonstrated by Tversky (1969) who showed that material could be coded in either visual or verbal form in S.T.M., depending on the subjects' expectations about whether the subsequent test of recognition would use verbal or pictorial material. Similarly, O'Connor and Hermelin (1972) in an investigation of the effect of input modality (visual or auditory) on memory organisation, found modality of input induced either a spatial or a temporal set, and thus influenced stimulus coding. The nature of the input and subjects' expectations would appear to determine to a large extent the code used to process the material.

One needs to remember that the kind of imagery or strategy that subjects use in a formal experimental test may be constrained by the nature of the test and the test materials. Subjects need therefore to be given the opportunity to adopt their own preferred strategy and to process information in their own way as far as is possible within the necessary experimental constraints. We need to discover when, and under what circumstances, a person chooses to process information in a particular way, and since the human being is complex the answer is also bound to be very complex.

## 3.2 Research into the nature of memory coding of the deaf - the state of the art.

A question that has been raised on a number of different occasions concerns the ability of profoundly and severely prelingually deaf children, who have little or no speech, and who are generally deficient in their everyday verbal skills, to retain information in memory. The imperfectly behaving organism once more provides us with the possibility of studying other means of memory storage besides speech coding.

Many of the early studies compared the performance of deaf and hearing children on a variety of tasks involving visual memory, many using a memory span procedure, i.e. the straightforward recall of a series of sequentially presented items. Memory span is in fact one of the oldest tests in psychological testing, and was used as long ago as 1908 by Binet in his intelligence scale. Digit span is also currently included as one of the verbal sub-tests of the W.I.S.C. Generally speaking, one finds agreement amongst the studies that the deaf show a deficit in memory span performance compared with hearing controls (e.g. Pintner & Paterson (1917), using visually presented digits, more recently replicated by Olsson and Furth (1966); and Blair (1957), using both forward and backward digit span, picture span and domino span).

In addition to these quantitative comparisons, tests of memory span are also of interest because they throw light on a further aspect of the problem viz. structural processing. Since there is no intrinsic order within the sequences, subjects have to integrate the traces if they are to retain the randomly presented items in the correct sequence. This raises the whole question of the role of linguistic-temporal coding in this type of processing. Blair (1957) found that whereas hearing children had longer forward spans than backward (and both were longer than the spans for the deaf children), there was no difference in the forward and backward spans of the deaf subjects. It has been suggested (Conrad and Rush, 1965) that the deaf were "freed" from auditory imagery (which is necessarily serial) and retained a visual image, and could, therefore, "read back" in either direction with equal facility. O'Connor and Hermelin (1976) have since replicated Blair's finding regarding forward and backward recall. It may be then,that deaf individuals use a spatial code, based on visual imagery, rather than a linguistic-temporal one, and that this cognitive strategy impairs their memory span performance, or any memory processing involving sequentially presented material. It would appear that linguistic coding (which is by nature temporal) is vitally important for processing successively presented items, and that visual imagery is relatively inefficient at handling sequential information (Conrad, 1973; Paivio & Csapo, 1969). This suggestion is further supported by repeated experimental reports that deaf individuals find it easier to process items presented simultaneously than successively, and are more successful at it (e.g. Furth & Pufall, 1966; Olsson & Furth, 1966; Withrow, 1968).

The association between verbal language mediation and successive learning ability that is implied by these findings is further supported by Pufall and Furth (1966) who found that none of the four-year-old hearing children they tested were successful at tasks involving successively presented items, but that some were by the age of 6, whereas the majority of the four-year-olds were successful with simultaneous presentation. Similarly, Freeman (1975) found that hearing children between the ages of 5 and 8 exhibited increasing preference for temporal order of recall. The use of temporal coding by hearing individuals is not always, however, as predominant as Hermelin and O'Connor (1973) have suggested. There is mounting experimental evidence that hearing individuals can, and do use either temporal or spatial coding (e.g. Healey, 1975; Mandler & Anderson, 1971). Beck, Beck and Gironella (1977) failed to replicate the strong preference for temporal coding reported by O'Connor and Hermelin (1973) and found that there were two underlying cognitive sets, one for temporal, and one for spatial coding, and that they were available to every hearing subject. Beck et al. (1977) also tested 24 deaf children and found that some of the subjects recalled the sequences in the correct temporal sequence, some in the correct spatial sequence, and some using a random sequence. The relationship between ability to use articulatory imagery and ability to process sequential information remains to be investigated experimentally and will be tackled in Experiment 1.

It is generally recognised that,when a memory task involves material that is not easy to verbalise, and which consequently hearing children cannot easily store in verbal form, the memory performance of deaf children is as good as, or even better than that of hearing controls. For example, Olsson and Furth (1966) found no difference between deaf and hearing subjects in their ability to memorise nonsense forms, and Blair (1957) reported that deaf subjects performed better than the hearing controls on both the Knox Cube and the Memory for Designs tests.

So, how do the profoundly and severely prelingually deaf encode information in S.T.M.? This fundamental question raises an issue that is of both practical (e.g. educational) and theoretical importance. The known degree of deafness ensures that there can be no possibility of an acoustic component to any speech code, and therefore, the use of phonological coding (a speech-based verbal code that includes acoustic imagery) in the S.T.M. processing of deaf children, which for hearing subjects predominates, is highly unlikely. Deaf children who are either profoundly or severely deaf from early life only learn to articulate, if at all, with a great deal of difficulty, in the absence of auditory feedback. We must therefore think solely in terms of articulatory coding, rather than in terms of the acoustic processing utilised by hearing individuals in S.T.M. coding. It also seems likely that deaf children use different coding strategies based on their communication methods and teaching methods.

One of the earliest attempts to study memory coding of a group of deaf individuals was that of Conrad and Rush (1965) who employed the experimental procedure that had previously been used with hearing subjects (Conrad, 1962, 1964, 1965) with older deaf subjects (aged between 13 and 20). They found that the deaf subjects did make consistent errors, but that these were not acoustic confusions. They were investigating the obvious possibility that some deaf children might be coding in terms of visual shapes or shape cues, but concluded "although deaf subjects do make consistent memory errors, there is no conclusive evidence that these depend on shape cues" (p.341), and they referred to a "consistent encoding procedure which is at present obscure" (p.343). This conclusion is rather similar to that of Arochová and Halmiová (1975) who also refer to "other as yet unelucidated modes of information recording and retrieval" (p.264). A similar experiment to that of Conrad and Rush

(1965) was carried out by Wallace and Corballis (1973), with the addition of a 10-second interval between presentation and recall. Their results support the findings of Conrad and Rush, and also imply that the deaf do make extensive use of a visual shape code in short-term recall.

More recent studies suggest that several encoding procedures may possibly be utilised by the deaf, and that these are becoming increasingly less obscure. Conrad (1970) reported two experiments that suggest a dichotomous classification of deaf school children into those who rely primarily on articulatory coding, and those who rely on some other mediating code which Conrad prefers to designate as 'non-articulatory' - a 'safe' term allowing for the possibility of other codes. In a follow-up study, Conrad (1972b, p.176) wrote:"The use of speech coding is not all-or-none. It is inconceivable that it should be, inconceivable that subjects totally ignore all the other identification cues present". The profoundly deaf do not appear to have a single code available for memorising that is as highly developed and adapted for the purpose, as speech coding is for the hearing (Conrad, 1972c). Even the most oral deaf children, as a group, did not approach anywhere near the level of speech coding used by the hearing subjects (Conrad, 1972b). Therefore, Conrad argues that "We must expect more volatile coding systems in the deaf than in the hearing; more varied coding both between and also within subjects" (p.178). He developed a procedure which can be used to determine whether or not a deaf child is using internal speech when reading words to be recalled, using two sets of words:

(a) a set of very similar sounding words (e.g. do, you, too, blue, etc.)

(b) a set of words that do not sound alike, but which look more similar (e.g. bird, darn, lane, tone, etc.)

A comparison of relative levels of memory recall performance on the two lists provides an indicator of whether or not a child is using internal speech as an aid to retention (Conrad, 1973).

Whilst this work was being undertaken by Conrad, Thomassen (1970) was carrying out a similar investigation. He concluded that articulation seemed to aid memory retention in some deaf subjects but that it certainly did not play a large role, and could not explain all S.T.M. coding in the deaf. Thomassen also made the point that even when articulation was used, it was not necessarily as advantageous for the deaf, as it was for the hearing subjects. Meanwhile Arochová and Halmiová (1975) reported that deaf adolescents verbalised items out aloud during a memory recognition experiment, whilst hearing individuals did not. They suggest that the acoustic-verbal coding of hearing subjects is replaced by kinaesthetic-articulatory coding.

So far, only the possibility of articulatory and visual memory coding systems has been considered, both of which, as previously discussed, are used by hearing persons. The deaf may possibly make use of other codes based on kinaesthetic features arising from manual communication - manual mediation in the form of fingerspelling and/or signs. As Conrad (1972b, p.178) wrote: "The extent of the use of a fingerspelling code in memory needs serious consideration". Locke (1970b,1973) argued that kinaesthetically similar dactylic gestures would tend to be confused in memory in much the same way as phonetically similar items are confused by the hearing. He found, however, using 9 consonants selected for their apparent kinaesthetic similarity in the one-handed fingerspelling configurations, that the results suggested that ".. deaf subjects do not encode orthographic stimuli with a dactylo-kinaesthetic system exclusively, if at all" (Locke, 1970b,p.233). The errors appeared to be systematic and based on visual similarities (e.g. RB, YK, PR letter-pairs tended to be confused in memory). Perhaps other codes besides fingerspelling were being used - the "more volatile coding" about which Conrad (1972b) wrote. Clear-cut error data are not therefore to be expected.

Locke and Locke (1971) continued to investigate the different methods of coding information used by the deaf to recall lists of letters paired on the basis of phonetic, visual or dactylic similarity. They tested three groups of subjects - deaf with intelligible speech (ID), deaf with unintelligible speech (UD), and hearing controls (HC). Throughout the course of the experiment both active fingerspelling and articulatory movements were observed. It was assumed that coding activity could be inferred from the configuration of specific recall errors. An analysis of the results showed that all three groups recalled the items at essentially similar levels, but that the types of confusion error made, differed markedly between the groups. The HC group made more errors explainable on the basis of phonetic similarity than the ID and UD groups, whereas visually similar letters were confused more frequently by the UD subjects than the ID and HC subjects. The UD group confused significantly more dactylically similar letter-pairs than the ID subjects, who in their turn confused more than the HC group (who confused very few dactylically similar letters). It was observed that more UD than ID subjects rehearsed dactylically, and that nearly all the HC subjects used phonetic coding. It would appear that deaf children's communication capabilities and their apparent coding strategies in S.T.M. agree quite closely. Here we find some support for the use of some of the features of fingerspelling in memory storage.

Bellugi, Klima and Siple (1975) have also investigated the possibility of some form of manual mediation, based on A.S.L. They employed an error analysis technique similar to that used by Conrad

(1964, 1965) in their experimental study of the ability of deaf children of deaf parents (for whom A.S.L. was the 'natural' language) to store signs in memory. They found that the errors made by the deaf using signs were visually similar, and that intrusion errors were based on formational properties of the signs themselves (the 'sig', 'dez' and 'tab' parameters). This experimental evidence suggests that these formational parameters of signs are psychologically real for native signers, and is a parallel finding to that of the phonologically-based errors of hearing individuals.

The experimental results presented thus far provide fairly conclusive evidence that deaf children (and presumably deaf adults too) may use various different methods of processing information for memory storage, including articulation and internal speech, shape and other visual cues, and sign and fingerspelled representations. This evidence suggests that phonological mediation is not an indispensable feature of human memory. It should be of interest to memory theorists to discover the extent to which visual information can be stored in memory.

The 'straight' comparisons of memory processing differences between deaf and hearing subjects, such as were undertaken by Conrad & Rush (1965), and Locke and Locke (1971), need now to be developed into more detailed investigations of individual differences of information-coding for memory storage by the deaf.

## 3.3 Distinctive features.

If we are to perceive items and objects in the world around us, we have to learn to distinguish between them. As Gibson & Levin (1975, p.15) wrote:

> In order to identify something as unique, we must know its alternative - what it might have been, but isn't quite. Things

> come in finite sets, and there are feature contrasts within the set that are shared in different degrees by the members of the set. We shall refer to these as "distinctive features", which permit specification with respect to a set of alternatives ... Distinctive features are relational, not absolute like building blocks or elements.

They then went on to write that an item is "characterised by a pattern of distinctive features that is unique" for that item, but that "members of a set may differ by few or many features - that is, features are shared within the set to different extents" (p.15).

3.3.1 Distinctive features as applied to speech sounds. Jakobson & Halle (1956), and Jakobson, Fant & Halle (1963) elaborated the concept of distinctive features and applied it to the phonemes of human speech. All speech sounds are composed of bundles of features whose parameters are both articulatory and acoustic in nature. A small set of feature-contrasts like voiced-voiceless (e.g. 'pit' and 'bit' are distinguished only by the presence or absence of voicing of the initial consonant) are suffient to distinguish all the phonemes of all the languages in the world, and render each one unique, since the set may be combined in many different ways.

Wickelgren (1965) reported that letter-names sharing a common phoneme were more likely to be confused in memory. He argued that the possession of a common phoneme implies the possession of the entire set of common features which compose the phoneme. Each phoneme is assumed to consist of a bundle of phonologically distinctive features that can be encoded for memory. The ultimate basic units are not known, but it is assumed that they combine to form phonemes which in their turn combine to form larger units, i.e. syllables and words.

It is further assumed that items sharing similar features will be coded in a similar manner in memory. If the distinguishing feature(s) fade(s), one is left with only the features in common, which may lead to a systematic error, i.e. an error that is similar in some way to the original stimulus. "Some of the features of a consonant can be recalled when others cannot, producing a systematic tendency for the errors in short-term recall to have distinctive features in common with the correct consonant" (Wickelgren, 1966, p.397). If on the other hand, the original items are quite different one from another, then more 'information' may be lost, through decay or interference, before the item becomes indistinguishable. Similar items become indistinguishable more rapidly as a result of less information.

Therefore, on the basis of a shared-feature hypothesis, a letter that shares a common sound with several other letters is more likely to be forgotten than a letter that shares a common sound with relatively few other items: the greater the number of items sharing a common property, the greater the probability of making an error when it is only partially recalled. For example j (dʒei), k(kei), a (ei) and h (eitʃ) all share the common vowel sound 'ei'. If the other distinctive features were forgotten and all that was recalled was the vowel sound, then the probability of guessing correctly would be .25. Similarly, b (bi:), c (si:), d (di:), e (i:), g (dʒi:), p (pi:), t (ti:) and v (vi:) all share the common vowel sound 'i:' - the probability of guessing correctly among all the available possible letters containing the particular vowel 'i:' in the same position is only .125. The dependence/independence of these features is not fully understood, but Wickelgren (1965, 1966) suggested that there must be partial independence, otherwise systematic errors would not occur.

Working with deaf children whose hearing loss prevents input of auditory information, and who therefore lack acoustic imagery, the main concern was with articulatory rather than acoustic features. In the present experiment, interest was centred on the production of letter names rather than phonemes (e.g. /bi:/ not /b/). Since no table of descriptive characteristics based on articulatory features could be found in the literature, such a table had to be compiled for the letters used. O'Connor (1973) provided the linguistic basis to the articulatory phonetics necessary for the production of this table (see Appendix C), which was used to predict the articulatory similarity (AS) of the letter-pairs (Section 3.5.4).

3.3.2 Visual features. Letters of the written alphabet form a set, each character differing from the others by one or more visual characteristics. These features have been studied less than those of speech sounds (discussed in the previous section). However, attempts have been made to construct intuitively a possible 'descriptive chart'.

In one of the earliest of these studies, Tinker (1928) investigated the relative intelligibility (sic) of letters, digits and certain mathematical signs using a short-exposure technique. The percentage of times that an item was read correctly gave the intelligibility score for that particular item. Hodge (1962) undertook a similar study, again concerned with legibility. Applied problems such as these, involving maximal legibility in visual displays, have not produced an index of similarity that could be used to predict visual confusability of alphabet letters.

More recently, Gibson (1969, 1971) produced a table of the various visual features which she believed were important in visual recognition. She felt that features such as straight lines (horizontal, vertical and diagonal), and curved lines formed the basis for the graphical coding of letters.

Briggs and Hocevar (1975) have devised a distinctive-feature analysis for upper-case letters. They used four major features - curvature, horizontal linearity, vertical linearity and diagonality to discriminate between the upper-case letters of the English alphabet. They found that the confusability of letter pairs was directly related to the percentage of features that the letters shared in common.

Kuennapas (1966, 1967), and Kuennapas & Janson (1969) carried out similar studies in Sweden using the Swedish alphabet. The results of their experimental studies of visual perception and memory of upper-case letters led them to isolate three geometrical factors - rectangularity, roundness and vertical linearity. They also studied the 28 lower-case letters using multidimensional similarity analysis and isolated 9 factors of which vertical linearity and roundness were found to be the most important. They produced a visual similarity matrix using the scale 0 (no similarity) to 1000 (identity). This appears to be the only empirical attempt to provide a precise scale of the visual similarity between lower-case letters. Similar studies, such as that of Briggs and Hocevar (1975), have only been concerned with upper-case letters.

Fisher, Monty & Glucksberg (1969) wrote a paper entitled 'Visual confusion matrices:fact or artefact?' in which they examined "any evidence for the common assumption that there exists a basic 'pattern of confusions' between upper-case letters of the alphabet" (p.111). They found little evidence for this assumption, and suggested that confusion matrices are a function of the procedures and techniques by which they are generated. It appears that important variables such as exposure duration, report-technique (forced/free report) and letter-style require further study. Meanwhile one needs to be aware of the possible/probable limitations of the generality of visual similarity indexes. In the light of this evidence, the visual similarity matrix generated by Kuennapas & Janson was not used in the present experiment. (In addition, the Swedish alphabet lacks a 'w' and a different grapheme for 'a' was used).

Psychologists are still searching for a feature detection theory of pattern recognition and letter identification. There is psychological evidence to support a feature detection analysis of patterns (Neisser, 1967), yet the 'rules' governing the perception of distinctive features of letters, even of a standard script, have not yet been identified. The shape differences between some letters, such as 'O' and 'Q' (which can easily be identified by the majority of children after about the age of 8) appear to be far less than those between the same letter written in differing scripts (e.g. 'a' and 'ɑ'). Great variations in hand-printed characters can easily be identified, suggesting that invariant physical features may not be at the heart of a general theory of feature detection. This being the current state of thinking, no attempt was made to introduce a distinctive-feature analysis into the present experiment, or to enter the theoretical realms of a feature detection theory. Instead, a coded system was devised to describe letter shapes precisely (see Appendix D). The number and relative positions of shape attributes shared by pairs of letters were used as an index of similarity and to predict their potential visual confusability (Section 3.5.4). The letter style (Letraset Futura Medium 72 pt, Sheet 111) used for this shape analysis was the same as that used in Experiment 1 (cf. Fisher, Monty & Glucksberg, 1969).

3.3.3 A discussion of possible visual and kinaesthetic characteristics of fingerspelling. From the discussion in the previous two sections, it should be clear that a descriptive analysis of fingerspelling might be usefully undertaken in much the same way. However, as yet there has been no attempt to systematise the visual and kinaesthetic similarities of either one- or two-handed fingerspelling. One must assume that both the visual 'image' of the hand, and the kinaesthetic sensations arising from the positioning and movements of the fingers and hands, are important attributes. It is likely, therefore, that such a descriptive system will be very complex.

For the purposes of the present study however, no such elaborate analysis was attempted. Instead, a relatively crude estimation of similarity was used, similar to that employed by Locke & Locke (1971). It was based on:

(i) Ratings from hearing subjects with no prior experience of fingerspelling, who were asked to rate the 56 pairs of letters relevant to the present experiment for visual similarity. A scale of 1 (highly similar) to 5 (highly dissimilar) was used.

(ii) Comments made by the deaf children themselves regarding the confusability of various fingerspelled letters.

This rather inadequate estimation of similarity, and hence potential confusability, nevertheless enabled the experimenter to extract the pairs of fingerspelled letters that were obviously highly similar. These were the most important for the present experiment; others, less similar, were excluded as they were more difficult to rate, and there was no close correspondence between judges' ratings.

### 3.4 A test for articulatory intelligibility.

The articulatory intelligibility (AI) (not the speech intelligibility) of each deaf child included in the present experiment, was tested. The 16 alphabet letters which were to be used in the memory span test were presented visually in random order, to each child individually, who named them aloud, speaking into a Marconiphone stereo tape-recorder (Model 4218). The tape-recording provided a permanent record of the children's utterances, and, in addition, reduced the possible stress involved in facing a panel of judges. If a child obviously made a mistake, or stumbled over a letter name, an announcement was made to this effect, and the item was repeated.

The tape was then played to four judges. Two were familiar with the speech of deaf children (though not with that of this particular sample), and two were not familiar with 'deaf' speech, but were well acquainted with phonetics. Each of the judges was given a short, preliminary practice session listening to, and becoming familiar with, 'deaf' voices and 'deaf' speech. Subsequently each of the judges listened uninterrupted to the entire list of the 16 letter names articulated by each child. The lists were then repeated, with a short interval after each articulated letter name, during which the judges wrote down the letter they thought they had just heard (not a phonetic transcript). Finally, each list was played through a third time to allow the judges to verify what they had written.

According to Miller, Heise & Lichten (1951, p.331), a sound is intelligible when "it is possible for an average listener with normal hearing to distinguish it from a set of alternative units". The number of letter names, produced by each individual deaf child, that were correctly identified by each of the four judges provided a quantitative measure of performance. On the basis of these AI scores, the deaf subjects were divided into three groups:

AI 1 - Good articulatory intelligibility (≥ 10)

AI 2 - Average " " (5 - 9)

AI 3 - Poor " " (≤ 4)

AI scores and AI grouping were used as a basic characteristic to distinguish between children within a single deaf population, and as the independent variable in Experiments 1, 2, 3 and 4 in an attempt to correlate cognitive activity - in particular perceptual recognition (Experiment 2) and memory performance (Experiments 1, 3 and 4) - with AI.

## 3.5 Experiment 1: An investigation of the immediate memory coding of severely and profoundly prelingually deaf children.

This experiment is a further attempt to analyse in detail the immediate memory coding preferences of a sample of deaf children using an error analysis technique. The design used in Experiment 1 is not identical to that of any other previously undertaken, various changes and modifications having been introduced as a result of previous experience. The aim of this first experiment is two-fold,,to provide a baseline and a specific experimental frame of reference for the remaining visual information processing experiments of the study, and to test a precise set of predictions concerning the potential confusability of pairs of alphabet letters. Rather than an ad hoc explanation of memory confusions in terms of possible visual, articulatory and kinaesthetic similarity (cf. Conrad, 1970) between the items, a set of precise predictions regarding the degree of similarity between letters was devised in the form of similarity coefficients which were based on the number of shape or articulatory attributes possessed in common. The results of this initial experiment can then be compared with previous findings, and be used as a foundation for the remaining eight experiments of this study, which have not previously been undertaken with deaf subjects. Without such an 'anchor' for comparison, it is difficult to relate even the most general findings of an in-depth study of this kind which is undertaken within a single educational establishment, to other studies, or to other cognitive behaviours.

3.5.1 Immediate memory span. A memory-span technique, originally developed and used by Conrad (1971a) to investigate the chronology and the development of covert speech in hearing children aged between 3 and 11 years, was used with deaf children aged between 8 and 16 years. Pictures, as used by Conrad, were replaced by alphabet letters.

3.5.2 Stimuli chosen. Alphabet letters were chosen because they were familiar to the children and could be represented orally, manually and graphically. In previous studies (e.g. Cimbalo & Laughery, 1967; Conrad, 1970, 1973; Conrad & Rush, 1965) sets of letters were selected, each relating to one particular critical variable (e.g. acoustic similarity). In the present study two sets of 8 letters were chosen - the first for overall articulatory similarity (List A: ɑ, d, f,j,k,s,t,x) and the second for overall visual/shape similarity (List B:b, h,m,n,q,v,w,y). These two lists allowed an individual's coding preferences to be revealed. For example, presented with a letter 'd' from List A an individual may recall (from within the group of 8 letters - 7 being wrong alternatives) the letter 't', suggesting an articulatory confusion in memory, or, alternatively, the letter 'ɑ' may be recalled suggesting a possible shape confusion. The provision of such a range of possible error types may, it is believed, be more informative than using groups of letters (such as those employed in previous experiments) in which only one type of memory confusion can be made because of restrictive experimental design. This experimental provision is also less open to the criticisms of Craik & Lockhart (1972), and Garner (1970) concerning the processing demands imposed by the experimental paradigm and the stimuli used, as was mentioned in Section 3.1.5, and should provide individuals with greater freedom to code and process the simple verbal stimuli - letters - in their own way. The present test was designed to discover what coding occurred and avoid undue constraint upon possible coding strategies.

### 3.5.3 The prediction of letter-pair confusions in immediate memory.

For the present experiment, precise predictions were made concerning the pairs of letters most likely to be confused. These predictions were based on the assumption that letters sharing the most attributes - articulatory, visual (shape) and/or kinaesthetic, are more likely to be confused in memory. The 16 letters selected for the present immediate-memory span experiment incorporated strongly anticipated articulatory, visual and kinaesthetic confusions.

#### 3.5.3.1 Possible articulatory confusions:

List A: ɑ, d, f, j, k, s, t, x.

Highly similar:

| | |
|---|---|
| d/t (di:/ti:) | share the same place of articulation (P) - alveolar; the same mode of articulation (M) - plosive stop; and an identical vowel ending. |
| f/s (ef/es) | are the same with respect to voicing (V) - fortis; share the same mode of articulation - fricative stop; and an identical vowel beginning. |
| f/x (ef/eks) | are the same with respect to V - fortis; share the same M - fricative; and an identical vowel beginning. |
| s/x (es/eks) | are the same with respect to V - fortis; share an identical vowel beginning; and an identical consonant ending. |

In the Medium range of similarity:

j/ɑ (dʒei/ei), k/ɑ (kei/ei) and k/j (kei/dʒei) all share an identical vowel ending.

List B: b, h, m, n, q, v, w, y.

Highly similar:

b/v (bi:/vi:) are the same with respect to V - lenis;
share the same P - labial;
and an identical vowel ending.

m/n (em/en) are the same with respect to V - lenis ;
share the same M - nasal;
and an identical vowel beginning.

In the Medium range of similarity:

q/w (kju:/dblju:) share an identical vowel ending.

The 6 pairs of letters which are 'highly similar' and share the most articulatory attributes are the most likely to be confused in memory given that the correct letter is not recalled and that the subject is using articulatory coding. The 4 letter-pairs from the 'medium range' are less likely to be confused than the 6 pairs mentioned above, yet their confusion-probability is greater than for the remaining 46 pairs of letters which share few or no articulatory attributes. (For a more detailed description of the articulation of letter names see Appendix C). All the letter pairs in the High and Medium range of similarity were classified as articulatorily similar (AS) for the purposes of Experiment 1.

### 3.5.3.2 Possible visual/shape confusions:

List A: k/x, ɑ/d, t/f and t/k.

List B: h/n, y/v, m/n, w/v, h/m and h/b.

These 10 pairs of letters were all rated as 'highly similar' and share the most shape attributes, and were classified as visually similar (VS) for the purposes of Experiment 1. (See Appendix D for a more detailed description of the shape-coding of the letters).

3.5.3.3 Possible kinaesthetic confusions (for two-handed fingerspelling):

List A: k/d

List B: v/n, m/n and q/y.

It should be noted that the confusion in memory of the letters 'm' and 'n' (from List B) is not easily categorised, since 'm' and 'n' are highly articulatorily, visually and kinaesthetically similar. All three AI groups should, therefore, confuse m/n equally often, and if letters are coded multidimensionally in memory this should be the most potentially confusable pair of letters.

### 3.6 Hypotheses.

It was hypothesised that:

(1) Confusions occurring between letters stored in immediate memory will differ according to the preferred mode of communication of the deaf individuals and the different types of coding (articulatory, visual and kinaesthetic) used by the subjects, and will be associated with AI.
The individuals in AI Group 1, being capable of relatively clear speech, are able to articulate the letter names and will therefore be more likely to confuse articulatorily similar (AS) letters, of the type predicted in Section 3.5.3, than the remaining two AI groups. Hence AI scores should correlate positively with number of AS confusions.
The individuals in AI Group 3 being less able to articulate intelligibly will, through necessity, make greater use of visual and possibly kinaesthetic imagery, and will, therefore, make more visual and kinaesthetic confusions in memory, of the type predicted in Section 3.5.3, than AI groups 1 and 2. AI scores should correlate negatively with number of VS confusions.

(2) Memory span may vary according to list-type (list A or B) and the coding strategies used by the deaf children:

Individuals in AI Group 1 will have a lower memory-span score on list A (the list incorporating the greater number of articulatory-confusion possibilities), than list B (incorporating more visual-confusion possibilities). Individuals in AI Group 3, on the other hand, will have a lower memory-span on list B than list A since they, from necessity, must make greater use of visual imagery.

These differential effects, however, may not be very pronounced since articulatory, visual and kinaesthetic cues may all contribute, to a greater or lesser extent, to multidimensional letter representation in memory, in which case primary coding differences may be masked.

(3) The individuals in AI Group 1 with higher AI scores should be better able to use a linguistic-temporal code, and should therefore perform better on memory-span tasks, irrespective of letter-list, than those in AI Group 3, if temporal coding is important in memory-span performance.

(4) It is expected that AI scores will correlate negatively with hearing loss (both high and low frequency losses).

## 3.7 Method.

3.7.1 Subjects: 36 deaf children (19 boys and 17 girls) aged between 12.7 and 16.8 years were tested from the Upper School: 12 from AI Group 1 (good articulators), 12 from AI Group 2 (average articulators), and 12 from AI Group 3 (poor articulators). In addition 24 deaf children (11 boys and 13 girls) aged between 8.5 and 12.1 years were tested from the Middle School: 8 subjects from each of the three AI groups mentioned above.

3.7.2 Materials. Two lists of letters were used.

List A - a, d, f, j, k, s, t, x.

List B - b, h, m, n, q, v, w, y.

Each of the above 16 lower-case letters was printed (in black Letraset - Futura Medium 72pt, Sheet 111) centrally onto a white card measuring 6 x 6cm, and covered with transparent protective film. Two such sets of 16 cards were prepared. The script and size of the letters were selected to maximise legibility of the visual input so that errors due to mis-perception or discrimination difficulties would be highly unlikely. A metronome was used to pace the rate of presentation.

3.7.3 Design and procedure. A within-subjects design was used, i.e. each child was tested on both letter-lists. The independent variable was the AI grouping and the dependent variables were the immediate memory span scores and the types of memory confusions made by the deaf subjects. Since deaf children from the N.C.S.D. had been previously tested (Dawson, 1973) and their ability to remember lists of items found to be generally rather limited and to vary considerably between individuals, a memory span procedure was chosen for the present experiment. Letter sequences presented to each of the children were lengthened steadily on successive trials according to individual differences in memory ability. If sequences of fixed length had been used with all the children, some individuals would have found the sequences very easy and would have made no, or few, errors, whilst others would have found the sequences too long to memorise and would, therefore, have made many errors. Discouragement due to continual failure was thus avoided.

Each child was tested individually in a room free from visual distraction. A complete set of 8 letters, either List A or List B, was laid out in a row face upwards on the table in front of the subject but was kept covered up. The order of these 8 letters was re-arranged after each trial. Letters were drawn randomly from the duplicate 'pack' of 8 cards, either List A or List B, and were presented, one at a time face upwards, for approximately

1 second, and then turned face downwards before proceeding to the next letter. A metronome was used to pace the presentation rate since the auditory click was not distracting to the deaf subjects. Although Conrad (1962) used a presentation rate of .75 seconds/letter,and believed this to be sufficiently slow to avoid the possibility of perceptual errors occurring, a slower rate was employed here to allow for the possibility that dactylic coding may be slower than articulatory coding of the visual input. A faster presentation rate might restrict the range of encoding strategies and perhaps prevent the use of an optimal strategy. Immediately after the prescribed number of letter stimuli had been presented, the other set of 8 letters was uncovered and the subject was required to match from memory and in any order, the sequence of letter stimuli still face down, against the appropriate letters of the duplicate set. No time limit was imposed, but the children were encouraged to respond as quickly as possible. When satisfied with his/her matching response, the child was allowed to turn over the sequence of face-down cards to test the accuracy of his/her match from memory. The experimenter recorded each letter sequence presented and each sequence as remembered (matched) by the subject. During a preliminary practice session, six trials using 2-letter sequences were presented to each subject to ensure that all the instructions and the test procedure had been fully understood. Pre-training was continued until each subject responded correctly on three successive trials using 2-letter sequences.

At the beginning of the test session, each child was presented with a 2-letter sequence. If this was successfully remembered, a further sequence of 3 letters was presented. This process of lengthening each successive new trial by one letter continued until the maximum of 8 was reached, or until a mistake occurred. When a child failed to remember a sequence of letters correctly, another sequence, containing the same number of letters, was presented. If successful on this second attempt, the procedure was continued as before. After two consecutive failures occurred on a sequence of any given length, or alternatively after an 8-letter sequence was correctly remembered, the entire procedure was begun again, starting once more with a 2-letter sequence. Eight such repetitions were carried out with each child. If, by chance, a sequence of letters drawn randomly from the 'pack' spelled an English word (e.g. s - a - d from List A) the sequence was excluded.

The average inter-trial interval was 10 seconds, and the entire test session for each child lasted for between 20 and 30 minutes. Each subject was tested on two separate occasions, and to control for possible practice effects, the order of presentation of Lists A and B on test sessions 1 and 2 was randomised for each subject.

3.7.4 Scoring. Sequences were scored letter by letter, and a letter was only scored as correct if it occurred in the correct relative position within the sequence of letters. Any letter not correctly recalled was recorded as a 'confusion' occurring in memory between the letter which had been presented in that particular position and the letter recalled in that particular position within the letter sequence. Sequences containing a single such letter-confusion were extracted for further, more detailed, analysis. A matrix of these latter confusions was constructed to show the frequency with which a particular incorrect response was made to a particular stimulus-letter. Since letter-pairs shared the same predicted degree of confusability, the matrix was collapsed into 28 cells instead of the possible 56 cells, thereby increasing the number of confusions recorded in each cell without distorting the results. (So for example, the number of times a 'd' was recalled instead of the 't' presented, and vice versa, was recorded in the same cell of the matrix.)

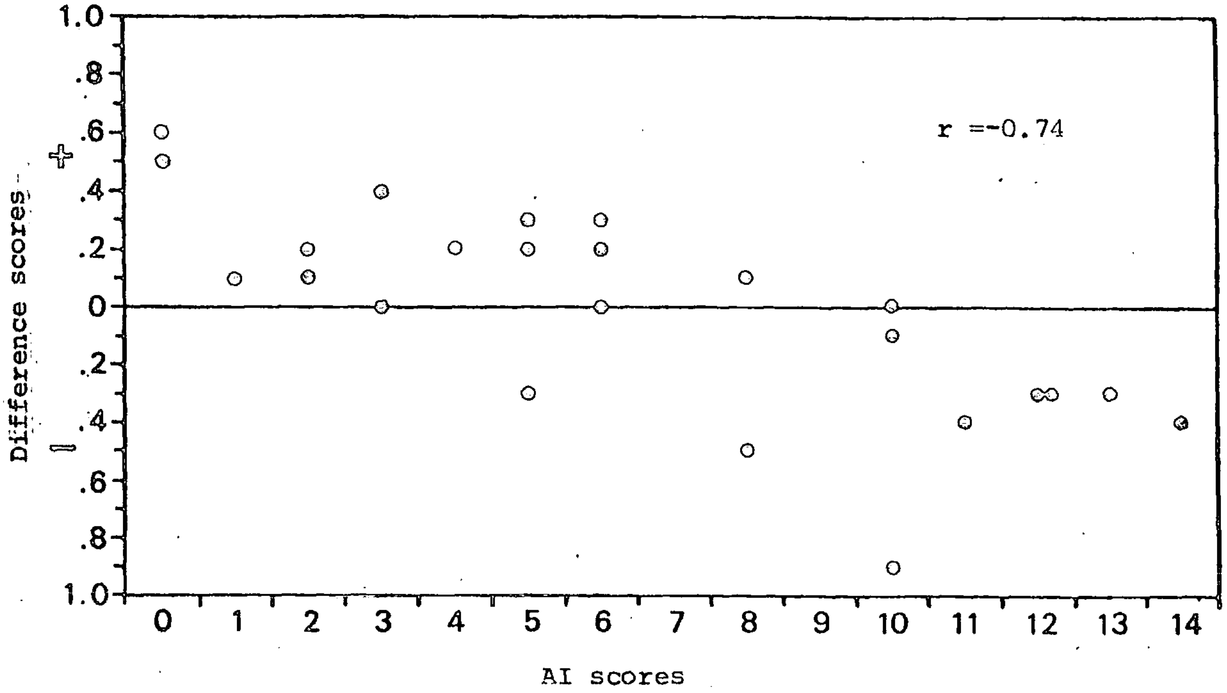
The greatest number of letters correctly remembered before making errors on the two consecutive letter sequences that followed (which were one item longer),was recorded for each subject. The mean of these scores over the 8 repeated trials was calculated to give an overall memory span score for each individual on Lists A and B separately. The data for the two age-groups were, for the most part, analysed separately.

### 3.8 Results.

3.8.1 Immediate memory span. Immediate memory span was defined, for the purposes of the present investigation, as the maximum number of letters that were correctly recalled in sequence. The immediate memory span was averaged over the eight trials for each of the two letter-lists separately (see Appendix E). The difference (d) between the immediate memory span scores for the two letter-lists, i.e. List A - List B, was calculated for each subject to test the hypothesis that memory span will vary according to the list-type (the potential confusability of letters within the list) and AI group. The results of the Jonckheere Trend Test (Jonckheere, 1954) showed, as was predicted, that individuals in AI Group 1 scored higher on List B (containing more VS letters) than on List A (containing more AS letters), and vice versa for AI Group 3 ($s = 147$, $p = .01$ for the older age group; and $s = 128$, $p = .0003$ for the younger age group). The allocation of AI scores to AI Groups 1, 2 and 3, although convenient, does not allow for very precise correlation-type analyses. The correlation between the difference scores and the actual AI scores was therefore calculated. Figure 3-a shows the negative correlation between the difference scores and the AI scores for the younger ($r = -.74$, $p < .002$) and the older age groups ($r = -.37$, $p < .05$).

Figure 3-b shows the considerable overlap in immediate memory span scores between the two age groups, for List A and B separately. The ages

Younger age group



Older age group

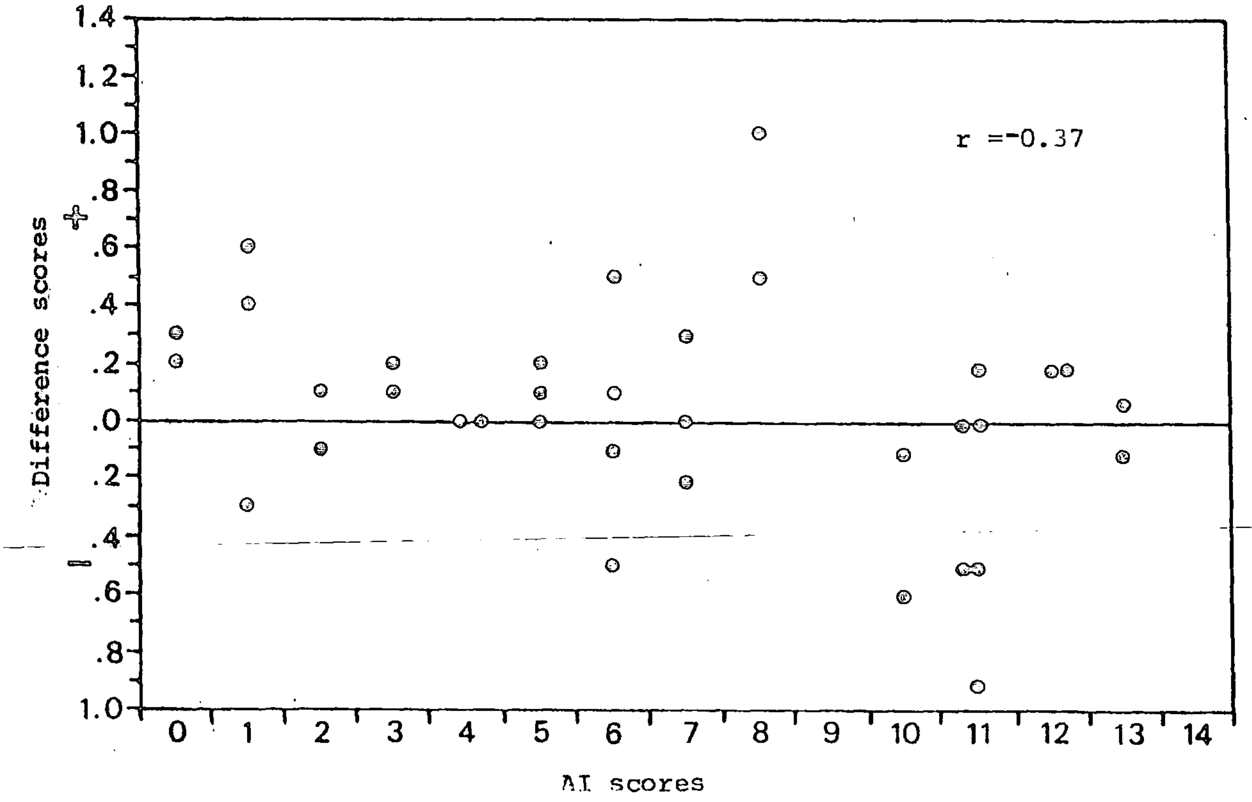


Figure 3-a. Differences between immediate memory span scores (List A-List B) as a function of AI for the older and younger deaf subjects.

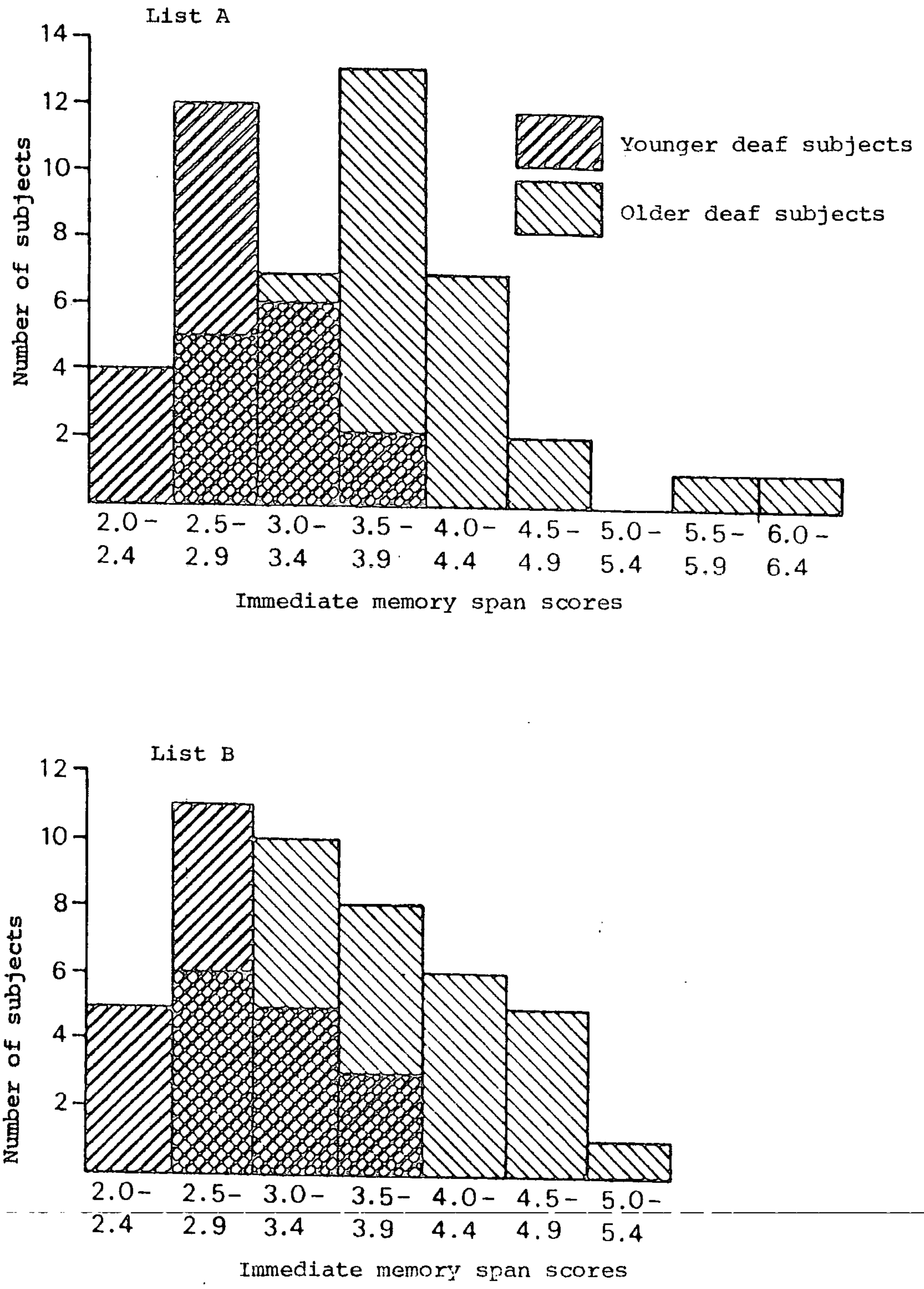


Figure 3-b. Histograms of the immediate memory span scores for List A and List B as a function of age.

of all the deaf subjects lay on a continuum across the two age groups and there was no overlap in age between the two groups. There was a positive correlation between memory span scores and age across the two age groups ($r = .5$ for List A, and $r = .58$ for List B).

There was no evidence that the individuals in AI Group 1 were able to process the sequentially presented items better than AI Group 3 for the older age group ($s = 13$, $p = .42$ for List A, and $s = 59$, $p = .31$ for List B). However, for the younger age group, whilst no such difference was found between the memory span scores of the three AI groups on List A ($s = 14$, $p = .46$) there was a highly significant difference on List B ($s = 116$, $p < .001$). The scores for AI Group 3 where significantly lower. Possible reasons for this will be suggested in the discussion section.

3.8.2 Item errors. Regardless of memory coding and retrieval cues some items will be forgotten or confused within the memory system. Every instance of a letter-confusion (or item error) occurring singly within a sequence was recorded, and a matrix constructed to show the frequency of confusions between particular pairs of letters. A casual inspection of the distribution of these letter-confusions within the matrices in Tables 3-a and 3-b suggests that not all the confusions occurred at random. As can be seen from the matrices, some pairs of letters were relatively often confused, whilst others were confused less frequently. The former category largely consisted of those pairs of letters which possessed attributes in common - whether articulatory, shape and/or kinaesthetic. Generally speaking, a larger number of letter-confusions occurred in the predicted confusion categories than in the non-predicted categories (i.e. the so-called 'distinctive' letter confusions).

The numbers of VS and AS pairs of letters that were confused in immediate memory by the three AI groups are presented in Figure 3-c. The

Older age group

| Younger age group | a | d | f | j | k | s | t | x | |
|---|---|---|---|---|---|---|---|---|---|
| a | - | 15 | 2 | 3 | 2 | 9 | 4 | 7 | a |
| d | 7 | - | 4 | 6 | 7 | 8 | 9 | 4 | d |
| f | 1 | 3 | - | 9 | 9 | 8 | 25 | 9 | f |
| j | 8 | 4 | 5 | - | 6 | 5 | 10 | 2 | j |
| k | 3 | 6 | 3 | 9 | - | 7 | 14 | 14 | k |
| s | 3 | 2 | 7 | 1 | 1 | - | 4 | 20 | s |
| t | 3 | 9 | 15 | 8 | 12 | 7 | - | 6 | t |
| x | 1 | 1 | 3 | 2 | 7 | 5 | 4 | - | x |
| | a | d | f | j | k | s | t | x | |

Total: 228 pairs of letter confusions

Total: 140 pairs of letter confusions.

Table 3-a. Matrix of singly occurring letter-confusions (List A).

Older age group

| Younger age group | b | h | m | n | q | v | w | y | |
|---|---|---|---|---|---|---|---|---|---|
| b | - | 12 | 2 | 5 | 9 | 14 | 2 | 6 | b |
| h | 7 | - | 11 | 15 | 3 | 8 | 5 | 6 | h |
| m | 3 | 11 | - | 14 | 4 | 5 | 13 | 6 | m |
| n | 4 | 10 | 9 | - | 3 | 12 | 3 | 3 | n |
| q | 7 | 2 | 1 | 4 | - | 3 | 3 | 7 | q |
| v | 6 | 3 | 2 | 14 | 2 | - | 11 | 16 | v |
| w | 3 | 4 | 8 | 6 | 2 | 5 | - | 9 | w |
| y | 5 | 4 | 2 | 3 | 5 | 11 | 4 | - | y |
| | b | h | m | n | q | v | w | y | |

Total: 210 pairs of letter confusions

Total: 147 pairs of letter confusions.

Table 3-b. Matrix of singly occurring letter-confusions (List B).

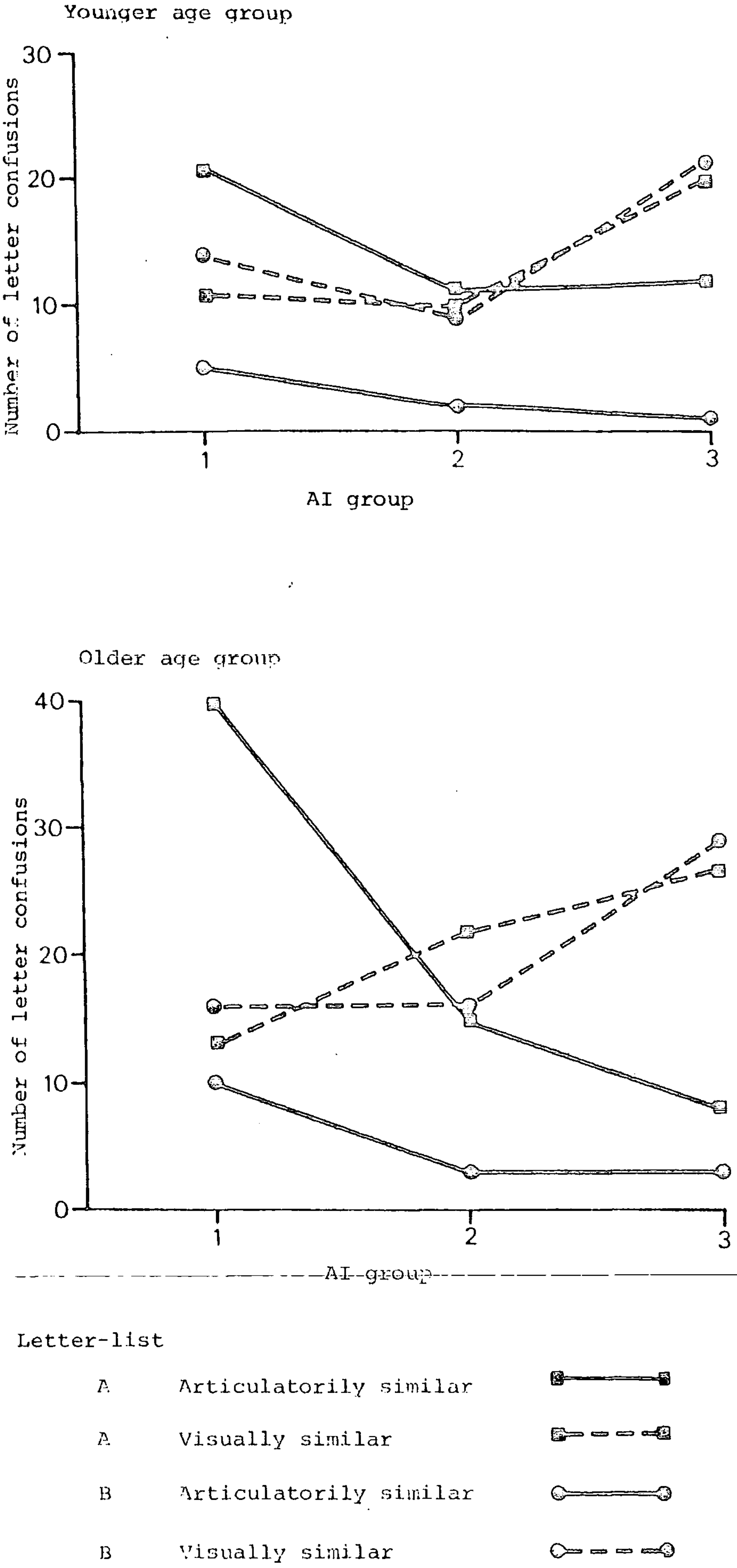


Figure 3-c. Number of visually and articulatorily similar letter confusions which occurred singly within letter sequences from List A and List B as a function of AI group.

absolute number of AS and VS confusions differed according to AI group and according to letter-list (as a result of the deliberate manipulation of the number of VS and AS confusions possible within each of the two letter-lists), but the relative number remained relatively constant across the two letter-lists for each AI Group. The number of AS and VS confusions made by both the older and the younger deaf subjects differed according to their articulatory skills. As was predicted, individuals in AI Group 1 made more AS confusions than either AI Groups 2 or 3,and AI Group 3 made more VS confusions than AI Groups 1 and 2. Both of these results support the original hypotheses.

A further analysis was carried out to look at possible interactions between the three factors - AI Group, Letter-list and Type of letter-confusion (see Figure 3-c).The results of the 3 (AI) x 2 (Letter-list) x 2 (Type of letter-confusion) split-plot factorial analyses of variance are shown in the summary tables in Table 3-c. The three main effects were significant for both the younger and the older age groups - Older age group - for AI:$F(2,33) =3.78, p<.05$; for Letter-list:$F(1,33) =24.34, p<.001$; and for Type of letter-confusion:$F(2,33) =6.94$, $p<.05$. For the Younger age group: for AI:$F(2,21)=3.55, p<.05$; for Letter-list:$F(1,21) =13.79$, $p<.01$; and for Type of letter-confusion:$F(2,33) =9.55$, $p<.01$. The interactions between AI and Type of letter-confusion, and Letter-list and Type of confusion were also significant ($F(2,33) =13.14$, $p<.001$, and $F(1,33) =16.04$, $p<.001$ respectively for the older age group; and $F(2,21) =5.06$, $p<.05$, and $F(1,21) =6.58$, $p<.05$ respectively for the younger age group). In addition the interaction between AI and Letter-list was significant for the older subjects ($F(2,33) =5.08$, $p<.05$), as was the third-order interaction between all three factors. ($F(2,33) =5.42$, $p<.01$). As might be expected, given the design of the experiment, the effects of the three factors were not independent of each other.

Table 3-c. Summary table of the 3 (AI) x 2 (Letter-list) x 2 (Type of confusion) split-plot factorial analysis of variance.

Older age group:

| Source of variance: | df | SS | MS | F | p |
|---|---|---|---|---|---|
| Between subjects | (35) | | | | |
| AI | 2 | 7.68 | 3.84 | 3.78 | <.05 |
| Error (a) | 33 | 33.56 | 1.02 | | |
| Within Subjects | (108) | | | | |
| Letter-list | 1 | 21.0 | 21.0 | 24.34 | <.001 |
| AI x Letter-list | 2 | 8.76 | 4.38 | 5.08 | <.05 |
| Error (b) | 33 | 28.48 | 0.86 | | |
| Type of letter-confusion | 1 | 14.1 | 14.1 | 6.94 | <.05 |
| AI x type of letter-confusion | 2 | 53.3 | 26.6 | 13.14 | <.001 |
| Error (c) | 33 | 66.9 | 2.03 | | |
| Letter-list x type of letter confusion | 1 | 16.7 | 16.7 | 16.04 | <.001 |
| AI x letter-list x type of letter confusion | 2 | 11.3 | 5.63 | 5.42 | <.01 |
| Error (d) | 33 | 34.3 | 1.04 | | |
| Total | 143 | 295.99 | | | |

Younger age group:

| Source of variance | df | SS | MS | F | p |
|---|---|---|---|---|---|
| Between subjects | (23) | | | | |
| AI | 2 | 6.4 | 3.2 | 3.55 | <.05 |
| Error (a) | 21 | 18.94 | .9 | | |
| Within subjects | (72) | | | | |
| Letter-list | 1 | 13.5 | 13.5 | 13.79 | <.01 |
| AI x letter-list | 2 | 0.44 | .22 | .22 | ns |
| Error (b) | 21 | 20.56 | .98 | | |
| Type of letter-confusion | 1 | 13.5 | 13.5 | 9.55 | <.01 |
| AI x type of letter-confusion | 2 | 14.3 | 7.16 | 5.06 | <.05 |
| Error (c) | 21 | 29.69 | 1.41 | | |
| Letter-list x type of letter confusion | 1 | 13.5 | 13.5 | 6.58 | <.05 |
| AI x letter-list x type of letter confusion | 2 | 1.94 | .97 | .47 | ns |
| Error (d) | 21 | 43.06 | 2.05 | | |
| Total | 95 | 175.83 | | | |

There was an insufficient number of kinaesthetically similar letter-confusions to look at group differences, since only 25 pairs of letters that were obviously kinaesthetically similar were confused by the younger age group, and 26 by the older subjects.

As was predicted, number of VS confusions was negatively correlated with AI scores ($r = -.5$, $p < .002$ for the older age group, and $r = -.34$, $p < .1$ for the younger age group). It was also anticipated that the number of AS confusions would correlate positively with AI scores ($r = .65$, $p < .002$ for the older deaf subjects, and $r = .37$, $p < .1$ for the younger subjects).

Six ordered contingency tables were constructed to investigate the relationship between: (i) the frequency of confusion and the visual similarity coefficient (based on the proportion of shape attributes possessed in common), and (ii) letter-confusion frequency and articulatory similarity (based on the proportion of common articulatory attributes). Table 3-d shows the letter-confusion frequency as a function of increasing visual similarity for the entire group of deaf subjects (i.e. both older and younger age groups and all three AI Groups together (N =60), and combining the letter-confusions which occurred from List A with those from List B). Tables 3-e and 3-f present the same data for AI Groups 1 and 3 respectively (again for the combined age groups). Similarly, the frequency of letter-confusions as a function of increasing articulatory similarity are shown for the entire group (Table 3-g), for AI Group 1 (Table 3-h) and for AI Group 3 (Table 3-i). The frequency of letter-confusions, when ordered along the visual similarity, and the articulatory similarity dimensions, supported the suggestion that the likelihood of a confusion would be a positive function of the degree of similarity between the presented and the recalled items.

Table 3-d Scale of Visual Similarity (High)

Frequency of confusions

| | 0 | .1 | .13 | .14 | .17 | .2 | .22 | .25 | .29 | .3 | .33 | .36 | .4 | .43 | .44 | .5 | .6 | .67 | .7 | .75 | .8 | .83 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3 | | | | | | 1 | | | | | | | | | | | | | | | | |
| 4 | 1 | | | | | 1 | | | | | | | | | | | | | | | | |
| 5 | | | 1 | | 1 | 1 | 1 | | | | 1 | 1 | 1 | | | | | | | | | |
| 6 | | 1 | | | 1 | | | | | | | | | | | | | | | | | |
| 7 | | | | | 1 | | | | 1 | | | | 11 | | | | | | | | | |
| 8 | | | 1 | | | 1 | | 1 | | | | | | | | | | | | | | |
| 9 | | | | 1 | | | | | 1 | | | | | | | 1 | | | | | | |
| 10 | 1 | | | | | 1 | | | | 11 | | | | | | | | | | | | |
| 11 | | 1 | | | | 11 | | | | 1 | | | | | | | | | | | | |
| 12 | | | | | | 1 | | | | | 1 | | | | | 11 | | | | | | |
| 13 | | | | | | | | | | | | | 1 | 1 | | | | | | | | |
| 14 | | | | | 1 | | | | | | | | | | | | | | | | | |
| 15 | | | | | 1 | 1 | | | | | | | | | | | | | | | | |
| 16 | | | | | | | | | | | | | | | | 1 | | 1 | | | | |
| 17 | | | | | | | | | | | | | | | | | | | | | | |
| 18 | | | | | | | | | | | 1 | | | | | | | | | | | |
| 19 | | | | | | | | | | | | | | | | | | | 1 | | | |
| 20 | | | | | | | | 1 | | | | | | | | | | | | | | |
| 21 | | | | | | | | | | | | | | | 1 | | | | | | 1 | |
| 22 | | | | | | | | | | | | | | | | | | | | 11 | | |
| 23 | | | | | | | | | | | | | | | | | | | | 1 | | |
| 24 | | | | | | | | | | | | | | | | | | | | | | |
| 25 | | | | | | | | 1 | | | | | | | | | | | | | | 1 |
| 26 | | | | | | | | | | | | | 1 | | | | | 1 | | | | |
| 27 | | | | | | | | | | | | | | | | | 1 | | | | | |
| 28 | | | | | | | | | | | | | 1 | | | | | | | | | |
| 40 | | | | | | | | | | | | | | | | | | | | 1 | | |

Table 3-e Scale of Visual Similarity (High)

Frequency of confusions

| | 0 | .1 | .13 | .14 | .17 | .2 | .22 | .25 | .29 | .3 | .33 | .36 | .4 | .43 | .44 | .5 | .6 | .67 | .7 | .75 | .8 | .83 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | | 1 | | | | | | 1 | | | | | | | | | | | | | | |
| 1 | 1 | | | | 11 | 1 | 1 | | 1 | 1 | | 1 | | | | | | | | | | |
| 2 | 1 | | 11 | | 11 | 11 | | | 1 | 1 | | | 1 | | | 11 | | | | | | |
| 3 | | 1 | | 1 | | 11 | | | | | 111 | | 11 | 1 | | 1 | | 1 | 1 | | | |
| 4 | | | | | | 1 | | | | | | | 1 | | | 1 | | 1 | | | | |
| 5 | | | | | | 1 | | | | 1 | | | 1 | | | | | | | | | |
| 6 | | | | | 1 | | | | | | | | | | 1 | | | | | 1 | | |
| 7 | | | | | | 1 | | | | | | | | | | | | | | | | 1 |
| 8 | | | | | | | | | | | | | | | | | | | | 1 | 1 | |
| 9 | | | | | | 1 | | | | | | | | | | | 1 | | | 11 | | |
| 14 | | | | | | | | 1 | | | | | | | | | | | | | | |
| 15 | | | | | | | | 1 | | | | | | | | | | | | | | |
| 19 | | | | | | | | | | | | | 1 | | | | | | | | | |

Table 3-f Scale of Visual Similarity (High)

Frequency of confusions

| | 0 | .1 | .13 | .14 | .17 | .2 | .22 | .25 | .29 | .3 | .33 | .36 | .4 | .43 | .44 | .5 | .6 | .67 | .7 | .75 | .8 | .83 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | | | | | | 1 | | | | | | | | | | | | | | | | |
| 1 | | | 1 | | | | | | | | | 1 | 1 | | | | | | | | | |
| 2 | 1 | 1 | | | 1 | 1111 | 1 | 1 | 11 | 11 | 1 | | | | | | | | | | | |
| 3 | | | 1 | 1 | 11 | 111 | | | | | | | 1 | | | 1 | | | | | | |
| 4 | | | | | 1 | 1 | | | | | | | 11 | | | 1 | | | | | | |
| 5 | 1 | 1 | | | | | | 1 | | | 1 | | 1 | | | 1 | | | | | | |
| 6 | | | | | | | | 1 | | 1 | | | | 1 | | | | 1 | | | | |
| 7 | | | | | | | | | | | 1 | | | | | 1 | | | | 1 | | |
| 8 | | | | | 1 | | | | | | | | | | | | | | | | | |
| 9 | | | | | | | | | | | | | | | 1 | | | | | 1 | 1 | |
| 10 | | | | | | | | | | | | | | | | | | | 1 | | | |
| 11 | | | | | | | | | | | | | | | | | | | | 1 | | |
| 12 | | | | | | | | | | | | | 1 | | | | | | | | | |
| 13 | | | | | | | | | | | | | | | | | | 1 | | | | 1 |
| 14 | | | | | | | | | | | | | | | | | | | | | | |
| 15 | | | | | | | | | | | | | | | | | 1 | | | | | |
| 16 | | | | | | | | | | | | | | | | | | | | 1 | | |

Frequency of letter confusions as a function of increasing visual similarity for the total group (Table 3-d), AI Group 1 only (Table 3-e) and AI Group 3 only (Table 3-f).

Frequency of letter confusions as a function of increasing articulatory similarity for the total group (Table 3-g), for AI Group I only (Table 3-h) and for AI Group 3 only (Table 3-i).

Table 3-g Scale of articulatory similarity

Frequency of confusions

| | No shared articulatory features | 1 shared articulatory feature: | | | 2 shared articulatory features: | | | Identical vowel ending | Identical vowel ending plus | | | Identical vowel ending plus identical consonant + V |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | M | P | V | VP | MP | VM | | VM | VP | MP | |
| 3 | 1 | | | | | | | | | | | |
| 4 | | | 1 | | | | | | | | | |
| 5 | 111 | | | 1 | 1 | 1 | | 11 | | | | |
| 6 | 1 | | 1 | | | | | | | | | |
| 7 | 111 | | | | 1 | | | | | | | |
| 8 | 1 | | 1 | 1 | | | | | | | | |
| 9 | 11 | | | 1 | | | | | | | | |
| 10 | 11 | | | 1 | 1 | | | | | | | |
| 11 | | | 1 | | 1 | | | 1 | | | | |
| 12 | 11 | | | 1 | | | | | 1 | | | |
| 13 | 1 | 1 | | | | | | | | | | |
| 14 | 1 | | | | | | | | | | | |
| 15 | | | | | | | | 1 | 1 | | | |
| 16 | 1 | 1 | | | | | | | | | | |
| 17 | | | | | | | | | | | | |
| 18 | | | 1 | | | | | | | | | |
| 19 | 1 | | | | | | | | | | | |
| 20 | | | | | | | | | | 1 | | |
| 21 | 1 | | | 1 | | | 1 | | | | | |
| 22 | 11 | | | | | | | | | | | |
| 23 | | | | | | | | | 1 | | | |
| 24 | | | | | | | | | | | | |
| 25 | | | 1 | | | | | | | | | 1 |
| 26 | | | | 1 | | | 1 | | | | | |
| 27 | | | 1 | | | | | | | | | |
| 28 | | | | | | | | | | | 1 | |
| 40 | | | | 1 | | | | | | | | |

Note:

M = Mode of articulatio

P = Place of articulatio

V = Voicing

Table 3-h Scale of articulatory similarity

Frequency of confusions

| | No shared articulatory features | 1 shared articulatory feature: | | | 2 shared articulatory features: | | | Identical vowel ending | Identical vowel ending plus | | | Identical vowel ending plus identical consonant plus V |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | M | P | V | VP | MP | VM | | VM | VP | MP | |
| 0 | 1 | | 1 | | | | | | | | | |
| 1 | 111 | | 1 | 1 | 11 | | | 1 | | | | |
| 2 | 111 | | 1 | | 11 | 1 | | | | | | |
| 3 | 1 | | 11 | 1111 | | | 1 | | | | | |
| 4 | | 11 | | | | | 1 | 1 | | | | |
| 5 | 1 | | | 1 | | | | 1 | | | | |
| 6 | 11 | | | | | | | 1 | | | | |
| 7 | | | 1 | | | | | | 1 | | | |
| 8 | 1 | | | 1 | | | | | | | | |
| 9 | | | 1 | 1 | | | | | 11 | | | |
| 14 | | | | | | | | | | 1 | | |
| 15 | | | | | | | | | | | | 1 |
| 19 | | | | | | | | | | | 1 | |

Table 3-i Scale of articulatory similarity

Frequency of confusions

| | No shared articulatory features | 1 shared articulatory feature: | | | 2 shared articulatory features: | | | Identical vowel ending | Identical vowel ending plus | | | Identical vowel ending plus identical consonant plus V |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | M | P | V | VP | MP | VM | | VM | VP | MP | |
| 0 | | | | | | | | 1 | | | | |
| 1 | 11 | | | | | | | | | | | |
| 2 | 111 | | 11 | 1 | 1 | | | 111 | 1 | 1 | | |
| 3 | 111 | | 1 | 11 | 11 | 1 | | | 1 | | | |
| 4 | 111 | 1 | | | | | 1 | | | | | |
| 5 | 111 | | 1 | 1 | 1 | | | | | | 1 | |
| 6 | 11 | | | 1 | | | | | | | | 1 |
| 7 | | | 1 | | | | | | 1 | | | |
| 8 | 1 | 1 | | | | | | | | | | |
| 9 | 11 | | | 1 | | | | | | | | |
| 10 | 1 | | | | | | | | | | | |
| 11 | 1 | | | | | | | | | | | |
| 12 | | | | 1 | | | | | | | | |
| 13 | | | 1 | | | | 1 | | | | | |
| 14 | | | | | | | | | | | | |
| 15 | | | 1 | | | | | | | | | |
| 16 | | | | 1 | | | | | | | | |

There was a highly significant positive correlation ($\tau_c$ =.43,$p<.00003$, Kendall, 1970, p.147) between visual similarity and the number of confusions made by the entire group, and also by AI Group 1 ($\tau_c$ = .35,$p < .002$), and AI Group 3 ($\tau_c$ =.42,$p < .00003$). The correlations between articulatory similarity and frequency of confusions were smaller, and more variable across the AI groups ($\tau_c$ =.16,p =.057 for the entire group; $\tau_c$ =.33,p =.0008 for AI Group 1; and $\tau_c$ =-.12,p =.11 for AI Group 3). It would appear that ordering the letter-pairs along the dimension of increasing visual similarity is a better predictor of the overall frequency distribution of item errors than the dimension of articulatory similarity. The correlations were unexpectedly high in view of the fact that ordering the confusions along a single dimension of similarity, such as visual similarity, overlooked the fact that pairs of letters could also be articulatorily similar and/or kinaesthetically similar, and did not allow for multidimensional similarity. Thus for example, the pair of letters 't' and 'd' are highly articulatorily similar, and by comparison less visually similar, and will therefore occupy a different position along the similarity axis according to the dimension with the same number of confusions, and thereby distort the overall pattern of results.

It is interesting that the frequency of confusions correlated highly with increasing visual similarity for the entire group, and also for AI Groups 1 and 3 separately. Only the latter high correlation was anticipated. These findings suggest that visual shape cues were an important feature in the memory processing of all the deaf children tested, irrespective of their articulation skills. The picture emerging from the articulatory similarity dimension is less clear. Overall, articulatory similarity correlated less highly with frequency of letter-confusion for the entire group. As one would expect, this dimension was not relevant for all the deaf subjects, particularly those in AI Group 3 who could not articulate the letter-names intelligibly. But, as was predicted, articulatory similarity correlated more highly with frequency of letter-confusion for AI Group 1 who were able to articulate relatively intelligibly, and for whom therefore the dimension of articulatory similarity was relevant.

3.8.3 Order errors. Pairs of transposed letters (e.g. the letter-sequence 's-x-d-a' recalled as 's-x-a-d') were also studied to discover whether these order errors also reflected similar types of confusion as a function of articulation ability, as was found for the item errors. Once again the pairs of letter-transpositions from Lists A and B were combined. The results of the Jonckheere Trend Test showed that there was no difference in the number of order errors (i.e. the overall number of sequences in which the correct letters were recalled in an incorrect order) across the three AI groups for either the older ($s = 17$, $p = .4$) or the younger age group ($s = 20$, $p = .3$). Nor was there a difference in the number of VS transpositions made by the three AI groups ($s = 17$, $p = .4$ for the older age group; and $s = 21$, $p = .27$ for the younger subjects). AI Group 1 did however transpose significantly more AS letter-pairs than either of the other AI groups, and AI Group 3 fewest ($s = 264$, $p < .0007$ for the older subjects; and $s = 103$, $p < .002$ for the younger age group). The implications of these findings for the temporal-linguistic coding hypothesis will be discussed in the following section (Section 3.9).

3.8.4 Correlation analyses of subject and experimental variables. For each of the 60 individuals tested in the present experiment, the following personal data was available from the school records: chronological age, reading age (Young's Group Reading test), W.I.S.C. Performance scores, and pure-tone hearing losses measured at 250, 500, 1000, 2000 and 4000 Hz. (See Appendix E for the raw scores.) In order to evaluate the results further, the relative contribution of these subject variables was studied. It was found that age and I.Q. scores did not correlate very highly with reading ability, AI scores, hearing loss,or the number of VS, AS, or D confusions made. In the older age group the most significant of these correlations was between I.Q. and reading age (r =.34, p =.15). In the younger subjects, as one might expect in a population whose reading ability stagnates from the age of about nine onwards, age correlated more highly with reading age (r =.42, p<.02). Age was also significantly positively correlated with AI scores (r =.45, p< .02), and negatively correlated with high frequency hearing loss (r =-.57, p< .01). Of particular interest was the correlation between AI Scores and some of the remaining variables (see Table 3-j). AI scores correlated significantly with the memory span difference scores and both low- and high- frequency hearing losses and, for the older age group only, with the number of VS and AS confusions.

| | Memory span difference scores | Hearing Loss: Low Frequency | High Frequency | VS Confusions | AS Confusions |
|---|---|---|---|---|---|
| Older Age Group: | -.38* | -.69** | -.78** | -.5* | .65** |
| Younger Age Group: | -.74** | -.58** | -.72** | -.34 | .37 |

* p< .05
** p< .002

Table 3-j. Correlations (r) between AI scores and some of the variables and dependent measures from Experiment 1.

To isolate the effect of AI scores, the effects of age, intellectual ability and reading age were partialled out (see Table 3-k). With the exception of the correlation between AI scores and number of AS confusions for the younger age group, which was reduced to a low, non-significant correlation, there were no changes of any consequence. The interaction of

| | Memory span difference scores | Hearing Loss: Low Frequency | High Frequency | VS confusions | AS confusions |
|---|---|---|---|---|---|
| Older Age Group: | -.39* | -.78** | -.88** | -.43* | .71** |
| Younger Age Group: | -.77** | -.52* | -.64** | -.55* | .18 |

* $p < .05$
** $p < .002$

Table 3-k. Correlations (r) between AI scores and some of the variables and dependent measures with age, I.Q. and reading age partialled out.

age, I.Q. and reading age variables did not appear to have a very marked effect on the experimental variables. High- and low-frequency hearing losses were highly correlated for both the older ($r =.76$, $p < .0001$) and the younger age groups ($r =.54$, $p \leqslant .01$). Also of interest are the correlations between hearing losses and types of letter-confusion. For the older subjects, low frequency hearing loss was significantly correlated with number of VS confusions ($r =.41$, $p < .02$), and with number of AS confusions ($r =-.54$, $p < .0002$), and similarly for the high-frequency losses ($r =.39$, $p < .02$, and, $r =-.57$, $p < .002$ respectively). For the younger age group low- and high-frequency losses were also correlated with number of VS confusions ($r =.39$, $p =.059$, and $r =-.42$, $p =.04$ respectively). When the effects of age, I.Q. and reading age were partialled out, the correlations between hearing loss and number of confusions remained largely unchanged, except that the correlation between low-frequency loss and number of AS confusions was increased for the younger subjects.

3.8.5 Multiple regression analysis. Amongst the 11 variables mentioned in the previous section, two different types of measures are to be found: 1) Subject variables - measures which the experimental subjects brought with them to the test session (age, high- and low-frequency hearing losses) and psychometric measures (I.Q. and reading age).

2) Experimental variables - data collected during the experimental sessions, namely the number of VS, AS and D letter-confusions, the total number of single letter-confusions, and the memory span difference scores. Both the subject and the experimental variables were included in the set of predictor variables. A step-wise multiple regression analysis provided a measure of the overall degree of relationship between the set of predictor variables and the AI scores (the criterion measure) for each age group.

In the older age group high frequency hearing loss was the best predictor of AI scores and accounted for 60% of the variance. (High freqency hearing losses were, in their turn, highly correlated with the low-frequency losses.) The next best predictor was reading age which accounted for a further 12% of the variance, and number of articulatory confusions contributed a further 7%. Together, 3 of the 11 predictor variables, namely high-frequency loss, reading age and number of articulatory confusions accounted for over 80% of the total variance of the AI scores.

In the younger age group the memory span difference scores were found to be the best predictor of AI and accounted for 55% of the total variance. Again, reading age was the second best predictor accounting for a further 12% of the variance, and high-frequency losses contributed a further 5%. Together, the difference scores, reading age and high-frequency hearing loss accounted for over 72% of the total variance of the AI scores. Of the subject variables, high-frequency hearing loss and reading age turned out to be the most accurate predictors of AI scores for both the younger and the older deaf subjects. The best experimental variable predictor was, for the older age group, number of AS letter-confusions, and the for younger subjects, the differences between memory span scores on the two letter-lists which differed in their potential visual and articulatory confusability. The reason that low-frequency hearing loss is not included high in the list of predictors, for either the older or younger age groups, may not be because it is unimportant, but rather that there is no independent contribution made by the low-frequency losses, which are highly correlated with the high frequency hearing losses.

### 3.9 Discussion.

The results supported the hypothesis that letter-confsions would vary according to the ability of the deaf subjects to articulate intelligibly. This finding replicates the earlier study of Locke and Locke (1971), who reported that communication abilities and apparent coding strategies in S.T.M. agreed quite closely. THe articulation skills of the deaf were found to be important determinants of memory-coding preferences.

3.9.1 Immediate memory coding and letter-confusions. As was predicted, the deaf subjects in AI Group 1 confused more AS letters than AI Groups 2 and 3, whilst the individuals in AI Group 3 confused more VS letters than either Group 1 or 2. Conrad and Rush (1965, p.342) suggested the possibility that "poor deaf subjects do use more shape coding than good deaf subjects". If by 'poor' they are referring to deaf individuals unable to articulate clearly (equivalent to the present AI Group 3),then the present results verify their findings.

There was no evidence of a decrease in the number of VS confusions with age. There did however appear to be an increase in the use of articulatory coding across the age groups, for all three AI groups, the increase being greatest, as one would expect, for AI Group 1. Whenever speech coding was available (as judged by AI scores) to the deaf subjects, it appeared to be used, its use being reflected by a marked increase in the number of AS letters that were confused during immediate memory processing. It would be instructive therefore to undertake a more detailed longitudinal study, controlling age in addition to AI. Such an investigation should attempt to study the possible relationship between the teaching and development of speech skills (which frequently do not begin until the deaf child attends school), and experimental evidence for the use of covert speech in cognitive tasks. It would provide a "deaf" counterpart to the study previously undertaken by Conrad (1971a) involving 3 to 11-year-old hearing children, in which he reported a developmental lag between the acquisition of speech and the use of covert speech cognitively. Mere ability to articulate does not necessarily imply that it will affect cognitive behaviour in younger subjects at least, and Conrad suggested that it was not until the age of 5 that speech was employed by the 'normal' hearing child for internal representation.

When each individual subject was used as his or her own control to calculate the differences in memory span scores between the two letter-lists, these difference scores correlated highly with the AI scores. The deaf subjects in AI Group 1 were significantly worse at remembering List A (containing more AS letters) compared with List B (containing more VS letters), and vice versa for AI Group 3. As anticipated, the potential confusability of the two letter-lists affected memory span as a function of the deaf subjects' ability to articulate intelligibly; the differences between Lists A and B were apparently sufficient to affect recall, and hence memory span, differentially according to AI.

The general picture that is emerging from the experimental scores of the younger age group suggests that they were not able to use memory coding strategies as efficiently as the older subjects. The individuals in the younger AI Group 3 were significantly handicapped in their ability to recall sequences of letters that were highly visually similar compared with the other subjects in the younger age group. The older deaf subjects in AI Group 3 on the other hand, appeared to have developed their visual coding strategies sufficiently so that they were better able to deal with the visually similar forms - possibly, they had learned to code visual information multi-dimensionally. The correlation between AI scores and number of VS and AS letter-confusions was also lower for the younger age group, again suggesting less well-developed coding strategies. And, when age, I.Q. and reading age were partialled out, the correlation between AI scores and number of articulatory similar confusions was significantly reduced for the younger subjects, whilst this had little effect on the correlation scores of the older subjects. The realised effects of AI were more apparent in the older deaf subjects, for whom ability to articulate had become largely independent of other external measures. During the development of speech skills, however, AI appears to be more highly correlated with factors such as age, I.Q. and reading ability.

In 1965, Conrad and Rush wrote that "the obvious possibility is that deaf subjects use shape cues" (p.341). The present findings provide further evidence of visual coding on the basis of shared shape-attributes. In fact some of the deaf subjects actually commented on the similarity between certain of the letters, notably 't' and 'f' which they referred to as 'nearly the same'. If it is at all possible to talk about a 'predominant code' among deaf individuals, then for this sample at least it would appear to be visual, since all those tested seemed to be using some visual coding to a greater or lesser extent, whereas the use of articulatory coding was more restricted, and was largely dependent on AI group. This finding is similar to that of Carey and Blake (1974) who also reported that the confusions made by their deaf subjects were predominantly visual. Since upper-case letters were used in the latter experiment, unlike the present study, their results are a further indication of the use of visual coding.

Chase and Posner (1965) found, using a target-letter and a circular array of letters that were either visually or auditorily similar to the target-letter, that visual similarity had a more marked effect when the task involved visual matching. When, however, a memory factor was introduced, the effect of visual similarity was reduced and auditory similarity had a more marked effect. Visual memory for verbal items in hearing individuals (Paivio, 1971) is frequently overlaid by a phonemic memory, particularly in experimental test sessions, but in deaf subjects visual memory is more apparent, and the duration of visual images must be longer than the estimates of two seconds or less suggested by Sperling (1960), and Smith and Carey (1966) for hearing subjects.

One can infer from the use of visual coding by the deaf subjects tested in the present experiment, that there is a non-verbal visual store beyond the icon (Neisser, 1967). This suggestion is in line with findings reported by other researchers. For example, Henderson (1972,p.446) postulated that "auditory-verbal S.T.M. is supplemented by a post-iconic visual store" in 'normal' subjects, and Warrington and Shallice (1972) reported clinical evidence of a separate post-perceptual visual S.T.M. system. Estimations of the durability of short-term visual storage appear to differ. Phillips (1974) found, using random visual patterns, that visual storage became less effective over the first few seconds, whereas Kroll, Parks, Parkinson, Bieber and Johnson (1970) reported that the visual code decayed little, if at all, over periods as long as 25 seconds. Possible reasons for these apparent discrepancies may be the amount of incentive to concentrate on the visual code provided by the experimenter, also, it may be easier to represent and maintain the visual trace of familiar forms, such as letters, than of random visual patterns. There does however, appear to be some agreement that there is a visual store beyond the sensory store, and this has now been experimentally demonstrated for both deaf and hearing individuals.

These findings are more in line with a multi-component memory model, such as that put forward by Craik and Jacoby (1975, p.180) who wrote: "The position suggested, then, is that while short-term encoding can involve any set of features which are activated or attended to, verbal items may usually be held in terms of their phonemic features". Certainly the earlier models of theorists such as Sperling (1967) did not allow for the processing and retention of visual information beyond a visual sensory store. The translation of verbal items presented visually into an auditory-vocal memory store may be a more common strategy with hearing subjects, but it is not a necessity as the present experiment, and others undertaken with deaf subjects, demonstrate. It is important therefore to distinguish between coding skills that are unavailable (as is acoustic coding to the majority of prelingually deaf individuals) and those that are available but not always used. Visual coding in hearing individuals would appear to belong to this latter category, its use being largely determined by experimental constraints.

The overall pattern of letter confusions was in agreement with the hypothesis that the probability of an incorrect response is a function of the number of attributes shared by the presented and recalled item, whether visual or articulatory. The psychological reality of these 'features' is not being claimed on the basis of the present evidence, but it would seem that the descriptive approach adopted here is consistent with the psychological findings.

The results for the three AI groups and for the individuals within these groups also provided additional support for Conrad's (1972c) suggestion that memory storage in the deaf was more complex than in the case of hearing individuals, and for the 'more volatile coding' (Conrad, 1972b) of the deaf. Certainly articulatory coding could not explain all the confusions made by the deaf subjects. There was also evidence of considerable variation within the total group, both across AI groups and between subjects. The present findings from a simple cognitive processing task clearly demonstrate the lack of homogeneity that exists even within a relatively small sample drawn from a single educational establishment.

The data for the letters that are kinaesthetically similar were not so clear-cut. Few of the letters within the two lists were obviously highly similar kinaesthetically (with the exception of 'k' and 'd' from List A, and 'v' - 'n' and 'q' - 'y' from List B), and there were therefore insufficient data to analyse in any detail. Observational records, however, did provide extensive evidence of the use, without specific instructions to do so, of fingerspelling. During the course of the experimental sessions some of the deaf subjects were observed articulating aloud, or mouthing the letter-names silently, 'writing' in the air or on the table (invisibly), but the most frequently employed 'aid', irrespective of ability to articulate, was that of fingerspelling. There was no evidence of differential use of fingerspelling by the three AI groups; several of the individuals in AI Group 1 supplemented their articulation of the letter-names by also fingerspelling the letters. Liben and Drury (1977) have also reported that many of the deaf subjects whom they tested used fingerspelling in an experiment involving visually presented letter-stimuli. Not only did the deaf subjects in the present study fingerspell the letters as they were presented, but they also made use of elaborate hand-configurations for entire sequences of letters, employing a distorted gesture for several letters in a single, fixed hand-configuration; a similar finding was reported by Dornic, Hagdahl and Hanson (1974). It was not clear whether or not any of these accompanying activities were actually necessary for memorising.

A further observation of interest was that only 8 of the 60 subjects (and all from the older age group) actively rehearsed the items, the remaining subjects merely identified each individual letter at time of presentation by either fingerspelling or articulating its name, but made no attempt to cumulatively rehearse the items in sequence (this was also reported by Liben and Drury, 1977). The 'automatic' reaction of the majority of the deaf subjects to label the items at time of presentation may possibly be attributed to the common classroom practice of requiring deaf children to label items as a regular exercise or drill.

An intensive training programme in the use of cumulative rehearsal strategies, (using either fingerspelling or vocalisation) along the lines of the intensive remediation programme designed by Espeseth (1969), would possibly increase the visual - sequential memory span abilities of the majority of the group, since without exception, it was those individuals, who of their own accord actively rehearsed the items,who scored highest on immediate memory span. It may be that lack of practice at memorising lists of items, and consequently lack of development of the appropriate rehearsal strategy, is largely responsible for any deficiency in memory span abilities.

Wallace and Corballis (1973) reported that the deaf subjects they tested only resorted to fingerspelling when sequences were long and the memory system overloaded, but there was no evidence from the present experiment to support their theory. Fingerspelling was used for the shortest and the longest letter-sequences alike by those individuals who chose to fingerspell, and since the majority of sequences were within memory span, the immediate memory system was rarely overloaded.

It is clear from this and from previous studies that the use of fingerspelling, and the extent to which information is encoded manually should be seriously considered. More evidence of kinaesthetic coding was found in the present experiment than in an earlier study by Locke (1970b), and further evidence will be presented in Chapter 7, from Experiment 9. Relatively little is at present known about kinaesthetic storage. Motor memory has not been studied extensively but the few studies that have been carried out (e.g. Adams, Marshall & Goetz, 1972; Diewart, 1975; Posner, 1967) have suggested that motor memory has quite different central-processing requirements, and is not linked, directly at least, to visual storage. In addition to our lack of knowledge about kinaesthetic storage and about scaling of kinaesthetic similarity, it is also proving very difficult to disentangle the visual and kinaesthetic components of fingerspelling and dactylic coding. Perhaps future work should be concerned more directly with recording EMG activity and sub-manual responses associated with the use of fingerspelling and signs for problem-solving, studies similar in fact to those already attempted by Max (1937) and, more recently, by McGuigan (1971).

It is difficult to compare the relative efficiency of different types of imagery used by the deaf subjects in the present experiment. A striking feature of the results was the lack of obvious quantitative differences in immediate memory-span scores, across the three AI groups, apart from those relatively small differences related tothe manipulation of the potential confusability of letters within the two letter-lists. On the basis of the similarity of these memory-span scores one cannot assume that articulatory coding was better than visual coding for these deaf subjects. Qualitative differences in type of letter-confusion were more noteworthy than the quantitative differences. Ability to articulate did not appear to affect memory span scores as predicted by a temporal-linguistic coding hypothesis.

It is however, possible that the level of skill in articulation attained by these deaf individuals, even those in AI Group 1, was not sufficient for useful speech coding. There is no code used by the deaf as highly developed as speech coding in hearing individuals (Conrad, 1972b). As Thomassen (1970) found, articulation (speech coding) does not play a large role and does not explain all the memory coding of deaf individuals. It would be inconceivable to suggest that the use of speech coding was an all-or-none affair, and that deaf subjects ignored all the other cues that they normally use to identify items, namely visual and manual cues.

3.9.2 Immediate memory span. The present results showed no ceiling effect as is commonly found; none of the deaf were consistently able to retain a sequence of 8 unrelated items. Yet, when talking about the span of apprehension, Miller (1956) referred to the "magic number 7 ± 2". In fact only 2 of the 36 subjects in the older age group had a memory span even approaching 5 items, and therefore within the lower limits of Miller's estimation. Generally speaking all the deaf subjects had very low immediate memory span scores on both letter lists, with a mean of 3.7 items for the older age group (12 to 16-year-olds) and 2.8 items for the younger age group (8 to 12-year-olds). These low memory-span scores are similar to those reported by Pintner and Paterson (1917) who found an average of 2.1 digits for the 7 to 12-year-old deaf subjects and 3.5 for the 13 to 15-year-olds. More recently Ross (1969) tested 180 congenitally deaf and 180 hearing subjects and found an average memory span of 4 for both the deaf and hearing groups using visual symbols. He observed that the process which Miller (1956) refers to as "chunking" and which enables more items to be stored in memory, is only possible with trial repetitions. Ross argued that if stimuli were presented seriatim and once only (as in memory-span experiments) then opportunities for chunking were very restricted. He claimed that under such experimental conditions, when items had to be remembered in exact sequential order, the typical results were not of the order of 7 ± 2, but that an average of between 4 and 5 items could be remembered by naive subjects. The present findings regarding the immediate memory span of the deaf would appear therefore to be in line with previous results.

3.9.3 The retention of order information. Poor retention of order information was previously found (Dawson, 1973) with successive presentation of 8-item sequences (of outline drawings, letters and shapes) when item recognition was probed. The deaf subjects tested could accurately recognise whether or not a probe-item had been seen before, but were significantly inferior, when compared with hearing controls, in their ability to report where, within the sequence, the item had occurred, when the probe-item had previously been presented. Thomassen (1970) also found that a decrease in auditory imagery had a relatively marked effect on ability to retain order. The recall of sequence may be a property of the verbal system; order may not be an intrinsic property of visual imagery. If this were the case, one would expect to find a difference in the present experiment in the number of order-errors made by the three AI groups. No such difference was found in the number of sequences in which all the items were recalled correctly but in the wrong order (including pairs of letter-transpositions). Either order-information can be encoded within the visual image, which previous evidence would suggest is unlikely, or, the articulatory imagery of the deaf with the best speech skills was not sufficiently fully developed to affect and improve the retention of order-information. It cannot be assumed that a phonological code is more efficient than a visual one, only that it is more widely used by hearing individuals, and that it may aid the retention of order-information.

The anticipated negative correlation between AI scores and hearing loss (high and low frequency) demonstrates the relationship between hearing and ability to speak. It is interesting that the high frequency hearing losses correlated more highly with the AI scores than the low frequency losses, and also accounted for a greater proportion of the variance. For the higher speech frequencies account for the majority of the consonant sounds in English and it is these that carry the most information in speech, thus high frequency losses are more handicapping,in terms of speech development, than low frequency losses.

3.9.4 An assessment of the present experiment and suggestions for further research. In the present experiment the vowel 'a' was used in List A since it is articulatorily similar to the letters 'k' and 'j', and visually similar to the letter 'd'. It is clear, however, that vowels are better omitted from such letter-lists since their inclusion greatly increases the likelihood of generating meaningful letter sequences, i.e. words. Special care and attention was continually necessary to avoid the generation of words such as 's - a - d' - a possible random combination of the letters from List A.

The inclusion of a multisyllabic letter-name, namely 'w' (in List B) should also be avoided in future studies. The multisyllabic nature of the name possibly made it more distinctive, and therefore potentially less confusable,than the remaining letter-pairs. This may partly explain why 'q' and 'w' were rarely confused even by individuals in AI Group 1. In addition, 'w' turned out to be one of the two letter-names that the deaf subjects found most difficult to pronounce. Very few of the deaf children, including those who could articulate most clearly, were able to pronounce it sufficiently intelligibly for it to be consistently recognised by the judges (referred to in Section 3.4). The other letter that caused pronunciation difficulties was 'q' (also from List B) which a few of the deaf children (but an insufficient number to be of significance) labelled as 'kwiː'. These two isolated examples illustrate some of the problems that can arise in an experimental study of this nature, and which could all too easily be overlooked in the event of the experimenter being a complete stranger to the school, and to the deaf subjects themselves. Had teacher's ratings of AI ability been adopted, and no record made of each individual subject's attempts at pronouncing the names of all the letters used in the experiment, idiosyncracies of this kind might never have been discovered and taken into consideration on an individual basis. Frequent confusion in memory of the letters 'q' and 'v' ('kwiː'and 'viː') would be far more difficult to understand and account for using a less individualised experimental approach, such as is frequently adopted.

Since the letters 'm' and 'n' were classified as visually, articulatorily and kinaesthetically highly similar, they had therefore to be omitted from the specific categorisation of confusion-type used in the analyses. As however they were one of the pairs of letters that were most frequently confused during immediate memory processing by both the older and the younger deaf subjects, irrespective of AI group, one might tentatively interpret such a finding as evidence of multidimensional coding of letters in immediate memory. This idea certainly warrants further study and could possibly be extended to other pairs of letters of a similar nature.

In a follow-up study, it would be interesting to repeat the present experiment using a longer gap between presentation and recall. This interval could then be: (i) left unfilled;

(ii) filled with unrelated kinaesthetic activity;

(iii) filled with unrelated articulatory activity;

(iv) filled with unrelated visual activity.

The relative effects of such sources of interference on performance, and on the type of memory coding possible, could then be observed.

One cannot conclude from the relatively low memory span scores that these deaf individuals therefore suffer from poor memory in a general sense. Observation of everyday behaviour certainly provided evidence of very adequate working memories, be it remembering a shopping-list, or recalling in detail the events of a film seen previously on television. It is nonetheless useful to study a very limited example of cognitive behaviour, such as immediate memory, in an artificial experimental setting, to discover more about the nature and complexity of memory coding differences in the deaf. Certainly the use of 'simple' familiar stimuli, such as alphabet letters, makes one aware of the flexibility of the memory system, and demonstrates the varied nature of representation in memory even of stimuli as simple as these.

In this first experiment both older and younger deaf subjects were tested. In the subsequent 8 experiments however, only the older deaf subjects, from the Upper School, were tested. This decision was made for two reasons: (1) within each age-group the between-group (AI groups) analyses of Experiment 1 turned out to be of greater interest than a comparison of performance according to age; and (2) the experiments are themselves (particularly the reaction time studies) more suitable for use with older rather than younger subjects, irrespective of hearing ability.

### 3.10 Summary.

The immediate memory coding preferences of a group of 60 deaf children (24 from the Middle School, and 36 from the Upper School) were studied as a function of ability to articulate intelligibly. Successive presentation of lower-case alphabet letters in sequences of increasing length (between 2 and 8 items) was followed by immediate free-recall using retrieval cues. As predicted, significantly more articulatorily similar letters were confused by individuals in AI Group 1, who could articulate intelligibly, than by those in the other two AI groups. All the subjects confused visually similar letters in immediate memory, but those in AI group 3 confused significantly more than the other two groups. A little evidence, mainly observational, for dactylic coding was also reported.

In the present chapter interest has been focussed on memory coding, but in order for items to be correctly recalled they must first be correctly perceived. In Experiment 1, special effort was made to ensure that the presentation was sufficiently slow to eliminate the possibility of confounding perceptual confusions. In the following chapter the perceptual processing of alphabet letters will be discussed and investigated.

# CHAPTER 4

# VISUAL PROCESSING OF LETTER STIMULI

## 4.1 Visual perception.

In the present chapter the perceptual organisation of the deaf subjects is explored. Since perception and memory are very closely related (perception referring to immediate, and memory to past, experience) these two cognitive processes are inextricably linked in everyday behaviour. As Haber (1970, p.104) wrote: "Visual perception is as much concerned with remembering what we have seen as with the act of seeing itself". Consequently both perceptual and memory processing are investigated in the following three experiments.

As long ago as 1931, Hofmarksrichter was interested in the question of cognitive 'compensation' for loss of hearing. He suggested that severe deprivation in one perceptual channel, in this case auditory, may influence the effectiveness of another perceptual channel, i.e. visual. Implicit in his ideas was not a physical increase in visual acuity as such, but a psychological change - an increase in the mental activity stimulated by vision. Basically what Hofmarksrichter was suggesting was that the deaf make greater use of visual coding strategies, compared with their hearing counterparts (who are not incapable of adopting and using visual encoding strategies, but who seem to prefer verbal coding). The reliance of deaf individuals on visual perceptual channels is not in itself surprising given the nature of their handicap. What is however of greater interest, and is not at present fully understood, is the role of naming in a visual-matching task,be it articulatory or kinaesthetic, and the different strategies found within a sample of prelingually deaf adolescents.

Surprisingly, few researchers have tackled the problems of studying the visual perception of deaf individuals outside the field of visual perception of speech, and the problems associated with lip-reading (e.g. Erber, 1974). The classic large-scale study of visual perception carried out 25 years ago by Myklebust and Brutten (1953) is still frequently quoted, and this reflects the paucity of more recent substantial studies on the subject. As Myklebust and Brutten rightly point out, visual perception is the deaf child's most essential system for confronting his environmental situation and for assimilating information. It is therefore of both theoretical and applied interest to learn more about the nature of the perceptual system of the deaf. Yet despite the potential importance of such work, few experimental psychologists have expressed any interest. Myklebust and Brutten were concerned with differences in the perceptual responses between their deaf and hearing subjects, whereas in the three experiments described in the present chapter (as was also true of Experiment 1) emphasis is placed on investigating differences within a deaf sample, rather than between groups of deaf and hearing subjects.

During the course of their study, Myklebust and Brutten (1953) administered a battery of five tests (each of which related to an aspect of visual perception) to 55 deaf subjects and 55 hearing controls aged between 8 and 10 years. They concluded from their results that the deaf subjects were retarded in their ability to construct continuous figures from models made up of discrete elements. They inferred that deaf children experience difficulties in perceptual situations in their daily lives which demand the integration of discrete and discontinuous elements into meaningful configurations. However, the question of ability to sequence visual items in time and space is of peripheral concern to the experiments described in the present chapter. On the other hand, certain methodological features of the experimental work of Myklebust and Brutten were clearly relevant to the present study, and will be referred to later.

Since subjects' perceptual processing cannot be directly observed, evidence concerning strategies used is necessarily indirect. Interest is therefore focussed on: (i) how the interval between stimulus presentation (a brief visual display) and response is bridged, and (ii) on the properties of the cognitive systems involved. The fundamental assumption is that by measuring, under carefully controlled conditions, the latency of the response, one can make inferences concerning the intervening cognitive processes. This, the method of latency analysis was developed over a century ago by Donders (1868), a Dutch physiologist. His early attempts led to controversial discussions and criticisms regarding methodology (e.g. Boring, 1950), however the last 12 years has seen a marked renewal of interest in the use of reaction time experiments, and new experimental procedures have been developed. The rationale of Donders' subtractive method has been subsequently adopted by experimental psychologists such as Posner and Mitchell (1967) and Sternberg (1969) to study sequential stages of information processing. In the latter study using a memory-scanning task, Sternberg found that some mental activities could be broken down into stages which occur in sequence. He discovered that different experimental factors affected the amount of time needed for different stages of processing and that there was no interaction between the stages, and suggested that the sequential stages took amounts of time that were additive.

## 4.2 Posner's letter matching paradigm

The five experiments (Experiments 2, 3, 4, 5 and 6) reported in this and the following chapter are all based on a reaction time (RT) paradigm. Experiments 2, 3 and 4 use an experimental technique developed by Posner (e.g. Posner and Mitchell, 1967) which has led to a considerable body of research in visual information processing (e.g. Bamber, 1969; Parks, Kroll, Salzberg and Parkinson, 1972; Posner, 1970; Posner, Boies, Eichelman and Taylor, 1969). The task consists of judging whether two visually presented items (usually letters) are 'the same' or 'different', using reaction time as the dependent variable. The matching technique is fully exploited - the subjects were required to judge whether (a) two letters were physically identical - Level 1 instructions (e.g. AA), or (b) two letters shared the same name - Level 2 instructions (e.g. Aa), or (c) two letters were conceptually similar - Level 3 instructions (e.g. a and e are both vowels). On each trial a binary classification 'same' or 'different' was made by the subject, and the length of time required to make such a decision was recorded and used as an index of the length of time needed to process the stimuli at that particular level of coding. The rationale behind the use of three levels of processing (shape, name and conceptual) is that a visually presented letter can be processed in terms of its physical configuration, or it may also be coded verbally by its name, or coded conceptually as a vowel or consonant. Posner describes these three forms of processing as different levels of abstraction, but also acknowledges that these different levels of coding are not mutually exclusive.

The principal finding was that in the name-matching tasks, 'same' reaction times were faster for pairs of letters which Posner called 'physically identical' (e.g. AA), than for pairs that were physically different and yet shared the same name (e.g. Aa). The former reaction times were between 70 and 90 msecs faster than those based on name identity (Posner and Mitchell (1967) reported an average of 70 msecs faster, Posner and Keele (1967) 80 msecs faster, and Posner (1969) 90 msecs faster). The inference being that subjects can match letter stimuli on the basis of 'physical identity' faster than they can on the basis of name identity. Letter pairs that are highly similar but not quite identical, i.e. differing in size but not in shape (e.g.Cc) were also investigated. Posner and Mitchell (1967), and more recently Corcoran and Besner (1975) have found the mean response latencies to the letter-pair Cc and cC were longer than those for CC and cc, but faster than for name matches such as Aa and aA. Posner and Mitchell reported that these items took an average of 19 msecs longer than 'physically identical' matches, and referred to them as 'analog matches'. It has been suggested that analog matching depends on "operations like size variation or rotation, which can be performed within the visual system and need not require contact with past experience" (Posner, 1969, p.57).

Posner and Keele (1967) introduced a variation of the matching technique, and incorporated a short interval between the presentation of the two stimuli to be compared, to find out whether visual information is affected by a delay. They found that after a delay of 1.5 seconds (they tested at 0.5, 1.0, 1.5 and 2.0 second intervals) the difference between name-matches based on 'physical identity' and those based on name identity was reduced to about zero, a finding that has been replicated by Posner, Boies, Eichelman and Taylor (1969).

Phillips and Baddeley (1971) have criticised Posner's method of using RT differences for 'physical' and name matches to estimate the duration of visual S.T.M., because, they argue, he is confounding the decay of the visual trace with the development of a name code. The point at which the difference between the 'physical' and name identity match RT disappears represents the combined effect of a fading visual trace and a developing name code. Once the name code had developed to a point at which it allows faster RTs than the visual code, subjects presumably use it in preference to the visual trace, even though the latter may continue to be available. Although valid, the criticism of Posner by Phillips and Baddeley is not entirely warranted, for Posner (1969) himself recognised that the lack of a difference between 'physical' and name identity RTs could not by itself be taken to mean that the visual code was entirely lost. For example, Posner, Boies, Eichelman and Taylor (1969, p.4) explained their finding that visual information became less efficient over time by suggesting that either "the visual code loses clarity over time, because it becomes less salient",or "because the name information improves in efficiency". The efficiency of a visual match is possibly relatively quickly lost in visual matching tasks because little incentive is provided to preserve the visual aspect of the letter in addition to its name. The presence of one form of coding does not therefore necessarily exclude others, since even after naming, subjects may still retain visual images. Posner, Boies, Eichelman and Taylor (1969) reported that when the visual aspect of a letter was made a completely reliable cue, the efficiency of physical matching was better maintained.

There appears to be general agreement that visual identification must precede name coding in a visual matching task but that the name code subsequently develops (if the stimuli can be verbally labelled) and is frequently used in preference to visual coding. At the same time it has been well established that acoustic/articulatory recoding of visually presented letters also occurs in S.T.M. (as has been discussed in the previous chapter), and it is therefore at this point that memory and perceptual processes seem to be very closely related.

A further question that has been raised concerns whether name and visual processing occur in parallel or in a serial fashion. Experimental evidence suggests that visual and name coding can be manipulated separately. For example, Posner and Taylor (1969) reported that physical matches were no faster than name matches when the items were visually similar. The effect of visual context increased the time necessary for physical matches without changing name match RTs. They inferred that visual and name codes must be stored separately otherwise visual similarity would affect both name and visual matches. Similarly, Cohen (1969) found that RTs were only lengthened when stimuli were both visually and acoustically confusable. She suggested that comparisons were normally made in both channels and that confusability in a single channel therefore had no effect whilst the alternative channel was unimpaired. The effect of both visual and articulatory similarity on response latency is investigated in Experiment 4 as a direct follow-up of Experiment 1.

The majority of the studies reported in this section have employed letter stimuli in the visual matching tasks, and this in itself has important implications. Young children must, during the early stages of learning to read and write, be primarily aware of the visual shape of letter-forms. However, with experience, letters become linked with other associations such as their letter names, the fact that they are either a vowel or a consonant, and, for the deaf, their fingerspelled representations. All of these are learned correspondences. For the majority of adults and older children, letters are very familiar, highly overlearned, ubiquitous patterns and represent a relatively simple, well-known set both in terms of perceptual forms and names. Each visual letter, whatever its particular script, has a readily accessible name equivalent (name is employed loosely here to include fingerspelled 'names') - the naming response, although nearly automatic, relies on learned correspondences. As Posner, Lewis and Conrad (1972) point out, the name of a letter can be regarded as an abstraction, in the sense that the name stands for a wide variety of perceptually different visual forms (e.g. A,a,ɑ etc.). Visual identification and subsequent naming appears to occur very rapidly in the case of familiar characters, and yet the experimental techniques developed by Posner and his colleagues allow the visual matching process to be isolated from subsequent types (or levels, the term employed by Posner) of processing.

Kolers (1972) takes issue over Posner's use of the phrase 'physical identity' to describe letter-pairs which comprise two identical letters (e.g. AA). He describes the choice of phrase as 'unfortunate', and given that there is some justification for Kolers' complaint, the term 'shape identity' will be employed from now on in the present study. Furthermore, Kolers proposed the rather implausible explanation of Posner's findings (namely the shorter response latencies for letters which were of identical shape), that people in general were more used to judging whether two items look alike than judging whether they shared the same name. In the light of evidence that subjects choose to recode stimuli linguistically, and given that letters come from such a familiar set which can be named very rapidly, Kolers' suggestion would appear to be questionable.

Posner and colleagues employed techniques which depended on short visual exposures for which a tachistoscope is particularly well-suited. Myklebust and Brutten (1953) considered the applicability of the use of tachistoscopic exposure techniques to the study of visual perception in deaf children. They suggested that although the deaf were seen to be at a disadvantage in timed test-items generally, they argued that an experimental technique that allowed deaf subjects to respond in their own time to briefly presented stimuli, without any score penalty, was not specifically unfair to the deaf. They concluded that tachistoscopic exposure techniques were appropriate to the study of visual perception in deaf children. They did however find that their deaf subjects required a longer exposure than the hearing controls in order to correctly reproduce the dot patterns presented; special care was therefore taken in the five experiments described in this and the following chapter, to ensure that the tachistoscopic exposure was sufficiently long to allow the deaf subjects to assimilate the entire visual display prior to stimulus processing.

The 'same-different' response technique employed by Posner et al. allows the experimenter to examine stimulus identification and subsequent coding processes under minimal response demands, and is therefore well-suited to the rationale of the experiment. Subjects are required to compare items according to a prescribed criterion and decide whether or not the stimuli are 'the same' or 'different' by this criterion. The task demands are therefore relatively simple and the technique is sufficiently uncomplicated to allow it to be used with deaf adolescents. One might predict that it would require less time to judge two stimuli as 'different' than 'the same', since one can only be sure that two stimuli are identical after checking every aspect. However the experimental literature on the comparison of simple, unidimensional stimuli reveals that the relationship between 'same' and 'different' RTs is not invariant. Nickerson (1968) has suggested that the relationship between mean response latencies is affected by the difficulty of discrimination required, and the codability (nameability) of the stimuli involved. In the present experiments however, interest was focussed on differences between the 'same' trials, rather than between 'same' and 'different' trials (the latter equalling the former in number), and consequently the technique was slightly modified for Experiments 2 and 3. Instead of requiring the subjects to press one response key for 'same' and another for 'different' (as was required by Posner, and used in Experiment 4 for reasons which will become evident later), the deaf subjects were instructed to press a single hand-held switch if the two stimuli were 'the same', and to make no response when the stimuli were 'different'. The binary classification was thus left basically unaltered, except that no response latency data were collected for the 'different' trials in Experiments 2 and 3.

A within-subjects design was used in the following three experiments and each subject was tested on all the stimulus items randomly ordered. Such designs have recently been criticised by Poulton (1973, p.119) who went as far as to write: "The day should come then when no reputable psychologist will use a within-subject design, except for a special purpose, without combining it with a separate groups design". Whilst the issue of 'range effects' is undeniably important in certain areas of research (e.g. psychophysics), Poulton certainly overstated his case as Rothstein (1974, p.200) was quick to point out in a reply to Poulton:

> Except for some circumscribed areas, the repeated measures design provides an excellent alternative to the independent groups design when sampling error is likely to be high and/or the availability of subjects is likely to be low.

It was largely for the latter of the two reasons mentioned by Rothstein that a within-subjects design was used in Experiments 2, 3 and 4, since there was an insufficiently large number of subjects in the Upper School to undertake an independent groups analysis. As Greenwald (1976, pp. 315-6) points out: "The within-subjects design can therefore represent an immense experimental economy, particularly when per-subject costs are considerable in relation to per-treatment costs". In addition it would be virtually impossible to adequately control for the many extraneous subject variables which might influence the dependent variable. Between-subject variance was frequently greater than the within-subject variance resulting from the experimental conditions. Under these circumstances therefore, the advantages of a repeated-measures design far outweighed any possible disadvantages.

The three experiments reported in this chapter all make use of the Posner RT paradigm. In Experiment 2 the two alphabet letter-stimuli were presented simultaneously and the task was one of discrimination, whilst in Experiments 3 and 4 the alphabet letters were presented successively thus creating a memory task. In all three experiments the subjects had to compare the two letter-stimuli along a given dimension - either shape or name, and decide whether or not the two letters were 'the same' or 'different'. By imposing these two processing dimensions, the experimenter is forcing the subjects to use either visual or name cues to process the letters. The naming response is not necessarily restricted to articulation, and for the purposes of the present study a kinaesthetic response, i.e. fingerspelling, is also likely to be used for naming by at least some of the deaf subjects.

The same individuals were used as subjects for all three RT experiments (Experiments 2, 3 and 4). Some, but by no means all, had also acted as subjects in the previous immediate memory experiment (this was solely determined by subject availability), since the likely carry-over was believed to be negligible. It was felt that familiarity of each individual deaf subject with the experimenter was of far greater importance, and this condition was met.

## Experiment 2: An investigation of shape and name codes in a visual letter-matching task.

The aim of this experiment was to compare the ability of the three AI groups - the good, average and poor articulators - to match letter-pairs using shape and name cues. Four types of letter-pair were presented:

(1) letters with the same name, shape and size (e.g. RR; ss);

(2) letters with the same name and shape, but differing in size (e.g. Vv; sS);

(3) letters with the same name, but differing in shape and size (e.g. Aa; rR);

(4) letters with a different name and shape (e.g. Ar; SV).

Each subject was tested on two occasions. During one test session the subjects were required to match the letter-pairs for shape, i.e. the letter pairs in the first two of the above types should have been categorised as 'the same', and those in the remaining two types as 'different'. These instructions differed from the 'Level 1' instructions used by Posner and Mitchell (1967). In their study the subjects were required to classify letter-pairs as 'physically identical' and thus AA was classified as 'the same' and Cc as 'different'. In the present task however, subjects were instructed to classify the letter-pairs by shape and therefore both AA and Cc were classified as 'the same'. In a second test session, the deaf subjects were required to match the letter-pairs by name, and thus the first three of the above types should have been categorised as 'the same', and those in the fourth group as 'different', the former differing also in the degree of their shape similarity. The speed and accuracy of the processing of these various types of letter-pair, using shape and name cues, was compared as a function of ability to articulate (AI group).

### 4.3 Hypotheses.

It was hypothesised that: 1) The findings of Posner et al. (e.g. Posner and Keele, 1967; Posner and Mitchell, 1967) with normally hearing subjects would be replicated with the deaf subjects, i.e. when matching letters by name, the letters of the same shape, size and name would be processed faster than those of the same name and shape but differing in size, which in their turn would be processed faster than those with the same name but differing in shape and size.

2) There would be no difference between the three AI groups in ability to process the different types of letter-pair using shape cues. All the deaf subjects, irrespective of ability to articulate, would be able to match letters by shape and make use of visual cues equally efficiently (as was shown by Experiment 1).

3) If articulatory responses were employed only for naming purposes there would be a difference in the ability of the three AI groups to process the different types of letter-pair by naming - AI Group 1 would be able to name the letters faster than either of the other two AI Groups. However, all the deaf subjects, irrespective of their ability to articulate intelligibly, could also fingerspell; if therefore kinaesthetic naming responses were

employed by the subjects, one would expect there to be no difference between the AI groups.

### 4.4 Method.

4.4.1 Subjects: 36 individuals from the Upper School aged between 13.2 and 16.5 years served as subjects. All were either profoundly or severely prelingually deaf with an average hearing loss of 74dB over the lower frequencies and 87dB over the higher frequencies (i.e. 'cc',Lewis 1968). Articulatory intelligibility scores (see Experiment 1, Section 3.4) were used to assign individuals into the three AI groups - 12 in AI Group 1, 2 and 3; age, sex, reading age and non-verbal intelligence scores were matched across the AI groups. All subjects had normal vision, or vision corrected to within normal limits.

4.4.2 Apparatus and stimuli used. A Cambridge two-field tachistoscope was used to present the pairs of letter-stimuli to the subjects. A single hand-held switch connected to the timer was pressed by the subjects to record their response judgements. Response latencies were measured correct to the nearest millisecond by an Advanced Digital Counter (Model SC3) timer which was also connected to the tachistoscope.

The letter-pairs were printed in the same script as was used for Experiment 1, (Letraset Futura medium 72 point, Sheet 110 for upper-case and Sheet 111 for lower-case letters) on white cards (20cm x 10 cm). The first letter of each pair was always situated ½° to the left of the central fixation point, and the second letter ½° to the right. Each letter-pair subtended a horizontal visual angle of approximately 3°.

For the name-matching task:

192 stimulus cards were prepared for this experiment. Each of the letter combinations was to be presented on 8 trials, but since order of the letters within a pair did not appear to affect response latency, certain letter-

combinations were summed. So, for example, Aa and aA were each presented on 4 trials, and AR, Ar, aR and ar were each presented twice and summed over the eight trials. Thus, the letter-pairs RR; rr; SS; ss; VV; vv; AA; aa were each printed individually onto 8 cards; Aa; aA; Rr; rR; Ss; sS; Vv; vV were each printed onto 4 cards, and the above 8 letters (4 upper-case - A, R, S, V and 4 lower-case - a, r, s, v) were systematically combined into every possible combination of letter-pair and each printed onto 2 stimulus cards (i.e. AR; Ar; AS; As; AV; Av; aR; ar; aS; as; aV; av;
SA; Sa; SV; Sv; SR; Sr; sA; sa; sV; sv; sR; sr;
RA; Ra; RS; rs; RV; Rv; rA; ra; rS; rs; rV; rv;
VA; Va; VR; Vr; VS; Vs; vA; va; vR; vr; vS; vs).

<u>For the shape-matching task</u>:

160 stimulus cards were used for this experiment and these were taken from the set of 192 cards prepared for the name-matching task, the only difference being that 64 of the systematic combinations of all the letters (listed in full above) were presented instead of the complete set of 96. The 64 cards were drawn randomly from the pool of 96 for each individual subject.

4.4.3 <u>Design and procedure</u>. Each subject was tested individually on two occasions separated by approximately two weeks. Half of the subjects in each of the three AI groups were randomly selected to do the name-matching task during the first test session, whilst the remaining individuals began with the shape-matching task. During the second test session the subjects always did whichever of the two tasks they had not done in the first test session.

The subject was seated at a table, and the height of the two-field tachistoscope was adjusted to suit each individual so that he or she could comfortably look through the viewing hood. The experimenter was seated on the other side of the table in order to load the tachistoscope with the stimulus cards, activate stimulus presentation and record the RTs and errors. The subject was provided with a single hand-held switch which he or she held in the preferred hand. The switch was pressed to record the subject's decision about whether the two letters in the stimulus array were 'the same' or 'different' according to the criterion of the experiment, i.e. name- or shape- matching (see Figure 4-a). The push-button response of the subject terminated the millisecond timer which had been initiated by the onset of stimulus presentation. Each stimulus card was presented for 100 msecs, which was sufficiently long to allow every subject to identify the two letters in the stimulus array accurately. The problem of a 'ready' signal for the deaf subjects was overcome by using mirror communication. A mirror (2' x 8') running along the width of the table made it possible for the subject and experimenter to communicate manually. At the start of every trial the subject would watch the experimenter load a stimulus card into the tachistoscope (without being able to see the letter-pair printed on the card) and await a nod of the head from the experimenter which was the sign to look into the viewing hood at the pre-stimulus field. The latter was blank with a small black star situated at the central fixation point and was illuminated at the same brightness as the target field. The subject was required to fixate on the black star for about 2 seconds until the stimulus card was presented for 100 msecs, followed by the post-stimulus field identical to the pre-stimulus field. The subject was instructed to press the hand-held switch whenever the two letters in the stimulus array were 'the same' according to the criterion of the experiment, and not to respond when the letters were 'different'. Both speed and accuracy of response were emphasised to each individual subject both before and during the test sessions, i.e. subjects were instructed to respond as quickly as possible keeping the number of mistakes to a minimum. After each trial immediate feedback was given to the subject regarding the correctness of the response and the actual reaction time in milliseconds; this information was particularly

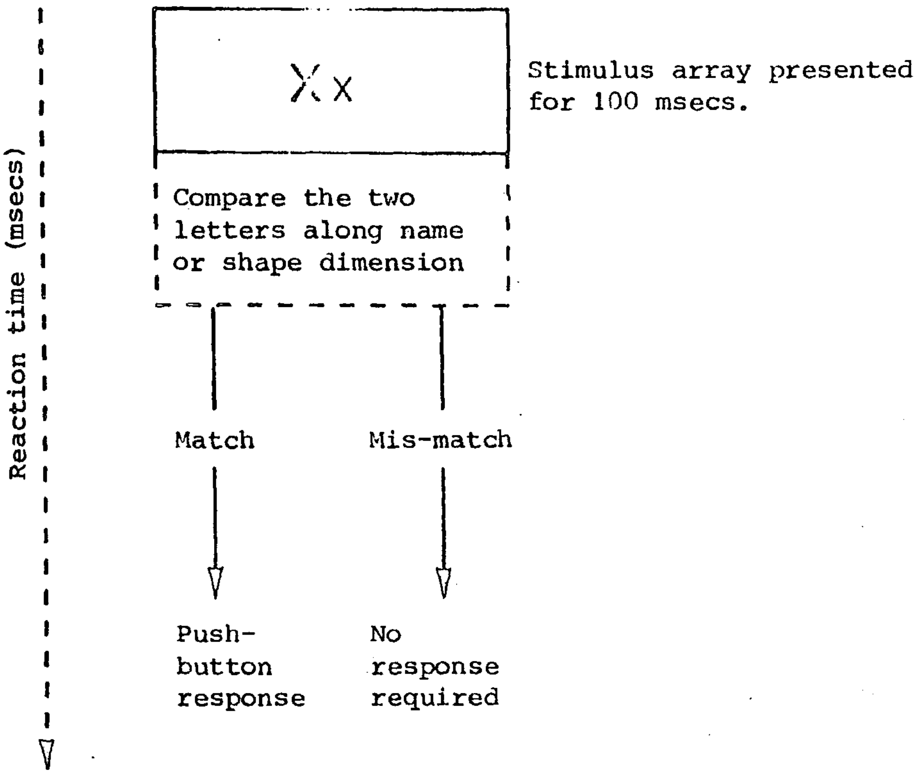


Figure 4-a. A schematic diagram for making a response in the visual letter-matching task (Experiment 2).

important for the maintenance of a high level of motivation throughout the test session. Every subject was given a set of 24 practice trials at the start of every test session, using letter-pairs which were similar to, but not the same as, the actual letter-pairs shown during the test session. The practice sessions enabled the subjects to become familiar with the instructions and requirements of the task and with the sort of stimuli that would be used, and they provided the opportunity for RTs (which in unpractised subjects are initially very variable) to level out. The number of 'false alarms', i.e. pressing the response-button when no such response was necessary was quite high at first, but these rapidly reduced in frequency during the practice trials.

Each test session lasted between 45 and 55 minutes and was consequently divided up into five blocks of trials - the 24 practice trials followed by four further blocks of test trials, with 48 test trials per block for the name-matching task and 40 for the shape-matching task. The five blocks of trials were each separated by a 3-minute interval during which the subjects were able to rest. Overall there were the same number of 'same' and 'different' trials, and within each block of trials this number was also equal. The order of occurrence of the 'same' - 'different' trials was random with the restriction that no more than four trials were presented in succession where the correct response was a repetition of one particular response (see Rabbitt, 1968). The inter-trial interval was approximately 5 seconds.

After every trial, in which a subject responded by pressing the hand-held switch, the reaction time was recorded by the experimenter and a note was made if the response had been incorrect. No response latency data were collected for the 'different' trials for which the correct reaction was no response, but a note was made of the number of occasions on which the subjects failed to respond correctly by pressing the response key when two letters were in fact 'the same'. The experimenter also recorded on which trial, block and type of letter-pair the mistakes occurred.

### 4.5 Results.

The correct response latencies were averaged over the repeated presentations of each pair of letters for each subject. Since the reaction times across the various letter-pairs within each of the main types were similar they were averaged for each type of letter-pair. Thus for the shape-matching task, the data for all the letters of the same shape and size were averaged, and similarly for all the letters of the same shape but differing in size. For the name-matching task, a further category - those letters with the same name but different shape and size - was also included.

4.5.1 Shape-matching task. The mean correct response latencies of each AI group for the two types of letter-pair classified as 'the same' are shown in Table 4-a (see Appendix F for raw data). There were relatively large differences in speed of reaction between individual subjects - some responded faster to both types of letter-pair, others more slowly. It was however, the overall pattern of performance that was the interesting feature, rather than the absolute levels (and this was true for all the reaction time experiments reported in this study), and it was therefore particularly striking that the pattern of results was consistent for all subjects.

| AI Group | Type of letter-pair: | Same shape & size (e.g.AA) | | | Same shape, different size (e.g. Ss) | | |
|---|---|---|---|---|---|---|---|
| | | | (sd) | % error | | (sd) | % error |
| 1 | | 435 | (46) | 4.6 | 479 | (46) | 5.2 |
| 2 | | 445 | (40) | 4.9 | 494 | (46) | 5.7 |
| 3 | | 437 | (34) | 4.4 | 483 | (35) | 5.2 |

Table 4-a. Mean correct response latencies (msec), standard deviations and percentage error for the two types of letter-pair classified as 'the same' in the shape-matching task, as a function of AI Group.

As was hypothesised, and is clearly shown in Figure 4-b, there was no difference between the three AI groups in ability to match the different types of letter-pair using shape cues. The RT data were analysed using the non-parametric Wilcoxon matched-pairs signed ranks test, since homogeneity of variance, necessary for an analysis of variance, could not be assumed owing to the different numbers of items that were presented and averaged for the different types of letter-pair. The subjects processed the letter-pairs which were the same shape and size significantly faster than those which were the same shape but different size ($T = 0$, $p < .01$ for all three AI groups). The mean differences between the RTs of the two types of letter-pair were very similar for all three AI groups (44 msec,49 msec and 46msec for AI Groups 1, 2 and 3 respectively).

The overall percentage of errors did not differ between the AI groups: 5.8% for AI Groups 1 and 2 and 6.1% for AI Group 3. AI Group 1 made 7.0% 'false positive' type of error (i.e. subjects responding 'same' when the letters were in fact 'different'), 6.5% by AI Group 2 and 7.6% by AI Group 3. The majority of these 'false positives' tended to be fast, premature responses which were considerably faster than the mean RT for correct responses, and most of the subjects realised their mistake as soon as they had responded. A higher proportion of these errors did not occur, contrary to expectation, on the trials where the letters were a different shape and size but shared the same name, which half of the subjects,(those who did the name-matching task first) had previously classified as 'the same'. And, as can be seen from Table 4-a,the percentage of 'false negatives' (i.e. no response when the letters were 'the same' and a response should have been made) was also similar across AI groups for both types of letter-pair.

4.5.2 Name-matching task. The mean correct response latencies of each AI group for the three types of letter-pair classified as 'the same' are

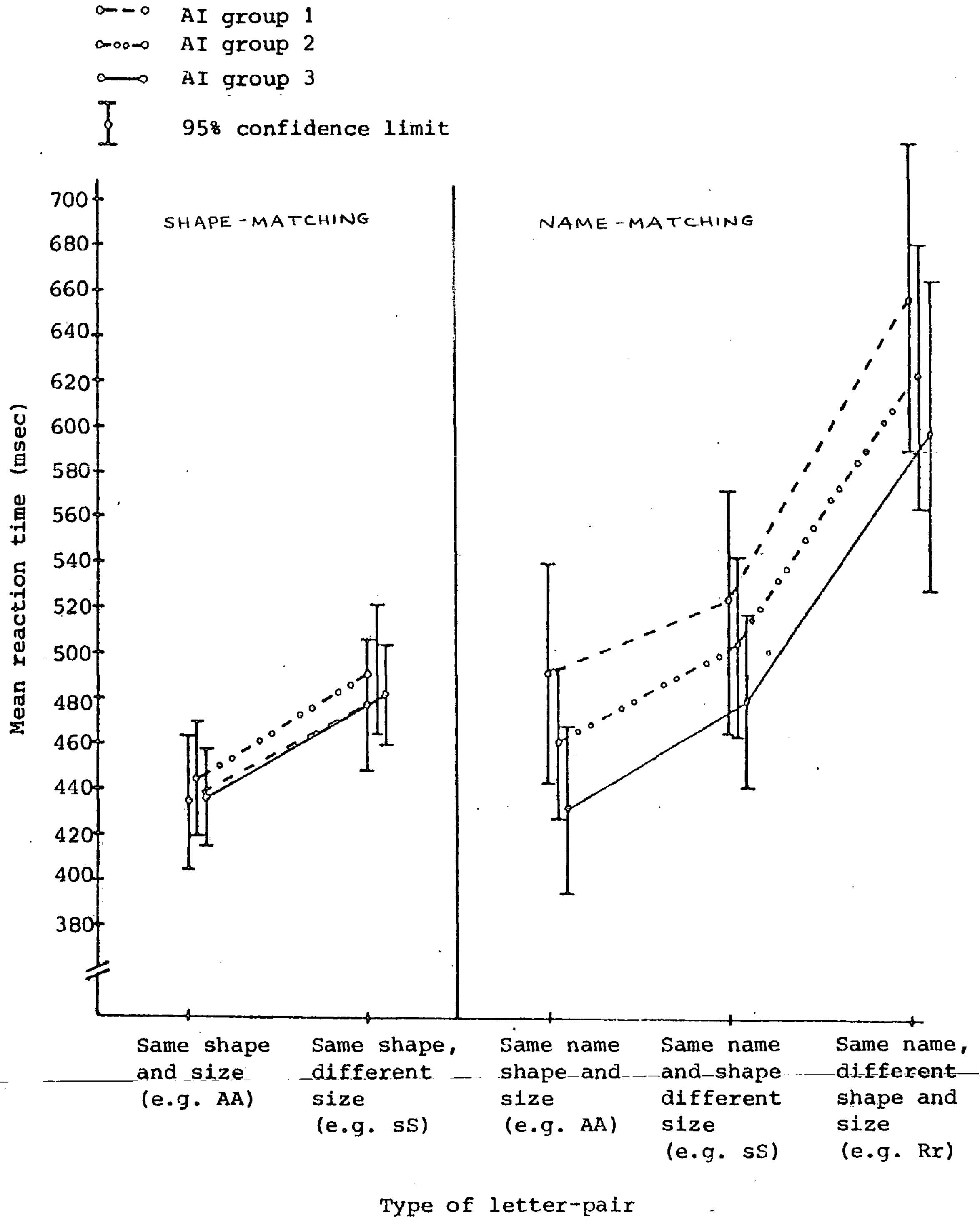


Figure 4-b. Mean correct response latencies for the different types of letter-pair classified as 'the same', as a function of AI group

shown in Table 4-b and Figure 4-b (see Appendix F for raw data).

| | Type of letter-pair: | Same name, shape & size (e.g.AA) | Same name & shape, different size (e.g. Ss) | Same name, different shape & size (e.g. rR) |
|---|---|---|---|---|
| AI Group: | | (sd)% error | (sd)% error | (sd)% error |
| 1 | | 493 (77) 6.1 | 525 (79) 7.3 | 661 (109) 9.9 |
| 2 | | 462 (53) 5.9 | 505 (64) 7.3 | 626 ( 94) 9.4 |
| 3. | | 433 (59) 5.2 | 481 (60) 6.8 | 599 (109) 9.4 |

Table 4-b. Mean correct response latencies (msec), standard deviations and percentage error for the three types of letter-pair classified as 'the same' in the name-matching task, as a function of AI group.

Within-subject analyses across the three types of letter-pair using the Friedman two-way analysis of variance by ranks showed that the letters with the same name, shape and size were processed significantly faster than those with the same name and shape but differing in size, which in their turn were processed significantly faster than the letters which had the same name but were a different shape and size ($X^2 r = 15.52$, $p < .001$ for AI Group 1, $X^2 r = 17.28$, $p < .001$ for AI Group 2 and $X^2 r = 15.52$, $p < .001$ for AI Group 3). Once again, the pattern of response latencies was consistent for all subjects. The present findings for deaf subjects replicate those of Posner and Keele (1967), and also those of Posner and Mitchell (1967) for normally hearing individuals, although there were also some differences which will be mentioned later.

Unlike the shape-matching responses, there were some differences between the three AI Groups, as shown by the 95% confidence limits in Figure 4-b. AI Group 3 processed all three types of letter-pair faster than AI Group 2, who in their turn processed all the letter-pairs faster than AI Group 1. Contrary to expectation, the individuals in AI Group 1 who were able to articulate did not match letters by name more efficiently than either AI Group 2 or 3 who were less able to articulate intelligibly, nor was there any difference between the AI Groups, as one might predict if fingerspelling was employed for naming purposes by all the subjects. Possible explanations of these unexpected findings will be discussed in the following section.

The mean difference in naming response latency between letters that were the same shape and size and also had the same name (e.g. AA) and those which only shared the same name but differed in shape and size (e.g. Rr) was calculated for each subject (see Appendix F), and averaged for each AI group. The letter-pairs which shared only the same name were matched by name significantly more slowly than those which were also the same shape and size by all three AI Groups (t - Test for correlated samples, $t = 8.18$, 10.62 and 8.47 for AI groups 1, 2 and 3 respectively $p \leq .001$). These mean differences were strikingly similar for all three AI groups (168 msec, 164 msec and 166 msec for AI Groups 1, 2 and 3 respectively) and were considerably longer than the equivalent figures reported by Posner and his colleagues for hearing subjects, which were of the order of 70 to 90 msec. So although the overall pattern of results was similar for both deaf and hearing subjects, the deaf individuals were substantially slower at matching by name letters that were a different shape and size than those that were the same shape and size as well as having the same name, compared with the normally-hearing subjects tested by Posner et al. As one would expect, it took longer to match letters by name when there were no visual cues of shape and size to help.

The mean difference in naming response latency between letters that were the same shape and size (e.g. AA) and those which were the same shape but differed in size (e.g. sS) was also calculated for each subject (see Appendix F), and averaged for each AI Group. All the subjects matched by name the letter-pairs which differed in size but were the same shape significantly more slowly than those which were the same shape and size (t - Test for correlated samples, t =4.98, 7.02,and 6.38 for AI Groups 1, 2 and 3 respectively, $p < .001$). Again, these mean differences were greater than those reported by Posner and Mitchell (1967) for normally-hearing subjects. Whereas in the latter study they reported an average 19 msec difference, the equivalent figures in the present experiment were 32 msec, 43 msec and 48 msec for AI groups 1, 2 and 3 respectively.

The overall error rate was slightly greater for the name-matching than the shape-matching task: 7.1%, 7.2% and 6.5% for AI Groups 1,2 and 3 respectively. AI Group 1 made 7.1% 'false positives', AI Group 2, 7.6% and AI Group 3, 6.9%, there being no difference between the AI Groups. As in the shape-matching task, the majority of these 'false positives' tended to be fast, premature responses. The percentages of 'false negative' type error are shown in Table 4-b, and these differed not between AI groups but across the different types of letter-pair, and seemed to mirror the RT data.

A direct comparison of response latency data from the name- and shape matching tasks was also possible since two of the types of letter-pair used were identical for both tasks, namely the 64 letter-pairs which had the same name, shape and size, and the 16 letter-pairs which shared the same name and shape but differed in size. Posner and Mitchell (1967) reported an average difference of 24 msec between processing the same letter-pairs using Level 1 ('physical identity') and Level 2 ('name identity') instructions in favour of faster processing at the former level. Similarly, the response latency data of the deaf subjects clearly showed that the different task instructions employed in the present experiment (i.e. matching by shape or by name) also led to differences in RT. As can be seen from the mean correct response latencies shown in Figure 4-c, the effect of the different instructions differed according to AI group, and these are compared in Table 4-c.

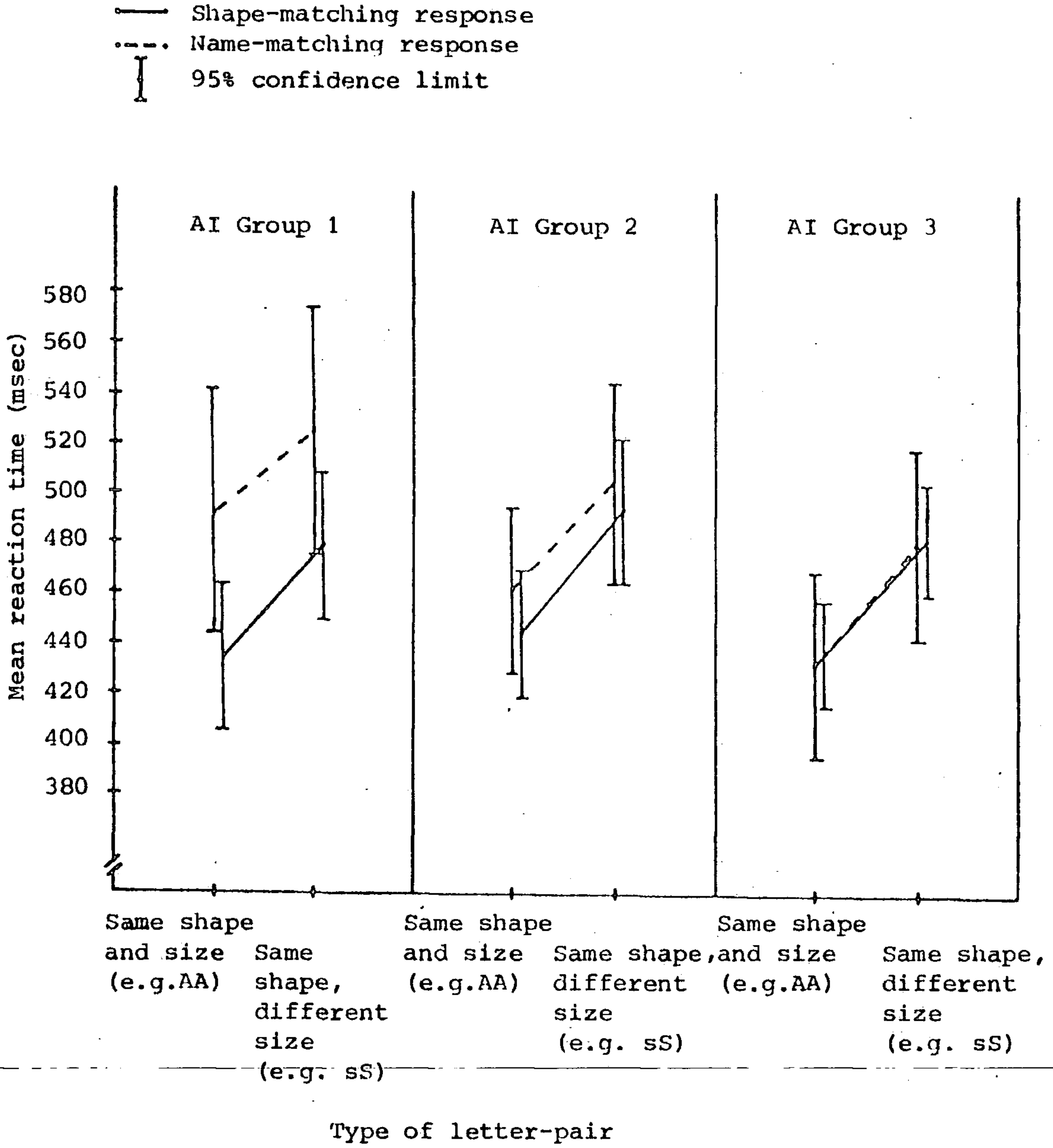


Figure 4-c. A comparison of the speed of matching by shape and by name the different types of letter-pair, as a function of AI group.

| Type of letter-pair: | Same name, shape and size | Same name and shape, different size |
|---|---|---|
| AI Group 1 | Shape-matching faster than name-matching responses | |
| | Mean difference = 58 msec | Mean difference = 46 msec |
| | $t = 5.1$, $p < .001$ | $t = 3.4$, $p < .01$ |
| AI Group 2 | Shape-matching faster than name-matching responses | |
| | Mean difference = 17 msec | Mean difference = 11 msec |
| | $t = 1.9$, n.s. | $t = 1.2$,n.s. |
| AI Group 3 | Name-matching faster than shape-matching responses | |
| | Mean difference = 4 msec | Mean difference = 2 msec |
| | $t = 0.3$, n.s. | $t = 0.2$, n.s. |
| Posner and Mitchell (1967) | Shape-matches faster than name-matches | |
| | Mean difference = 24 msec. | |

Table 4-c. A comparison between the mean correct response latencies of the shape- and name-matching tasks, as a function of AI Group.

The subjects in AI Group 1 matched both types of letter-pair significantly faster by shape than by name, and the mean difference was considerably greater than that reported by Posner and Mitchell (1967). AI Group 2 showed a similar trend although the mean differences were smaller and non significant. The mean differences of AI Group 3 were also non-significant and the name matches were actually slightly faster on average than the shape matches, thus differing from the other two AI Groups.

These group differences were studied in greater detail for they obscured some fairly marked individual differences within the groups (see Appendix F for individual subject's data). There was considerable uniformity within AI Group 1 - of the 24 comparisons between name and shape-matches for the two types of letter-pair, 20 of the name matches were slower than the shape-matches. This was not so for AI Group 2 where 9 of the 24 comparisons were contrary to the overall group trend, the differences being however, fairly small and ranging between 2 and 31 msec only. On the other hand, the results from AI Group 3 were not clear-cut. These individuals were not able to match letters equally well using name and shape cues as the group results would suggest, but instead some individuals were able to match faster by shape, whilst others were faster using name responses. Name-matching was faster than matching by shape in 15 of the 24 comparisons, which is opposite to the findings of Posner and Mitchell (1967) for normally-hearing subjects, and also those of AI Group 1. The remaining 9 comparisons were in the opposite direction, but unlike AI Group 2, the magnitude of the differences was equally great in both directions, thereby cancelling each other out in the group data. The individuals in AI Group 3 would appear to be employing different strategies - some seeming to prefer to use name responses, others shape cues.

## 4.6 Discussion.

In general the results from both the shape- and name-matching tasks were similar to those reported by both Posner and Mitchell (1967) and Posner and Keele (1967). The different instructions for matching resulted in fairly consistent differences in the amount of time required to process the different types of letter-pair. From their findings, Posner and Mitchell (1967) inferred that there were two 'nodes of processing' in addition to the two levels of instruction (Level 1 based on 'physical identity' and Level 2 based on 'name identity'). They postulated that the first node of processing was based on 'physical identity', and the second node on 'name identity'. With Level 1 instructions therefore, only the first node of processing was necessary in order to classify a pair of stimuli as 'same' or 'different'. However, with Level 2 instructions it was necessary to test at Node 2 in addition to Node 1 before a pair of letters could be classified.

For the present study, the main interest of the work of Posner and his colleagues lies in the experimental technique which they developed to study visual and name matching behaviour in the laboratory. This technique was applied to the problem of investigating individual differences, within a small sample of prelingually deaf subjects, in ability to match letters either by shape, or by name, as a function of ability to articulate intelligibly. Consequently, discussion of the results of the present experiment will provide no additional insight into the model of visual processing advanced by Posner et al., but instead will concentrate on the particular aim of investigating possible differences between the AI Groups.

The finding of no difference between the three AI groups in their speed of processing pairs of letters using shape cues was to be expected in a sample of subjects, who, by the very nature of their handicap, are forced to rely heavily on visual cues. The fact that there was no absolute difference between the groups was also reassuring, since it makes it less likely that subsequent differences may be explained by inherent group differences, thereby making ability to articulate more plausible as an explanation of the differences in name-matching performance. The consistent differences in RT suggest that visual processing is affected by size differences as well as by the actual physical shape of the stimuli (the use of 'physical identity' for matching by Posner and Mitchell (1967) rather than the shape-matching criterion used here, did not allow the earlier investigators to make such an observation). When letters within a pair were the same shape, but differed in size, the visual matching process was significantly slower compared with letters of identical shape and size. Thus, the visual attributes of both shape and size would appear to be important in the visual processing of pairs of stimuli, even of those as familiar as alphabet letters.

In the name-matching task, the failure of AI Group 1 to name the letters faster than the other two groups is not easy to explain unless one assumes that manual naming responses were employed by those deaf subjects unable to articulate letter-names. Since articulation of the letter-names was stressed to each subject at the beginning of the task, it is highly likely that the deaf subjects would employ the articulated letter-names if they possibly could. This may also help to explain why individuals in AI Group 1 'opted' to use a strategy that was possibly not the optimal one, given that they too were able to use fingerspelling as competently as any of the other deaf subjects, including the individuals in AI Group 3 who obviously had less 'choice'. Possibly,the sheer amount of effort necessary for a deaf person to produce an articulatory naming response was responsible for the slower processing. Whatever the reason, the deaf subjects able to articulate the letter-names took the longest time to match the letters by name.

Inthe shape-matching task, it was found that visual aspects affected speed of visual processing. Similarly, the visual aspects of the letters also appeared to affect speed of name-matching decisions - the greater the visual similarity (shape and size) between the letters within a pair,the faster they were named. This finding replicates the earlier results of Posner and Keele (1967), Posner and Mitchell (1967) and Posner et al. (1969), and lends support to the suggestion that there are two nodes of processing with Level 2 instructions (based on name identity).

The absolute differences in RT between the three AI Groups across the three different types of letter-pair have already been discussed. Using the mean RT for matching by name letter-pairs with the same name, shape and size as a baseline, however, and employing a subtractive technique, revealed some interesting similarities between the AI Groups. When the baseline RT was subtracted from the mean RT for the letter-pairs which shared only their name in common for each of the AI Groups, the relative differences in speed of naming (i.e. the amount of additional time required to match letters which share the same name only compared with those sharing the same shape and size) between the three AI Groups were zero. There was no difference in the amount of additional time necessary to respond 'same' to letter-pairs sharing only the same name, whether the naming response used be articulatory or kinaesthetic. Therefore, whatever the cause of the overall slower name matches of AI Group 1, it affected all three types of letter-pair similarly, irrespective of the degree of visual similarity of the letters. Under these circumstances it would seem fairly reasonable to suggest that the differential amounts of time that are likely to be required to produce the two different naming responses - articulatory and kinaesthetic - by the deaf subjects was responsible for the absolute RT levels.

The relative differences in speed of naming referred to in the previous paragraph which were similar for all three AI Groups were very large (approximately 160 msec or about one-third of the associated mean RTs) compared with equivalent figures previously reported with normally hearing subjects - 70 msec (Posner and Mitchell, 1967), 80 msec (Posner and Keele, 1967) and 90 msec (Posner et al., 1969). The mean differences in response latency between the letters that were the same shape but a different size presented a similar picture. Once again, the mean differences were greater than reported for normally hearing subjects.

One might tentatively suggest that the deaf subjects were unable to name letter-stimuli as efficiently as the normally-hearing subjects when name identity was all that there was in common between the letters of a pair, and when there were no additional shape or size attributes to aid the letter-matching decision. However, before such a conclusion may be drawn with any kind of certainty, two possible confounding variables need to be considered and tested. The most obvious differences between the deaf subjects used in the present experiment and the hearing subjects tested by Posner and colleagues, was the age factor - the latter individuals were all University students and were therefore between 3 and 6 years older. Age may, in fact, not be a critical factor, but since name responses are based on learned correspondences, age is almost certainly important at earlier stages in development, and one would need therefore to discover where the asymptote occurs and age ceases to be of importance. It would also be necessary to investigate whether these large differences persist with practice; for although there was little evidence of practice effects within either of the test sessions of the present experiment, it would be interesting to discover whether, with more extensive practice on successive days (which was the case in the study by Posner and Mitchell, 1967), the deaf subjects still appear to be slower at naming alphabet letters presented visually in a letter-matching task.

Posner and Mitchell (1967) reported that the 'physical identity' matches were faster than the 'name identity' matches for normally hearing subjects. A similar comparison, using the shape-matching RTs as a baseline for the name-matching RTs, was carried out for the deaf subjects, and produced some interesting and unexpected findings. The individuals in AI Group 1 presented the most consistent results which, although the differences were larger than those reported for normally hearing subjects, were similar overall to the pattern of findings of Posner and Mitchell (1967).

Both the normally hearing subjects and the deaf individuals in AI Group 1 (i.e. the most articulate of the present deaf population) matched the letter-pairs with the same name, shape and size, and also those of the same name and shape, but differing in size, faster by shape, than by name. As has been discussed before, the latency of the naming responses of the deaf subjects in AI Group 1 was once again considerably longer than that of normally hearing subjects, suggesting that although able to produce relatively intelligible speech sounds, these deaf individuals were still not able to produce and utilise verbal naming responses as efficiently as normally hearing individuals.

Meanwhile, the results for AI Groups 2 and 3 are considerably less straight forward and are increasingly different from the general pattern of findings for normally hearing individuals. It would appear that as ability to articulate intelligibly decreases, and consequently one assumes the ability to utilise articulatory naming responses, the pattern of results deviates increasingly from faster responses for shape-matching than for matching by name. Unfortunately, Posner and Mitchell (1967) do not provide any information regarding individual differences in response patterns that may be concealed by the mean group differences of 24 msecs in favour of faster processing by shape than by name, of the letter-pairs which were the same name, shape and size. There was no significant difference in the mean RTs of AI Groups 2 or 3 in ability to use shape or name cues for matching letters. Since the shape-matching responses of all three AI Groups were so similar, these results would seem to suggest that these deaf individuals were able to name the alphabet letters relatively faster than those in AI Group 1, which is in fact quite possible for those reasons already discussed, viz. the effort required and the possible use of non-optimal strategies. The explanation of the findings is not however as simple as that, owing to the lack of consistency between individuals within the groups. In AI Group 2, three of the 12 subjects matched both types of letter-pair faster by name than by shape (unlike the normally hearing subjects), and for half of the subjects in AI Group 3, i.e. 6, the same was true. Thus, 11 individuals in AI Group 1, 9 from AI Group 2, and 6 from AI Group 3 processed the letter-pairs faster by shape than by name, as did the normally hearing subjects, whilst the mean responses of the remaining subjects in each of the groups were in the opposite direction.

It is not easy to explain these apparent differences in absolute speed of processing. Certainly it would appear highly unlikely that different cognitive strategies were being employed by different individuals, since the improbable outcome of such a suggestion would be that those individuals who matched letters faster by name than by the visual attributes of shape and size were able to by-pass the stage of visual identification in the naming process! The finding discussed earlier, namely that relative speed of the naming responses was determined by the degree of visual similarity (shape and size), would also make the foregoing suggestion unlikely. Some alternative explanation, possibly related to 'external' factors in the experimental procedure, had therefore to be sought. Close scrutiny of the data finally revealed a relationship between the absolute level of RTs and amount of practice in the form of previous testing. Although there was little evidence of the effect of practice within the trials of individual test sessions, there was evidence that the RTs of whichever test was performed during the second test session were faster, irrespective of the nature of the matching task. Familiarity with the experimental set-up and with procedural and response requirements seemed to make a substantial difference throughout the second test session to absolute speed of responses. Therefore the six subjects in AI Group 2 and 3 who were given the name-matching task after the shape-matching one appeared to be using name cues faster than shape cues, when in reality it was the point at which the task occurred in the test programme that was the critical feature. A similar but less pronounced effect was also observed for AI Group 1 - the six individuals who did the name-matching task second, appeared to be naming the letter-pairs relatively faster, i.e. the mean difference between name and shape-matching was reduced, compared with the remaining subjects who started with the name-matching task, and for whom the mean differences between name and shape-matching responses were greater.

The above findings clearly illustrate, as was stressed earlier, the fact that absolute comparisons in terms of processing speed are less informative than relative levels, and may even be misleading. All the previous comparisons that have been made and discussed have been based on data from within a task, and mainly concerned with relative patterns of response rather than absolute levels of processing in terms of response speed. The effect of practice is also demonstrated - not only does the experimenter need to be aware of possible effects of practice within a single test session, but also between test sessions. The design of the present experiment allowed useful comparisons of response patterns to be made, but, as a result of unexpected carry-over between experimental test sessions, valid and meaningful comparisons of absolute RTs across the two sessions were not possible. In future, name and shape-matching trials should be either randomly distributed or in blocks, and tested within a single session, rather than in two separate experimental sessions.

In the following experiment name-matching trials alone were further investigated since, as one would expect, it was name-matching behaviour that differentiated the AI Groups, thereby making it unnecessary to include both kinds of trial within a single test session, as discussed in the preceding paragraph. Instead of presenting the two letters of each pair simultaneously, as in the previous experiment, the two letters of a pair

($L_1$ and $L_2$) were presented with a 2-second interval between them. This procedure was first employed by Posner and Keele (1967), and subsequently used by Posner, Boies, Eichelman and Taylor (1969). In the earlier study, the inter-stimulus interval (ISI) was varied between 0 and 1.5 seconds, testing at 0, 0.5, 1.0 and 1.5 second intervals, whilst in the latter study a 2.0 second interval was also included. In both experiments it was found that as the ISI increased in duration, there was a decreasing mean difference between the 'physical' and the name-match RTs. At 2 seconds, Posner et al. (1969) reported that the mean difference between 'physical' and name-matches was not significant and was only about 15 msec. The advantage of matching using visual over name cues appears to be lost after about 1.5 seconds delay - the name code has presumably increased in efficiency with the introduction of a time interval and has therefore been used in preference to the visual trace. Experiment 3 is a partial replication, using deaf subjects, of the 2-second ISI condition employed by Posner et al. (1969) in an attempt to discover whether the name code becomes as efficient over a 2-second interval as in the case of normally-hearing subjects, with the result that it is used in preference to shape coding.

In the first two experiments all three AI Groups, with articulatory intelligibility ranging over a continuum from good, through average to poor, were investigated. In Experiment 2, it was the 'extreme' groups, i.e. AI Group 1 and 3, whose RTs were most similar on the shape-matching task and most different on the name-matching task. It was therefore felt to be most profitable to follow-up in a third experiment these two AI groups, thereby isolating the effect of the independent variable - ability to articulate - and thus the 'intermediate' group was omitted. In correlational-type analyses of the kind used in Experiment 1, the full range of AI scores (incorporating AI Group 2) adds weight to the findings. However, in group comparisons of the type employed in Experiment 2, and which will also be used in the following two experiments, the inclusion of a group of subjects in the middle of the range is less useful. In fact AI Group 2 would be interesting as a study in their own right to discover whether individuals who are unable to articulate intelligibly are still able to use their utterances as symbolic mediators in cognitive functioning.

Experiment 3: An investigation of ability to use name codes over an interval of 2 seconds in a visual letter-matching task.

In this experiment exactly the same design and procedure was used as for the name-matching task of Experiment 2; the only change was the introduction of a delay of two seconds between presentation of $L_1$ and $L_2$, necessitating the use of a three-field tachistoscope in place of the two-field model previously employed. The aim of the experiment was to compare the ability of the two extreme AI Groups, i.e. the good and the poor articulators, to match by name the 192 letter-pairs used in the previous experiment after a 2-second delay.

### 4.7 Hypotheses.

It was hypothesised that: 1) Unlike the name-matching task of Experiment 2, there would be no difference between AI Group 1 and 3 in their speed of processing the different types of letter-pair by name, since the 2-second ISI would allow sufficient time for all the subjects to name $L_1$ by whichever means they chose - articulatory or manual - and should therefore adequately compensate for possible production difficulties of AI Group 1.

2) The findings of Posner et al. (1969) for normally hearing subjects would be replicated with deaf subjects and no difference would be found between the mean correct response latencies for the three types of letter-pair sharing the same name, but differing in shape and size. The earlier advantage of visual cues would be outweighed by the increased efficiency of the name code developing over the 2-second interval between presentation of the first and second letters of each pair.

## 4.8 Method .

4.8.1 Subjects: The same 12 individuals from AI Groups 1 and 3 who were tested in the previous experiment were also used as subjects in the present experiment. All the subjects therefore had the same amount of experience and practice on RT experiments, and all had completed the same set of test trials for the name- and shape-matching tasks of Experiment 2.

4.8.2 Apparatus and stimuli used. An Electronics Developments standard three-field tachistoscope was used to present the two stimulus cards of each trial to the subjects. The same millisecond timer and hand-held response switch were arranged and connected to the tachistoscope as for Experiment 2.

The same set of 192 letter-pairs used for the name-matching task of Experiment 2 was presented in this experiment. Individual letters were in the same script as for Experiments 1 and 2, (Letraset Futura Medium 72 point, Sheet 110 for upper-case and Sheet 111 for lower-case letters). They were printed at the point of central fixation onto tachistoscope cards (20.5 cm x 10 cm). Instead of making up the entire set of stimulus cards necessary for the 192 test trials, as was done for the previous experiment, a pool of cards was used to create the 64 different sequences of letters that were required. Thus, each of the 8 letter-forms (i.e. A, ɑ, R, r, S, s, V and v) that were needed was printed centrally onto 10 stimulus cards, and these 80 cards then formed the pool from which the correct sequences of letters were drawn.

4.8.3 Design and procedure. The basic design and procedure of the previous name-matching task was repeated in the present experiment. Channel 1 of the tachistoscope was used to present a blank illuminated field with a central fixation point (the same black star as before). The subjects were required to fixate on this star after the visual 'ready' signal until $L_1$ (the MS or memory stimulus) was presented in Channel 2 for 100msec. Immediately following $L_1$, the blank field was again illuminated for 2 seconds followed

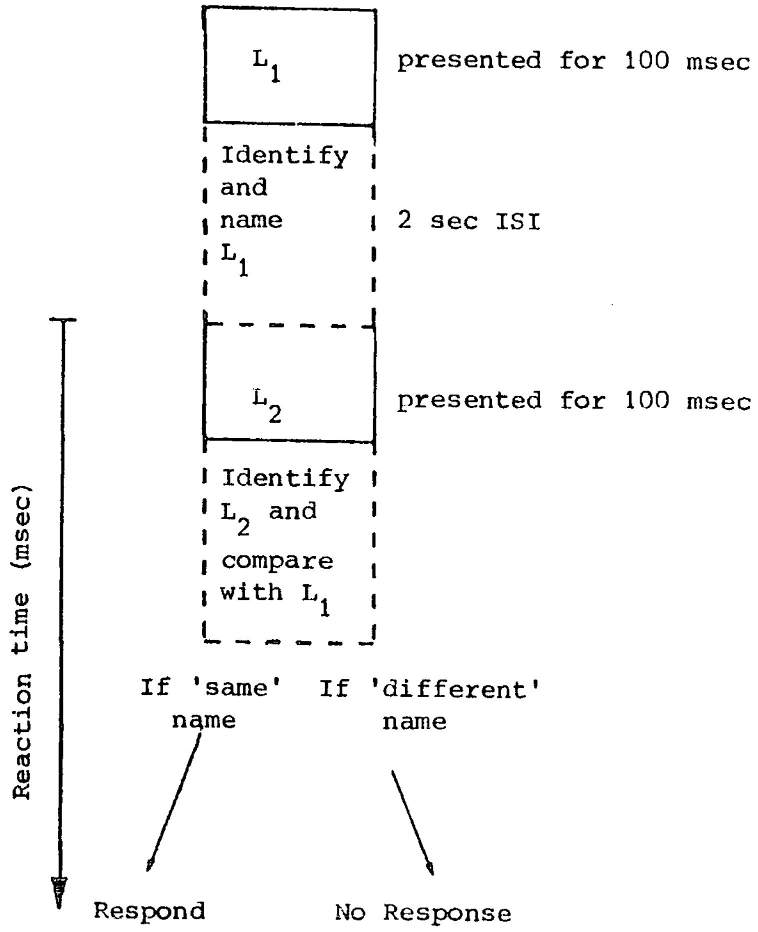


Figure 4-d. A schematic diagram for making a response in the visual letter-matching task (Experiment 3).

by $L_2$ (the CS or comparison stimulus) presented for 100 msec in Channel 3 (see Figure 4-d). As before,no response was required after $L_1$, but when both the MS and CS had the same name the subjects were required to make a push-button response, and otherwise, when the two letters did not have the same name, to make no response. Each subject began the experiment with a further set of 24 practice trials, similar to, but not identical with, the test trials. The test session lasted between 50 minutes and one hour, and was divided into 6 blocks of 32 trials, each separated by a short rest period. The order of presentation of the letter-pairs was determined by randomly selecting stimulus cards from the set of 192 prepared for the name-matching task in Experiment 2 on each of which was printed a pair of letters, which was subsequently assembled using the two appropriate stimulus cards from the pool prepared for the present experiment. As before, selection was random with two constraints - that there were the same number of 'same' and 'different' trials within each block of trials, and that no more than four trials were presented in succession where the correct response was a repetition of a particular response.

The RT was recorded to the nearest millisecond by the experimenter for each correct 'same' response. Concerning the errors, a note was made of (1) the RT of 'false positives' and where they occurred; and (2) the number of 'false negatives' and where they occurred.

## 4.9 Results.

As for Experiment 2, the mean correct response latency was calculated for each of the three types of letter-pair (i.e. those sharing the same name, shape and size; those sharing the same name and shape but differing in size; and those sharing only the same name and differing in shape and size) for each individual subject (see Appendix G), and for the two AI Groups (see Table 4-d and Figure 4-e). There were again relatively large differences in RT between individuals within the groups as the standard deviations presented

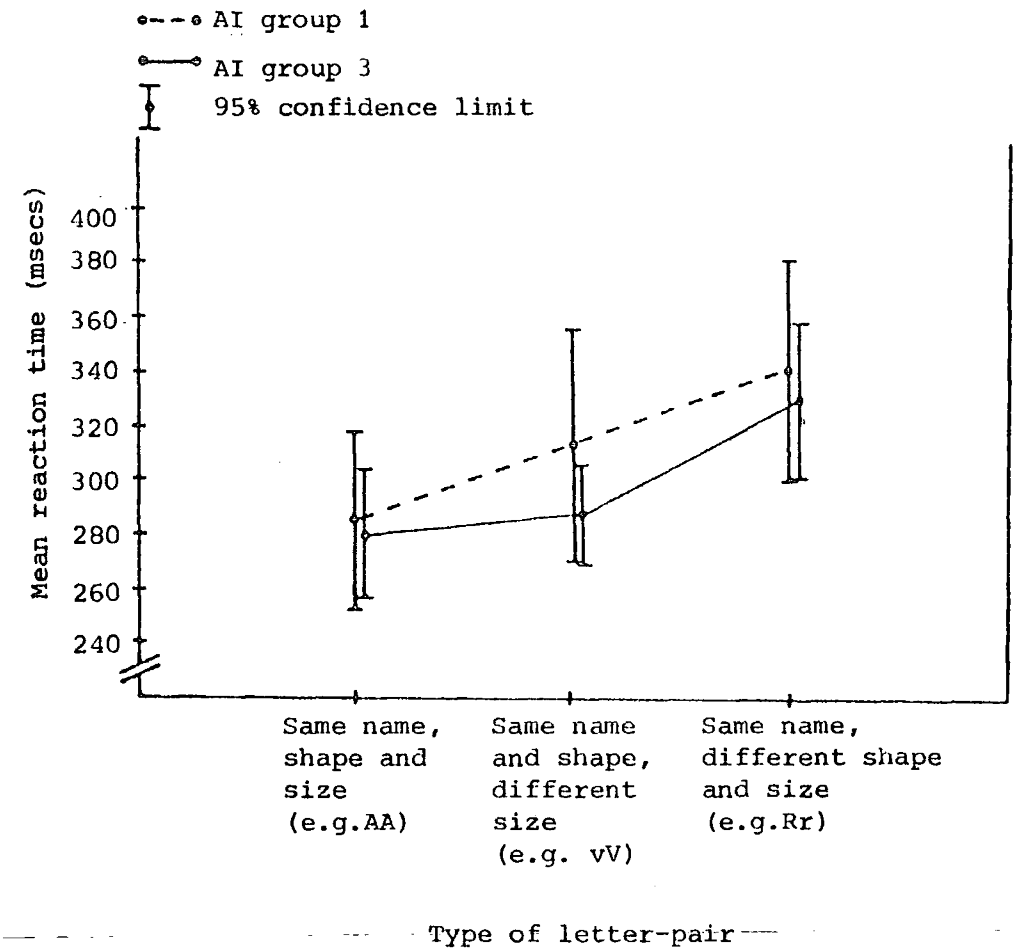


Figure 4-e. Mean correct response latencies for the three types of letter-pair classified as 'the same' in a name-matching task using a 2-second ISI, as a function of AI group.

in Table 4-d demonstrate, however the overall pattern of results was fairly consistent.

| Type of letter-pair: | Same name, shape and size (e.g. AA) | | | Same name and shape, different size (e.g. sS) | | | Same name, different shape and size (e.g. Rr) | | |
|---|---|---|---|---|---|---|---|---|---|
| AI Group: | | (sd) | % error | | (sd) | % error | | (sd) | % error |
| 1 | 286 | (52) | 4.2 | 314 | (69) | 4.7 | 342 | (64) | 5.2 |
| 3 | 281 | (39) | 3.6 | 289 | (28) | 4.2 | 331 | (46) | 5.2 |

Table 4-d. Mean correct response latencies (msec), standard deviations and percentage error for the three types of letter-pair classified as 'the same' in the name-matching task with a 2-second interval between presentation of $L_1$ and $L_2$ for the two AI Groups.

As was hypothesised, the differences between the two AI groups in their mean speed of matching the three different types of letter-pair were considerably less than on the name-matching task in Experiment 2 (which was identical except for the use of the 2-second ISI), and were not significant (t-Test for independent samples, $t = 0.34$, $p > .05$ for the letter-pairs with the same name, shape and size; $t = 1.21$, $p > .05$ for the letter-pairs with the same name and shape but differing in size; and $t = 0.48$, $p > .05$ for the letter-pairs differing in shape and size but with the same name).

A within-subject analysis across the three types of letter-pair using the Friedman two-way analysis of variance by ranks showed that the subjects in AI Group 1 processed the letters with the same name, shape and size significantly faster than those which differed in size only, which in their turn were processed significantly faster than the letters which had only their name in common and were a different shape and size ($X^2 r = 8.8$, $p < .02$). The RT data of AI Group 3 for the different letter-types were analysed using the Wilcoxon matched-pairs signed ranks test which showed that there was no significant difference between the mean correct RTs for the letter-pairs with the same name, shape and size and those with the same name and shape but differing in size (T = 19, $p > .05$), but that there was a significant difference between the mean correct RTs for the letter-pairs with the same name and shape but differing in size and those with the same name only and which differed in shape and size (T = 0, $p < .01$).

Posner et al. (1969) reported data for the relative differences in speed of processing the pairs of letters with the same name, shape and size, and those differing in shape and size with only their name in common. The same comparison was made for the deaf subjects. The mean difference between the above two types of letter-pair was calculated for each individual (see Appendix G), and each AI group. Both groups of deaf subjects processed the letter-pairs sharing only the same name significantly more slowly than those with the same name, shape and size in common (t-test for correlated samples, t = 8.53, $p < .001$ for AI Group 1 and t = 7.24, $p < .001$ for AI Group 3). These mean differences were similar for both AI groups (i.e. 56 msec for AI Group 1 and 51 msec for AI Group 3) and were quite different from the eqivalent figure reported by Posner for normally hearing subjects, namely a non-significant difference of 13 msec. Contrary to expectation, it still took the deaf subjects longer to match letters by name when there were no visual cues of shape and size to help, even with a 2-second ISI. Thus, the hypothesis that the results of Posner et al. (1969) would be replicated with deaf subjects was not supported by the present findings.

A similar comparison, and one not made by Posner, was drawn between those letters that were the same name, shape and size and those which differed in size only but had the same name and shape. The mean difference in naming response latency between these two types of letter-pair was calculated for each subject (see Appendix G), and each AI Group. The letters differing in size were matched significantly more slowly than those with the same shape and size by AI Group 1 (t-Test for correlated samples t = 4.22, $p < .01$, but the mean differences were not significant for AI Group 3 ($t = 1.41$, $p > .05$). Possible reasons why this last comparison should be different from the preceding three will be discussed in the following section.

The absolute speed of the correct 'same name' responses was considerably faster in Experiment 3 compared with the RTs in Experiment 2 - the mean differences were between 150 and 300 msec faster. But, in the light of the confounding effects of practice that are almost certainly involved when making such a comparison, given the method of randomisation of the two test sessions employed in Experiment 2, this was not pursued any further.

The overall percentage of errors made by the 2 AI groups did not differ - 4.8% and 5.0% for AI groups 1 and 3 respectively. Both groups made slightly fewer 'false positive' type of errors than in the two previous letter-matching tasks of Experiment 2, presumably the result of the additional practice. AI Group 1 made 5.2% of 'false positive' responses and AI Group 3, 6.0% - the majority in both cases being premature responses which were recognised almost immediately afterwards as being incorrect responses. The percentages of 'false negative' type of error are shown in Table 4-d. There was no consistent difference between the two AI groups, but a small difference across the three different types of letter-pair reflecting corresponding increases in RTs.

## 4.10 Discussion.

It was assumed that when the two letters ($L_1$ and $L_2$) of each pair were presented successively, some form of representation of the first letter must be stored in memory and used in the comparison with $L_2$. Since the subjects were required to match the letters by name, one would expect a name code to be stored and used to compare $L_1$ and $L_2$. With the introduction of a 2-second ISI, the difference between the processing speed of AI groups 1 and 3, found in the previous name-matching task, was almost eliminated, and was no longer significant. This finding suggests that there was a 'production' difficulty for AI Group 1 when, as in the previous experiment, there was no time lag between presentation of the two letters of each pair.

Although the status of the visual code studied by RT methods is not entirely clear, it is interesting to note that with a 2-second ISI the normally hearing subjects did not appear to be using visual features in the name matching task, whereas the deaf subjects were. This was inferred from the finding that visual similarity (shape and size) was apparently no longer differentially affecting RT in the normally-hearing subjects, whilst for the deaf subjects the mean differences between the three types of letter-pair differing in shape and size were still significant. In fact, the mean differences of the deaf subjects were nearly as large between those letters with the same name, shape and size and those with the same name but differing in shape and size with a 2-second ISI as for the normally-hearing subjects (Posner and Mitchell, 1967) with no interval between presentation of $L_1$ and $L_2$. Previously it was suggested that differences in age of the subjects and therefore their experience, might account for the different pattern of findings for the different groups (deaf and normally-hearing) but in the light of this most recent set of RT data, this would seem to be far less likely. The RTs collected in the present experiment were considerably faster and less variable than those collected in Experiment 2, suggesting that the deaf subjects were performing the task optimally and that neither additional practice nor additional experience would be likely to produce any significant improvement. One is left therefore with the finding that the deaf subjects were still making use of visual cues over a time interval of 2-seconds when normally-hearing subjects appear to be making greater use of name coding. It would be interesting therefore to repeat the present experiment with deaf subjects using longer ISIs to discover whether or not they continue to use visual cues in a name-matching task. It may be, as Posner et al. (1969) suggested, that as the visual aspect of a letter is made a more reliable cue, or, in the case of the deaf a more efficient cue, the efficiency of 'physical matching' is better maintained. It would also be interesting to repeat the experiment using 'non-verbal' items in the matching task, to investigate more directly the duration of the visual code in deaf and hearing subjects.

Posner et al. (1969) did not compare relative speed of processing letter-pairs with the same name, shape and size and those differing in size but with the same name and shape. Had they presented such letter-pairs (as Posner and Mitchell (1967) did)they might conceivably have found no significant difference with a 2-second ISI, as they did for those letter-pairs that were 'physically identical' and those with the same name. It is therefore interesting to note that whilst a significant difference was found for AI Group 1 (a similar finding to the two comparisons discussed in the preceding paragraph), no such difference was found for AI Group 3. There was no significant differential effect attributable to the size differences in the processing speed of individuals in AI Group 3. These deaf individuals, like the normally-hearing, appeared not to be relying on visual size cues to make their 'same name' response. Although this trend was apparent in the group analysis of the mean difference data, not much weight should be attached to this isolated finding beyond possibly inferring that these deaf individuals were making less use of visual cues in this particular name-matching comparison where letters sometimes differed on the visual dimension of size. When the same group of subjects were matching by name letters that differed along both size and shape dimensions, the effects of visual similarity were again apparent.

In the present experiment only a small sample of alphabet letters was used in each of the various types of letter-pair, and so in a future replication a greater range of different letters should be employed in an attempt to discover whether the present findings could be generalised to other letters that fall into the same types (e.g. Bb; Dd; Ee; Gg; Hh;

and Tt all differ in shape and size, and Cc; Kk; Ww; Xx and Zz differ in size but not shape). However, one would then be faced with the problem of deciding how many different letter-pairs to include within each type of letter-pair and how many replications of each particular different letter-pair would be necessary. Should all the letters included in the letter-pairs that differ in shape and size and those differing in size only be presented in both upper- and lower-case forms in the same name, shape and size category of letter-pairs? If so the experimenter would be faced with the decision whether to devise a fairly comprehensive experiment with a vast number of trials (bearing in mind the minimum number of replications of each different letter-pair that is reasonable, and that there has to be an equal number of 'same' and'different' trials), or a more limited experiment using a relatively narrow range of items. The latter is of course more manageable given the limited span of attention of experimental subjects and the possibility of the confounding effects of practice and/or fatigue over a vast number of experimental trials, even if they are arranged in blocks.

It should also be mentioned that the present findings could also possibly be explained by suggesting that, using the particular method of matching the three different types of letter-pair that were classified as 'same', only one-third of the 'same' trials actually required a name code, since shape was completely reliable for the remaining 64 trials in which the letters were always the same shape and size, as well as name. The subjects could possibly therefore have been using visual code to match the majority of the letters correctly, and this would explain the present pattern of results. If in fact this was being done, then one would expect to find a greater proportion of 'false negative' type errors on the 32 trials when shape was not a reliable indicator for a correct matching response. No such difference was found. However, in any future replication, the number of letter-pairs within each of the three types of letter-pair should be equal, which would mean 32 trials within each of the three letter-types in an experiment like the present one (192 trials with each subject), thereby facing the experimenter with the kind of problem discussed above of deciding which four letters should be used in the same name, shape and size trials (assuming 8 replications of each). Adopting such a procedure in future would ensure that visual attributes of the letters were a less reliable cue for matching, and make it less feasible to interpret the findings in terms of the possible useof visual coding by the subjects,rather than the presumed name coding (presumed because of the nature of the task and the instructions used). If in fact such a replication were carried out and the results were different, i.e. a significant reduction in the mean differences between the three types of letter-pair was found, the present findings would still be of interest in as much as the deaf subjects 'chose' to use a visual code even when there was a 2-second interval between presentation of the letters to be matched, and were able to maintain visual coding over this, and possibly even longer periods of time. Normally-hearing subjects on the other hand would be highly unlikely to use a visual code given the same experimental conditions with a 2-second ISI.

In the following experiment the two letters of each letter-pair were again presented successively with a 2-second ISI in an attempt to investigate the effect of visual and articulatory similarity between letters within a pair on RT. Unlike the previous two experiments in which the 'same' responses were the most interesting, it was the 'different' trials that were of central interest in Experiment 4. Since the deaf subjects appeared to be coping quite adequately with the demands of the RT tasks, and were responding surprisingly accurately (the overall error rate was never greater than 7.2% for any AI group), it was decided to alter the kind of response required of the subjects. Instead of a single hand-held response key which was pressed whenever the letters were 'the same' and no response being required if the letters were 'different', a pair of standard telegraph keys was used, one of which had to be pressed when the letters were 'the same' and the other pressed when 'different'. Although these response requirements were considerably more demanding than those previously employed, it was felt that whilst earlier the deaf subjects would probably have been unable to cope, they would now, after a substantial amount of practice and hence familiarity with the other features of the RT task, be able to make this new response choice quite successfully. The design of the present experiment was such that it was important to record RT data for both 'same' and 'different' trials, instead of only one set of trials.

## 4.11 Experiment 4: An investigation of the effect of visual and articulatory similarity on speed of matching pairs of letters by name over a 2-second ISI.

The present experiment was intended as a direct follow-up of Experiment 1 to discover whether the previously found differential effects of visual and articulatory confusability would be carried over to the visual matching task developed by Posner and colleagues and employed in the previous experiments.

The effects of both visual and acoustic similarity have been investigated in normally-hearing subjects by a number of different researchers using both visual matching and memory tasks. For example, Chase and Posner (1965) presented a single visual letter ('target') which was surrounded by a circle of between 1 and 4 additional letters ('array'); the letters of the target and array were either visually or acoustically confusable. They found that visual similarity had a marked effect on visual matching speed, whilst acoustic similarity had no effect, but that the effect of visual similarity was greatly reduced when a memory factor was introduced. Similarly, Kaplan, Yonas and Shurcliff (1966) also varied the level of visual and acoustic confusability between a target item and the background items in a visual search task, and found that visual confusability produced interference whilst acoustic similarity had no effect. Dainoff and Haber (1967) have also suggested that memory load is an important determinant of interference from acoustic confusability.

Posner and Taylor (1969) carried out a RT study to look at the effects of visual and acoustic confusions on RT. They employed the experimental procedure that was used by Posner and Keele (1967), with a short interval between presentation of $L_1$ and $L_2$, (which was also employed in Experiment 4) and found that a visually similar context increased the times for 'physical' matches but had no effect on the name match RTs. However there was no effect of acoustic context on the speed of name matches. Since the two letters to be matched by name ($L_1$ and $L_2$) were not themselves acoustically similar - the effect being created by the context of two additional letters surrounding $L_1$ - it is not surprising that no acoustic confusions were found. Consequently,in Experiment 4 the similarity of the two letters within each letter-pair was directly manipulated.

More recently, Dainoff and Haber (1970) reported that letter-comparisons drawn from an acoustically confusable population of letters required longer processing by name for both 'same' and'different' judgements, and more errors were made. When two letters sounded different, the subjects were able to press the 'different' key relatively quickly. When however the letters sounded similar or were identical but known to be potentially confusable with the others used in the study, the letters were processed more slowly (about 40 msec longer). They also found no difference between the same-case and the mixed-case conditions and concluded: "Thus, once processing reaches the node-2 level, all visual characteristics of the stimuli cease to affect processing" (p. 105). WHen they talk about 'node-2 level' they are referring to the processing of letters by name,and therefore the above statement does not hold true for the apparent name-matching behaviour of the deaf subjects tested in Experiment 3. Their postulation will once again be put to the test in Experiment 4. In their experiment, Dainoff and Haber appear to have confounded visual and acoustic confusability in their choice of letters. They used the letters B, D, P, and T for the acoustically similar group and F, I, M, and Q for the non-confusable group and wrote that visual confusability had been held to a minimum, quoting the study by Hodge (1962). In fact they ought to have realised that within the population of acoustically similar letters, upper-case B, D and P are in fact amongst the most visually similar. It is axiomatic that letters are only appropriate for a study of the effect of visual confusability, if they are <u>not</u> also acoustically similar. Their choice of letter stimuli is therefore questionable, and as a consequence their results also. In their concluding paragraph, they do in fact refer to a personal communication from Hochberg who warns them that an inherent correlation might exist between acoustic and visual confusability. This is in fact a similar criticism to the one being made above, except that it is the present writer's belief that the correlation between the two forms of confusability need not be as high as was the case in the study carried out by Dainoff and Haber. With careful selection from within the two sets of acoustically similar and visually similar letters, which do overlap, it is quite possible to choose letters that are highly confusable on one of the dimensions and relatively dissimilar on the other, and this in fact has been successfully achieved in a number of experiments (e.g. Experiment 1 of the present study; Conrad, 1964, 1970; Thomassen, 1970 etc.).

Cohen (1969) has also studied confusability of letter-stimuli using a RT technique. She found that RTs were only significantly lengthened when letters were both visually and acoustically similar, and argued that comparisons are normally made in both channels (visual and acoustic) so that confusability in a single channel produces no effect since the alternative channel remains unimpaired. This suggestion is further supported by the subsequent finding that when only one channel is made relevant by experimental manipulation, a single type of confusability in the relevant channel raises RTs as much as double confusability when both visual and acoustic processing is possible. In the experiment next to be described, confusability was deliberately restricted to a single channel, and letter-pairs were either highly visually confusable or highly articulatorily confusable, in order to investigate whether either or both of these types of confusability would affect RT for name-matching. Since a letter has to be visually identified before it can be named, one would predict on the basis of Cohen's studies that both visual and acoustic channels must be used, and that therefore only double confusability, i.e. letters that are both visually and acoustically similar, should affect RT.

In Experiment 4, visual and articulatory similarity of the 'different' letter-pairs was varied. From the results of Experiment 1, the three most visually similar letter-pairs which were confused most frequently in immediate memory processing were selected, likewise for the three most articulatorily similar pairs of letters, and three that were neither visually nor articulatorily confusable, and which were rarely confused in memory were also chosen. These 9 letter-pairs formed the basis of the 'different' trials, and the letters chosen were also presented in an equal number of 'same name' trials. As in Experiment 1, articulatory confusability was investigated this being relevant to deaf subjects, rather than acoustic confusability which is more relevant to normally-hearing subjects. The letter-pairs had to be matched by name as in the previous experiment, and therefore once again only AI Groups 1 and 3 were tested - the two groups that differed most widely in their ability to articulate intelligibly.

### 4.12 Hypotheses.

It was hypothesised that:1) There would be no significant difference in name-matching RTs for the 'same' trials between AI groups 1 and 3.

2) Both AI Groups 1 and 3 would show significantly slower RTs and make more errors on the 'different' trials that were visually confusable, since the results of the previous three experiments have shown that both AI groups rely heavily on visual cues for visual information processing tasks.

3) AI Group 1 would process the articulatorily confusable 'different' trials significantly more slowly than AI Group 3 for whom articulatory similarity is not a relevant dimension,and should not therefore cause interference.

4) The letter-pairs that were neither visually nor articulatorily similar (i.e. those that were 'distinctive') would be processed significantly faster by AI Group 1 than the other two types of 'different' letter-pair which were either visually or articulatorily confusable. Whilst for AI Group 3 there should be no significant difference between the RTs for the 'distinctive' and the articulatorily confusable letter-pairs, since the latter dimension is not relevant to these individuals.

### 4.13 Method.

4.13.1 Subjects: The same 12 individuals in AI Groups 1 and 3 who were tested in the two previous RT experiments were also used as subjects in the present experiment.

4.13.2 Apparatus and stimuli used. The apparatus and lay-out of the previous experiment was employed in the present experiment, the only difference being that a pair of standard telegraph keys was used in the place of the single hand-held switch.

Four types of letter-pair were used:

(1) Letters with the same name (bb; ff; hh; nn; ss; tt; vv; xx; and yy);

(2) Letters with a different name which were visually confusable (tf; vy; nh);

(3) Letters with a different name which were articulatorily confusable (bv; sx; dt);

(4) Letters with a different name which were neither visually nor articulatorily confusable (tx; sy; df).

Each of the 10 letters (i.e. b, d, f, h, n, s, t, v, x, y) needed to assemble the letter-pairs were printed centrally onto 8 stimulus cards using the same script as for Experiments 1, 2 and 3 (Letraset Futura medium 72 point, sheet 111). These 80 stimulus cards formed the pool from which the correct sequence of letters for each individual trial was drawn. As before, the letters were printed at the point of central fixation on the tachistoscope cards (20.5 cm x 10 cm).

4.13.3 Design and procedure. With the exception of a few minor modifications, the design and procedure were the same as for the previous experiment. $L_1$ and $L_2$ were both presented for 100msec with a 2-second ISI. No response was required after $L_1$, but after presentation of the second letter of the pair, the subject was required to press one of the telegraph keys when the letters were 'the same',and the other when 'different'. The position of the two response keys was counterbalanced for hand across subjects. Half pressed the 'same' key with their dominant hand and the 'different' key with their non-dominant hand; and the remaining subjects had the opposite arrangement. Each subject sat, ready to respond, with their index fingers poised over the two response keys.

Each subject began the experiment with a set of 24 practice trials, similar to, but not the same as, the actual test trials, to enable them to become familiar with the new response requirements. During the 144 test trials each of the 9 letter-pairs with the same name was presented 8 times, and each of the 9 letter-pairs with a different name 8 times - four in one order and the other four in the reverse order, i.e. bv and vb. The test session lasted between 30 and 40 minutes, and was divided into 5 blocks of trials, the 24 practice trials being followed by 4 blocks of 36 test trials, each separated by a short rest period. The order of presentation of the 144 letter-pairs was determined by randomly selecting a card from a box containing 144 cards, and on each was written a single pair of letters which was then subsequently presented on that particular trial; this process was repeated for each trial. Selection was therefore random with two constraints - that the number of 'same' and 'different' trials was equal within each block, and that no more than four trials were presented in succession where the correct response was a repetition of a particular response. The RT was recorded to the nearest millisecond for every trial, and a note made whether the response had been correct.

## 4.14 Results.

The mean correct response latencies for the letter-pairs with the same name were calculated for each individual subject (see Appendix H), and for the two AI groups (see Table 4-e and Figure 4-f). Similar mean figures were calculated for the correct RT data from the three different types of letter-pair which had different names (i.e. the visually confusable letter-pairs; the articulatorily similar letter-pairs; and those that were 'distinctive'). Once again there were large between-subject differences in RT, but the overall pattern of results was fairly consistent within each AI Group.

| Type of letter pair: | 'Same name' | 'Different name' | | |
|---|---|---|---|---|
| | | Visually Confusable | Articulatorily Confusable | 'Distinctive |
| | (sd)%error | (sd)%error | (sd)%error | (sd)%err |
| AI Group 1 | 333(52) 2.2 | 491(81) 14.6 | 461(82) 8.3 | 409(76) 3.1 |
| AI Group 3 | 310(56) 3.1 | 476(92) 27.1 | 409(84) 1.4 | 399(72) 2.8 |

Table 4-e. Mean correct response latencies (msec), standard deviations and percentage error for the 'same name' and the 'different name' types of letter-pair in a name-matching task with a 2-second interval between presentation of $L_1$ and $L_2$, for the two AI groups.

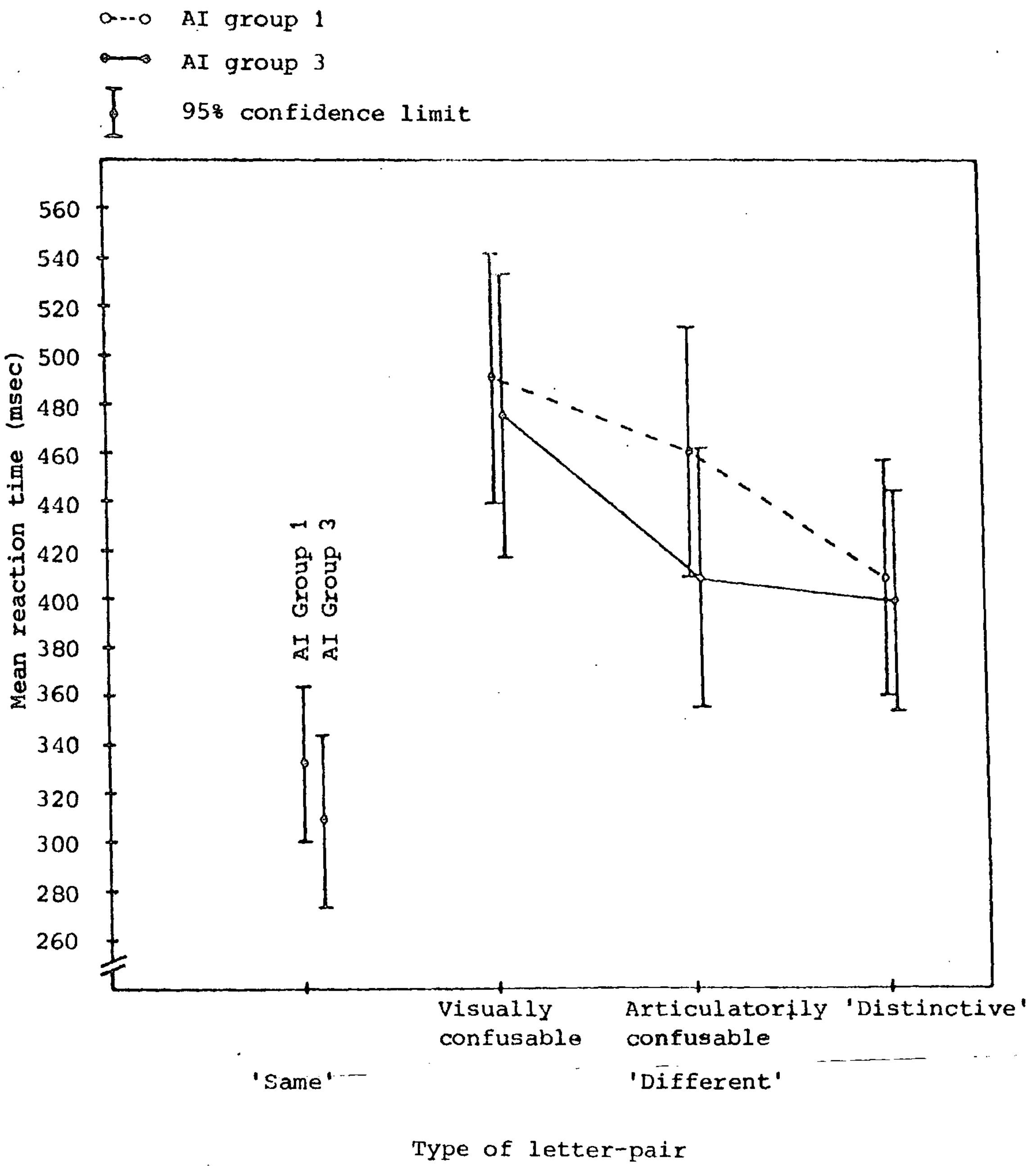


Figure 4-f. Mean correct response latencies for the letter-pairs classified as 'the same' and the three types of letter-pair classified as 'different', as a function of AI group.

For the two AI groups there was, as was hypothesised, no significant difference between the mean RTs to the letter-pairs with the same name (t-Test for independent samples, t =1.03, p$>$.05). This result replicates the finding of no difference in speed of naming of Experiment 3. The 'same' responses were consistently faster than any of the three types of 'different' response, including the 'distinctive' letter-pairs for which there was no interference from the two main sources of confusability - visual and articulatory. This pattern of results between 'same' and 'different' responses has been repeatedly found on the RT studies of this kind carried out by Posner and colleagues (e.g. Posner and Mitchell, 1967; Posner and Taylor, 1969), and may reflect the relative ease of codability of the letter stimuli employed in the majority of these experiments - a suggestion put forward by Nickerson (1968) to explain the relationship between the two responses which is not invariant.

The pattern of RTs of the 'different' responses was the most interesting result of the experiment. As predicted, there was no significant difference in the amount of interference from the visually confusable letters as shown by slower processing between the two AI groups (t = 0.4, p$>$ .05). Both AI groups processed the visually similar letter-pairs significantly more slowly than the 'distinctive' letter-pairs which were also correctly responded to as 'different' (t-Test for correlated samples t = 8.2, p$<$ .004 for AI Group 1; and t = 5.5, p $<$ .001 for AI Group 3). However, a finding that was not expected was the discovery that visual confusability produced a greater interference effect than articulatory confusability even in AI Group 1. From this one might infer that these deaf subjects were relying heavily on the visual form of the input to the information processing channel. The efficiency of the information processing system is significantly impaired when the visual input is confusable, and one can only speculate on the potential effects of this in everyday life.

The articulatorily confusable letters were processed faster by AI Group 3 than AI Group 1. This particular dimension of the letter-stimuli was not relevant for the former group and consequently did not interfere with the overall speed of processing the letters by name. Although the mean difference between RTs for the two groups was over 50 msec it was just less than significant at the 5% level (t-Test for independent samples, t =1.6, 1.7 being the critical level for a one-tailed test at the 5% level). The trend of the results was most definitely in the predicted direction. Clearly, articulatory similarity was affecting the speed of name processing of AI Group 1 more than Group 3, and this is also reflected by the finding that, as hypothesised, the articulatorily confusable letters were processed significantly more slowly than the 'distinctive' letter-pairs by AI Group 1 (t-Test for correlated samples, t = 4.95, $p < .001$) but that there was no difference for AI Group 3 (t = 1.7, $p > .05$). Finally, there was no significant difference between the mean correct RTs to the 'distinctive' letter-pairs of AI Groups 1 and 3 (t = 0.3, $p > .05$), as one might expect for pairs of letters which, like those with the same name, do not bring visual or articulatory 'noise' to the name processing channel.

The error data in the present experiment were considerably more varied than in the two previous RT experiments. Overall, the error rate for AI groups 1 and 3 was remarkably low, given the more demanding response choice (7.0% and 8.6% respectively); these figures however concealed large differences both in the types of error made and also where they occurred. Both AI groups made relatively few 'false negative' type errors, i.e. pressing the 'different' response key when in fact the letters were 'the same' (2.2% and 3.1% for AI Groups 1 and 3 respectively), and most of these were 'motor' errors - pressing the wrong key and realising immediately the mistake. Many more 'false positives' were made by both AI Groups (8.7% and 10.4% for AI groups 1 and 3 respectively), and these were distributed unevenly across the different types of letter-pair. As might be expected, relatively few errors were made on the 'distinctive' letter-pairs (3.1% for AI Group 1, and 2.8% for Group 3), and the pattern of errors for the other two types of letter-pair differed according to AI Group. Both groups made most errors on the visually confusable letter-pairs, but AI Group 3 made nearly twice as many as AI Group 1 namely 27.1% as compared with 14.6%, so although there was no significant difference in RTs between the two groups, faster processing speeds were achieved at the expense of accuracy in AI Group 3. As one might expect, AI Group 1 made more errors on the articulatorily confusable letter-pairs than AI Group 3 (8.3% and 1.4% respectively) - the slower RTs of AI Group 1 for the articulatorily similar letters were also associated with a considerably greater number of errors. These false 'same' responses appear to have resulted from a failure to detect the difference between the two letter stimuli - the subjects were mistakenly responding 'same' when in fact the letters were only similar. Unlike the case of 'false negatives', the subjects were rarely aware of their mistaken responses, even to the extent of frequently expressing surprise on being informed of the error. Overall, the pattern of error responses echoed the RT data and provided additional insight into the processing strategies of the two AI groups.

## 4.15 Discussion.

Previous studies of the confusability of letters (e.g. Chase and Posner, 1965; Kaplan, Yonas and Shurcliff, 1966) have found that visual confusability produces ~~a greater interference effect on visual matching tasks,~~ whilst acoustic confusability interferes with memory performance. In the present experiment using deaf subjects instead of normally-hearing individuals, and employing a task that involves a memory factor, both visual and articulatory confusability affected the amount of time required to produce the correct response. The latter type of confusability however, only affected AI Group 1, the only individuals able to articulate the letter-names relatively intelligibly.

One can infer from the increased RTs and number of errors of AI Group 1 that they were aware of, and making use of, articulatory attributes of the letters for their name-matching responses. AI Group 3 on the other hand showed no such evidence, their RTs did not differ from those on the 'distinctive' letter-pairs which required an identical 'different' response. The most likely basis of their name-matching responses was fingerspelling, and in order to test out this idea, the experimenter positioned herself at the side of the tachistoscope instead of behind, so that she was able to observe any finger movements in any of the deaf subjects. Some of the individuals in AI Group 1 were actually heard producing the letter names,in other cases mouth movements were observed, presumably letter names. None of the individuals in AI Group 3 made any sound during the trials, but five of them were actually observed moving their fingers, whilst at the same time keeping their index fingers over the telegraph keys, and sometimes the hand configuration was clearly recognisable, after presentation of $L_1$, as a letter of the manual alphabet. On this occasion the deaf subjects were making use of their knowledge of one-handed fingerspelling, one presumes as a result of the constraints over hand positioning and movement of the RT task, since two-handed fingerspelling was usually preferred by the majority of the deaf children, and was employed when no restrictions were imposed in Experiments 1 and 9.

Possibly, greater use of observational evidence should be made in future studies of this nature, ideally by employing a person who is familiar with deaf people and able to interpret their manual responses. Detailed observational records of this kind, taken by someone who is unaware of the independent variable and the purpose of the study, would provide an invaluable source of additional evidence. As it was, under less ideal circumstances, and having to run the experiment at the same time, the experimenter was able to observe some examples of behaviour which endorsed earlier suppositions concerning the different means of processing the letters by name employed by the two AI Groups.

Cohen (1969) found that normally-hearing subjects used both visual and acoustic channels to process confusable letters, and that neither visual nor acoustic confusability were sufficient alone to significantly lengthen response latencies, unless only one of the processing channels was, by experimental manipulation, made relevant. However, neither of the groups of deaf subjects tested in the present experiment required 'double confusability' before interference in speed of processing occurred - the individuals in AI Group 1 were affected by confusability in either the visual or the articulatory channels, and AI Group 3 by visual confusability alone. Whereas the effect of visual similarity appears to become 'lost' when normally-hearing subjects employ some kind of verbal labelling (acoustic coding) in a memory task, the deaf individuals seem to have been more aware of the visual features of any stimulus array, and these appeared to have affected their ability to 'translate' the visually presented letters into their name equivalents. One can only infer that the naming process of hearing individuals is possibly more automatic than in deaf subjects, and less influenced by secondary visual attrubutes such as size and script. It would be interesting to find out whether, at the end of a particular experiment, deaf and hearing subjects differed in their ability to recall the precise forms of the letters used (e.g. A, a or ɑ) in a naming task in which the visual form of the letters was not emphasised nor was it of central importance. It is also possible however, that if the deaf subjects had not been instructed to use a name-matching response in the present experiment, they too might have been able to employ the visual and articulatory processing channels more flexibly, and been able to compensate more efficiently for a single source of confusability.

In the present experiment in which only lower-case letters were employed, as in Experiment 1, shape was a completely reliable clue to the correct response - same letter shape was associated with same name, and different shape with different name. This was in fact a weak feature of the present design which should of course be rectified in any future replication. Fortunately however, it did not appear to produce a confounding effect on the results, since both observation and the interference from articulatory confusability suggest that the deaf subjects were in fact using name responses, as had been repeatedly emphasised throughout the test sessions.

When visual similarity was manipulated directly (unlike the indirect manipulation of 'visual context' employed by Posner and Taylor (1969) with normally-hearing subjects), the effect of visual confusability was to increase the amount of time required by the deaf subjects to make the name matches. Thus, contrary to one of the conclusions drawn by Dainoff and Haber (1970) that visual characteristics cease to affect speed of processing at the name level, these deaf subjects seemed to be influenced by the degree of visual similarity even when processing the letters using articulatory or kinaesthetic naming responses. This finding replicates a similar finding in Experiment 3, and provides additional support for the suggestion made earlier, that visual confusability of the stimulus array affects the ability of these deaf individuals, unlike hearing subjects, to name the letters.

## 4.16 Summary.

In the present chapter a series of three RT experiments was carried out to investigate the effect of the independent variable - ability to articulate - on relative speed of processing pairs of letters using either shape or name cues. The letter-pairs were presented briefly and differed in their degree of visual and name similarity.

In Experiment 2 both name- and shape-matching performance was investigated. All the deaf subjects matched by shape the letter-pairs which were the same shape and size faster than those which differed in size but were the same shape, and, as hypothesised, there was no significant difference between the three AI groups. Meanwhile, on the name-matching task, AI Group 3 processed the letter-pairs faster by name than the other two groups, and AI Group 1 slowest; all the subjects did however match the letter-pairs with the same name, shape and size faster than those which differed in size, which in their turn were processed faster than those which had only their name in common and differed in both shape and size. It was suggested that AI Group 3 were using fingerspelling to process the letters by name, and that by comparison this was faster and more efficient for name-matching than the articulatory responses employed by AI Group 1 which required considerably more effort to produce.

A 2-second ISI was introduced between presentation of $L_1$ and $L_2$ in the name-matching task in Experiment 3, and the same three types of letter-pair were used as in the previous experiment. The same overall pattern of differences was found between the three types of letter-pair differing in their degree of shape, size and name similarity, the only difference being that the name-matching responses of AI Group 3 were no longer significantly faster than those of AI Group 1. The introduction of the 2-second ISI seemed to provide sufficient time to compensate for the assumed production deficit of AI Group 1.

In Experiment 4, the same name-matching task with a 2-second ISI was again employed to investigate the effect of visual and articulatory confusability on speed of decision when the letters were 'different'. Visual confusability produced the greatest interference effect and there was no significant difference between AI groups 1 and 3. As hypothesised, articulatory confusability interfered with the speed of naming responses of AI Group 1, but had no effect on AI Group 3 for whom the dimension of articulatory similarity was not relevant. The latter responses of AI Group 3 were not significantly longer than those for the 'distinctive' letter-pairs, and, as expected, there was no significant difference between the two AI groups in their ability to process the 'distinctive' letters.

Overall, the general picture emerging from the findings of these three experiments is that the subjects appeared to be relying heavily on the visual characteristics of the stimulus-array, and that whenever there was some visual 'noise' in the input to the visual information processing system, this would affect latency of naming responses. The effect of visual similarity appeared even at the level of processing letters by name, and influenced the processing speed of all the deaf subjects.

# CHAPTER 5

# WORD-RECOGNITION

In the previous two chapters we have looked at memory and the perception of meaningless strings of letters presented visually. In the present chapter we shall be concerned with extending the study of visual information processing of more meaningful letter-strings, i.e. words, in an attempt to discover the possible forms of representation used by a group of prelingually deaf individuals for word-recognition.

In Chapter 3 it was suggested that the deaf relied heavily on the visual representation of letters in a simple immediate memory processing task. In the present chapter their reliance on orthographic structure of the written word is investigated, using a lexical-decision task (deciding whether or not a written letter-string is an English word). Mediation of word identification as a function of manipulated relations between pairs of words is studied using reaction time data as a clue to the underlying cognitive operations involved in lexical decisions and word-recognition.

One must assume that the cognitive representations of perceived verbal material are related to, or constrained by (initially at least) the method of presentation and hence mode of perception. Individuals with normal hearing can both hear verbal language (auditory input) and read verbal language (visual input), whilst the profoundly and severely deaf, who lack functional hearing, can read the printed word (see Section 2.1.3) and 'read' signs and fingerspelled words. In order to be accurately perceived, all verbal language has initially to be presented visually to the deaf, and it is the subsequent processing of the visual input, in this case written words, that this study attempts to probe and investigate. But, to begin with, word-recognition studies undertaken with normally hearing adults will be discussed.

## 5.1 Theories of visual word-recognition and experimental evidence from hearing individuals.

Currently, there is an increasing awareness of, and knowledge about, the features that are encoded, and the processes involved when a word is recognised. Quite sophisticated techniques have been developed to investigate word-recognition processes and the possible role of visual and/or phonetic codes between perceiving a stimulus word and its stored representation. Three theories have been put forward to describe the psychological processes that take place when printed words are recognised:

(1) The graphemic-encoding hypothesis suggests that a written word is recognised directly from its visual representation which is used to locate the meaning of the word in the 'lexicon' (lexical memory). But since, it has been claimed, over 1200 words can be read per minute by a skilled reader, which is much faster than the maximum possible rate of vocalisation or sub-vocalisation of the words (e.g. Landauer, 1962), it has been suggested by some (e.g. Bower, 1970) that skilled readers at least, must be able to recognise printed words without recoding them phonologically.

(2) The phonemic-encoding hypothesis supposes that word-recognition involves a conversion of the graphemic representation into the phonological representation of the word, which is then used to access word-meaning in the lexicon. Support for this hypothesis is derived from the existence of covert speech and the great body of experimental evidence which suggests that visually presented items are stored phonemically (e.g. Conrad, 1962; 1964, and other studies previously discussed in Section 3.1.3).

(3) The dual-encoding hypothesis is a combination of the previous two theories. This model presumes that both visual and phonological representations of a printed word are used to retrieve meaning in the lexicon.

The graphemic-encoding hypothesis has been criticised by several theorists in the light of more recent evidence. As Meyer, Schvaneveldt and

Ruddy (1974) have pointed out, prose is highly redundant and although speed readers may read 1200 words per minute, they may actually process only a few hundred of these words, and, because of the redundancy of language, still display high levels of understanding. The actual number of words processed may, therefore, be more in line with sub-vocalisation rates. Meyer et al. also discuss the possibility that phonological representations may involve abstract features rather than covert speech. They critically assess some of the experimental studies which support the graphemic encoding hypothesis. Bower (1970), using bilingual subjects and a task that involved translating Greek into English, manipulated the graphemic form of words (an analogous example would be replacing a word like 'photograph' with the graphemic pseudo-word 'fotograf'). Bower reported that these passages took much longer to translate, and argued that this would not have been the case if phonemic recoding had occurred, and consequently inferred that direct visual recognition had been used. Meyer et al. (1974) suggested an alternative interpretation of Bower's findings, namely that reading may involve a visual 'pre-processing' stage that is influenced by graphemic structure. Alternatively, graphemic structure may also influence ability to convert a letter-string into a phonological representation. Either of these alternative explanations can account for Bower's results.

Another study carried out by Baron (1973) also cast doubts on the validity of the graphemic-encoding hypothesis. Baron presented visually and phonemically congruent phrases (e.g. 'I knew him.'), visually anomalous but phonemically congruent phrases (e.g. 'I new him.'), and visually and phonemically anomalous phrases (e.g. 'our no car'). The subjects were required to decide whether the phrases 'looked meaningful' or 'sounded meaningful'. He found that the visually and phonemically congruent phrases took less time to classify as sounding meaningful than the visually anomalous and phonemically congruent phrases. He also found that time taken to judge that phrases did not look meaningful was the same for the visually anomalous and phonemically congruent phrases as for the visually and phonemically anomalous phrases, but that the subjects made more errors with the former phrase-type. From these results Baron suggested that word meaning can be accessed directly from visual representations of words, without phonemic encoding, although such encoding could also be used. Such a conclusion provides support for the dual-encoding hypothesis.

Meyer, Schvaneveldt and Ruddy (1973; 1974) themselves found that pairs of graphemically similar words (e.g. 'couch' and'touch') actually interfered with word-recognition performance, compared with the phonemically similar words and the control words. They concluded that "Visual word recognition is mediated at least part of the time through phonological representations" (p. 318).

Thus, there does not appear to be much unequivocal evidence to support the hypothesis that written words are recognised directly from their visual representations. For deaf individuals, however, whose ability to encode words phonemically is very restricted compared with normally hearing people, the experimental findings may be rather different, and this is investigated in Experiment 5.

There is a considerable body of experimental evidence from hearing subjects which supports the phonemic and the dual-encoding hypotheses. Rubenstein,Lewis and Rubenstein (1971a and b) reported stong evidence from two experiments to support the hypothesis that visual word-recognition involves phonemic recoding. Using a lexical-decision task they presented either single words or non-words. The subjects were required to decide whether or not each string of letters that was presented was an English word. Rubenstein et al. found a facilitatory effect of homographs (words with more than one meaning, e.g. bulb - meaning either 'electric light' or 'part of a plant') on response latencies. They also manipulated the pronounceability and 'legality' (according to rules of English word structure) of the non-words, and found that the subjects took least time to classify pronounceable, 'illegal' words, and longest to classify the nonsense words which were both othographically and phonemically legal (e.g. 'plind'). In a second experiment they manipulated the homophonic relation of the non-words to existing English words (e.g. 'brane' was presented as a non-word that is homophonically related to the word 'brain'), and found that their subjects were slower to classify homophonic non-words as non-words than the non-homophonic non-words. More recently, Rubenstein, Richter and Kay (1975) presented additional evidence of phonemic recoding, again manipulating the pronounceability of non-words. They confirmed the previous findings of Rubenstein et al. (1971a and b), Stanners, Forbach and Headley (1971), Snodgrass and Jarvella (1972), and Walker (1973), that the less pronounceable the non-word, the quicker it is recognised as a non-word, even when presented visually.

In support of the dual-encoding hypothesis, La Berge and Samuels (1974) suggest that subjects may in fact commonly use both visual and verbal means for processing words, whilst Kleiman (1975), and Hawkins, Reicher, Rogers and Peterson (1976) postulate that visual and verbal processes are alternative processing strategies in word-recognition.

Meyer and Schvaneveldt (1971) and Meyer, Schvaneveldt and Ruddy (1973) have also investigated the effect of word association on word-recognition processes, using a similar technique. Both studies found that pairs of commonly associated words (e.g. 'bread' and 'butter') were responded to faster than pairs of unassociated words (e.g. 'bread' and 'nurse').

In summary, the studies of word-recognition in normally-hearing subjects reviewed in this section, suggest that in a laboratory setting at least, graphemic similarity between word-pairs interferes with, and phonemic similarity facilitates, word-recognition processes. Pronounceability and semantic associations also appear to be important factors determining the speed and accuracy of lexical-decision responses. Meyer, Schvaneveldt and Ruddy (1974) in summing up their own study, describe the extent of our present understanding of the factors influencing word-recognition in a passage that is worth quoting at length:

> Of course, our results do not prove that it is impossible to recognise printed words directly from their visual representations. Visual information is certainly sufficient for recognising some non-verbal objects in the real word. Under various circumstances, people may also comprehend words directly from their visual representations. For example this could be true of individuals who read nonalphabetic writing such as Chinese. (p. 318)

Their statement referring to the possibility that 'people may also comprehend words directly from their visual representations' may also have some important bearing on word-recognition processes of the prelingually deaf.

The basic procedure employed by Meyer and Schvaneveldt (1971), Meyer et al. (1973, 1974), and Rubenstein et al. (1971a and b) to investigate how a person processes isolated letter-strings, involves measuring the time taken (reaction time) to classify visually presented strings of letters as English words or as non-words - a lexical decision task. The relation between pairs of words was manipulated (e.g. graphemic, phonemic, or semantic similarity between words), and type of non-word varied (e.g. pronounceability, legality). Pairs of letter-strings were presented either simultaneously (e.g. Meyer and Schvaneveldt, 1971)and the subjects were required to decide whether or not both letter-strings were words and respond positively, or if one, or both were non-words, respond negatively; or successively (e.g. Meyer et al., 1974), in which case subjects were required to classify each string of letters individually, as either a word, or non-word: Reaction time was assumed to be a function of the relations between words. Mean response latencies to the various types of stimuli used were then compared, and facilitation and interference effects investigated.

## 5.2 Verbal learning in the deaf.

Recently, the ability of the deaf to process both printed words and signs has been studied. Of particular interest is the extent to which individuals, who have learned sign language and use it fluently with deaf peers, employ this manual system as their means of processing verbal information. If manual mediation or representation is employed by the deaf this may have important implications for how the information is processed, organised and stored. For clarity of presentation the studies will be divided into two categories: (1) those investigating ability to learn word-lists; and (2) those investigating ability to process both words and signs.

5.2.1 Experimental investigations of word-learning. One of the earliest studies of this kind was undertaken by Doehring and Rosenstein (1960) when they tested accuracy of visual recognition (using written responses) of briefly presented single letters, trigrams and 4-letter words. They found that the younger deaf subjects (aged 8 - 11) were significantly less accurate in their ability to retain the presented stimuli than the hearing controls of the same age, but that there was no difference between the older groups (12 - 16 years); the deaf subjects appeared to have made up their visual word-recognition deficit by the age of 16.

Several studies have subsequently investigated word retention whilst manipulating word-type. Paivio (1971) systematically varied the abstractness-concreteness dimension of words and suggested that visual imagery is important even for normally hearing individuals. The question that is then raised is the extent to which the deaf, who are forced, by the nature of their handicap, to rely more heavily on visual cues, are able to utilise this visual coding. Blanton, Nunnally and Odom (1967) found that the deaf relied more heavily on graphemic associations in word-association tests and a word-pair learning task than did the hearing controls. More recently, Craig (1973) reported that the deaf retained high-imagery words (concrete nouns) better than low-imagery words (abstract nouns), and suggested that the deaf had stored the verbal information in the form of visual coding. Similarly, a Russian study (Rozanova, 1970) also reported that the orthographic structure of words is particularly relevant to deaf people; just as visually similar letters were frequently confused in immediate memory by the deaf (see Chapter 3: Experiment 1), Rozanova reported that words of a similar orthographic structure were also confused in memory.

The 'signability' of English words has also been investigated. Putnam, Iscoe and Young (1962) manipulated the sign similarity of the words they used. They chose words which had either very similar or highly dissimilar manual sign equivalents. They found that the deaf subjects were capable of discriminating between the members of a pair of words with similar signs, and learned these words faster than those with dissimilar sign equivalents. Odom, Blanton and McIntyre (1970) have also studied the learning of English words (8 words with sign equivalents and 8 words without sign equivalents), and found that the deaf recalled more words than the hearing control group. The superior word recall of the deaf subjects was attributed by Odom et al. to their better ability to recall the signable words in the word-list. Word recall was facilitated for the deaf when the words had single manual sign equivalents.

Word-association tasks have also been used by several investigators. Nunnally and Blanton (1966) reported that deaf subjects were frequently unable to give an association to a word, and that when they did, more of their associations could be attributed to visual experience. They concluded that "as a group, words are less meaningful to the deaf than to normals" (p. 87). But, as Bonvillian, Charrow and Nelson (1973, p.330) commented: "These results [referring to those of Nunnally and Blanton] might instead be explained by assuming that sign language is the natural language of the deaf, that signs do not have specific English word referents, and that English-English associations are mediated through sign". This latter possibility is investigated in the second of the two word-recognition experiments reported in this chapter, Experiment 6.

Koplin, Odom, Blanton and Nunnally (1967) also used a word-association technique to compare deaf and hearing individuals, but unlike Nunnally and Blanton (1966), they found that the word associations of the deaf were similar to those of younger hearing subjects. These apparently discrepant findings may be explained by differences in the samples of subjects tested and classified as 'deaf'. As Experiment 1 clearly demonstrated, a diversity of cognitive strategies are found even within a single educational establishment. Differences between populations in different educational establishments, particularly those that cater for specific problems, are therefore likely to be even more marked, and account for the different results. Similarly, the findings of Blanton and Nunnally (1967), and Gibson, Shurcliffe and Yonas (1968) contradict each other. The results of the former study suggested that pronounceability of CVC nonsense syllables was an irrelevant feature for the deaf, who performed equally well on the high and low pronounceable trigrams. The hearing subjects, on the other hand, as might be expected, remembered the highly pronounceable trigrams significantly better. Gibson et al.,however, reported that the deaf were sensitive to variations in pronounceability, and that they did make use of pronunciation cues. This latter finding will certainly only be applicable to some, and not all, deaf individuals; some do have intelligible speech and are, therefore, aware of pronunciation, whilst for others, who are unable to articulate intelligibly pronounceability is unlikely to be a relevant feature.

Other studies have used paired-associate learning tasks to investigate the verbal learning of the deaf. For example, Conlin and Paivio (1975) varied the visual imagery and the signability (which they defined as "a measure of the ease with which a word can be represented as a gestural sign" (p.335)) of the words learned in the paired-associate lists by deaf and hearing subjects. They found that both deaf and hearing subjects were able to take advantage of the visual imagery aroused by the high-imagery nouns during learning, whereas signability facilitated recall for the deaf group only. Also using a paired-associate verbal-learning task, Moulton and Beasley (1975) manipulated the semantic association and the similarity of sign equivalents of the word pairs. Their results also showed that the deaf subjects could code verbal material on a sign basis (replicating the findings of Conlin and Paivio, 1975), but that the semantic coding strategy adopted by this particular group of deaf subjects appeared to be more efficient than their sign coding strategy. It is possible that the manipulated relations between the words were so obvious that the subjects adopted different learning strategies for the experimental task, instead of those they would normally have used.

To sum up, the studies reviewed suggest that in an experimental laboratory situation at least, visual imagery, and the orthographic structure of words, facilitated verbal learning performance in the deaf. Pronounceability and signability also appeared to be important factors but ones that operate less generally in the deaf population as a whole, depending on ability to articulate, and communicate in sign language. The signability dimension would be as irrelevant to a deaf individual who knew no sign language as it is to the hearing population at large. The full extent to which these factors play a role in everyday verbal learning, remains to be determined.

5.2.2 Experimental investigations of the ability of deaf individuals to process signs and English words in parallel. Bellugi and Siple (1974) investigated the ability of a group of deaf individuals to remember signs taken from ASL, and commented on the relationship existing between an English word and its manual sign equivalent. They postulated that "The relation between a sign in ASL and an English word is a good deal more remote than the relation between the spoken and written versions of English words" (p.229). It is this ability to transform information between written English and signs that is investigated by the studies discussed in this section.

Siple, Fischer and Bellugi (1977) presented a list of items (both signs and English words) to a group of deaf college-students. Subsequently, they tested recognition of the list by presenting a new list of items (in which half were new items whilst the remainder had previously been presented, and of the items previously presented, half were in the same form (sign or word) as before and the other half in the opposite modality). False-recognition responses (i.e. saying that an item had occurred previously when it had not) were examined for evidence of the organisation of items in LTM. They concluded tha the deaf subjects treated the signs and words as lexical elements from two separate language systems, and suggested that signs were better encoded by the deaf, and that the words were possibly sometimes translated into their sign equivalents. Frumkin and Anisfeld (1977) used a very similar technique; they presented lists of items and the deaf subjects were required to say whether or not each new item had appeared before. The later items were either related to preceding ones in their surface form (orthographic structure), or meaning, or were totally unrelated. They also used false recognition errors as an index of memory coding, and found more false recognition responses were made to related (both the orthographically and the semantically similar words) than to unrelated words. Similar results were found for signs that were formationally similar, and also semantically related signs.

The experimental evidence reviewed in the previous sections certainly suggests that the orthographic structure of words and the possibility of sign encoding of English words are important factors in verbal learning in the deaf. In the following two experiments the role of these factors in recognising isolated words will be further investigated using the same experimental paradigm as Meyer and Schvaneveldt (1971) used with normally hearing subjects. The aim of the present investigation is to discover more about word recognition in deaf individuals. Do the deaf use speech recoding, and/or sign recoding, and/or visual coding in a lexical-decision task?

Two strings of letters are presented simultaneously using a tachistoscope, and the subjects are required to decide whether or not the letter-strings are English words as quickly and as accurately as possible, recording the decision by pressing one of two response keys. A lexical decision can only be made accurately after word identification. It is assumed that response latency depends on the operations mediating printed word-recognition prior to a lexical-decision task. In Experiment 5 the effects of graphemic and phonemic relations between words are independently examined. Response latencies to pairs of graphemically similar and phonemically similar words are compared with those for control words for both deaf and hearing subjects. In Experiment 6 the effect of similarity of sign-equivalents is investigated and compared with words which have no sign equivalent and could, therefore, only be presented manually using fingerspelling, and with control words (words with non-similar sign equivalents). Interest is focussed on the Word-Word pairs (eliciting positive responses), but in both experiments half the trials included nonsense words:Word-Non-word, Non-word - Word and Non-word-Non-word sequences (negative responses) to provide a control procedure for response choice. The non-words were anagrams of the words used in the experiments, created by randomly re-ordering the letters.

Miller, Bruner and Postman (1954) found a relationship between the order of approximation to English and the accuracy with which tachistoscopically presented letter-sequences were reported. The more closely a letter-sequence approximates to English, the easier it is to encode in terms of existing language structures. In the light of this evidence, the non-words were made to look as unlike English words as possible - approaching zero-order of approximation to English, and were relatively unpronounceable (cf. Rubenstein et al., 1971b). A non-word such as 'blean' or 'brume' would have very likely confused the young deaf subjects and made the task extremely difficult if not impossible for them to do (none of the previous studies with the normally-hearing used non-adult subjects),and would have resulted in very high error rates.

Semantic relations between Word-Word pairs were not manipulated in the present experiments; every word-pair was chosen and assumed to be similarly unassociated in meaning to avoid meaning as a confounding variable. The relatively limited vocabulary of the deaf individuals, together with the experimental constraints, complicated word selection. It has been shown (e.g. Claxton, 1975; Forster and Chambers, 1973; Whaley, 1978) that word frequency is correlated with speed and accuracy of recognition. Matching the frequency of the word stimuli is, therefore, recognised to be an important experimental procedure. The Thorndike-Lorge word frequency count (1944), or its equivalent, is usually used to control for word-frequency (e.g. Paivio & Csapo, 1969). In their study of the verbal learning abilities of a group of deaf subjects,Odom, Blanton and McIntyre (1970) employed a word-frequency list based on the written language norms of normally-hearing individuals, the appropriateness of which is questionable for deaf subjects. Since appropriate language norms do not exist for the deaf, word-frequency could not be controlled for in the present study in the normal manner. However, much attention was paid to stimulus word selection, particular care being taken to ensure that every word was within the reading vocabulary of each deaf individual tested. Two teachers, and two ex-pupils, of the N.C.S.D.

were asked to generate as many word-pairs as possible that would comply with the experimental requirements regarding the internal relations of each word-pair, and would be within the general reading vocabulary of the deaf children from the Upper School. From this pool of word-pairs the test stimuli were selected. Words that had more than one pronunciation (such as 'wind') were not included. Finally, a list of 200 randomly ordered English words was prepared (including all the 128 words selected for use in Experiments 5 and 6 and 72 additional words) and presented to every deaf and hearing subject, as a pre-test check that everyone could read, and know the meaning of, all the words.

## Experiment 5: An investigation of the effect of graphemic and phonemic similarity on visual word-recognition.

### 5.3 Hypotheses.

It was hypothesised that the deaf subjects would:

1) recognise the graphemically similar words faster than the control words;
2) recognise the graphemically similar words faster than the hearing controls.

It was also hypothesised that the hearing subjects would:

1) recognise phonemically similar words faster than the deaf subjects;
2) recognise the phonemically similar words faster than the control words.

### 5.4 Method.

5.4.1 Subjects: 26 children (13 boys and 13 girls) were randomly selected from the Upper School. Reading ages ranged from 7.7 to 9.11 (median:8.4 years) whilst their chronological ages ranged from 12.7 to 15.8 years (median:13.11 years). All were either severely or profoundly deaf - mean hearing loss was 'cd' (Lewis, 1968) with a mean loss of 79 dB for the better ear over the lower frequencies and 90 dB over the higher frequencies.

12 normally hearing children (6 boys and 6 girls) from Marden Bridge Middle School, Whitley Bay, aged between 12.5 and 13.3 years acted as control subjects (median age:12.10 years). All the subjects were of average,

or above-average intelligence; all were right-handed, and all had normal vision, or vision corrected to within normal limits.

5.4.2 Apparatus. A Cambridge two-field tachistoscope was connected to an Advanced Digital Counter (Model SC3) millisecond timer. The timer was controlled by two standard telegraph keys, one operated by the right, and the other by the left hand. 96 white tachistoscope cards (20 cm x 10 cm) were prepared with two strings of letters (either words or non-words) printed horizontally, one above the other, in Letraset Futura medium 48 pt, Sheet 116. A small black star placed centrally on a white card was used as the central fixation point in the blank field.

5.4.3 Stimuli. The test stimuli consisted of 48 Word-Word (WW) pairs:

Type 1: 16 pairs of words which are graphemically similar (words of the same length differing by one letter only) but phonemically dissimilar (e.g. 'pint' and 'mint').

Type 2: 16 pairs of words which are phonemically similar but graphemically dissimilar (e.g. 'six' and 'sticks').

Type 3: 16 pairs of control words, obtained by randomly interchanging words from the previous two lists, such that no obvious relations, either phonemic or graphemic, existed within each word-pair (e.g. 'knee' and 'cow').

Length of word ranged from 2 to 6 letters.

The remaining 48 pairs of stimuli consisted of 24 Non-word - Non-word (NW - NW) sequences, 12 Non-word - Word (NW - W) sequences and 12 Word - Non-word (W - NW) sequences. The non-words did not generally follow the rules of English orthography or phonology, and were not to be found in the English language (using Webster's New Collegiate Dictionary, 1976). The non-words were anagrams of the original words, and were created by randomly re-ordering the letters within each of the words used in the W-W pairs, thus holding letter-frequency and letter-sequence length constant for the words and the non-words. Table 5-a shows the 48 W-W pairs used in Experiment 5.

5.4.4 Design and procedure. Subjects were seated in front of the tachistoscope, the height of which was adjusted to allow comfortable viewing into the hood. Each subject was tested individually in a 40 minute session which included the block of 24 practice trials. The latter were administered in the same way as the trials that followed in the test session, except that different letter-strings were used. The practice trials enabled the subjects to become familiar with the experimental procedure and consisted of 12 W-W 6 NW-NW 3 NW-W and 3 W-NW sequences. The 96 test trials were divided into four blocks of 24 trials with a short rest interval between each block. At the start of each trial, the experimenter gave a visual 'ready' signal, a nod, which could be seen by the subject in the mirror which ran alongside the table on which the tachistoscope was placed. At the signal, the subjects were instructed to look into the viewing-hood and fixate on the centrally-positioned small black star which remained visible and lit until the presentation of two letter-strings. The stimuli were presented well above threshold with regard to luminance, clarity and duration (.5 second). The subjects were required torespond as soon as possible after the onset of the stimulus presentation. Response latency was the dependent variable.

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Type 1. Graphemically similar but phonemically dissimilar pairs of words:

home - come; pull - dull; but - put; cash - wash; few - sew;
food - good; too - toe; boot - boat; cut - cat; lost - post;
low - cow; mind - mink; both - moth; mint - pint; cave - have;
done - bone.

Type 2. Phonemically similar but graphemically dissimilar pairs of words:

know - no; eye - why; sew - so; write - right; saw - poor;
key - tea; tail - whale; you - who; door - more; shoe - to;
high - my; sea - be; sticks - six; white - fight; foot - put;
knee - he.

Type 3. Graphemically and phonemically dissimilar pairs of words (controls):

home - right; good - my; mink - he; dull - why; cat - sticks;
bone - sea; cow - knee; poor - but; wash - be; boat - six;
tail - pint; eye - moth; toe - key; no - have; poor - cut;
more - too.

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Table 5-a. The 48 word-pairs presented in Experiment 5.

The letter-strings were displayed horizontally one above the other, in lower-case letters, and subtended a visual angle of between 2° and 6°, depending on length (2 to 6 letters), and a vertical angle of about 7°. The upper letter-string was always centred on the spot where the central fixation point had been, but lay approximately 2° above it. The first letter of the bottom string was always lined below the initial letter of the top string.

The subjects did not have to name the words, but were required to decide whether or not both strings of letters were English words. When both were words the 'yes' key had to be pressed with the index-finger of the preferred hand by half the subjects, to indicate a positive lexical decision, otherwise the 'no' key was pressed using the non-preferred index-finger to indicate a negative decision (i.e. when one or both of the letter-strings were not English words). For the remaining subjects the hands were reversed and the non-preferred index finger was used for positive lexical decisions and the preferred for the negative decisions. The left and right index-fingers were always held ready over the respective telegraph keys. On half of the 96 trials a 'yes' response was correct and on the remaining trials a 'no' response. The subjects were instructed to respond as quickly and as accurately as possible; accuracy was emphasised. Reaction time (RT) was measured (to the nearest millisecond) from the onset of presentation of the stimuls card to the finger-press response which operated the timer. The subjects were told immediately after each trial whether or not their response had been correct, and, in order to encourage fast and accurate responses, were permitted to see the timer-display on which their reaction time was shown.

A within-subjects design was used for the reasons previously outlined in connection with Experiments 2, 3 and 4 (see Section 4.2). Once again the advantages of a repeated measures design far outweighed any possible disadvantages. Each subject was tested on all 96 pairs of stimuli randomly ordered and the appropriate within-subject statistical analyses were undertaken.

5.4.5 Scoring. The reaction time and the correctness of the judgement was recorded for each of the 96 test trials. The number of errors and the reaction time data for each of the six stimulus-categories was averaged for each subject prior to statistical analysis.

## 5.5 Results.

The principal data are the mean reaction times of the correct responses and the percentage of errors for each type of stimulus which are shown in Table 5-b.

5.5.1 Response latency data. As can be seen from Table 5-b and also from Figure 5-a, speed of decision when both letter-strings are words (W-W pairs) was influenced by the physical relations between the words. The deaf subjects processed the graphemically similar (GS) word-pairs faster (mean difference = 88 msecs) then the phonemically similar (PS) word-pairs, which in their turn were processed a little faster than the control (C) word-pairs (mean difference = 10 msecs), i.e. GS < PS < C. These results suggest that graphemic similarity was a powerful factor in the deaf subjects affecting the speed of lexical decision in a yes/no classification task. This facilitatory effect of graphemic similarity occurred consistently in 25 of the 26 deaf individuals in the experimental group. A substantially smaller and comparatively insignificant facilitation effect of phonemic similarity (compared with the control W-W pairs) occurred in 17 of the 26 deaf subjects.

The hearing control subjects on the other hand responded faster to PS word-pairs than to the control W-W pairs (mean difference = 16 msecs), which in their turn were processed faster than the GS word-pairs (mean difference =16 msecs), i.e. PS< C < GS. Phonemic similarity affected speed of lexical

| | Type of letter-string: | | | | | | | Mean RT (msecs) | | Percentage Errors | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Top String | | Bottom String | Graphemic relation | Phonemic relation | Response category | Proportion of trials | Deaf Ss (sd) | Hearing Ss (sd) | Deaf Ss | Hearing Ss |
| Type 1 | W | - | W | Similar | Dissimilar | Yes | .167 | 660 (150) | 719 (159) | 3.1 | 4.2 |
| Type 2 | W | - | W | Dissimilar | Similar | Yes | .167 | 728 (192) | 687 (136) | 4.1 | 2.8 |
| Type 3 | W | - | W | Dissimilar | Dissimilar | Yes | .167 | 738 (207) | 703 (141) | 4.3 | 4.2 |
| | W | - | NW | | | No | .125 | 925 (220) | 934 (172) | 24.4 | 26.0 |
| | NW | - | W | | | No | .125 | 824 (235) | 830 (204) | 10.6 | 13.8 |
| | NW | - | NW | | | No | .25 | 743 (185) | 747 (153) | 3.5 | 2.2 |

Table 5-b. Mean response latencies and percentage error for each stimulus-category presented in Experiment 5.

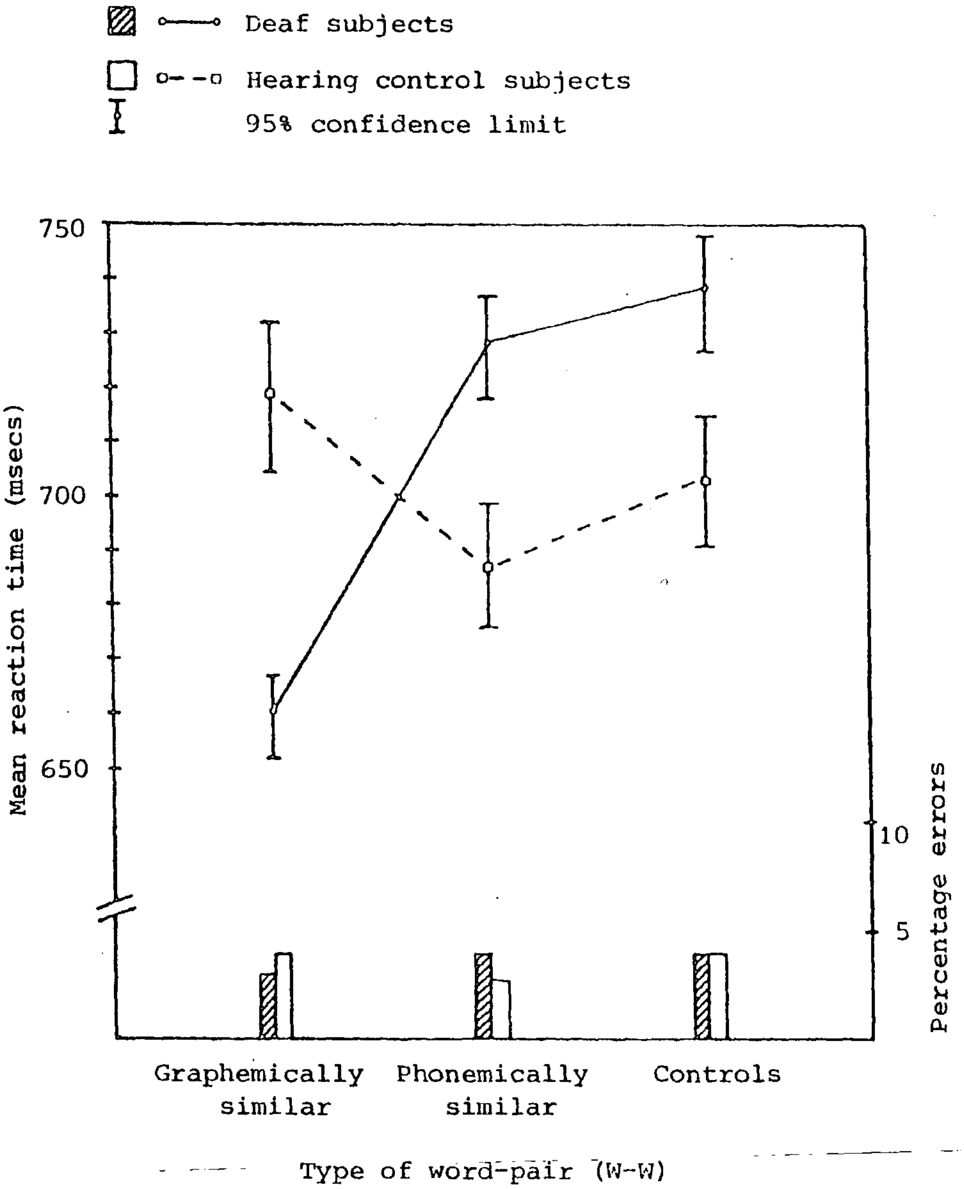

Figure 5-a. Lexical-decision latency as a function of hearing ability and graphemic/phonemic relations between word-pairs.

decision in 9 of the 12 hearing subjects, and half of the hearing control group showed evidence of interference from the graphemically similar W-W pairs compared with the control W-W pairs. These differences in RT were found to be reliable across different W-W pairs within a stimulus-category, and were also fairly consistent across individual subjects within the group.

The relatively large standard deviations of the reaction time data (up to 29% of the mean) reflect the large individual differences that are quite commonly exhibited by relatively unpractised experimental subjects. The within-subject statistical analyses are however more sensitive to differences between stimulus-categories than is reflected by the large standard deviations.

The response latency data (using mean correct RT) of the 26 deaf and 12 hearing subjects for the three categories of W-W pair were analysed by a 2 (Hearing status)x 3 (Stimulus-category) factorial analysis of variance with repeated measures on the second factor and using an unweighted means solution (Winer, 1971 , pp. 375-7). Subjects were treated as a random effect, whilst items which were selected to be a representative , rather than a truly random, sample, consequently had to be treated as a fixed effect (cf.Wike and Church, 1976). See Appendix I for a fuller discussion of the "Language-as-a-fixed-effect fallacy" (Clark, 1973).

The results of the analysis of variance are shown in Table 5-c. Of the two main effects only stimulus-category was significant ($F(2,72) = 5.35$, $p < .01$), and the interaction between Hearing status and Stimulus-category was also highly significant ($F(2,72) = 17.33$, $p < .001$. (This latter interaction can clearly be seen in Figure 5-a).

| Source of variance: | df | SS | MS | F | p |
|---|---|---|---|---|---|
| Between Ss: | (37) | | | | |
| A (Hearing status) | 1 | 243.98 | 243.98 | 0.007 | ns |
| Ss within groups | 36 | 1,278,439.99 | 35,762.22 | | |
| Within Ss: | (76) | | | | |
| B(Stimulus-category) | 2 | 15,793.8 | 7,896.9 | 5.35 | $<.01$ |
| A x B | 2 | 51,138.28 | 25,569.14 | 17.33 | $<.001$ |
| B x Ss | 72 | 106,223.7 | 1,475.33 | | |
| TOTAL | 113 | 1,460,839.75 | | | |

Table 5-c. Summary table of the 2 (Hearing status) x 3 (Stimulus-category) factorial analysis of variance - unweighted means solution.

In addition planned comparisons between the phonemically similar and the control W-W pairs, and the graphemically similar and the control W-W pairs were carried out for the deaf and hearing groups separately using the Dunnett test against control (Winer, 1971, pp. 89-90). Neither of these comparisons were significant for the hearing group ($t = 0.42$ for both comparisons). The hypothesis that the hearing subjects would process the phonemically similar W-W pairs significantly faster than the control W-W pairs was not therefore supported, although the differences were in the predicted direction. For the deaf group, the difference between the phonemically similar and the control W-W pairs was not significant ($t = 0.29$), as might be expected, but a significant difference was found between the graphemically similar and the control W-W pairs ($t = 2.3$, $p < .025$, one-tailed test). As was hypothesised, the deaf subjects did process the graphemically similar W-W pairs significantly faster than the control words.

Difference scores between mean reaction times were also calculated for each individual within the deaf and hearing groups for:

(1) graphemically similar - control W-W pairs;

(2) phonemically similar - control W-W pairs;

(3) graphemically similar - phonemically similar W-W pairs, and were compared using the Mann-Whitney U test. The graphemically similar word-pairs were processed significantly faster than the control W-W pairs by the deaf subjects than the hearing subjects ($z = 3.8$, $p < .0007$), whilst there was no significant difference between the two groups in their ability to process phonemically similar W-W pairs relative to the control words as judged by response latencies. A highly significant difference was however found between the two groups on the difference scores for the graphemically similar and the phonemically similar W-W pairs - the deaf subjects processed the former W-W pairs faster than the latter, whilst the opposite was true for the hearing subjects. There was therefore very little overlap in the distribution of the difference scores of the deaf and the hearing subjects ($z = 4.1$, $p < .0003$). As was hypothesised, the deaf subjects processed the graphemically similar word-pairs significantly faster than the hearing subjects, whilst the hearing subjects processed the phonemically similar word-pairs significantly faster than the deaf individuals, although the overall mean response latency averaged over all the three W-W stimulus-categories was very similar for the deaf and hearing groups - 709 and 703 msecs respectively.

The negative responses (to the three non-word categories) were of secondary interest compared with the word-pairs, but will be briefly discussed. As shown in Figure 5-b, the mean response latencies for the non-word categories were very similar for the deaf and hearing groups. The mean response latencies to the NW-NW pairs were consistently faster than the NW-W pairs for 33 of the 38 (deaf and hearing) subjects, and the responses to the W-NW stimuli were consistently slower than the NW-W

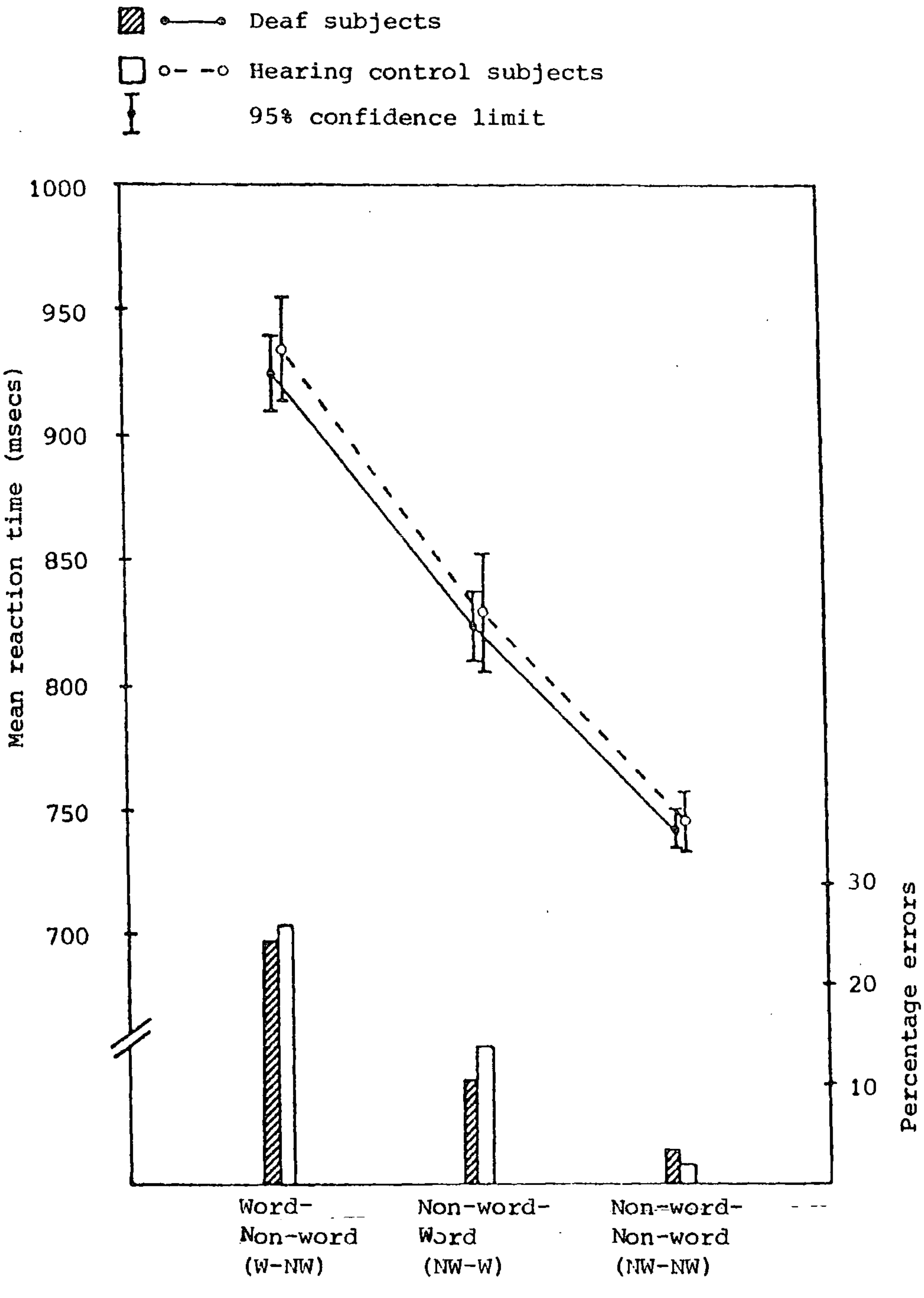

Figure 5-b. Lexical-decision latency for the non-word pairs as a function of hearing ability (Experiment 5).

stimuli for 35 of the 38 subjects. Generally, the non-word stimulus-categories were processed more slowly than the word pairs, as has also been reported by other researchers (e.g. Forster and Chambers, 1973; Nickerson, 1965). Some individuals were however able to respond negatively to the NW-NW pairs faster than they were able to respond positively to the W-W pairs. This was true for more of the hearing than the deaf subjects, and possibly reflects the greater familiarity of hearing individuals with the rules of English orthography and phonology compared with the deaf, which might possibly make the task of rejecting non-words both faster and easier.

The 96 test trials were presented randomly to each subject - the items both within and across the stimulus categories appeared in a different order for each individual. The reaction time data within each of the six stimulus-categories was therefore studied according to order of presentation for evidence of either range effects (Poulton, 1973) or a practice effect. There was however, no indication that subjects' responses were influenced by the range of experimental conditions. In fact, when questioned after the test session, the subjects were unaware that the relations between the W-W pairs had been manipulated, and were only aware that the task was concerned with ability to make lexical decisions. Neither was there any direct evidence of any systematic practice effect across trials - reaction times did not become increasingly faster with practice.

5.5.2 Error data. Response latency data cannot be fully understood without taking the number and the distribution of errors into consideration. Prior to the experiment the maximum acceptable error rate was set at 10%, and any subject failing to meet this criterion was discarded and replaced by another subject. The overall error rate was relatively high - 8.3% for the deaf, and 8.9% for the hearing control group. The distribution of errors however differed considerably across the six stimulus-categories as shown in Table 5-b, and also in Figures 5-a and 5-b. The most striking difference was between the word- and the non-word categories, with nearly three times as many errors occurring in the latter category. Both the deaf and hearing groups made by far the greatest number of errors on the W-NW items (24.4% and 26% respectively). The majority of these incorrect responses were considerably faster than the correct judgements on W-NW stimuli, suggesting that the subjects had pressed the response-key prematurely after only processing the top letter-string (a word). The overall distribution of errors was very similar to the pattern of mean correct response latencies across the six stimulus-categories - as the mean response latency increased so did the number of errors. These results cannot therefore be directly explained by a general speed-accuracy trade-off, and may be at least partly attributed to different processing demands. According to Norman and Bobrow's (1975) analysis of processing limits, the task could be described as generally 'data-limited'. Increasing the allocation of processing resources would probably have very little effect on performance, either speed or accuracy - processing is largely independent of processing resources.

A detailed study of the errors showed that subjects did not consistently respond incorrectly on certain of the stimulus-items - the errors appeared to be randomly distributed over times within each stimulus-category. Some errors seemed to have been due to lapses of attention, and more frequently, to hand-response confusions. Although subjects were never specifically asked to correct their errors, many were aware that they had made an incorrect response on a particular trial before being informed of their mistake by the experimenter.

## 5.6 Discussion.

In the present experiment, individuals were faced with the task of deciding whether or not a sequence of letters was an English word. Obviously when presentation is visual, preliminary identification of component letters is bound to be based on visual features, but the question still remains, whether the spelling pattern and/or the sound pattern was used to access lexical memory, i.e. an individual's long-term representation of language in memory. The results showed that both of the variables studied - graphemic and phonemic similarity, were determinants of word-classification time, but that these two variables produced rather different effects in the deaf and the hearing subjects.

There was no evidence of the general visual word-recognition deficit reported by Doehring and Rosenstein (1960) for younger deaf subjects, although many of the deaf individuals tested in the present experiment were of a similar age. Most of the deaf subjects tested in Experiment 5 appeared to be relying heavily on graphemic cues for visual decoding of the word-pairs, and more heavily than the hearing control subjects, thereby replicating the earlier findings of Blanton, Nunnally and Odom (1967) for memory. It may be that visual cues provided a substitute for the phonemic cues and auditory decoding which is employed by the majority of normally hearing individuals. Here, as in the two previous chapters, visual cues again appear to play a vital role. Just as visual features were found to be important for the recognition and memory of individual alphabet letters (Experiments 1 - 4 inclusive), and for the memory of words (e.g. Frumkin and Anisfeld, 1977; Rozanova, 1970), the present findings provide yet further evidence, this time for word-recognition, of the importance of orthographic cues. Gradually, experimental data is accumulating in support of Conrad's tentative suggestion (1972c) that deaf individuals might rely on the visual image of printed words in thinking and memory.

The present results do not shed much light on the question of whether deaf subjects use speech recoding in a lexical decision task. There was overall only a small, non-significant facilitation effect of phonemic similarity compared with recognition of the control words. This small group effect however masked important individual differences. Five of the 26 deaf individuals were clearly using speech coding as efficiently as graphemic cues, as judged by their reaction times and the facilitatory effect of phonemic similarity relative to the control word-pairs. All these five individuals had intelligible speech compared with the general standard of intelligibility of the entire deaf sample tested, and their hearing losses were all in the severe (hearing losses of between 65 dB and 80dB) rather than the profound, range. There were a further six individuals who showed no evidence at all of any facilitation effect of phonemic relations, and who responded similarly to both the phonemically similar and the control word-pairs; in both cases the responses were considerably slower compared to the graphemically similar word-pairs. The group results were misleading in as much as they masked these very important individual differences in ability to process the different types of word. The 11 extreme' individuals outlined above provide further evidence of the need for, and the importance of, the kind of experimental approach adopted in the previous four experiments which were designed to incorporate an awareness of individual differences. Further indirect evidence that speech coding was not being employed by the majority of the deaf subjects, is that the pronunciation of the graphemically similar word-pairs did not interfere with speed of lexical decision although the pronunciation of each of the words within each pair was quite different, as for example 'home' and come'. It is these pronunciation differences which are the most likely source of interference for hearing individuals who recode the words phonemically - differences which were largely irrelevant to many of the deaf subjects.

The results from the deaf subjects provide additional support for Baron (1973) who concluded that meaning could be derived from visual cues, without the necessity of phonemic cues, although he did acknowledge that a phonemic code could also be used. They also reinforce an idea put forward by Meyer, Schvaneveldt and Ruddy (1974) who, like Baron, recognised that it might be possible to recognise printed words directly from their visual representation.

Contrary to expectation, the response latency data from the hearing subjects did not replicate the findings of Meyer, Schvaneveldt and Ruddy (1973, 1974). A significant interference effect from graphemic similarity and the significant facilitation due to phonemic similarity was not found, although the small, non-significant differences were in the same direction as those reported by Meyer et al. One possible explanation for this difference may be the use, in the present study, of words that were carefully selected using the everyday and reading vocabulary of the deaf adolescents as a guide. Just as it is inappropriate to employ with the deaf a word-frequency list based on the written-language norms of hearing children, it may be equally inappropriate to the hearing individuals when the procedure is carried out in reverse. The everyday vocabulary of this sample of deaf adolescents is quite possibly idiosyncratic. Alternatively, the similar response latencies across different stimulus-categories may be evidence of the versatility and flexibility of word-recognition processes as suggested by Spoehr (1978). Normally-hearing individuals may in fact be able to compensate for experimental manipulations and use both graphemic and phonemic cues as and when the situation demands.

The graphemic-encoding hypothesis, which until now has largely lacked unequivocal experimental support, is supported by the results from the deaf subjects. If however one takes the results of the deaf and hearing subjects together, then the dual-encoding hypothesis is the only one of the three theories outlined in Section 5.1 that accounts for both sets of experimental data adequately. The handicapping condition of deafness forces individuals to rely more heavily on visual cues, but it is also possible that normally-hearing individuals can, and do make use of graphemic associations (e.g. Kleiman, 1975).

While word-recognition tasks may not closely resemble the processes involved in reading in everyday life, the present findings may have some important implicationsfor the teaching of reading. Most children are taught to read English by learning to associate sounds with printed words. Evidence for the importance of orthographic representation in word-recognition, may also be critical when teaching young deaf children to read. It may be that the shape of individual words should be emphasised to those deaf individuals who appear to rely on visual coding - this may be the best basis on which to teach non-oral verbal language.

The results of this pilot study in which subjects were treated as a random effect and items as a fixed effect (using $F_1$, Clark, 1973) may be generalised to other individuals of the deaf population, which is defined, for the purposes of the present experiments, as the deaf school from which the sample of subjects was drawn. There can be no suggestion in view of the differences existing between deaf schools (see Section 1.4) that the results may be generalised to all deaf individuals. For, as has already been suggested, the differences in speech skills, language ability, communication skills in general, and in their educational background and training would be of overriding importance, and would be likely to affect word-recognition performance - both ability and strategy. It is therefore necessary for similar experiments to be carried out in other deaf establishments in order to discover whether or not the findings may be replicated. Meanwhile, the question of generalisability with regard to items (in this case word-pairs) is far less straightforward,and there has recently been considerable debate over this particular problem (see Appendix I). Since items were treated as a fixed effect, it was realised that the results of the statistical analyses from this and the following experiment (Experiment 6) could not be generalised to other word-pairs of the same types. At the same time however, there is no obvious reason to believe that the particular selection of the 16 word-pairs used in each category was in any way peculiar, and that the results are not replicable. It is suggested therefore that the experiment should be repeated using a different selection of words, or possibly presenting different selections of word-pairs (drawn from a large pool of items) to each subject (Keppel, 1976). Such an approach relies on scientific inference rather than the statistical inference that has been suggested by Clark (1973), using a statistical model, min F', which is not as yet fully understood. Under these circumstances the way forward using scientific generalisation would seem to be preferable, and should be sought in any future study of the word-recognition processes of a group of deaf individuals that is undertaken in any depth.

It would also be of interest in the future to investigate the effect of semantic associations using the same experimental procedure, and to study the interaction of these various variables which, in isolation, influence word-classification time. One also needs to remember that the relative importance of various visual, sound and/or semantic cues in word-recognition may be influenced by the amount of context that is available. If, instead of a single-word recognition task, the semantic and syntactic context was also presented, then the visual and phonemic relationships might not be so important.

## Experiment 6: An investigation of the effect of similarity of sign equivalents on visual word-recognition.

This experiment was undertaken to provide information about the possible role of manual representation in the recognition of printed words. Just as in Experiment 5 the phonemic/graphemic relationship between words was manipulated, so in the present experiment, the type of manual mediation possible was systematically varied.

### 5.7 Hypotheses.

It was hypothesised that the deaf subjects would:

1) recognise the word-pairs with similar sign equivalents faster than either the control words, or those without sign equivalents;

2) recognise the control word-pairs faster than those without sign equivalents and which can only be represented manually using fingerspelling;

3) process the word-pairs with similar sign equivalents faster relative to the control words than the hearing subjects for whom signing is not a relevant dimension.

It was also hypothesised that the hearing control subjects would process all three types of word-pair equally proficiently and that there would be no difference in response latency across the W-W stimulus-categories since they did not know any sign language.

### 5.8 Method.

5.8.1 Subjects: The same group of 26 deaf and 12 hearing subjects tested in Experiment 5 also acted as subjects in the present experiment.

5.8.2 Apparatus, design and procedure. Exactly the same apparatus, design and experimental procedure (including the practice trials) was used as for the previous experiment; only the stimuli presented to the subjects were different. Each subject was required to use the opposite index-finger for the positive and negative judgements to the one they had used in Experiment 5.

5.8.3 Stimuli. The test stimuli consisted of 48 W-W pairs:

Type 1: 16 pairs of words with very similar sign equivalents but which are not semantically related (e.g. 'work' and 'green').

Type 2: 16 pairs of words which have no sign equivalents and which therefore have to be fingerspelled if they are to be represented manually (e.g. 'tiger' and 'fruit').

Type 3: 16 pairs of words with sign equivalents which are not similar, i.e. control words (e.g. 'cat' and 'good').

Length of word ranged from 3 to 8 letters. Table 5-d shows the 48 word-pairs presented in Experiment 6.

The remaining 48 test trials included 24 NW-NW trials, 12 NW-W trials and 12 W-NW trials. Once again the non-words were created by randomly re-ordering the letters within each of the words used in W-W pairs. The letter-strings were displayed as before and subtended a horizontal visual angle of between 3° and 8° depending on length of word, and a vertical visual angle of about 7°. The data were scored as for Experiment 5.

## 5.9 Results.

The mean RTs of the correct responses and the percentage of errors for each stimulus-category are shown in Table 5-e.

5.9.1 Response latency data. As can be seen from Table 5-e, and in Figure 5-c speed of lexical decision was affected by the different stimulus-categories. As was predicted, the deaf subjects responded faster to the W-W pairs with similar sign equivalents than to the control word-pairs, i.e. words with non-similar sign equivalents (mean difference = 28 msecs), which in their turn were recognised faster than those with no sign equivalents (mean difference = 63 msecs), i.e. word-pairs with similar sign equivalents $\lessdot$ control word-pairs $\lessdot$ word-pairs with no sign equivalents. The word-pairs with no sign equivalents were processed slower than the word-pairs with similar sign equivalents (mean difference =72 msecs). This finding suggests

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Type 1. Words sharing very similar sign equivalents but which are not semantically related:

who - sweets; nurse - red; black - apple; work - green;
poor - biscuit; shop - which; pen - shy; sheep - cruel;
library - always; school - soldier; friend - football;
live - map; dog - fed-up; please - laugh; soft - easy;
mad - rough.

Type 2. Words with no sign equivalents:

tiger - fruit; factory - mile; lake - rose; test - window;
field - cheese; way - metal; land - jam; shell - week;
lid - farm; carrot - danger; hobby - city; island - about;
town - tin; exam - wood; country - gold; picnic - part.

Type 3. Words with sign equivalents which are not similar (control words):

orange - girl; pencil - face; child - car; house - book;
light - nice; plate - flower; spoon - kind; hair - stupid;
fire - rabbit; ball - hat; king - coat; film - rain;
river - good; sun - fish; bird - man; think - brush.

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Table 5-d. The 48 word-pairs presented in Experiment 6.

that the presence of a sign equivalent is an important determinant of lexical-decision speed. 17 of the 26 deaf subjects processed the W-W pairs with similar sign equivalents (averaged across the 16 pairs) faster than any of the other categories of stimulus.

The hearing subjects on the other hand recognised the control W-W pairs faster than the word-pairs with similar signs (mean difference =30 msecs), which in their turn were recognised faster than the word-pairs with no sign equivalents (mean difference = 22 msecs). The mean differences between the response latencies were however smaller than those of the deaf subjects. Control word-pairs $<$ word-pairs with similar sign equivalents $<$ word-pairs with no sign equivalents. As might be expected for word-pairs manipulated along a dimension that was irrelevant to hearing individuals, namely manual representation, the

| Type of letter-string: | | | | | | Mean RT (msecs) | | Percentage Errors | |
|---|---|---|---|---|---|---|---|---|---|
| Top String | | Bottom String | Sign equivalent | Response category | Proportion of trials | Deaf Ss (sd) | Hearing Ss (sd) | Deaf Ss | Hearing Ss |
| W | - | W | Similar | Yes | .167 | 722(151) | 720(151) | 3.4 | 2.7 |
| W | - | W | No sign equivalent | Yes | .167 | 794(210) | 742(165) | 6.0 | 4.9 |
| W | - | W | Dissimilar | Yes | .167 | 731(179) | 690(135) | 3.4 | 2.8 |
| W | - | NW | | No | .125 | 949(183) | 978(166) | 23.6 | 28.3 |
| NW | - | W | | No | .125 | 815(212) | 812(193) | 12.5 | 14.8 |
| NW | - | NW | | No | .125 | 782(187) | 736(171) | 3.6 | 1.7 |

Table 5-e. Mean response latencies and percentage error for each stimulus-category presented in Experiment 6.

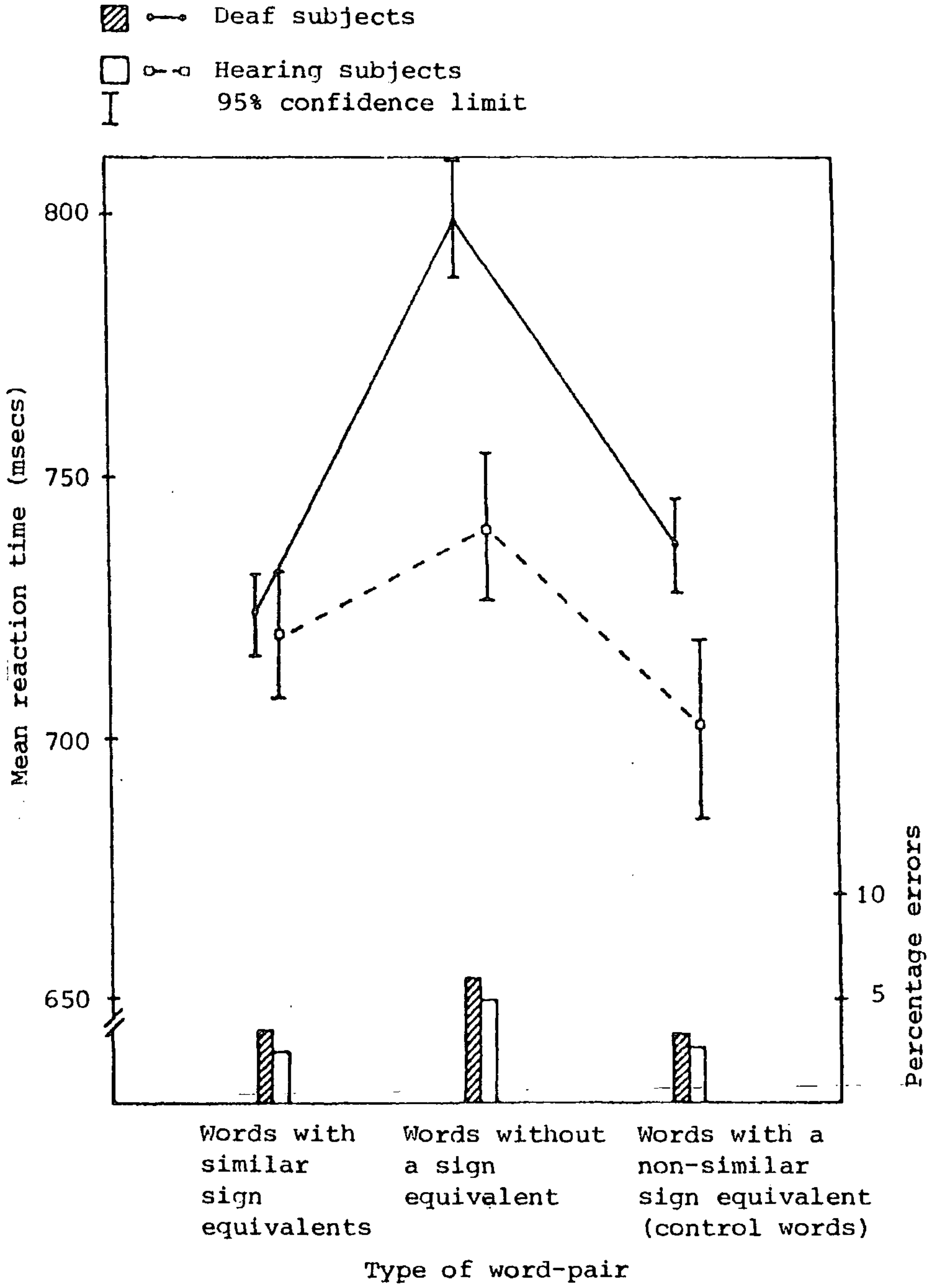


Figure 5-c. Lexical-decision latency as a function of hearing ability and signability of the word pairs.

pattern of responses was less consistent for the hearing control subjects compared with the deaf subjects. With the exception of the control words which were generally processed fastest, no other consistent trends emerged.

As in Experiment 5, the mean correct response latency data were analysed using a 2 (Hearing status) x 3 (Stimulus-category) factorial analysis of variance with repeated measures on the second factor and using an unweighted means solution (Winer, 1971, pp.375-7). For the reasons outlined in Experiment 5, subjects were again treated as a random effect, whilst word-pairs were treated as a fixed effect. The results of the analysis are shown in Table 5-f. Of the main two main effects only Stimulus-category was significant ($F(2,72) = 23.84$, $p < .001$), and the interaction between Hearing status and Stimulus-category was also significant ($F(2,72) = 5.71$, $p < .01$).

| Source of variance: | df | SS | MS | F | p |
|---|---|---|---|---|---|
| Between Ss: | (37) | | | | |
| A(Hearing status) | 1 | 25,390 | 25,390 | 0.8 | ns |
| Ss within groups | 36 | 1,121,870.04 | 31,163.06 | | |
| Within Ss: | (76) | | | | |
| B(Stimulus-category) | 2 | 53,136.68 | 26,568.34 | 23.84 | < .001 |
| A x B | 2 | 12,727.93 | 6,363.97 | 5.71 | < .01 |
| B x Ss within groups | 72 | 80,250.01 | 1,114.58 | | |
| TOTAL | 113 | 6,553,905.98 | | | |

Table 5-f. Summary table of the 2 (Hearing status) x 3 (Stimulus-category) factorial analysis of variance - unweighted means solution.

In addition, planned comparisons were carried out for the deaf and hearing subjects separately, comparing the word-pairs with similar sign equivalents, and also the word-pairs with no sign equivalents with the control word-pairs. The results of the Dunnett Test against Control (Winer, 1971, pp. 89-90) showed that neither of the comparisons were significant for the hearing control group ($t = 0.45$ for the word-pairs with similar sign equivalents compared with the controls; and $t = 0.98$ for the word-pairs with no sign equivalents compared with the controls). These results supported the hypothesis that there would be no significant difference between the mean reaction times across the three W-W stimulus categories. For the deaf subjects however, the difference between word-pairs with no sign equivalents and the control word-pairs was significant ($t = 2.04$, $p < .05$, one-tailed test), whilst the difference between word-pairs with similar sign equivalents and the control words was not significant ($t = 0.46$). As was hypothesised, deaf subjects did process the control words significantly faster than those without sign equivalents, but the results did not support the hypothesis that words with similar sign equivalents would be processed faster than the control words (with non-similar sign equivalents).

The difference scores between mean reaction times were also calculated for each individual subject for:

(1) word-pairs with similar sign equivalents - control word-pairs;

(2) word-pairs with no sign equivalents - control word-pairs:

(3) word-pairs with no sign equivalents - word-pairs with similar sign equivalents, and were compared for deaf and hearing subjects using the Mann-Whitney U test. The word-pairs with similar sign equivalents were processed significantly faster than the control word-pairs by the deaf subjects compared to the hearing control subjects ($z = 3.49$, $p < .003$).The deaf subjects also tended

to process the word-pairs with no sign equivalents more slowly than the control words compared with the hearing subjects ($z = 1.57$, $p = .058$), and also recognised the word-pairs with similar sign equivalents faster relative to those with no sign equivalents compared with the hearing control subjects ($z = 3.08$, $p < .001$). As was hypothesised, the deaf subjects recognised the word-pairs with similar sign equivalents significantly faster relative to the control words than the hearing subjects for whom sign mediation is not relevant.

The mean response latencies for the three non-word stimulus-categories are shown in Figure 5-d, and, as in Experiment 5, they are very similar for the deaf and hearing subjects. Once again the NW-NW pairs were processed faster than the NW-W pairs, which in their turn were processed faster than the W-NW pairs, and all the non-word stimuli were generally processed more slowly than the word-pairs.

A detailed examination of the response latency data produced no evidence of either range effects, or a practice effect resulting from the order of presentation of the items within the stimulus-categories.

5.9.2 Error data. The overall error rate was as high in the present experiment as in the previous one, despite the additional practice on the task, i.e. 8.8% for the deaf and 9.2% for hearing subjects. Once again the distribution of errors differed considerably across the stimulus-categories (see Table 5-e and Figures 5-c and 5-d). The deaf subjects made over three times as many errors on the non-word categories compared with the word-pairs, and for the hearing subjects the figure was over four times greater. Both the deaf and the hearing subjects made the greatest number of errors on the W-NW stimuli (23.6% and 28.3% for the deaf and hearing subjects respectively), and the majority of these incorrect judgements were faster than the mean correct response latency on the W-NW items, suggesting fast, premature responses. The errors did not consistently occur on certain

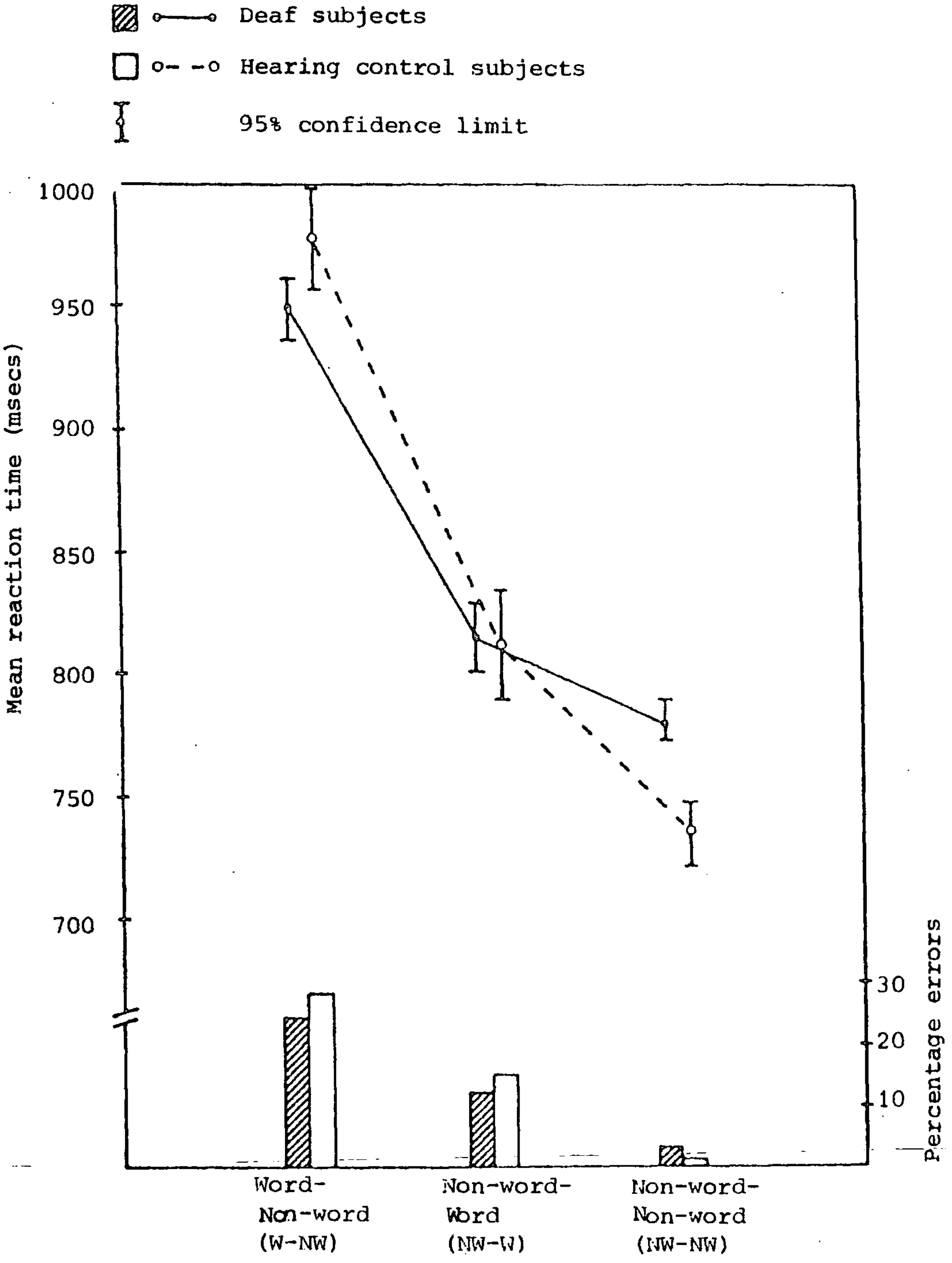


Figure 5-d. Lexical-decision latency for the non-word pairs as a function of hearing ability (Experiment 6).

stimulus-pairs, but were randomly distributed over all the items within each stimulus-category.

The distribution of errors was very similar to the pattern of mean correct response latencies across stimulus-categories, i.e. as the mean response latency increased, so did the number of errors. This direct relationship between number of errors and mean response latency suggests that speed was not being directly traded off for accuracy.

## 5.10 Discussion.

Previous studies have suggested that sign mediation is an important factor in learning and memory (Moulton and Beasley, 1975; Odom, Blanton and McIntyre, 1970). The results of the present experiment have shown that sign mediation is also an important determinant of word-recognition speed, thereby extending the above-mentioned findings to include an earlier stage in the processing of printed words, namely visual recognition.

The most striking finding was the effect of the presence/absence of a sign equivalent of the English words, irrespective of whether a sign was formationally similar to any other sign. In fact, contrary to expectation, similarity of sign equivalent only produced a small, non-significant facilitation effect relative to the control words. The important factor appears to have been the existence of a sign equivalent which would allow a single word to be encoded by a single motor unit instead of a whole series of motor units required by fingerspelling the word. It is assumed that deaf subjects would not discover a sign association between written words unless they were encoding the visual image of the printed words into its sign equivalent. Sign language was apparently providing these deaf subjects with a readily available source of labels for English vocabulary. The possibility of sign mediation raises the question of covert signing which is possibly similar to covert speech, and may serve the same purpose in cognitive functioning.

The present results provide experimental evidence to support the suggestion made by Bonvillian, Charrow and Nelson (1973) that English-English associations are mediated through signs, and, at the same time, contradict Bellugi and Siple's (1974) postulation that the relation between a sign in ASL and an English word is more remote than between spoken and written versions of English. This sample of deaf individuals at least (who use signs from one of the dialects of British sign language) certainly appeared to be using signs in close relationship to the words, a finding which might in fact reflect methods of instruction used by several of the teachers in the Upper School. Conlin and Paivio (1975) were unable to conclude from their study of imagery and signability using a paired-associate learning task, whether the effect of signability which they observed was the result of gestural mediation or rehearsal strategy. It is clear from the results of Experiment 6 that only sign mediation could possibly account for the speed of word-recognition achieved by the deaf subjects.

Although sign language is not relevant to hearing individuals, the control subjects responded more slowly to the non-signable word-pairs than to either of the other two word-pair categories (albeit the difference was not statistically significant). This general pattern of the mean response latencies of the hearing control subjects, whilst less consistent, was the same as that of the deaf subjects, and raises the possibility that words which have no sign equivalents are in fact either more abstract, or occur less frequently in daily communication, than signable words. A closer consideration of the 32 words that were presented within this category, suggested that they were not less abstract (care was taken to avoid this in the original item selection process). The fact however still remains, as a post-hoc realisation, that the deaf do have signs for all the objects/concepts that occur relatively frequently in everyday-type communication, and where there is no sign, and there is a need for one due to frequency of usage, then the deaf are likely to evolve a new sign within the communicative community to meet the need. The logical outcome of this line of argument is that words with no sign equivalent, such as 'tiger', are less frequently occurring words, and this would therefore explain the somewhat slower speed of recognition of such word-pairs by the hearing subjects (cf. Forster and Chambers, 1973; Whaley, 1978). It also emphasises the need for a word-frequency list based on the English vocabulary norms of the deaf. If however, such a word frequency count were available, the experimenter would still be left with the problem of controlling for word frequency (which Whaley (1978), using a step-wise regression analysis, found to be by far the most important factor determining word-recognition performance, and accounting for most of the variance) for two different populations of subjects with differing language norms.

It has to be remembered that signs differ between the various deaf communities in Britain. It is therefore not true to say that 'the deaf' lack a sign for say 'tiger', but that the deaf adolescents within the Newcastle deaf community lacked such a sign. Similarly, one cannot conclude from the present findings that sign mediation must be used for word-recognition, but that it can be used, and was used in a particular experimental situation when isolated pairs of printed English words were presented tachistoscopically, and when semantic variables were not a relevant feature.

Once again, this experiment, like the previous one, needs to be repeated using a different selection of words within each of the word-categories, or presenting a different selection of words (drawn from a pool) to each subject. It would also be interesting and informative to replicate the study on a different sample of deaf individuals drawn from the same population, and also on subjects from other deaf establishments where sign language is used.

## 5.11 General discussion and summary.

The experimental paradigm developed and used by Meyer and Schvaneveldt (1971) to investigate word-recognition proved to be a useful means of studying word perception in deaf subjects. The results of Experiments 5 and 6 suggest that at least two coding strategies were used by this particular sample of prelingually deaf adolescents to process the various word-pairs, namely visual imagery and sign language. A deaf adult stood up during the discussion session of the R.N.I.D./N.C.T.D. Education Meeting held in Harrogate (October 1976), and reported that he saw printed words in his dreams. The experimental evidence from Experiment 5 of the apparent importance of visual cues provides additional support for this anecdotal report.

Future studies using the same technique are needed to replicate and further explore the findings advanced in this preliminary study, and more specifically to investigate the relative importance of visual, phonemic and sign mediation cues, and of semantic associations, and also the interaction of these various factors. The relative importance of visual coding and sign mediation in word-recognition of deaf individuals is not, as yet, understood, either in general terms, or on a more individual basis. The latter may possibly prove to be the more profitable approach, initially at least.

In summary, the deaf subjects processed the graphemically similar word-pairs faster than the phonemically similar word-pairs, which were in their turn processed slightly faster than the control words. The deaf subjects also processed the word-pairs with sign equivalents (similar or otherwise) significantly faster than those with no sign equivalents. These group differences do however mask important individual differences within the group.

The hearing control subjects on the other hand, processed the phonemically similar word-pairs faster than the control word-pairs, which in their turn were processed faster than the graphemically similar word-pairs. The mean differences between the response latencies across the three word-pair categories were not as great as for the deaf subjects. Nor was there a significant difference in the speed of lexical decision of the hearing subjects across the word-pairs which were manipulated according to their signability - an irrelevant dimension for hearing individuals.

Most of the subjects, both deaf and hearing, responded correctly to word-pairs faster than they did to the non-word stimuli. They seemed to be carrying out a more exhaustive scanning process for the non-words than for the words, and hence were able to recognise words faster than they were able to reject non-words. Overall, the correct negative responses to the non-word stimuli were very similar for the deaf and the hearing subjects.

Stokoe (1976) highlights the difference between the output of signs as a language system and the use of signs as a code for verbal language, i.e. signs as manual symbols for words. In the present experiment we have been concerned with the latter of Stokoe's categories, that is with signs as manual symbols for words. The results of Experiment 6 raise the question of whether sign language mediation is also used for processing longer units of written English, namely sentences and passages of prose. This problem will be tackled in the following chapter, and the next experiment, Experiment 7, is concerned with the possible use of signs as a language system by the deaf subjects for remembering sentences. Many deaf individuals may speak or write English on command, but think in sign language.

# CHAPTER 6

## LANGUAGE I: MEMORY FOR SENTENCES

After studying deaf children's ability to process individual words in the previous chapter, and discovering the facilitatory effect of sign mediation in a lexical-decision task, the present chapter is concerned with the recognition, recall and comprehension of language. The key question here is the effect of language form on ability to remember simple sentences.

The relationship between prelingual deafness and language processing ability is an area of interest to educational and cognitive psychology. Recent interest in child language, first language learning and generative grammars generally,may be partly responsible for the increased concern with the language abilities of the prelingually deaf. This has led to the development of research in two directions:

1) studies of deaf people's proficiency in English, and
2) studies of sign language as the "natural" language of the deaf.

Many researchers have studied the verbal behaviour of deaf people, but since the oral language of most prelingually deaf individuals is relatively unintelligible and therefore difficult to transcribe, only a few researchers have been concerned with their spoken language (e.g. Brannon, 1968; Gemmill & John, 1977; Pressnell, 1973). Most of the studies have, therefore, concentrated on written language. Techniques that have been developed and used to study the syntactic structures of young children with normal hearing and their emerging grammars (e.g. McNeill, 1970; Menyuk, 1971) have also been applied to study the written language of deaf children.

## 6.1 Experimental studies of the written language of the deaf.

The overall picture emerging from experimental studies of the language of deaf children is rather confusing and somewhat contradictory. At one extreme there are those who suggest that there is no difference between the language of deaf and hearing children. For example, Heider and Heider (1940, p.42) wrote: "It is often quite impossible to say of a single composition whether it is written by a deaf or by a hearing child". At the other extreme Howarth and Wood (1977) state:

> There is now some evidence that, however language is taught to deaf children, whether manually, orally or by 'total communication', the deaf are not only linguistically retarded but also linguistically different. Studies of both language production and language comprehension suggest that the underlying organisation of knowledge and experience is somewhat different for the deaf. (pp.6-7)

Many comparisons have been made between the language of deaf and hearing children, looking at the productivity, complexity, the distribution of different parts of speech and the correctness of language used, beginning with the early work of Thompson (1936) and the classic study of Heider and Heider (1940). In order to understand these studies in greater detail, they will be divided into three main groups according to the conclusions drawn concerning the language of the deaf. The first group are those based on the supposition that the language system of the deaf and the hearing are the same, although possibly with some retardation in linguistic development and a greater number of grammatical errors made by the deaf. Secondly, there are those who have attempted to study the language of the deaf as a system in its own right, rather than as a deviant form of standard English. The third approach assumes that the deaf have no linguistic system at all, that they lack a system of rules to generate language. This final category comes nearest to the assumption that deaf children may be treated as "alinguistic controls".

Heider and Heider (1940) studied the sentence structure of deaf and hearing children and expressed the differences in quantitative terms, as a degree of retardation. They concluded that"Generally deaf children resemble younger or less mature hearing children" (p.73). However, they did also observe differences in sentence structure, including more simple sentences and the use of a "relatively large number of sentences which are shorter both in number of words and in number of clauses than those of the hearing". They go on to state:"The whole picture indicates a simpler style, involving relatively rigid, unrelated language units which follow each other with little overlapping of structure or meaning" (p.98).

Simmons (1962) also investigated the flexibility/rigidity of word usage using pictures to stimulate written composition. He measured the type-token ratio (T.T.R.), i.e. the ratio of the number of different words used to the total number of words in the language sample, and found that the deaf children had a lower T.T.R. than the hearing children, indicating less diversity of vocabulary.

MacGinitie (1964) used sentence completion tests to study ability to use different word classes in context, rather than their frequency of occurrence in free composition. Deaf and hearing subjects were required to complete each sentence by filling in the omitted word. MacGinitie found no striking differences in the pattern of difficulty of usage of different word classes for the deaf and hearing children. A similar technique, the Cloze procedure, was used by Moores (1970a) who reported that, in addition to poorly developed grammatical abilities, the deaf children exhibited restricted, stereotyped modes of expression and limited vocabulary.

More recently Davison (1977) analysed the errors in written language produced by a group of prelingually deaf children and found them to be

"...both deviant and delayed". She states that "A continuum of language development was seen, from systems which approximated more or less nearly to standard English through to complete acquisition" (unpublished abstract). Davison concludes that the existence of such a continuum suggests that deaf children are developing English rather than an idiosyncratic 'deaf language', even though the pattern of linguistic development is not exactly the same as for hearing children. All these studies are essentially alike in their assumptions that the language systems of deaf and hearing are similar.

Others have studied the language of the deaf as a system in its own right. Myklebust (1964) described the grammatical errors made by the deaf as "deafisms" but did not attempt to study the linguistic system responsible for generating such errors. Perry (1968) analysed all the written compositions produced by his deaf and hearing samples quantitatively in terms of the number of mistakes and the number of sentences, and qualitatively, analysing the type of error. As a result, he also concluded that deaf children produce characteristic errors - so-called "deafisms" - and found like Myklebust, no evidence for a decline in the number of mistakes made by the deaf children with increasing age. He found that expert sorters could "correctly classify sentences written by deaf and hearing children" (p.153), evidence which suggests that there must be some characteristic, distinctive features for such a classification to be possible.

Ivimey (1976) attempted to discover the syntactic structure of the language of the deaf. He analysed in detail the written language of one profoundly deaf 10½ year-old girl, using Chomsky's 1957 model of syntactic structures. On the basis of such an in-depth analysis he concluded that "The language of at least one deaf child is not a loose concatenation of English words. It is rule based and the sytax is not congruent with that of normal English", and that "The differences are so great that it seems more appropriate to categorise this corpus of data as a system of language 'sui-generis'"(p.112).

Finally, other studies have concluded that the deaf lack a linguistic system. Fusfeld (1955, p.70) described the written language of the deaf as a "....tangled web type of expression in which words occur in profusion but do not align themselves in an orderly array". Furth (1971, p.68) goes on to further elaborate this point:

> Most deaf persons in our society know some English words or phrases; but admittedly the most vital aspect of the living language is not single words but the structure of the language into which single words are fitted to form meaningful sentences .... It is precisely this general structure that hearing children assimilate with relative ease and the vast majority of deaf children fail to attain with an adequate degree of competence.

To those unfamiliar with deaf children, the above findings may appear contradictory. However, they are probably less puzzling to those who have gained experience of the deaf within different deaf schools, with their various selection procedures, communication methods and educational techniques. It is perhaps even to be expected that studies of the written language of different samples of deaf children drawn from different educational establishments, such as those previously discussed, would produce contradictory findings.

An extreme case of the differences that exist between deaf schools is exemplified by a comparison of the N.C.S.D. (the school used in the present study) with the Mary Hare School, from which Davison (1977) selected her sample. The latter, being the only deaf grammar school in Britain and consequently highly selective (for intelligence, ability to lip-read and to benefit from an 'oral' education), is attended by the most 'verbal' deaf individuals in the country. The N.C.S.D., on the other hand, is a non-selective school, considered to be one of the most 'manual' educational establishments, where one finds a more 'non-verbal' sample of deaf children - children who have failed to acquire a verbal language adequately. The differences between these two samples of deaf children are such that it is highly probable that any conclusions drawn from analyses of the structure of written language of the pupils in these two schools, will differ markedly, as is shown later (Section 6.6).

Observation outside the classroom in the N.C.S.D. showed that the deaf children were able to communicate information fluently and efficiently between themselves using sign language. Yet, when required to relate some incident using written language, they were unable to do so at the same level of sophistication, and were reduced to a fairly basic level of communication. However, as we shall see from the 24 written sentences selected for use in Experiment 7, the meaning of their written language is not totally obscured by the deviant grammatical structures, although the frequent and regular departures from standard English are striking.

6.1.1 <u>General problems associated with the study of verbal language</u>. Many general problems are involved in the study of verbal language-behaviour, whether of deaf or hearing individuals. Many of the investigators (e.g. Heider & Heider, 1940; Myklebust, 1964) have used pictures to generate the language samples for subsequent analysis. If a particular construction is not used, one cannot assume from these written samples that the subject does not know how to use it; this may be due to a lack of ability to produce particular constructions, or it may just be that the particular picture or sequence of pictures used did not elicit the structures. Linguistic competence, therefore, cannot be easily tested. Sentence-completion and sentence-correction tasks enable the experimenter to control the language constructions far more precisely, yet this still raises the problem of possible differences between the ability to use a particular grammatical form and habitual use of that same structure. It does however have the advantage that the vocabulary, the linguistic constructions and the subject-matter can be geared very precisely to the needs of particular groups of subjects.

Since verbal language must be formally taught to deaf children, it is also quite possible that language production may be directly related to the particular type of instruction received, and to the methods, including the form of communication, used. Therefore, the language of deaf children may have to be regarded, in part at least, as a product of schooling. Walter (1955, 1959) considered this problem, first studying a group of children from a single school in Australia, and then following this up with a further study of 58 deaf children taken from 3 Australian and 4 English schools for the deaf. She found some similarities but also many variations. The similarities serve to remind us of the common problems shared by most profoundly or severely prelingually deaf children in learning verbal language, and the variations indicate the differences due to circumstance.

6.1.2 Some examples of the written language of deaf children. Deaf language, whether written, signed or spoken, shows infrequent use of tense, and omission of various grammatical features. Examples such as "I want go", "There lost the dog", and "Your lives nearly shops" should all be quite familiar to, and easily recognised by many teachers of the deaf, parents of deaf children and the few psychologists, linguists and psycholinguists who are interested in the language production of deaf children. All the above examples were produced by prelingually deaf adolescents of average or above-average non-verbal intelligence. Similar examples have been reported in the French publication "Communiquer"(June 1973, p.49) e.g. "Le petit garçon peur la souris", and "La voiture va achète avec tout neuf". Other examples are also to be found in the literature, for example Fusfeld (1958, p.255) quoted a note written by a 19½-year-old deaf boy, who, after 13 years of schooling in the United States,wrote: "Tell mother I wants she come here at 1.00 between 1.30 because I have some dirty sweaters and shirts and she can take them and wash and need money".

A report on the work of the Schools Council Project on the language development of deaf pupils (Wollman & Hickmott, 1976), includes a short passage of free composition, written by a 9-year-old deaf child:

> All about me.
> I am 9 year old. I am boy. I have live in Farm. Live Mummy, Daddy with Elaine. I am baby calf. I am have house. I am sheep. I am have samll house. I am cow. I am have new cars. I am cat. I am have garden. I am baby chicken. I am have barn. I am have cock. I am have gate. I am have geese. I am have flowers. I am have yes tractor. I am have bales. I am have yes trailer. I am have blackberries. I am have blackcurrants. (p.6)

The use of stereotyped repetitions or "carrier phrases", such as 'I am have' creates a relatively rigid style and may well reflect set language patterns that have been taught and learned by heart, and which are reproduced at a given signal. Heider and Heider (1940, p.75) also noted that the deaf used "...more fixed phrases that could be learned and used as units".

All the evidence presented so far would seem to indicate that there are some very important differences between the written language of deaf and hearing people. In most of these studies however, the principal concern has been the categorisation of errors and the description of written language, whereas in the present study the central issue is the effect of different language structures on memory recognition and recall and on comprehension, and goes beyond the descriptive level.

6.1.3 Studies of deaf children's understanding of, and memory for, written language. Brill and Orman (1953) tried to train deaf children to remember simple English sentences, but reported that when the sentences were 4 or 5 words and longer, the subjects found it difficult to recall the sentences. They concluded that the only way to bring about a lasting improvement in memory would be a raising of the language abilities of the deaf children. Odom and Blanton (1967) compared the learning of 4-word segments of written English by deaf and hearing children using:

(i) English phrases of the form Verb + Article + Adjective + Noun (e.g. 'paid the tall lady'); (ii) the same words in non-phrases of the form Noun + Verb + Article + Adjective (e.g. 'lady paid the tall'); and (iii) the same four words in a scrambled order (e.g.'lady tall the paid'). The hearing subjects recalled the English phrases well but the other two forms interfered with their ability to recall the phrases correctly. The deaf children on the other hand, showed no differential recall as a function of phrase structure, i.e. there was no facilitation for recall of English phrases. Odom and Blanton concluded that the deaf do not possess the same perceptual or memory processes with regard to English as hearing children, but went on to observe:"This is not to say that they may not possess these characteristics with regard to Sign. It might be possible to conduct an experiment similar to the present one, but defining the segments according to the structure of Sign" (p.605). If deaf subjects were using a Sign code, the experimental variation, English structure, would be irrelevant to them. This was one of the ideas that was followed up and tested in the following investigation, Experiment 7, and which Odom and Blanton (1970 themselves examined. They used 3 types of reading material:

1. A standard version of a paragraph comprehension test.
2. A series of sentences representing the same information but designed to approximate the syntax of ASL.
3. The same sentences with scrambled word order.

They found that the deaf subjects were able to understand the sentences written in ASL better than those written in English, whilst the hearing subjects were better able to understand the English sentences than those written in sign language. Both groups experienced the greatest difficulty with the scrambled word order. Compared with the hearing subjects, the deaf experienced greater difficulty with the standard English paragraph.

Sarachan-Deily and Love (1974) investigated the underlying grammatical rule structure in the deaf. They tested two groups of deaf students (aged 15 to 19 years), one group had been taught using simultaneous fingerspelling and speech (the Rochester method), the other by a purely 'oral' approach, and a group of hearing controls. Each subject had to remember 12 sentences presented individually. A sentence was scored as correct if it was recalled as an exact copy of the original. The errors were classified as 'agrammatical-sentence errors', 'grammatical-sentence errors', and 'sentence deletions'. The errors made by the hearing subjects rarely violated English sentence structure, compared with the deaf subjects whose recalled sentences frequently were "...a gross violation of English sentence structure" (p.696). These results suggested that the deaf students had a limited syntactical competence for the basic rules of English syntax.

## 6.2 Experiment 7: An investigation of the effect of language form on recognition and recall.

This study was designed to compare the effect on subsequent memory of three language forms: standard English (SE) as investigated by Odom and Blanton (1967, 1970), sign language (SL) as studied by Odom and Blanton (1970), and "deaf English" (DE). The latter language form was included in the investigation in an attempt to determine whether there was sufficient similarity between the ungrammatical errors in the written language produced by deaf children (the 'deafisms') for DE to be considered as a non-standard dialect of English, perhaps of a similar standing to Black English Vernacular (Labov, 1972). It was suggested, therefore, that if this were the case, one would expect deaf children to find DE easier to process than SE.

The samples of DE used in the present experiment were collected from the unaided, free composition of deaf children from the same classes as the subjects who were tested. Since written language may well be affected by the educational and communication methods used with the deaf children, as suggested by Walter (1959), it was felt to be important that the language samples should be generated by deaf children of the same age, who had been taught by the same teachers using the same methods as the experimental group, since these 'external' variables relating to language teaching methods and communication methods may influence language production and the type of errors made.

All the deaf children tested were familiar with SL and fingerspelling and chose to communicate manually whenever they were free to do so, indicating a definite preference. In the classroom, however, English was taught and used as the basic means of communicating all taught subject matter. The effect of such a situation on their ability to process language was investigated in the present study.

Learning, one must assume, involves understanding. Children would probably find it more difficult to memorise language which they did not understand, or which was not part of their linguistic competence. If a person is to memorise sentences and reproduce them accurately, then he or she must have access to a system of internal linguistic rules similar to those used to generate the sentences. In so far as language is rule-based it must reflect some deep-lying competence; a fundamental assumption underlying this investigation was that if a deaf child repeatedly produced or reproduced certain syntactic forms, grammatically correct or otherwise, then it may be inferred that a system of rules is being used to generate these features.

If the language form of a sentence is not the same as that normally used during cognition it is likely that the preferred language mode will mediate, or even interfere with, subsequent recall or recognition, though probably less so in the latter case owing to the nature of the cues that are given. The structure of a sentence generated during recall should provide a useful indicator of the structure of language used cognitively. The critical distinction that is being made here concerns the difference between psittacism and language used for basic understanding and cognitive functioning.

## 6.3 Hypotheses.

1. The deaf children should find it easiest to memorise sentences written according to the syntax of SL because of their obvious preference for, and ability to communicate fluently in, sign language.

2. The deaf children should find it easier to remember DE sentences than SE sentences if the 'deafisms' of "deaf English" are characteristic of a deaf dialect and are generated by a linguistic system rather than random occurrences.

## 6.4 Method.

6.4.1 Subjects: 48 deaf children from the Upper School were selected - 6 at random from each of 8 classes. All the children were either severely or profoundly prelingually deaf - hearing losses ranged from 65 - 120 dB in the better ear. Their ages ranged from 13.2 to 16.5 years and their reading ages ranged from 6.9 to 8.7 years as measured by the Young's group reading test. There were 24 boys and 24 girls in the sample.

6.4.2 Materials. Single sentences were typed centrally onto each of 72 white cards (12 cm x 3 cm) for visual presentation. In addition a further 24 cards (12 cm x 6 cm) were prepared with four alternative forms (SE, DE, SL and a distractor item) of the same sentence, randomly arranged, each written on a single line, one under another, for use with the memory recognition group. All the cards were covered with transparent protective film. Paper and pencils were needed for the children's written answers. Duplicated copies of a page of mental arithmetic problems for use during the 30 second intervals between sentence presentation and subsequent recognition/recall. These intervals were timed with a stop watch.

6.4.3 Design and procedure. 24 short sentences, written by deaf children in the same classes as those children who were to be tested, were selected. Each sentence contained typical "deafisms", such as the incorrect substitution of the preposition 'to', and the use of the present tense of the verb instead of the past in the sentence: 'We arrive to London late' instead of 'We arrived in London late'. The sentences were collected from samples of unaided, creative, free composition. Each of the sentences was translated accurately into sign language, using the signs and syntax typical of the Newcastle deaf community, and every sentence was considered to be natural, grammatical, and semantically interpretable by native users of SL. The sentences were also 'translated' into standard English using the closest, most common, English equivalent. The written form of sign language looks very different and rather strange, for the seemingly 'ungrammatical' features of sign language, such as the lack of verb tense, were reflected in the written form. Since there is no systematic analysis of the syntactical structure of British sign language, a great deal of time and care was taken in the translation and compilation of the collection of sentences. Four experienced teachers of the deaf were consulted throughout the procedure, and this included a bilingual individual whose parents are deaf and who had been pupils at the N.C.S.D. Four ex-pupils of the school were also used to judge the acceptability of the translated sentences. Only after extensive discussion with all 8 local 'experts' were those sentence constructions, which they felt to be typical and correct, according to the 'rules' of SL, included.

The extracted meaning of the three forms (SE, DE and SL) of each sentence was identical (the full set of sentences is shown in Table 6-a).

The 48 deaf children were divided into two groups by allocating three children from each class to one group and the remaining three to the other group, matching the two groups for reading ability. Each child was tested individually and read 24 sentences presented one at a time. These sentences were selected randomly from the pool of 72 sentences (24 sentences each written in SE, DE and SL form) with the following restrictions: (i) that for every individual tested, each sentence number (i.e. 1 - 24 which corresponded to sentence meaning) was only presented once; and (ii) that 8 of the sentences were written in SE, 8 in DE and 8 in SL. The order of presentation of the 24 sentences was random with regard to language form. The overall presentation of sentences was balanced in as much that each of the 72 sentences was always presented once per three children tested. Each stimulus card with a single sentence written upon it was viewed for 20 seconds, followed immediately afterwards by a period of 30 seconds of unrelated mental activity - straightforward addition sums (e.g. 33 + 18 = ?). The children worked systematically through a sheet of 200 simple addition sums during the 30 second intervals, resuming at the point where they had previously left off. When the 30 second interval had ended, one group of deaf children was required to attempt a verbatim recall of the sentence, whilst the other group was required to recognise which of four alternatives they had previously been shown - a multiple-choice task. The four alternative types of sentence consisted of the SE, SL and DE forms (one of which the child had been presented with), and the fourth alternative was a distractor item, which somehow differed in meaning and was obviously wrong (for example, the 'opposite' or 'negative' meaning was conveyed). This distractor item did however, include approximately the same words as the other three choices, and was included to test whether the children had understood the meaning

| | | | Language Form: |
|---|---|---|---|
| 1 | a. | The boy kick the dog. | DE |
| | b. | The dog kicked the boy. | |
| | c. | Boy kick dog. | SL |
| | d. | The boy kicked the dog. | SE |
| 2 | a. | We late, London. | SL |
| | b. | We arrived late in London. | SE |
| | c. | We left London late. | |
| | d. | We arrive to London late. | DE |
| 3 | a. | How much does it cost? | |
| | b. | How much money you got? | DE |
| | c. | Money you got, how much? | SL |
| | d. | How much money have you got? | SE |
| 4 | a. | We walked two miles yesterday. | SE |
| | b. | Yesterday we two miles walk. | SL |
| | c. | Yesterday we walking two miles. | DE |
| | d. | Tomorrow we will walk two miles. | |
| 5 | a. | Last night I see monster on T.V. | DE |
| | b. | Last night I saw T.V. on the monster. | |
| | c. | See monster, last night, T.V. | SL |
| | d. | Last night I saw a monster on the T.V. | SE |
| 6 | a. | I have enjoy self. | DE |
| | b. | I have enjoyed myself. | SE |
| | c. | I have not enjoyed myself. | |
| | d. | I enjoy self a lot. | SL |
| 7 | a. | Where is your school? | |
| | b. | Where you live? | SL |
| | c. | Where you lived? | DE |
| | d. | Where do you live? | SE |
| 8 | a. | I want to go to the library to read. | SE |
| | b. | I want go library read book. | SL |
| | c. | I want to read the library in the book. | |
| | d. | I wanting go to library, read book. | DE |
| 9 | a. | I am fed-up to obey you. | DE |
| | b. | I am fed-up of obeying you. | SE |
| | c. | You must obey me. | |
| | d. | I fed-up obey you. | SL |
| 10 | a. | My little brother, home, hate. | SL |
| | b. | My little brother hates home. | |
| | c. | I hate my little brother at home. | SE |
| | d. | I am hate with little brother at home. | DE |
| 11 | a. | My father and uncle have same face like twins. | DE |
| | b. | My father and uncle are twins. | |
| | c. | My father and uncle look like twins. | SE |
| | d. | My father, my uncle look like same. | SL |
| 12 | a. | I watched a bad film. | SE |
| | b. | I watch bad film. | SL |
| | c. | I watched an awful film. | |
| | d. | I watched bad films. | DE |
| 13 | a. | It is my birthday today. | SE |
| | b. | Is it my birthday today? | |
| | c. | My birthday, today. | SL |
| | d. | I am birthday today. | DE |
| 14 | a. | I like visit in his school. | DE |
| | b. | He likes to visit my school. | |
| | c. | I like to visit his school. | SE |
| | d. | I like see his school. | SL |
| 15 | a. | I went home in a ship. | |
| | b. | I go over water, in ship. | SL |
| | c. | I went abroad in a ship. | SE |
| | d. | I went to abroad in ship. | DE |
| 16 | a. | I can swim as well as you can. | SE |
| | b. | I can swim same as you. | DE |
| | c. | I cannot swim as well as you can. | |
| | d. | I swim, same you. | SL |
| 17 | a. | Mother puts cake in over to cooking. | DE |
| | b. | Mother put cake in oven, cook. | SL |
| | c. | Mother puts a pie in the over to cook. | |
| | d. | Mother puts a cake in the oven to cook. | SE |
| 18 | a. | Her favourite lesson was sewing. | |
| | b. | Her favourite lesson is sewing. | SE |
| | c. | Her favourite, sewing. | SL |
| | d. | She likes best lesson is sewing. | DE |
| 19 | a. | He has two cats, one big, one small. | SL |
| | b. | He used to have a cat and a kitten. | |
| | c. | He has a cat and a kitten. | SE |
| | d. | He has one cat, one kitten. | DE |
| 20 | a. | I sometimes wearing a short dress. | DE |
| | b. | I sometimes wear a short dress. | SE |
| | c. | I sometimes wear short dress. | SL |
| | d. | I sometimes wear a long dress. | |
| 21 | a. | I have been take my friend to park. | DE |
| | b. | I took my boy-friend to the park. | |
| | c. | I took my friend to the park. | SE |
| | d. | I take friend, go park. | SL |
| 22 | a. | The child likes to play with sand. | SE |
| | b. | Child like play sand. | SL |
| | c. | The child likes play with sand. | DE |
| | d. | The children like to play with sand. | |
| 23 | a. | It was raining hard so we went home. | |
| | b. | Little rain, we went home. | SL |
| | c. | It was little rain so we went home. | DE |
| | d. | It was raining a little so we went home. | SE |
| 24 | a. | I paid 8 pence for the chips. | SE |
| | b. | I pay 8 pence, chips. | SL |
| | c. | I did not pay for the chips. | |
| | d. | I pay 8 pence to the chips. | DE |

Note: The underlined sentences are the distractor sentences that were used in the recognition task.

Table 6-a. The different language forms of the 24 sentences presented in Experiment 7.

of the sentences they had read, or whether they were merely guessing - one would expect 25% to be correct by chance alone. The order of appearance of the four alternatives on each card was randomised, but for a given sentence the order of the different sentence forms was identical. For example, a child might begin the test and be presented with sentence number 4, in SL form, i.e.:'Yesterday we two miles walk'. After 20 seconds of viewing and 30 seconds of mental arithmetic, the recognition card for sentence 4 would be presented:

4a We walked two miles yesterday.
 b Yesterday we two miles walk.
 c Yesterday we walking two miles.
 d Tomorrow we will walk two miles.

The child is required to recognise that it was sentence 4b he had seen previously, and write this code down on his response sheet, before progressing on to the next sentence. The order of the four alternatives on the recognition card for sentence number 4 is always the same, but other children were presented with other language forms of the sentence; sentence number and language form being randomised for each child. The test session lasted for about half an hour.

6.4.4 Scoring. The recognition and the recall groups were scored independently. For each child, and for each group, the total number of correct answers was recorded by language form. This scoring was 'blind' and was undertaken by an ex-pupil of the school. Spelling mistakes were not penalised, but were recorded, for a more detailed analysis by the experimenter.

## 6.5 Results.

Preliminary analyses revealed no significant sex differences and thus boys and girls were combined in all subsequent analyses.

|  | Language form |  |  |
|---|---|---|---|
|  | SE | DE | SL |
| Recognition Group[a] |  |  |  |
| Mean score: | 6.1 | 6.0 | 7.3 |
| Recall Group[a] |  |  |  |
| Mean Score: | 2.8 | 2.9 | 5.3 |

Note. Maximum score = 8

[a] There were 24 Ss in each group (See Appendix L for raw data).

Table 6-b. Mean recognition and recall scores as a function of language form.

6.5.1 Group Data. Reference to Table 6-b shows a marked difference in the mean scores of the memory recognition and recall groups: recognition performance was consistently better than recall performance over all three language forms, but the difference was reduced for sentences written and presented in SL. The mean scores for both recall and recognition of sentences presented in SE and DE were very similar, and were lower than for sentences presented in SL. The distribution of the recognition and recall scores for the sentences written in SE, DE and SL is clearly shown in Figure 6-a.

A randomised blocks analysis of variance was performed on the transformed scores (an arc sine transformation was used) of the recognition and recall groups separately (see Table 6-c). No significant difference between subjects was found in either the recognition or the recall group.

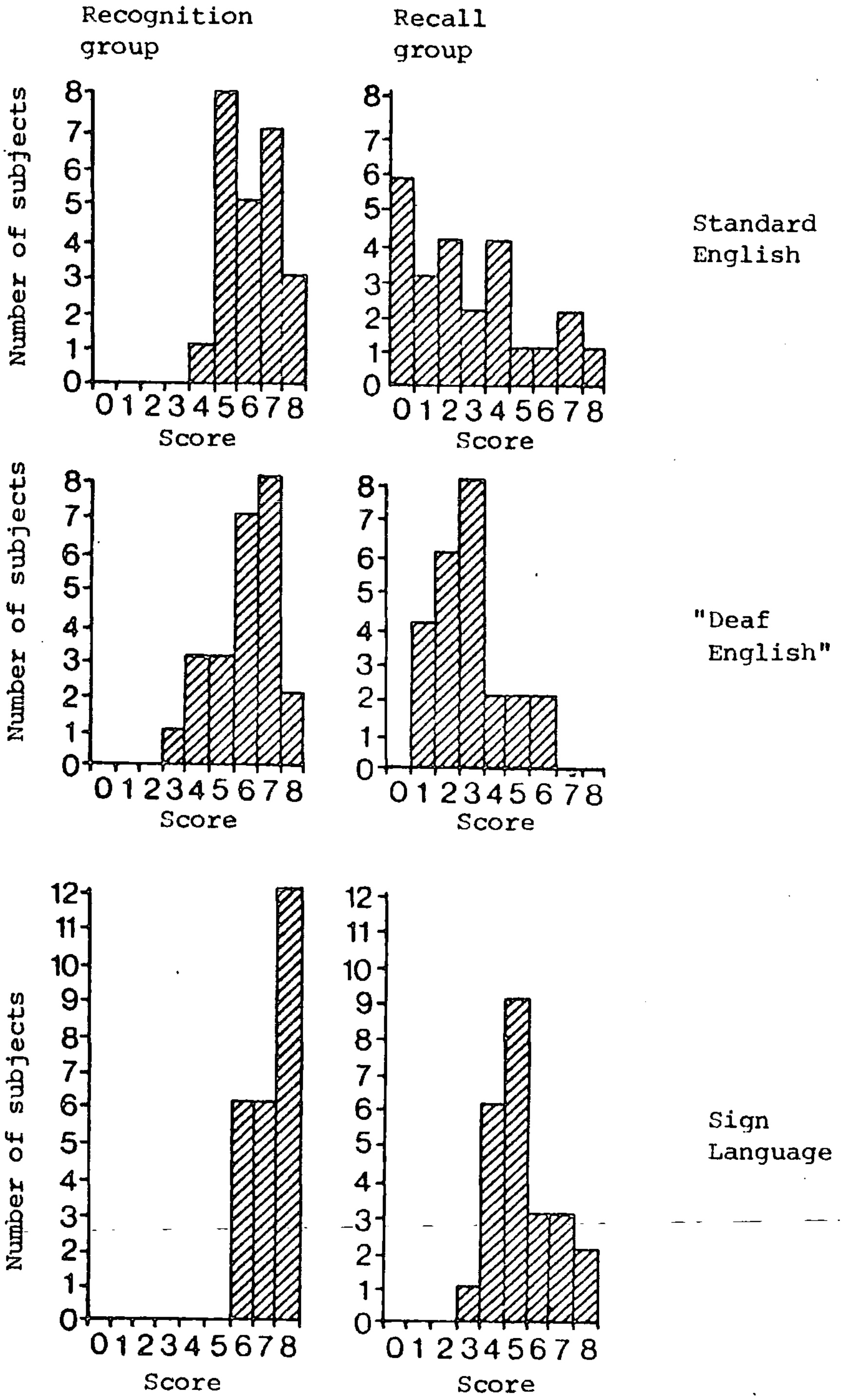


Figure 6-a. Recognition and recall scores as a function of language form.

Recognition Group:

| Source of variance | SS | df | MS | F | p |
|---|---|---|---|---|---|
| Subjects | 4073.24 | 23 | 177.1 | 1.08 | ns |
| Sentence type | 3522.02 | 2 | 1761.01 | 10.7 | $<.001$ |
| Ss x Sentence type | 7562.46 | 46 | 164.4 | | |
| Total | 15157.7 | 71 | | | |

Recall Group:

| Source of variance: | SS | df | MS | F | p |
|---|---|---|---|---|---|
| Subjects | 9288.66 | 23 | 403.85 | 1.5 | ns |
| Sentence type | 7635.84 | 2 | 3817.9 | 14.5 | $<.001$ |
| Ss x Sentence type | 12417.4 | 46 | 269.9 | | |
| Total | 29341.9 | 71 | | | |

Table 6-c. Summary table of the randomised blocks analysis of variance for the Recognition and Recall Groups.

Performance of both groups did, however, differ significantly according to language form ($F(2,46) = 10.7$, $p < .001$ for recognition; $F(2,46) = 14.5$, $p < .001$ for recall). Orthogonal comparisons of the SL and SE/DE treatments showed a very significant difference in favour of SL for both recognition ($F(1,46) = 21.28$, $p < .001$) and recall groups ($F(1,46) = 27.51$, $p < .001$). Neither group however, showed any difference between the SE and DE treatments (see Appendix L).

6.5.2 Individual data. A detailed study of the memory performance of individual children showed that in the recognition group, 12 children (that is half the group) recognised all the SL sentences correctly; 3 recognised all the SE sentences correctly; 2 recognised all the DE sentences correctly. In the recall group, 2 children recalled all the SL sentences correctly and no child scored less than 3; 1 child recalled all the SE sentences correctly, 6 children were unable to recall any of the SE sentences correctly and 3 were only able to recall one SE sentence correctly. No child recalled all the DE sentences correctly.

Of greater interest than isolated individual scores was a comparison of individual's relative ability to process SE and SL sentences. The two ordered contingency tables (drawn separately for the recognition and recall groups) in Table 6-d show the relative ability of each of the deaf subjects to process the SE and SL sentences. The diagonal hatched cells represent equal scores on both SE and SL sentences, i.e. no difference in ability to process SE and SL. Individuals whose scores lie above the hatched cells found it easier to process the SE sentences compared to the SL sentences. Whilst those individuals whose scores lie below the hatched cells (i.e. the majority of the deaf subjects) found it easier to process the SL sentences than the SE sentences.

---

Recognition Group[a]:

| | | | | |
|---|---|---|---|---|
| Number of SE sentences correctly recognised | 8 | | | 2 |
| | 7 | 3 | 3 | 2 |
| | 6 | 1 | 1 | 3 |
| | 5 | 2 | 1 | 5 |
| | 4 | | | 1 |
| | | 6 | 7 | 8 |
| | | Number of SL sentences correctly recognised | | |

Recall Group[a]:

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Number of SE sentences correctly recalled | 8 | | | | | 1 | | |
| | 7 | | | | 1 | | | 1 |
| | 6 | | | | 1 | | | |
| | 5 | 1 | | | | | 1 | |
| | 4 | | 1 | 2 | | 1 | | |
| | 3 | | | | 1 | | | 1 |
| | 2 | | | 2 | 1 | | | |
| | 1 | | | 1 | 1 | | 1 | |
| | 0 | | | 1 | 3 | 1 | 1 | |
| | | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| | | Number of SL sentences correctly recalled | | | | | | |

Note: Hatched cells represent equal scores for both SE and SL sentences.

[a] n =24

Table 6-d. Recall and recognition scores showing the relative ability of the deaf subjects to process the SE and SL sentences.

Sentences which were incorrectly recognised or recalled (by the criterion that the sentence produced from memory did not match the sentence input into memory) were of particular interest. In the recognition group a total,of 99 sentences (17%) were incorrectly recognised (see Table 6-e).

| | | Language form of presented sentence | | | |
|---|---|---|---|---|---|
| | | SE | DE | SL | TOTALS |
| Language form of sentence subsequently recognised | SE | - | 29 | 7 | 36 sentences were 'corrected' to SE. |
| | DE | 22 | - | 11 | 33 sentences were 'corrected' to DE. |
| | SL | 12 | 18 | - | 30 sentences were 'corrected' to SL. |

Table 6-e. The changes of language form, between sentence presentation and subsequent recognition of the 99 sentences incorrectly recognised.

Out of a total of 576 recognition responses, the distractor item was chosen only on 12 occasions (11 after presentation of SE sentences and 1 after a DE sentence). These results from the recognition group were not very illuminating since the alternative language forms were actually presented for the subjects to choose between. When the original form of the sentence was not correctly recognised by the deaf subjects, they showed no preference for selecting either of the alternative forms (Sign test (Siegel, 1956, pp.71-4) $x = 12$, $z = 1.55$, $p > .05$ when the original sentence had been presented in SE; $x = 18$, $z = 1.46$, $p > .05$ when DE; and $x = 7$, $z = 0.7$, $p > .05$ when SL).

The recall group recalled 313 of the 576 sentences (54%) incorrectly, and of these, 71 were recalled in the exact words of one of the other language forms, not previously seen by the subjects (See Table 6-f).

| | | Language form of presented sentence | | | |
|---|---|---|---|---|---|
| | | SE | DE | SL | TOTALS |
| Language form of sentence recalled | SE | - | 7[a] | 3[a] | 10 sentences were 'corrected' to SE[a] |
| | DE | 14 | - | 1 | 15 sentences were 'corrected' to DE. |
| | SL | 28 | 18 | - | 46 sentences were 'corrected' to SL. |

Note: [a] Only 3 individuals from the group of 24 children contributed to this score.

Table 6-f. The changes in language form, between sentence presentation and subsequent recall, of the 71 'corrected' sentences of the recall group.

It is interesting to note that all of the 10 sentences corrected to SE were due to just three individuals from the group of 24 children. The 15 sentences which were 'corrected' to DE provide further evidence of the generation of typical 'deafisms'. The vast majority of the sentences (65%) were 'corrected' to SL in spite of instructions, that were clearly understood, to recall the exact form of each sentence presented. When either SE or DE sentences were forgotten, significantly more subjects recalled the exact SL form than the alternative form (Sign test: $x = 14$, $z = 2.0$, $p = .04$ when the original sentence had been presented in SE, and $x = 7$, $p < .05$ when presented in DE).

The grammatical errors made in the written recall of the 126 SE sentences which were not correctly recalled (out of the total of 192 SE sentences presented), were classified according to type. By far the most frequent error made by these deaf children was the incorrect use of verb tense which occurred in 55 of the 126 sentences; the infinitive or present tense was most frequently substituted for the actual verb tense of the original sentence. In 24 sentences, a preposition was omitted, and in a further 14, an incorrect preposition was substituted. The indirect article was omitted on 24 occasions, and the direct article on a further 13. In 24 of the sentences a noun was used in the singular instead of the plural. Other errors, such as the use of the incorrect possessive, the omission of possessives and word order reversal were also recorded, but occurred less frequently.

Although ability to spell was not a major concern of the present experiment, and spelling mistakes were not penalised in any way, it was interesting to take a brief look at the mis-spelled words. A total of 152 words were spelled incorrectly and all the children made at least one spelling mistake. (A complete list of all the mistakes can be found at the end of Appendix L). Many were 'visual' errors such as 'kist' (kick), 'piece' (pence) and 'enyoyed' (enjoyed) in which letters were replaced by others which look similar.A number of words contained the correct letters but arranged in the wrong sequence, letters were transposed, as in 'lats' (last),'lekis' (likes), 'monters' (monster) and 'flim' (film). On occasions the children obviously have a mental picture of the letters making up a word but cannot remember the order in which they occur (e.g. 'favoiter' (favourite), 'libiray' (library), stoh (short)). There were also examples of letter omissions (e.g. 'monter' (monster), 'fater' (father) 'sort' (short)).

## 6.6 Discussion.

The deaf children predictably found it more difficult to recall the sentences, rather than merely recognise which sentence they had previously been shown, as has previously been found with hearing subjects (McDougall, 1904; Postman & Rau, 1957; Bruce & Cofer, 1965). The results from the recall task were more interesting than those from the recognition task, since the deaf children had actually produced the form of each response sentence themselves, and if these responses were more than rote memory of meaningless strings of words, then they should reflect an internal system of generative linguistic rules.

6.6.1 Differential recognition and recall of sentences according to language form. The results clearly showed that the deaf children's ability to recall the SE sentences was very poor, with fewer than 35% correctly recalled. One might, therefore, be tempted to conclude from this result that these children need to use English syntax more effectively as an aid to recall. An alternative and more likely conclusion would be that these results reflect a greater and more basic problem associated with inability of this particular group of deaf children, to use and process SE adequately. Even after reading a short sentence written in English, the majority were unable to remember the simplest of grammatical constructions. Compare this, however, with 66% correct recall of sentences written in SL. A similar pattern of results also emerged for the recognition group, although more sentences were correctly recognised than correctly recalled. SL sentences were both significantly better recognised and recalled than either the SE or the DE sentences, which suggests that SL was being processed more efficiently by these deaf children than either DE or SE.

Length of sentence, however, was a confounding variable. Since SL is less redundant, the SL sentences were generally shorter than the other sentences, an average of 4.5 words per sentence written in SL, compared to 6.0 and 6.1 for the DE and SE sentences respectively. A memory span factor may, therefore, have been operating, which could explain the similar performance scores for the DE and SE sentences, and the better performance for SL, on the basis of sentence length alone. The number of words in a single sentence ranged from 3 to 9, but a close examination of the results showed that the deaf children had been able to remember SL sentences which were up to 8 words long, and yet had failed to remember short sentences of 4 words written in SE and DE.

Number of words in the sentence (when all the sentences were relatively short) did not, therefore, appear to be as important as differences in language form, in determining relative ease of subsequent recall or recognition.

To the extent that recall and recognition reflects ability to process English, these deaf children did not appear to be as much at home in SE as in SL. The experimenter certainly observed many of the children, during test administration, using signs, and also fingerspelling the occasional word. Presumably, therefore, a deaf person who uses SL brings to the acquisition of English, many skills and grammatical structures which may well influence cognitive processing. The recall of the SE sentences may, therefore, have been mediated by SL. The differential recall as a function of language form, in favour of SL, supports the suggestion, made by Odom and Blanton (1967), that deaf children might be able to process SL in memory, since they did not seem able to process and recall English as well as hearing children; and also corroborates their experimental findings (Odom and Blanton, 1970).

Brill and Orman (1953) also found that the deaf children they tested experienced considerable difficulty in remembering simple English sentences, and concluded that only a raising of total language ability would improve the deaf children's memory performance. They also suggested that general inability to process English was responsible for the poor memory performance. Certainly, their recommendation of raising general language ability should create a desired, lasting improvement in memory performance, but such a proposal is unlikely to be well received by deaf educators who are continually striving to teach verbal language, with little apparent success. The present findings, however, suggest that improved memory performance could also be achieved by presenting sentences in a language form with which the children were more familiar, namely sign language.

The overall group results showed that the deaf children were better able to recall the SL sentences than those written in DE and SE. Whilst this was true for the majority of the children, there were three individuals whose performance was in the opposite direction. They were better able to recall SE sentences than those written in SL; these three individuals were responding more like the hearing controls studied by Odom and Blanton (1967, 1970). They also 'corrected' 10 sentences to SE when they had been presented with sentences written in DE or SL. These children at least, were sufficiently familiar with simple grammatical constructions in English, to be able to transform the original input into correct, grammatical English, although not specifically requested to do so. It would have been interesting to discover whether, in fact they had consciously switched to SE, or whether the correction had been unconsciously made during processing. Unfortunately, it is not easy to get a deaf child to introspect usefully on his/her activities, and it was not, therefore, possible to discover this information. One clear fact that did emerge, however, was that these corrections were not the result of a basic lack of understanding of the instructions on the part of the children concerned, and they were seemingly unaware of their 'mistakes'.

There was nothing that was obviously different in the background, the hearing losses or the linguistic competence of these few deaf children to explain why, or how,the differences might have arisen, but it is clear that it is exceptional individuals such as these, who should be studied in detail in the future, in an attempt to discover the developmental factors contributing to their success. For it is the goal of everyone who is involved in teaching language to deaf children to improve their competence in English - spoken and written, and their ability to read. When such 'successes' occur, they should not be dismissed as surprising exceptions, instead teachers need to be aware of, and understand, the reasons for both the apparent successes and, conversely, possible causes of failure to develop verbal language.

6.6.2 "Deaf English". The results clearly showed that neither group was able to remember the DE sentences better than those written in SE, as was hypothesised. In fact both the recognition and the recall scores for the DE and SE sentences were very close and significantly lower than those for the recognition and recall of SL. There was no difference in the deaf children's ability to process the DE and SE sentences. After completion of this study (July 1975), Charrow published the findings of some very similar experimental work (Summer 1975). She also had the idea that there might be enough commonality among deaf adolescents'errors in written English to justify the use of the term "deaf English" and its recognition as a non-standard dialect. Charrow used 50 "deaf English" sentences, collected from the written language of deaf teenagers, and 50 English sentences. She does not make it clear whether or not the former sentences were gathered from the same group of deaf children who were subsequently tested. Her aim was also to discover whether the deaf children would find the DE easier to process than the SE, and whether hearing controls would make more errors on the DE. Her results showed that the deaf subjects did find DE sentences easier to remember and repeat back than the hearing subjects. She also reported that the deaf children did not find the DE sentences any easier to recall and repeat correctly, than the SE sentences. Her results corroborated those of the present investigation exactly; the independent and isolated studies have both shown that DE is not processed very efficiently by deaf children, and no more effectively than SE. The "deafisms" which seemed to be typical, did not appear to be a non-standard English dialect common to a group of deaf people, even within a single school. The ungrammatical errors that were repeatedly generated by the deaf children were not subsequently reproduced accurately in memory. It would perhaps be interesting to repeat the above experiment on a more individualised basis, to discover whether individuals would recall the non-standard grammatical features which they persistently generate.

6.6.3 Speculations regarding the origin of "deaf English". It is important to consider why these recurrent non-standard features, that are so resistant to correction, and which remain even after years of being taught English in school, should arise in written English. How does "deaf English" originate? One is still, I believe, justified in using the term, if only to identify and describe the forms of non-standard English generated by the deaf. There have been few attempts to explain why deaf children make the errors they do.

The nature and occurrence of these errors suggest two possibilities: 1) Linguistic interference from sign language; as Ivimey (1977, p.93) writes, the major difficulty in perceiving language is "... not so much in the sensory modality involved in communication as in the structure of the cognitive model they bring to the communicative act". Certainly most of the mistakes analysed in the samples of "deaf English" collected for this study, and most of the grammatical errors made by the group of deaf children in the recall of the SE sentences, involved verb tense, omission or incorrect use of prepositions, and the omission of both indirect and direct articles. The same types of error have been reported by other investigators (for example Ivimey, 1976; Quigley, Montanelli & Wilbur, 1976; Wilbur, 1977) and yet would be rarely observed in the written language of hearing adolescents of average or above-average intellectual ability. Verb tenses are not conveyed in the same way in sign language as in English, and prepositions and articles are used less frequently. The source of many of the errors may, therefore, be traced back to sign language, suggesting some kind of linguistic interference from the children's knowledge of sign language.

2) Lack of sufficient experience of the correct form; Moores (1974) suggested that deaf English may be attributed to lack of adequate instruction in English, and does not accept the possibility of interference from signs.

The first of these two possibilities might warrant the use of the term 'deafisms' as suggested by Myklebust (1964); and the second, the term 'learningisms'. This latter term has only very recently been introduced into the literature by Ivimey (1977) who suggests that young children such as Adam and Eve (Brown & Bellugi, 1964), immigrant children as well as deaf children all make similar mistakes, and that they all share a common lack of exposure to English. He writes: "Thus we may conclude that instead of regarding the mistakes made by the deaf as "deafisms", arising from their specific handicap, or through the medium of communication used in their education, it would be more appropriate to see them as 'learningisms'" (p.98). Ivimey, unfortunately, does not extend this idea further as an explanation, and whilst it is probably not a complete explanation of the kind of mistakes that are found in deaf children's written language, the concept of 'learningisms' should help us to understand, why, after innumerable corrections, many deaf children continue to make the same mistake repeatedly. An example from McNeill (1966b,p.69) will elaborate this point - it is an exchange between a mother and her child:

C: "Nobody don't like me"
M: "No, say 'nobody likes me'"
C: "Nobody don't like me"
"
"
eight repetitions of this dialogue

M: "No, now listen carefully, say 'nobody likes me'"
C: "Oh! Nobody don't likes me".

This dialogue is a good illustration of the relative impenetrability of a child's grammar to the adult's grammar, in spite of numerous repetitions. Even when the mother emphasised the distinction saying "No, now listen carefully, say 'nobody likes me'", the child was still unable to imitate this sequence of three words. When the grammatical transformation is beyond the child's linguistic competence, imitation and repetition appear to be of limited value. Normal hearing children gradually develop and achieve adult grammatical competence in English, i.e. they are able to generate an infinite number of grammatically correct sentences. This then, is where the similarity must surely end, for the deaf child rarely arrives at the point of linguistic competence where grammatical English is easily produced, We can, however, draw from present knowledge and understanding of linguistics and language development, to help understand further the situation regarding the learning of verbal language by deaf children. The bizarre sentence constructions of many deaf people may reflect the underlying linguistic rules used to generate them, This being the case, no amount of correction, or drilling of surface structure, therefore,will improve the deaf child's ability to generate grammatical English, as shown in the example quoted by McNeill (1966b), when the linguistic rules governing the transformation from deep to surface structure are responsible for language output. It is at the transformational level that one should perhaps seek for, and find, differences between deaf and hearing children.

If correct English syntax is not a functional aspect of expressive language after 10 or more years of special education under the present system, it is unlikely ever to be so. It would seem inconceivable that many of the simpler rules of English grammar are not assimilated, despite access to correct written English and repeated correction, unless one accepts that the errors are more than 'learningisms'. Moores (1974), and possibly Ivimey (1977) too, seems to be denying the deaf children's fluent knowledge of sign language, and ignoring, or underestimating, their intrinsic linguistic abilities. When a hearing person is learning a foreign language, for example French, it may be frequently observed that native knowledge of one's own language interferes with one's written or spoken production of the foreign language. Similarly, it is likely that native knowledge of sign language would also interfere in an equivalent manner. Knowledge of sign language, including the structural features of sign language, could influence cognitive functioning and be responsible for the linguistic rules and the transformational grammar that generates non-standard English. Those who deny that sign language may ever constitute a child's first and primary language clearly cannot contemplate the possibility of such a source of interference.

Since the development of this line of argument, Brasel and Quigley (1977) have published a paper proposing a similar idea. They have recently been studying the influence of certain language and communication environments in early childhood on the development of language in deaf individuals. They recognise that early language input influences the child's developing language ability, and found that when the language was ASL, the child tended to develop grammatical rules different from those of SE. The only difference being that Brasel and Quigley refer specifically to ASL and in the present investigation the language was a dialect of British sign language. In all essential features the conclusions are similar to those of Brasel and Quigley, who systematically manipulated the experimental variables of English and non-verbal sign language, and manual/oral presentation of language, and provide additional weight to the present explanatory speculations. It would seem to be the case that deaf children draw on their knowledge of SL when their environment includes models of this language and this affects the development of their verbal language.

One might hypothesise, therefore, that the errors in deaf written language are the result of both 'learningisms' and 'deafisms', and not either one, or the other, as previously discussed by Ivimey (1977). Both would appear to be inextricably linked in the language development of deaf children. The present findings suggest that the deaf children might have been using a system of syntactic rules to generate written language largely drawn from the rules of sign language, and that the 'errors' are rule-based, and, therefore, resistant to correction. This hypothesis requires further study.

6.6.4 Language teaching methods. The present findings suggested that SE appeared to be like a foreign language to many of the deaf children who were tested. The majority seemed to be more at home using, and processing, SL. Teachers of the deaf can no longer afford to ignore this evidence that many of the deaf children used SL to mediate between the world of the classroom, where verbal language skills are taught and emphasised, and their own internal thought processes. It is still the case, however, that few teachers acknowledge, or make use of, competence in SL. English is largely taught to the deaf using English as the teaching medium, as if it were their first and native language, when, for most individuals in a residential school setting, it obviously is not. It has to be remembered that in a residential school, such as the deaf school in Newcastle-upon-Tyne, many of the deaf children begin school at the age of 2 or 3. At this early age the basic need to communicate is such, that the young deaf children very quickly acquire sign language from the few deaf children who have deaf parents, and who have been surrounded by sign language communication, at home, since birth. In a residential community, therefore, the difference in communication abilities between the deaf children of deaf parents and those of hearing parents is rapidly and considerably reduced. By the time the children reach the Upper School they are all fluent users of SL, whatever their home background. This knowledge of sign language, in some cases native, and in all cases fluent, may be a further possible factor contributing to the deaf children's inability to acquire the level of competence in verbal language that one might hope for from the amount of classroom teaching, in terms of both hours and years, that has been aimed at developing this language competence. The efforts are sadly not reflected in the majority of the deaf children's knowledge and use of English; children who appear to remain better able to use and process SL.

It may be then that the underlying principles of language teaching methods used in deaf education are at fault, and that failure of the majority of deaf children to develop proficiency in verbal language may primarily be due to shortcomings in instruction, and not due to inherent learning or linguistic difficulties of the deaf. In fact, Brennan (1976) has published a significant paper in which she examines some of the linguistic assumptions on which these methods are based. She argues that "Many of the principles underlying the methods in deaf education are totally unrelated to linguistic facts and are frequently at variance with present insights into the processes of language acquisition and the nature of language" (p.11). Such a linguistic evaluation of the situation and the experimental evidence presented here are surely sufficient to warrant a reappraisal of the language teaching methodology. No teacher in Britain would teach a foreign language to a hearing child ignoring the child's knowledge of English; the foreign language ($L_2$) is taught using English ($L_1$) as the teaching medium. Perhaps then English could be more effectively taught to deaf children on the same principles, as an $L_2$, drawing on the theory of foreign language teaching, and using SL as a language base, the $L_1$, to teach English. Such an approach would be similar to teaching SL to hearing people, (only in reverse) where SL is taught as a foreign language, and as Ingram (1977) observes, in a well-informed booklet 'Principles and Procedures of Teaching Sign Language', sign language instructors have been forced to look "to the heritage of second language teaching for more effective methods and materials" (p.3).

In fact,as long ago as 1958, Fusfeld suggested that "The task of acquiring language in the case of the deaf child is very much like our attempting to learn a foreign language" (Fusfeld, 1958, p.258). This idea that English is like a foreign language to deaf children has subsequently been endorsed by Charrow and Fletcher (1974) who found that deaf children of deaf parents who used A.S.L. at home, scored higher on the'Test of English as a Foreign Language'than deaf children of hearing parents.

Perhaps the time has come for deaf educators to consider seriously some of the practical suggestions that are being made both in the U.S. by Stokoe (1975) and, more recently in this country, by Brennan (1977), who are advocating that teachers should teach English via sign language. It certainly seems that deaf educators cannot afford to be unaware of, and ignorant about, the advances of knowledge in linguistics, particularly in the field of language learning, which corresponds so directly to their particular problems and needs. In the past there has not been much evidence of such an awareness.

The spelling mistakes that were collected from the written recall of the sentences suggested that the overall visual patterns of words were very important to these deaf children. Many of the mis-spelled words were visually similar to the original word. As might have been expected, there were no obvious phonologically-based spelling mistakes. Whilst the hearing child can make use of both visual and phonological patterns to help him/her to spell, the profoundly and severely prelingually deaf lack the phonological input and cues. Many of the mistakes, the letter transpositions in particular (e.g. 'flim' for film),would probably not have been made had the deaf children been able to sound out the words for themselves. The kind of spelling mistakes made by these deaf children is discussed further in the following chapter.

6.6.5 Future studies. The present investigation was concerned with the effect of language form on the deaf children's ability to process, and either recognise or recall, simple sentences. It is likely, however, that the effect of modality is far greater. Sign language, by its very nature, is very different from written English. It would be interesting, therefore, to repeat the experiment, presenting SL sentences manually, instead of in written form, and requiring the deaf subjects to recall the sentences manually; one could then compare their manual recall of SL with their written recall of SE. The facilitative effect of SL on recall is likely to be even greater under these conditions.

In the course of the present experiment the deaf subjects were merely required to reproduce short sentences they had previously seen and read, from memory. As a follow-up, it would be interesting to proceed with a further, more detailed linguistic analysis of written sentences generated by the deaf children themselves (as in the samples of 'deaf English' gathered at the start of the present study) to test the hypothesis that the deaf children were using a system of syntactic rules to generate English (in this case written, but this possibly also applies to spoken language), which were largely drawn from the rules of sign language. Such an investigation would require a linguistic analysis of the syntax of sign language, which has not as yet been tackled in this country, but should be high on the list of priorities of the British Deaf Association's study of sign language (1977 - 1979).

A comparison should also be made between written language generated in a 'naturalistic' situation, such as free composition in the classroom with that generated in an experimental setting. It might be that under experimental conditions, deaf children tend to respond by producing more concrete and stereotyped expression, thereby creating a rather false impression of their linguistic abilities. It might also help us understand why, on occasions, deaf children appear to be inconsistent and use a particular grammatical construction correctly on one occasion, and incorrectly on other occasions, within a short passage. It may be that the explanation lies in the occasional use of stereotyped phrases alongside of genuine spontaneous language production. It seems that such questions need to be studied before further conclusions can be drawn.

Emphasis was placed throughout the present investigation on exact recognition or recall of sentences from memory. This was a necessary requirement since the aim was to investigate possible sources of linguistic interference during cognitive processing of the sentences. In the situations of everyday-life, however, it is normally quite sufficient if one can recall the content of a message, without necessarily retaining its original, formal linguistic structure - the experimental requirement of exact recall may, therefore, have placed excessive, unnatural demands on the deaf children. Bearing this in mind the following experiment, Experiment 8, was designed to study the effect on comprehension of passages written in SL and SE. DE was omitted, since its effects in the present experiment were not as straightforward as had been previously anticipated. The question that remains to be answered, and which is tackled in the following chapter, is whether or not, these deaf children can understand more verbal language than they can reproduce. It is generally accepted amongst teachers of foreign languages that receptive skills make fewer demands than productive skills (e.g. Brooks, 1964; Pit Corder, 1973). Does the fact that nearly all the linguistic input in the classroom is SE affect the amount of information that is learned by the deaf children? Or, should the linguistic medium through which school subjects are taught be changed?

Hoemann (1974, p.520) concluded from a study which looked at deaf children's use of fingerspelling to label pictures that "The concurrent development of manual communication skills and English is important from a theoretical standpoint since it suggests that manual language fluency does not interfere with English language competence". In the light of the foregoing evidence, it would seem that such an assumption needs to be couched in more cautious terms. Certainly this particular group of prelingually deaf children showed considerable evidence of interference from sign language in their abilities to express themselves competently in English.

## 6.7 Summary.

The memory recognition and recall of simple sentences written in SE, DE and SL were compared. Generally, more sentences were correctly recognised than correctly recalled over all three language forms. However, significantly more SL sentences were both correctly recognised and recalled than sentences written in either SE or DE. There was no difference in the ability of the deaf children to correctly recognise or recall the SE and DE sentences. This particular sample of deaf children found it easier to process and remember SL, and appeared to be more at home using it.

# CHAPTER 7

## LANGUAGE II: COMPREHENSION AND SPELLING

The experiment in the previous chapter investigated ability to process sentences, which is a necessary condition for understanding, but is not sufficient, for some degree of processing can occur in the absence of adequate comprehension. In the following experiment a further issue was raised - the effect of SL and SE respectively, on comprehension; do the different forms of language, SE and SL, also affect comprehension?

### 7.1 The comprehension of language by deaf children.

If a person is to read fluently and understand what he reads, the reader must, it is assumed, have access to a system of internal rules similar to those used to generate the written language that is being read. Fusfeld (1955) reported that although the deaf children he tested were quite proficient in correctly recognising different forms of English (e.g. sentence structure, spelling, etc.), they could not grasp the meaning of the language - in particular paragraph meaning and word meaning, and were well below Grade standard. The results suggest that the deaf children found the comprehension of English very difficult. They appeared to master a sizeable printed vocabulary and yet experienced difficulty in understanding connected prose. The inadequate command of English of the majority of deaf people, may be largely responsible for this, and their comprehension of SL may be relatively better.

Conrad (1971b) tested a group of deaf children for comprehension after they had read prose passages either aloud, or silently, and found that vocalising did not affect comprehension for the 'articulators', but that the comprehension of the 'non-articulators' was adversely affected when they were required to read aloud. This situation may be directly analogous to introspective reports that it is harder to remember the information content of a long-distance telephone call during which one has had to strain to hear what was being said against background interference. In the first case of the deaf children reading aloud, the 'non-articulators' were being forced to concentrate hard on the act of vocalisation, and in the case of the long-distance telephone call, the listener is forced to concentrate hard on the act of hearing, in both cases subsequent processing of the input is adversely affected.

## 7.2 Experiment 8: An investigation of the comparative effectiveness of standard English and sign language on comprehension.

A further experiment, similar to the previous one, was carried out to test whether language form might also affect comprehension. Two simple, short stories, equated for difficulty, were translated from SE into SL; both were presented in written form. Manual presentation of SL would have introduced a further variable, besides language form, namely medium of presentation. After reading a story the children answered questions designed to assess their understanding and the amount of information they had retained.

Younger hearing children were also tested to investigate the possibility that the structure of the deaf SL was in fact a simpler form of language using fewer words and less redundancy than SE, and which hearing children can also process and understand as easily as SE. The normally hearing control subjects were aged between 7 and 11 and were matched for reading ability.

## 7.3 Hypotheses:

1. The deaf children should find it easier to understand, and to recall relevant facts and details, when stories are written in SL than when

written in SE, due to their superior ability to process SL.

2. Young hearing children will find a simple story written in SE easier to understand and recall than one written in SL, because of their familiarity with SE and the differences,never previously encountered, between SE and SL.

## 7.4 Method.

7.4.1 Subjects: 34 deaf children from the Upper School aged between 13 and 16 years with reading ages (as measured by Young's Group Reading Test, 1969) ranging from 7.0 to 8.8 years (mean 7.7, median 7.6) and 34 hearing children (including 12 remedial readers aged between 9.1 and 11.3, and 22 first-year juniors aged between 7.0 and 8.1 years), with reading ages (as measured by the Burt (Rearranged) Word Reading Test, Vernon 1967) ranging from 7.1 to 8.8 years (mean 7.8, median 7.8). There were an equal number of boys and girls in both groups.

7.4.2 Materials. Two short stories, A and B, were each written in a SL and SE version. (In the opinion of two experienced teachers of the deaf, both of the SE passages could be read by all the subjects in the deaf group). The four passages were designated $A_S$, $B_S$ and $A_E$ and $B_E$ respectively, and were typed onto white card using double spacing and extra-large size print (.5 cm high). Nine questions were asked about each of the two stories, and these were typed in SE onto two further sheets of card. (See Table 7-a for the four passages and associated questions.) Each card was covered with transparent protective film.

7.4.3 Design and procedure. The children were tested individually. Each child was given a story, either story A or story B, and was asked to read it slowly and carefully and then to answer the questions associated with the story. In the light of the findings of Conrad (1971b), no stipulation regarding whether the story was to be read silently or aloud,

Story $A_E$ (written in standard English)
On a hill near a wood there was a little house where three children lived alone with a big black dog. They loved to play in the wood. One day while they were playing they lost their dog. They looked for him all over the wood until it became too dark to see, so they had to go back home. They all felt very sad and they cried.

Story $A_S$ (written in sign language)
On hill near wood have little house live three children self and big black dog. Children enjoy play in wood. One day before, three children play in wood, dog lost, look for dog in wood, dark, children cannot see, go home. Children all sad, children cry.

Questions:

1. The little house stood on a ________?
2. Who lived in the little house?
3. Was the house near the wood, or far from the wood?
4. Where did the children like to play?
5. Who did they lose in the wood?
6. What colour was the dog?
7. Why did they stop looking for the dog?
8. Was the dog large or small?
9. Why did the children cry and feel sad?

Story $B_E$ (written in standard English)
My friend, Paul, and I have lots of fun together. Last Saturday we decided to go fishing in the lake near my house. We sat and fished for five hours but we did not catch anything, except an old boot. I was very disappointed. When I was running near the edge of the lake, I slipped and fell in with a big splash. I got very wet, so I had to go home and change my clothes.

Story $B_S$ (written in sign language)
My friend, Paul, and I lots fun together. Saturday before, we think go fish in lake near my house. We sit fish, five hours, catch nothing, catch old boot. I lot disappointed. I run near lake, fall in water, big splash. I wet a lot, I go home change clothes.

Questions:

1. What was the name of my friend?
2. What did we do together last Saturday?
3. Where did we go?
4. Where was the lake?
5. How long did we spend fishing?
6. What did we catch?
7. Why was I disappointed?
8. What happened when I was running near the water?
9. Why did I have to go home?

Table 7-a. The four passages and associated questions to test comprehension used in Experiment 8.

was made, and the children pleased themselves. The same procedure was followed for the second story. The design was, however, different for the two experimental groups. The deaf children were divided into two groups - $D_E$ and $D_S$ which were matched carefully for reading ability and memory performance (based on the previous results). Group $D_E$ was presented with stories $A_E$ and $B_E$ (i.e. both stories written in SE) and the other group, $D_S$, with $A_S$ and $B_S$ (both stories written in SL). The order of presentation of the two stories, A and B, was randomised.

The hearing children on the other hand read one story in SE and one in SL, and always began with a story written in English (i.e. $A_E$ followed by $B_S$ or $B_E$ followed by $A_S$). The within-subjects design allowed a direct comparison for each child between their comprehension of a story written in SE (the base-line) and their performance on a similar story written in SL. Thus a meaningful comparison could be made on the effect of SL on comprehension.

It was explained to the hearing children that one of the stories that they were going to read was written in 'deaf language', and that it might seem a little strange, because the words were English words but were put together in an unusual way. They were asked to read it and do their best to answer the questions about the story afterwards.

The informational content of the two forms of each story was identical, irrespective of language form, Each story included both narrative and description, the vocabulary was kept simple and was familiar to all the children.

The nine questions associated with each story tested the understanding and recall of both critical detail (e.g. John went home because he was wet) and incidental detail (e.g. the colour of the dog, i.e. black). All the questions were written in SE, but no child, deaf or hearing, was unable to understand them. In the case of difficulty, additional help was provided, and whenever necessary, a question was translated into SL for any deaf child who was unable to understand. The children had to answer the questions in order since some of the later questions provided clues to the answers of the earlier ones. All the children wrote their answers to the questions, which were marked and scored by the experimenter, according to their understanding and recall of the facts and details, rather than the correctness of their written expression, which, in the case of the deaf children, was frequently bizarre. The answers were marked at the end of each test session, after both stories had been read, while the child was still present to give additional explanation of answers where necessary.

7.4.4 Scoring. For each child, the number and percentage of correct answers out of 9 (the total number of questions associated with each story) was recorded for stories A and B separately.

### 7.5. Results.

Once again, no significant sex differences were found in a preliminary analysis of the data, and boys and girls were therefore combined in all subsequent analyses.

The comprehension scores showed that the two stories were comparable in difficulty. This being the case it was convenient to add the two scores for each deaf child, since both stories were read in one or other language form. In the case of the hearing group, however, each child read one story in SE and the other in SL, the scores for each story, therefore, (i.e. for each language form) were recorded separately.

The deaf children who read both stories in SL answered 259 (85%) of the questions correctly, and 4 of the 17 children in the group answered all 18 questions correctly. Those who read both stories in SE answered 241 (79%) of the questions correctly, but none answered all 18 questions correctly (see Appendix M for raw data). The matched pairs of deaf subjects answered significantly more questions correctly after reading both stories in SL rather than SE ($T = 21.5$, $p, < .01$), confirming the hypothesis that the deaf children would find it easier to understand stories written in SL than SE.

The ordinal dominance (OD) curve in Figure 7-a (Darlington, 1973) shows the cumulative frequency of the comprehension scores of the group of deaf subjects reading SE (Group $D_E$) as a function of the comprehension scores of the group of deaf subjects reading SL (Group $D_S$). The proportion of the area of the square under the OD curve equals the probability (.61) that a randomly chosen member of Group $D_S$ will have a higher comprehension score than a randomly chosen member of Group $D_E$.

The hearing children on the other hand consistently answered more questions correctly when the story was written in SE (287 questions, 94%) than when it was written in SL (235 questions, 77%), as was predicted ($T = 465$, $z = 4.78$, $p < .00003$). Nineteen of the hearing children ($n = 34$) answered all the questions correctly on the SE story, whereas only one of the hearing children correctly answered all the questions on the SL story. Thirty-one of the children had a higher comprehension score for the SE story than for the story written in SL, and the remaining three children scored the same for both the SE and the SL stories.

Figure 7-b shows the interaction between the deaf and hearing subjects' average comprehension scores and language form. The deaf understood and retained more of a story written in SL than one written in SE, as judged by the average number of comprehension questions correctly answered, whilst the hearing group answered considerably more questions correctly after reading a story in SE than in SL. The hearing group performed better, relative to the deaf group, on the SE and poorer on the SL.

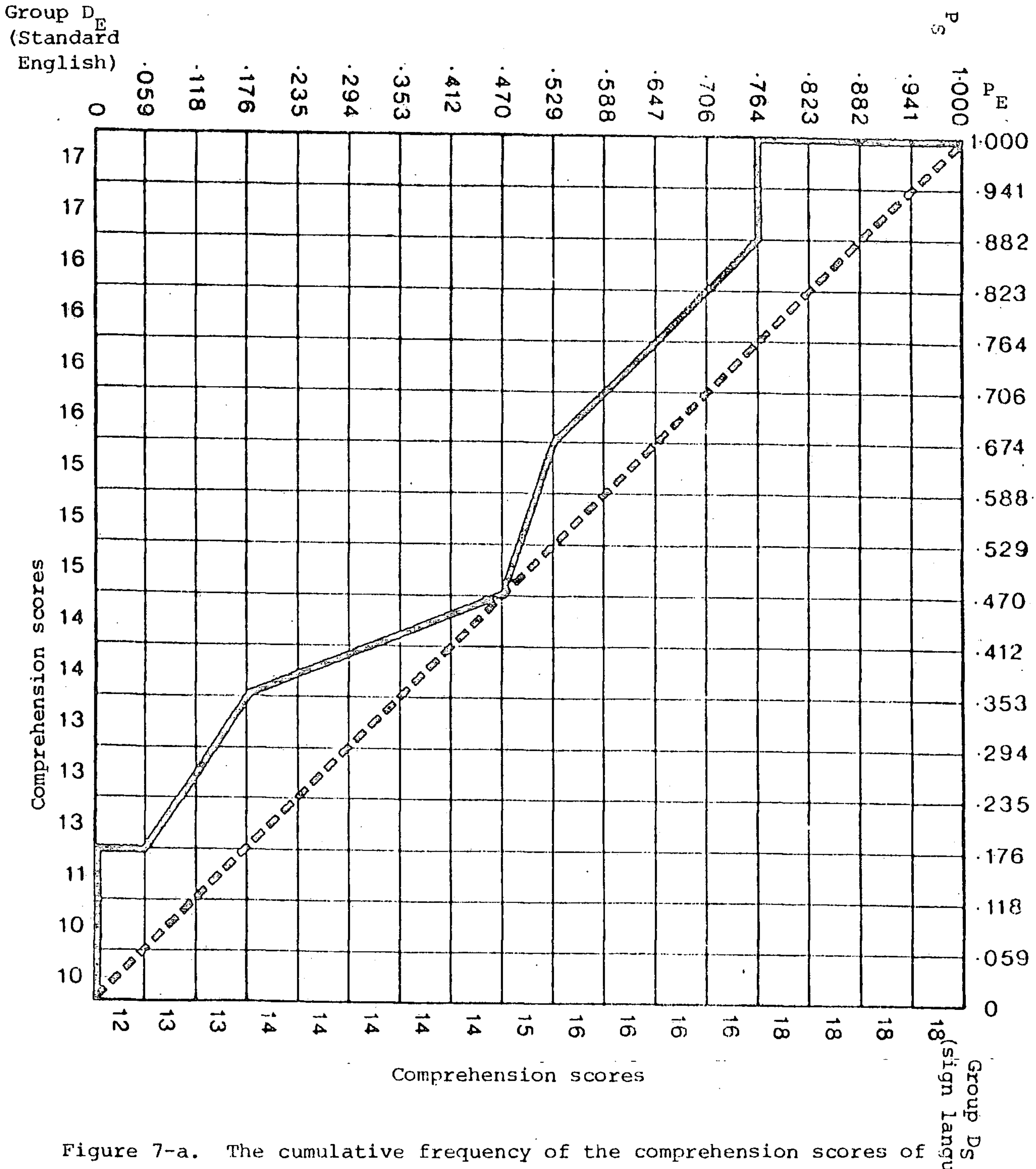


Figure 7-a. The cumulative frequency of the comprehension scores of Group $D_E$ as a function of the comprehension scores of Group $D_S$.

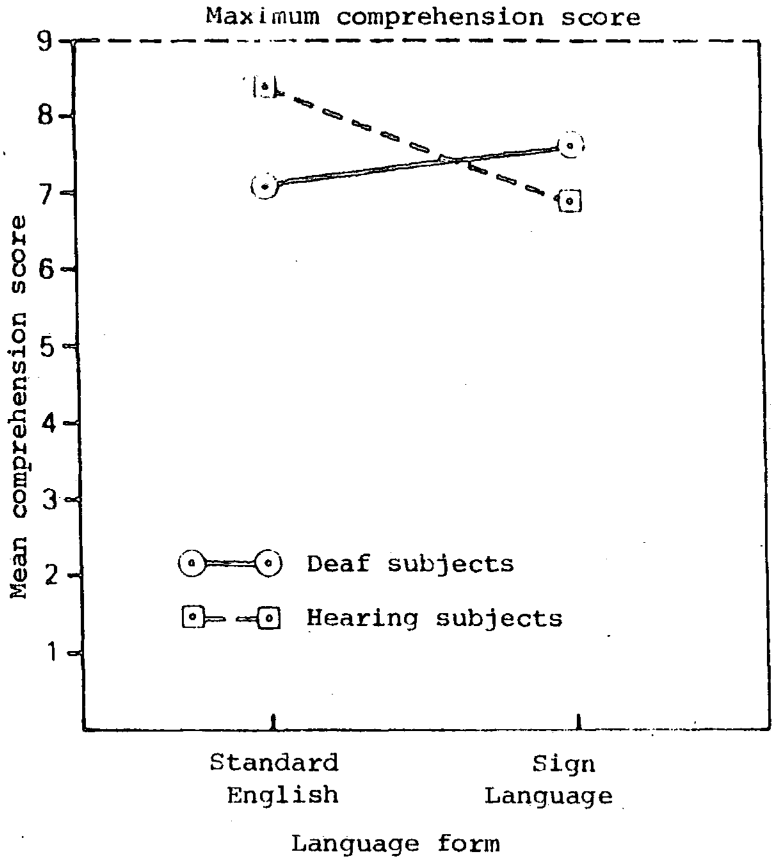


Figure 7-b. Comprehension performance after reading stories written in standard English and sign language as a function of ability to hear.

## 7.6 Discussion.

The results for the matched pairs of deaf children showed that understanding and retention of the factual content of simple stories was affected by language form. Thus the hypothesis that it would be easier to understand stories written in SL, with which the children were familiar (as shown by the results of the previous experiment) was confirmed. The present findings supported those of Odom and Blanton (1970) who found that deaf children could understand prose written according to the syntax of ASL better than SE, the major difference between the two studies being the use of a dialect of British sign language instead of ASL. Both studies suggest that the underlying organisation of knowledge and experience is somewhat different in those deaf individuals who use sign language as their native language.

The hearing controls obviously did not find SL as easy to understand as the deaf children, and were unable to repeat back any of the sentences in the SL story as they had been written. Their comprehension of a story written in SL was however adequate - an average of 77% of the questions testing comprehension of the story were correctly answered by the group as a whole. It appears that much of the meaning could be derived from individual English words and that the differences in language form were not so critical within the context of the simple stories that were used.

In Story B, which described a fishing trip, 7 of the 34 deaf children mistakenly read and understood 'boat' for the word 'boot'. By comparison only 1 of the 34 hearing children made this mistake (and then corrected himself) and this was one of the remedial readers. This kind of visual confusion is frequently observed in classroom work with deaf children. For example,many deaf individuals read the word 'friend' instead of the word 'field' in the following context - 'the girl was walking with her dog in a field'. This was understood to mean that the dog was the girl's friend. Deaf children, therefore, appear to be forced by their loss of auditory linguistic input to represent words visually, which could possibly explain this type of confusion.

The two stories that were used may have been too easy, reflected by the factthat many of the children, both deaf and hearing, answered all, or nearly all, of the comprehension questions correctly. The SE stories were in fact deliberately matched to the range of reading abilities of the experimental subjects, this being the case the potential facilitatory effect of SL on comprehension was minimised by ceiling effects.

The experiment should, therefore, be replicated exactly using passages that the children would find more demanding, involving for example, the type of language necessary to teach a geography or a history lesson. It would also be interesting to replicate the study using considerably younger deaf children from the Middle School, whose reading ages were in the same range as those of the older deaf children who were tested. Such a group of younger deaf subjects would not be difficult to find due to the plateau of reading ability at a fairly young age (discussed in Section 2.1.3), and certainly whilst still in the Middle School. Younger deaf children were not chosen initially, since it was felt to be desirable that the same age group should be used as were tested in Experiment 7, and most of the same experimental subjects were used so that memory and reading ability could be matched from the findings of the previous experiment. Obviously these two studies, Experiments 7 and 8, were very closely associated.

The written form of SL may be useful in an experimental study of the effect of language form but is of limited use when it comes to applying the findings in the classroom. No teacher is going to deliberately write prose according to the structure of SL. Of greater interest than the effect of structure studied here, would be the effect of modality. It is likely that signed prose would further facilitate subsequent comprehension of the material. A replication of this experiment comparing the comprehension of stories presented in manual SL and written English would be of greater applied value to the teacher of the deaf, who is primarily concerned with the practical question of how he or she might best communicate with a class of deaf children, and how best to convey information. The present study does however provide some evidence that modality, i.e. manual presentation is not the only advantage of SL. The structure of SL, even when presented in the unnatural written form, facilitated the subsequent recognition, recall and comprehension of simple language in this particular sample of deaf children.

### 7.7 Summary.

The comprehension of two short, simple stories written in SE and SL was compared for two groups of children, one hearing and one deaf. As was predicted, the deaf children understood stories written in SL significantly better, as judged by the number of questions correctly answered, than the stories written in SE. The hearing children, however, consistently answered more questions correctly after reading a story in SE than a story written in SL.

Whilst the controversy over the use of oral and/or manual methods of communication in the education of the deaf continues (see Section 1.4) with loyal and staunch supporters on either side, teachers of the deaf are using a variety of methods. This range of different methods is perhaps best reflected in the contents of a recent publication entitled

'Methods of communication currently used in the education of deaf children' (published by the R.N.I.D., 1976). Included in the list are speech and lip-reading, cued speech, the written word, sign languages and fingerspelling (either the British two-handed or the American one-handed systems).

Observation, both inside and outside of the classroom, suggested that certain combinations of these methods might be more profitably employed to communicate information in the classroom, than others. The present study was primarily concerned with the use of fingerspelling in the classroom.

## 7.8 The use of fingerspelling by deaf individuals.

Several people have included fingerspelling in their experimental studies of the effectiveness of different communication methods. Johnson (1948) reported that fingerspelling resulted in the best level of comprehension of language and concluded that it should be used as the classroom method of communication. Gates (1971) compared the retention of information presented via reading, lip-reading, manual communication and various combinations of these methods. He found that groups who had either only read the material, or who had read it in combination with other methods, were superior to those who were presented with the spoken mode, signed mode, or a combination of these two without the benefit of reading. Delayed recall after one week also produced similar findings. Gates concluded that his results highlight the effectiveness of print as a mode of communication with deaf children. It appears, however,that not all the students who were tested were fluent in manual communication - hardly, therefore, a fair evaluation of the different methods. In the following experiment, a follow-up of these two earlier studies, interest was centred on the optimal use of fingerspelling and the written word.

In the Russian literature (e.g. Morkovin, 1960) the use of fingerspelling as a highly successful aid to the development of receptive and oral expressive language by young deaf children has been emphasised. They have claimed to have succeeded in providing their deaf children with vocabularies of several thousand words by the age of 6, starting around the age of 2, and that the use of fingerspelling has also fostered the development of speech and speech-reading. In the Lewis Report (1968) 'The education of deaf children: the possible place of fingerspelling and signing', the successful use of fingerspelling by the Russians was again remarked upon:

> It appeared to us, from what we were shown, that the Russians are more successful than we are in the development of language, vocabulary and speech in deaf children once they enter the educational system, This seemed to us to be a strong point in favour of their method (use of fingerspelling from the very start as an instrument for the development of language, communication and speech). (p.45)

One reason for the apparent greater success of Russian education of the deaf might be the phonetic nature of the Russian language, where spelling is closely related to oral language; fingerspelling, therefore, would be of more use to the Russian deaf child, than to the deaf child learning English. If fingerspelling were to be of corresponding benefit to the spoken language of deaf children learning English, it would need to be based on a phonetic system in which each speech sound of English was unambiguously represented on the fingers (as it is in Cued Speech), rather than a system based on the 26 letters of the alphabet.

Fingerspelling is not the product of a natural language process, but it is a visually coded form of verbal language, and as such is regarded as offering deaf people a concrete, easily perceived means of communicating. The rapid sequence of finger movements presents a transitory trace of the written word. The transience of the rapid successive presentation of each word spelled is particularly striking; the "reading" of fingerspelling must involve S.T.M. operations; it is necessary to remember the symbols that have gone before, whilst reading those that are actually being formed - it is a more fleeting pattern than that of the written word. Is the fingerspelled word perceived as a whole as Gestalt psychologists might suggest? Tervoort (1961) draws our attention to the difference between letter by letter spelling which proceeds more slowly and the practised performance when words are presented as a unit and no longer as a sequence of letters. Moores (1970b) suggested that the three distinct letters in a word such as 'cat' are normally perceived as a whole, just as a hearing person does not hear the three distinct phonemes c-a-t, but an integrated sound. Zakia and Haber (1971) suggested that experienced fingerspellers attend more to the total pattern of hand configuration and not to individual letters, but found that this was not the case for nonsense words, when individual letters carried more significance and were attended to. New words, such as the French words presented in the following experiment, are likely to be processed as a sequence of individual letters.

The purpose of this exploratory study was to compare the ability of a group of deaf children, who were accustomed to using fingerspelling to process fingerspelled and written words. Effective communication between teacher and child is an essential requisite for educational attainment of deaf students. We are concerned, therefore, with the optimal use of fingerspelling as a tool for information transmission - as an instructional rather than a conversational communication method.

7.8.1 Active learning. A pragmatic approach and behaviouristic psychology emphasise that learning takes place through activity, and that thorough assimilation of information is best achieved by the active use of material. Fingerspelling can, and perhaps should, be actively employed in learning situations in the classroom. When presented with a new word the deaf should be encouraged to actively fingerspell it rather than passively receive the fingerspelled or written presentation of it given by the teacher. This may sound obvious, and too much like commonsense, particularly to those fimiliar with the work of great educationalists, such as Dewey, yet it is surprising how rarely this technique is actually put into practice in the classrooms of deaf schools.

In a paper entitled 'My Pedagogic Creed', Dewey (1897) wrote, under the sub-heading 'The nature of method': "I believe that the active side precedes the passive in the development of the child nature ... that consciousness is essentially motor or impulsive; that conscious states tend to project themselves in action." He then went on to say that the "Neglect of this principle is the cause of a large part of the waste of time and strength in school work. The child is thrown into a passive, receptive or absorbing attitude " (p.54). Similarly, Isaacs (1965) wrote:"It is the children's activity that is the key to their full development" and "Our part as teachers is to call out the children's activity" (pp. 151-2). Again the emphasis is on a practical, active , participatory approach.

Furth (1970) in a book written especially for teachers on the possible practical application of Piaget's theories suggested that education should focus on "activity which by itself implies involvement" (p.124). Just as Piaget talks about the development of knowledge on a <u>practical</u> plane during the earliest 'sensori-motor' stage of intellectual development, the acquisition of new spelling patterns on an <u>active</u> plane by deaf children actively using fingerspelling, is being suggested and investigated in the present study. This idea is in direct contrast to the passive roles of deaf children in the classroom that has been commented on in the French magazine 'Communiquer' (1973) "Nous pensons que l'éducation que reçoivent la plupart des sourds les amène a avoir un role passif" (p.49).

7.8.2 The possible role of kinaesthetic feedback. Chance observations in the classroom provided both direct and indirect evidence of the reliance of certain deaf children on kinaesthetic feedback as a basis of their knowledge and cognitive functioning. Children writing difficult words on the blackboard or in their exercise books, were seen to refer regularly to their hands, to fingerspelling, as they proceeded to spell the words - a kinaesthetic basis to spelling patterns and the retention of words perhaps? The use of fingerspelling by some children for cognitive processing, was also observed in most of the experiments previously carried out in this research study, and in the absence of explicit instructions to use it.

7.8.3 The spelling of deaf children. Woodford (1973) undertook a survey of the use of fingerspelling in schools for the deaf throughout the country. She found that one of the main reasons behind the use of fingerspelling in the classroom that she encountered was "to encourage a memory for the spelling of single words" (p.191). Fingerspelling may be a particularly useful aid to the learning and retention of spelling, particularly if new words are presented slowly. It is, therefore, important that the optimal use of fingerspelling in the classroom is studied systematically, rather than used intuitively by a few teachers of the deaf.

It has been argued that since the deaf are forced by their auditory handicap to be generally more dependent on visual input, that their ability to spell might be better than that of the average hearing child. This suggestion has been studied by several people. In an early study, Gates and Chase (1926) reported that deaf children aged 10 and older spelled better than hearing children matched for reading ability and I.Q.

Templin (1948) replicated the above findings and reported that this included the spelling of relatively difficult English words. More recently, Hoemann, Andrews, Florian, Hoemann and Jensema (1976) have again replicated earlier findings that deaf adolescents spell as well as, or better than, hearing norms, and extended their investigation to include younger deaf children who were only 6 years old. There was, however, no evidence from the results of Experiments 7 and 8, and from everyday observation, that the ability to spell of this particular group of deaf children was any better than that of any group of hearing children of similar age and ability. Such a comparison was not however, central to the rationale of the present experiment and was not, therefore, undertaken.

## 7.9 Experiment 9: An investigation of the optimal use of fingerspelling in the learning and retention of new spelling patterns.

A major concern in the classroom is how best to teach new vocabulary, particularly the spelling of new words, in a manner that is unambiguous, to a group of deaf children. The written word on the blackboard, or on flashcards, is probably the most obvious method, and the most widely employed in the classroom, particularly, by new teachers, who are not sufficiently competent in the use of fingerspelling. Alternatively, the teacher may fingerspell the word which is 'read' by the children - passive reception of fingerspelling. But perhaps the amount of information retained might be increased by active use of fingerspelling by the children themselves, or by combining the written word with active fingerspelling. These then were the four methods of presentation that were selected for investigation. When fingerspelling, no speech or lip movements were used, so that reception of the words through lip-reading and/or sound was not possible. This treatment was not, therefore, intended to represent the Rochester method, but to test the reception of fingerspelling alone.

French words were used because of their intrinsic novelty and interest value to the deaf children, thereby avoiding the problem of familiarity that could arise using English words, and the lack of motivation associated with the use of nonsense syllables. The latter would most probably have rapidly elicited the sign for 'rubbish', and permanent withdrawal of cooperation!

## 7.10 Hypotheses:

1. The deaf children will find it easier to recall the spelling of new words when they actively fingerspell the words themselves, rather than passively view the fingerspelled words on the hands of another person.
2. Presentation of the written word will provide a complete visual pattern of the entire word which should complement the transient nature of fingerspelling.
3. The longer words (sequences of letters) will be more difficult to remember than the shorter words, irrespective of method of presentation.

## 7.11 Method.

7.11.1 Subjects: 52 deaf children (24 girls and 28 boys aged between 13.5 and 16.7) were randomly selected from all classes, representing, therefore, all ages and abilities of the Upper School. All were competent in their use of fingerspelling, but differed in the intelligibility of their speech. All were prelingually deaf - average hearing losses ranged from 65 - 110 dB in the better ear, and more than three quarters of the sample were profoundly deaf (hearing loss $\geqslant$90 dB).

7.11.2 Materials: 32 flash cards (9 cm x 4 cm) were prepared with a single French word written centrally on each card using black Letraset (Futura Medium 48 pt, Sheet 116). Each card was covered with transparent protective film.

7.11.3 Design and procedure. 32 French words were chosen, avoiding as far as possible too many sequences of letters similar to those found in English spelling. No attention was paid to the pronunciation of the words. The eight 3-, 4-, 5-, and 6-letter words were:

(i) cou, qui, duc, rue, bol, sac, pas, ans.

(ii) jupe, fils, lait, donc, gant, neuf, bien, vert.

(iii) quand, hibou, terre, alors, chien, porte, lapin, fille.

(iv) garcon, enfant, foudre, soleil, miette, cochon, demain, triste.

The children within each class were randomly allocated to one of the four experimental conditions, thereby approximately matching each of the four groups for age, sex and learning ability. Subjects were tested individually, and were told that they were going to be taught some easy French words. They were told which method they were to use, and that they had to try and remember the new words and write them down after each new word had been presented. The testing room was well illuminated. When fingerspelling the hands were slowly dropped after each word and then brought back up to position before the beginning of the next word when the subject was ready to proceed. Each child had a short practice session lasting five minutes before the actual test session was begun. Exposure time of the printed word was similar to that required to fingerspell the word. The four groups were as follows:

Group F$\bar{F}$ - received fingerspelling - the experimenter fingerspelled the word using either one-or two-handed fingerspelling, according to any preference expressed by individual children. The children were requested not to attempt to fingerspell the new word to themselves (i.e. the passive reception of fingerspelled words).

Group FF - fingerspelling received and produced by the child - the experimenter fingerspelled each word as for group F$\bar{F}$, and then the child also fingerspelled the word before responding, thereby establishing a more active fingerspelling pattern.

Group W$\bar{F}$ - visual presentation of the written word - flash-cards were presented for between 5 and 10 seconds each, according to the length of word.

Group WF - visual presentation of the written word and fingerspelling produced by the child - the written form of each word was presented visually using the flash-cards as for group W$\bar{F}$ with simultaneous fingerspelling of the words by the child.

The children immediately wrote down the spelling of the French word as they remembered it. The words were presented in an order of increasing difficulty (assuming that shorter words, hence shorter sequences of letters, are easier to learn to spell than longer ones), beginning always with the 3-letter words and finishing the test session with the 6-letter words. The order of presentation of the 8 words of the same length was randomised. Each child was told immediately whether or not their written response was correctly spelled. If the word was incorrectly spelled on the first attempt, a second presentation, the same as the first, was allowed before proceeding with another word. If a child was experiencing obvious difficulties, and was showing signs of becoming very distressed at continued failure, the test was concluded at that point. The test session lasted between 20 and 25 minutes.

7.11.4 Scoring. Two scores were recorded for each of the four groups:

1) The total number of words, at each of the 4 different word lengths, spelled correctly on the first attempt.

2) The total number of words spelled correctly on the first and second attempts together.

The scoring was carried out by the experimenter.

### 7.12 Results.

All the children chose to use two-handed fingerspelling. This fact was not very surprising, despite the research project in the school, since most of them had been using two-handed fingerspelling for over ten years, and one-handed fingerspelling for less than one year. The majority of the children did at least attempt to spell all the French words presented to them. Errors of omission (writing nothing) were more frequent for the longer words, but did not occur often, and when they did, it was most often in group FF̄. The number of errors was expected to increase with word length, and this was found to be the case. A 3-letter word was so seldom wrongly spelled that the four different methods only produced a small effect. A 6-letter word was more difficult whatever the method, and so the effect of the various methods was more pronounced (see Appendix N for the raw data).

| | Length of French word (in letters): | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 3 | | 4 | | 5 | | 6 | |
| Attempt: | 1st | 1st&2nd | 1st | 1st&2nd | 1st | 1st&2nd | 1st | 1st&2nd |
| Group: | | | | | | | | |
| Fingerspelling received (FF̄) | 88 | 96 | 57 | 81 | 42 | 62 | 15 | 41 |
| Fingerspelling received and produced (FF) | 98 | 99 | 82 | 89 | 64 | 84 | 38 | 62 |
| Written word only (WF̄) | 94 | 99 | 81 | 93 | 67 | 81 | 45 | 63 |
| Written word and finger-spelling produced (WF) | 99 | 100 | 94 | 98 | 84 | 93 | 74 | 87 |

Table 7-b. Percentage of French words spelled correctly on the first and second attempts as a function of presentation method, production mode and word length.

Figure 7-c shows the percentage of words correctly spelled on the first attempt, by each of the four groups as a function of word length. It can be seen from Table 7-b and Figure 7-c that all the groups were 88% or more accurate when learning and reproducing the 3-letter words on the first attempt. On the 6-letter words however, accuracy ranged from 74% for Group WF to 15% for Group F$\bar{F}$ (on the first attempt only).

No differential effect of the four experimental conditions was observed between the first and second attempts. The main effects of the different treatments were still present after the second attempts had been included in the data and the relative levels of performance of the four groups were only slightly affected (see Figure 7-d). Since this study is concerned with the use of fingerspelling as an aid to learning spelling patterns, the results after the second attempt were analysed in greater depth.

The number of words correctly spelled decreased with increasing word length, for all four experimental groups. Since these groups had been matched for age, sex and learning ability, it was assumed that performance differences could be accounted for by the treatment differences.

| Source of variance: | SS | df | MS | F | p |
|---|---|---|---|---|---|
| Between Ss: | 315.58 | 51 | | | |
| Treatments: | 101.27 | 3 | 33.76 | 7.57 | <.001 |
| Presentation method | 50.04 | 1 | 50.04 | 11.22 | <.01 |
| Production mode | 50.04 | 1 | 50.04 | 11.22 | <.01 |
| Presentation x production | 1.19 | 1 | 1.19 | 0.27 | ns |
| Error (a) | 214.31 | 48 | 4.46 | | |
| Within Ss: | 415.5 | 156 | | | |
| Word length | 235.96 | 3 | 78.65 | 82.79 | <.001 |
| Treatments x word length: | 42.33 | 9 | 4.70 | 4.95 | <.001 |
| Presentation mode x word length | 20.7 | 3 | 6.9 | 7.26 | <.001 |
| Production mode x word length | 19.69 | 3 | 6.56 | 6.91 | <.001 |
| Presentation x production x word length | 1.91 | 3 | 0.65 | 0.68 | ns |
| Error (b) | 137.21 | 144 | 0.95 | | |
| Total: | 731.08 | 207 | | | |

Table 7-c. Summary table of the split-plot 2 (Presentation method) x 2 (Production mode) x 4 (Word-length) factorial analysis of variance.

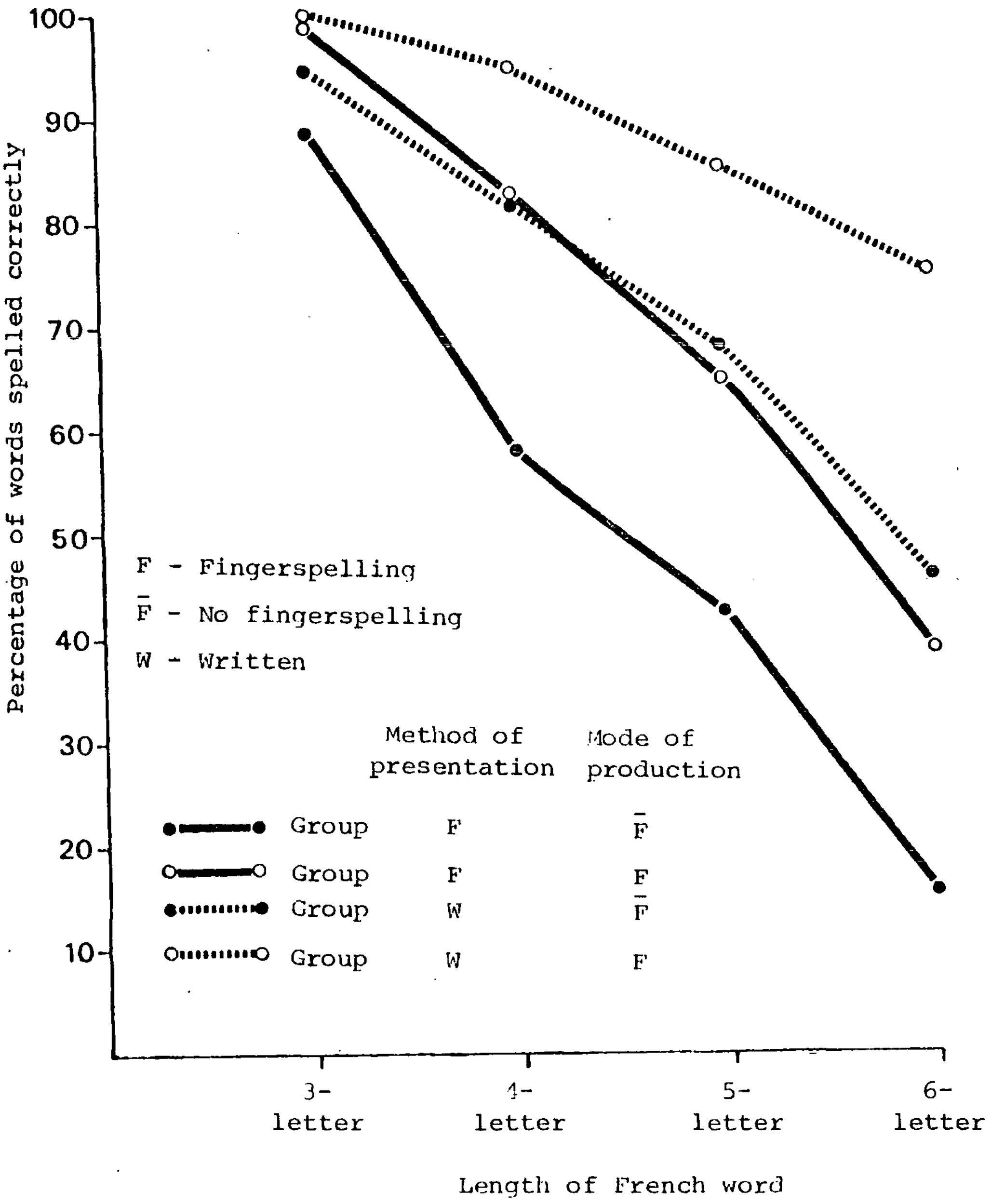


Figure 7-c. Percentage of French words correctly spelled on the first attempt as a function of word-length, presentation method and production mode.

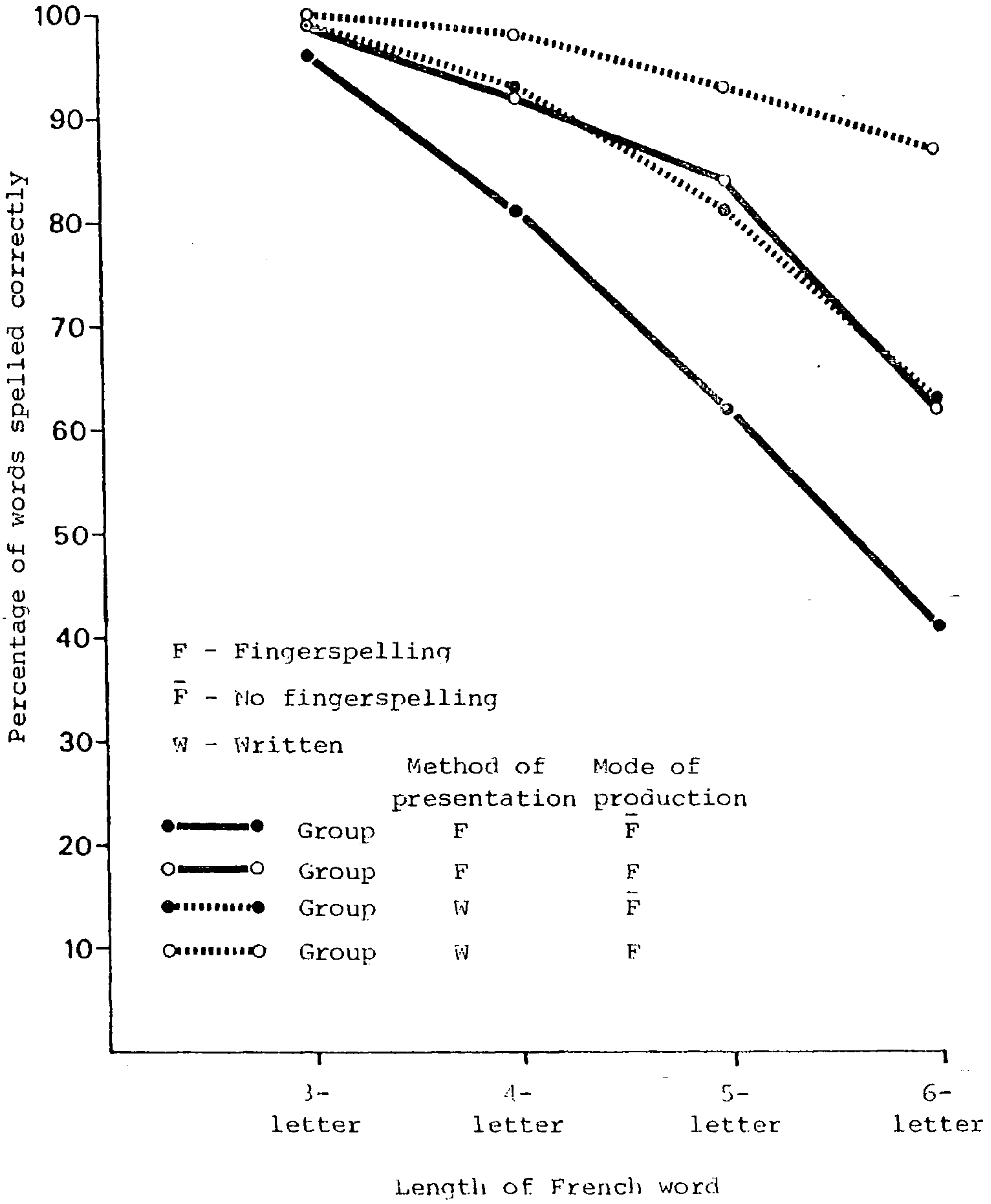


Figure 7-d. Percentage of French words correctly spelled after the first and second attempts as a function of word-length, presentation method and production mode.

A split-plot 2 x 2 x 4 factorial analysis of variance was carried out on the data for the first and second attempts together (see Table 7-c). The three main effects:presentation method, mode of production, and word length were all highly significant. Spelling was more accurately reproduced after written, rather than fingerspelled, presentation (F(1,48) = 11.22, $p < .01$). As was predicted active production of fingerspelling by the subjects significantly improved the accuracy of subsequent spelling of the words (F(1,48) = 11.22, $p < .01$). They also found it easier to retain the spelling of the shorter words than the longer ones (F(3,144) = 82.79, $p < .001$). The interaction between presentation mode and production mode was not significant. The treatments interacted significantly with word length (F(9,144) = 4.95, $p < .001$), and the effects of both written presentation (F(3,144) = 7.26, $p < .001$) and active production of fingerspelling (F(3,144) = 6.91, $p < .001$) became significantly more pronounced with increasing difficulty (i.e. for the longer word lengths). There was no significant interaction between the three main effects.

Spelling mistakes in which one letter was incorrect were analysed in more detail. There were 145 such errors (12 for 3-letter words, 41 for 4-letter words, 45 for 5-letter words, and 47 for 6-letter words), which were divided into 2 types:vowel substitutions and consonant substitutions.

Vowel substitutions - where a vowel was substituted for another vowel, for example 'enfint' (enfant) and 'virt' (vert). The 44 recorded errors of this type were unequally distributed over the four groups. A greater number of vowels were substituted after fingerspelled presentation of the French words (34) than after written presentation (10), whilst production mode did not affect the number of vowel substitutions.

Consonant substitutions - where a consonant was substituted for another letter of the alphabet, not necessarily a consonant, for example 'nert' (vert) and 'nenf' (neuf). 101 errors of this type were recorded and were, again,unequally distributed over the four groups. Unlike the vowel substitutions, method of presentation did not affect the number of consonant substitutions that occurred,whereas production mode did. Fewer consonants were substituted by those individuals who were required to actively employ fingerspelling (35) than by those who were not permitted to fingerspell (66).

The consonant substitutions were further analysed and categorised according to similarity. Some were visually similar (e.g. 'g' was substituted for 'q' in 'gui' (qui), and 'n' substituted for 'u' in 'nenf (neuf)). Others were kinaesthetically similar (e.g. 'solein' (soleil) and 'nert' (vert)). Those errors that were both visually and kinaesthetically similar were not included (e.g. b and p, m and n etc.). As might be expected more visual confusions were made with the written presentation (33) than fingerspelled presentation (17), and most of those of the former group were made by the group who were presented with the written word only (Group WF̄), i.e. 27 of the 33 recorded visual confusions. More kinaesthetically similar substitutions were made with fingerspelled presentation (15) than with written presentation (3).

The number of letter transpositions within words was also recorded, i.e. words in which the correct letters were included in the spelling of the word, but in the wrong order (e.g. 'groacn' (garcon) and alosr (alors)). The 62 errors of this type were randomly distributed throughout the written responses of all the four groups. Neither presentation method nor production mode affected the number of transposition errors.

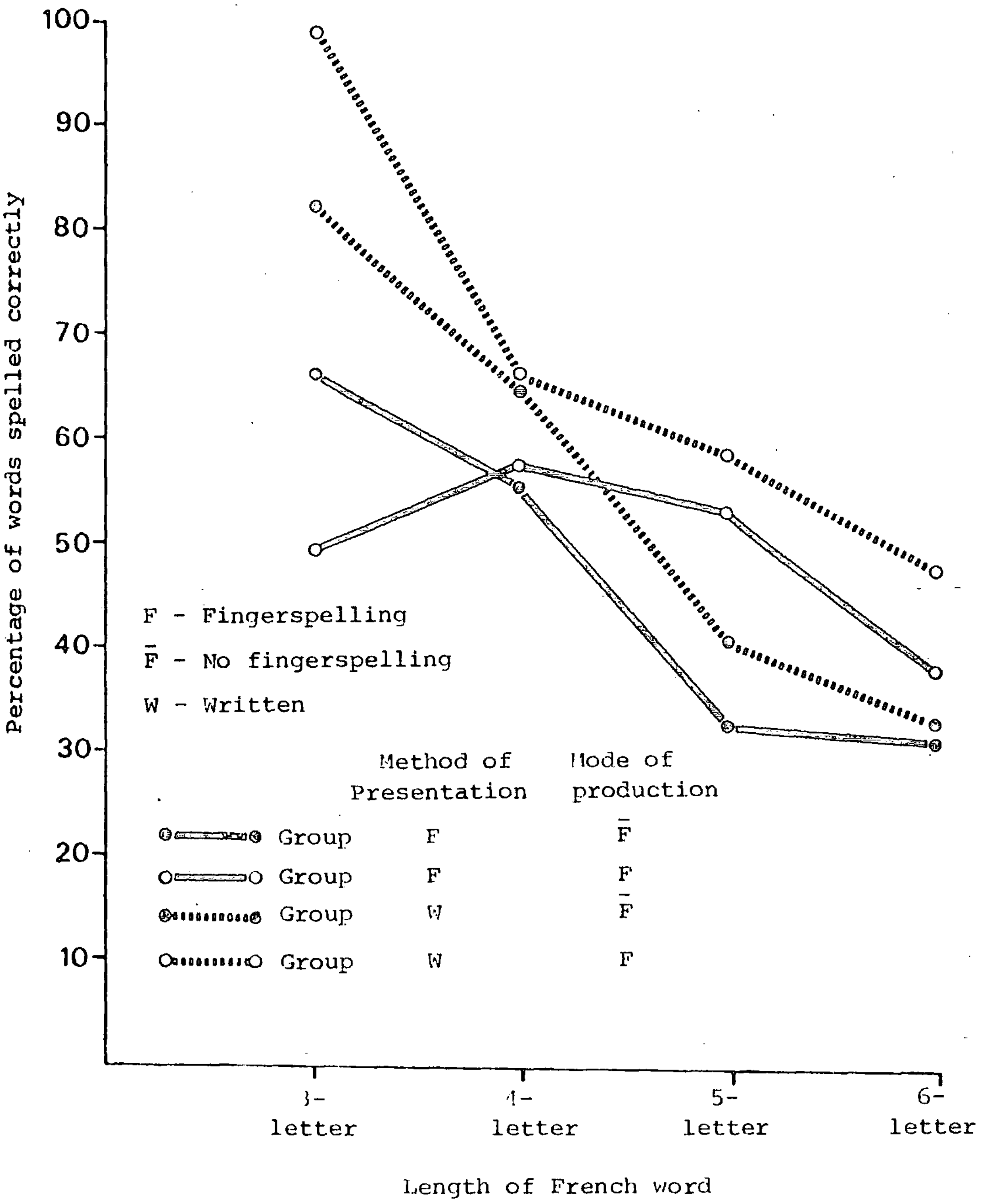


Figure 7-e. Number of words incorrectly spelled on the first attempt and corrected on the second attempt as a percentage of the total number of words presented twice.

Figure 7-e shows the likelihood of a spelling mistake on the first attempt being corrected on the second attempt. Once again, the data for the 3-letter words were not very informative, since few errors were made on the first attempt leaving, therefore, little room for improvement. For the longest words, written presentation accompanied by active fingerspelling most effectively increased the likelihood of spelling the word correctly on the second attempt, whilst fingerspelling presented alone was least effective. These results merely reflect the initial findings (looking at the first attempts only) concerning the relative effects of presentation method and production mode in a retention task.

## 7.13 Discussion.

Throughout this section it is necessary to bear in mind the use of fingerspelling at two different levels of linguistic function. Firstly as an aid to the acquisition and development of verbal language in young deaf children (e.g. Morkovin, 1960). And secondly, fingerspelling used as a secondary skill by older deaf children, as a rapid and accurate means of communicating information for the purposes of instruction and as a memory aid. It is this latter use that concerns us here.

Obviously, fingerspelling is not suitable, or even necessary, for the so-called 'oral successes' who are able to communicate orally, but could perhaps benefit deaf children such as those in the Upper School, who,after 8 to 10 years of special education, are still unable to speak intelligibly, and who, more important still, are severely limited by their lipreading skills and, therefore, receive a greatly reduced input of information. Consequently, they prefer to communicate manually. Surely by this stage, the age of 13 onwards, teachers should concentrate on the input of information (for deaf children learn few facts incidentally), rather than continue to labour the teaching of oral English, and thereby also reduce the amount of knowledge learned. As Furth (1966a, p.226) wrote:

"They do not know facts; they lack information". For only too often the deaf child leaves school at the age of 16 or 17,handicapped not only by his inadequate linguistic competence but also by a lack of, and deficiency in, general knowledge. The latter, which may occur as a result of concentration on the former problem, is an additional handicap and one which could possibly be alleviated. By comparison, hearing children of school-leaving age are usually applying their well-established linguistic skills and learning new knowledge. It would, therefore, be very useful to discover a method that would maximise the assimilation of information during learning for all manually communicating deaf children who are taught in groups.

There was no evidence here, as in Experiments 7 and 8 also, to support the notion that deaf children are more accurate at spelling than hearing children as was suggested and reported by Gates and Chase (1926), Templin (1948) and Hoemann et al. (1976). In my experience, the spelling of the deaf children was no better than the average hearing child and more in line with the "weakness in spelling" reported by Fusfeld (1955, p.67). But we are not however primarily concerned here with a comparison of the spelling abilities of deaf and hearing children.

From the results it is clear that the four experimental conditions did influence the retention of spelling patterns. Overall, written presentation produced better retention than fingerspelled presentation. These findings have subsequently been replicated by Stuckless and Pollard (1977) who compared the ability of 19 deaf children to process fingerspelled words in the context of sentences, and words presented in print in the context of written sentences. They found that printed words were more readily processed than the fingerspelled words by 18 of the 19 subjects, regardless of age and differences in English competence. Although the printed words were processed more satisfactorily than the fingerspelled words -

50% as compared to 64% for print, the latter does not assume a high level of processing and,as predicted, it was found in the present study that the production of fingerspelling by the deaf children themselves,i.e. active practice, can further improve levels of retention. If actively used, it appears that fingerspelling and the kinaesthetic feedback produced by the fingerspelling, are vital aids to learning and retention.

The finding that there were more vowel substitutions when the words were presented using fingerspelling compared to written presentation is not very surprising when one realises that hand configurations for the 5 vowels using the two-handed manual alphabet are very similar:one points with the index finger of the right hand to one of the five finger pads of the left hand - to the thumb pad for 'a' round to the little finger for 'u'. The study of letter confusions generally is a useful and informative means of discovering possible coding systems during cognition- an indirect method of discovering underlying processes. Logically, therefore, one would expect more 'adjacent' than 'non-adjacent' vowel substitutions to occur (e.g. when the vowel 'i' is forgotten,one would expect the adjacent vowels 'e' and 'o' to be substituted more frequently than 'a' and 'u'). A detailed examination of the pattern of vowel substitutions in terms of vowel position supported this prediction - over 70% of all vowel substitutions of both Groups FF and $\overline{FF}$ involved adjacent vowels. Whilst such an approach can provide valuable information, there are problems. One such problem encountered in undertaking a classification of letter confusion similarities, is the separation of visual and kinaesthetic components of a single letter. By kinaesthetic is meant the 'feel' or positioning of the hands, but there is also a visual component to hand configuration - these may look similar as well as feel similar. It is, therefore, impossible to categorise absolutely in this manner. To simplify matters, but bearing in mind the above limitations caused by the fact that fingerspelling was both visually received only, and also actively produced in this experiment (one of the critical independent variables), visual similarity refers to entire written similarity and/or similarity of hand configuration on the hands of another. Kinaesthetic similarity refers to felt similarities in hand positioning. Letters that were both visually and kinaesthetically similar, e.g. 'p' and 'd' could not, therefore, be easily categorised under the present system, and had to be excluded.

It is not sufficient to assume that all deaf children can assimilate new information easily when presented using fingerspelling. For fingerspelling may be a visual method of communication, and, therefore, suited to the needs of deaf children, but it is also transitory, the trace cannot be very permanent in such a temporal - sequential processing task. Fingerspelling is relatively difficult to read, and letter transpositions occurred frequently in the written responses of the children during the experiment. This applied to deaf children who had been using fingerspelling as a method of communication since the age of 7, which, for some of the children who were tested, meant 9 years of practice.

The spelling of the 5- and 6- letter words was clearly more difficult than the shorter words, and it was the performance of the four groups on these longer words that discriminated between the different methods of production and presentation. Group WF scored the highest level of recall - an average for the group of 74% accuracy on the first attempt for the longest words. This was the only experimental group that was able to process the spelling of long words satisfactorily. These children obviously benefitted from the kinaesthetic feedback from their own production of fingerspelling, and from the presentation of the complete visual written pattern of each word as a whole, that could be scanned as a spatial pattern, a Gestalt, which possibly complemented the transient nature of fingerspelling.

When fingerspelling was presented alone, Group $F\bar{F}$, the rapid, successive presentation of the letters and the transience of the trace made the subsequent retention of the spelling of the longest words very difficult, which was reflected in the very low average recall score for the group of only 15% on the first attempt. However, mean performance improved to 38%, with the addition of active fingerspelling production (and kinaesthetic feedback) to fingerspelled presentation, in Group FF. The relative 'advantages' of the Gestalt, or whole visual pattern of the written word only, and the kinaesthetic feedback from production after the transient presentation of fingerspelled words, appear to be similar. This was reflected by the very similar average performance of Groups $W\bar{F}$ and FF over all four word lengths after both the first, and the first and second attempts together (see Figures 7-c and 7-d).

The possibility of the perception of fingerspelled words as a Gestalt does not arise in this study which is concerned specifically with a learning task - the spelling of new words which were presented relatively slowly. However, as Tervoort (1961), Moores (1970b) and Zakia and Haber (1971) have suggested, with practice, a fingerspelled word may also be perceived as a single unit, rather than as a sequence of individual letters. It would be interesting, therefore, to repeat this study over a more extended period of time, in an attempt to discover how this might possibly influence the performance of the four experimental groups. The present, apparent 'advantage' of the whole pattern of the written word on retention, might be effectively counterbalanced by the fingerspelled Gestalt. Such an investigation would need to be carried out if one was interested in the optimal use of fingerspelling in normal, rapid communication in the classroom or in everyday situations, and the effect on subsequent information retention.

There were obviously individual differences in ability to understand language and significant overlaps in individuals' performance - some children are better at learning and retaining new information and would, therefore,be good using all the four methods discussed here. No search should be made for the 'best' method for teaching all deaf children, this is just not a realistic concept, and as Conrad (1970) and Furth (1966a) remind us - the deaf are not a homogeneous group. Should we not search, therefore, for the most appropriate method for a particular individual at a particular stage of development? This, the ideal, is unfortunately not functionally workable for the teacher in the classroom faced with a group of deaf children. We need therefore, to seek methods that maximise the amount of learning possible for the entire group as a whole. This study established to the experimenter's satisfaction that, at least for this sample of deaf children, they assimilated not only more, but also a satisfactory amount of information when presented with the written word and required to actively use fingerspelling.

The present findings support in part those of Johnson (1948) who concluded that fingerspelling resulted in the highest level of language comprehension, and Gates (1971) who suggested that print was the most effective means of communicating with deaf children. The results do, however, extend beyond these earlier studies, since the interaction between presentation method (written/fingerspelled) and mode of production (fingerspelling/no fingerspelling) was studied.

One of the advantages of fingerspelling is that in the experienced user it can be synchronised with speech. Normally, a person who fails to speak whilst communicating manually, deprives the children of additional cues; a teacher, therefore, would normally use speech and fingerspelling simultaneously in the classroom. The results reported here cannot be generalised to the Rochester method, and this would require further investigation. There is, however, no reason to believe that the present results should not be extended to one-handed fingerspelling. The letter confusions would obviously be different for the two systems, but the supplementary benefit provided by the written form of the word and kinaesthetic feedback, should be the same.

If some of the deaf children were processing the fingerspelling directly, and this is a real possibility, these individuals may have been penalised by the response task which was always written. The preceding experiment ought therefore, to be replicated using fingerspelled responses rather than written ones. It would also be of interest to study further the possible coding systems employed by the deaf children reading printed words and using fingerspelling. The experiment could be repeated with recall after a 30-second interval rather than immediate recall as was used here. The interval could be: (i) left unfilled; (ii) filled with mental rehearsal; (iii) a kinaesthetic interference task; or, (iv) a visual interference task, and the effects on subsequent retention studied.

The ability to process words, whether printed or fingerspelled, is essential for comprehension, and it appeared from the results discussed in this study, that the written form facilitated the processing of visually transmitted English, rather more than fingerspelling alone. Written displays can be used relatively easily when teaching a class of deaf children to spell new words, but are less practical in a normal communication context. Future technology may however, make it possible for spoken English to be simultaneously translated into print on a screen, thus providing a visual display of normal speech communication. But, even this would not be without its associated problems, for the current reading achievement of deaf people would be a major limiting factor. For the present at least, simple learning may be facilitated by the presentation of the material in written form, and by encouraging the deaf children to actively fingerspell new words to themselves. This modest practical suggestion may prove to be a considerable aid to verbal language learning in its early stages.

### 7.14 Summary.

The effect of presentation and production modes on subsequent retention of spelling patterns was studied. The spelling of 32 new words was learned using 3-, 4-, 5- and 6- letter French words. The shorter words were always easier to learn than the longer ones, whatever method of presentation and mode of production were used. It appeared to be easier to learn the longer words when they were presented in written form, rather than fingerspelled, and the kinaesthetic feedback provided by the children actively fingerspelling the new words to themselves also improved retention. The use of fingerspelling emerged in this study as a tool that could aid the learning of new spelling patterns.

### 7.15 General discussion of Experiments 7, 8 and 9.

The three experiments described in this and the previous chapter, have shown two recurrent features in the written language of these deaf children, which will be discussed here:

1. Bizarre word order and frequent grammatical errors.
2. Spelling mistakes after seeing all the words correctly spelled, including 'visual' errors and letter transpositions within the word.

These two features have also been reported in the current literature, and may be repeatedly observed both inside the classroom and within the deaf community at large.

Beginning with a consideration of the second of the features mentioned above, namely spelling mistakes, Fraser and Blockley (1973) suggested that the frequent transposal mistakes in the written work of deaf children (they quoted examples such as 'Jhon' and 'rianing') might arise from a defective grasp of either spatial and/or temporal relations. They worked with over a thousand children who were without speech, or who had inadequate speech, at the Braidwood Audiology Unit, and were repeatedly struck by evidence of poor appreciation of relations in time, and defective appreciation of relationships in space. Meaning from language is achieved by the correct ordering of words in space and time. The aim of Fraser and Blockley was to foster the acquisition of speech and language in these language disordered children; their theory of language development was based on the idea that remedying the child's perceptual disorder would help the child to relate the surface structure of the speech to the deep structure, which would in its turn bring about comprehension.

The errors they quoted are certainly familiar to those who teach or work with deaf children and occurred frequently in the written language generated in Experiments 7, 8 and 9. For example in the latter experiment, 62 such letter transposals were recorded (e.g. 'liat' (lait)). These transpositions of letters within words may be the result of a basic perceptual disorder, they could however, possibly result from inadequate visual imagery, or alternatively could have arisen from fingerspelling mediation, in which the actual letters were remembered but owing to the rapid, transient, sequential trace, and the possible overloading of memory processing capacity, the order of the letters was not correctly recalled.

The other category of language errors, which Fusfeld (1955) and Myklebust (1964) among others have studied, concerns the production of language in which words are not grammatically ordered. Are the language errors also the result of disordered perception of space and time as suggested by Fraser and Blockley?

Tervoort (1964) discussed the basic differences between a contact system based on sound and the ear, and one based on the eye. He explained that the eye was the organ of space and light, and the ear of sound and succession in time, and suggested that this provided an important distinction between the two communication systems. The typical characteristic of the perception of the ear is the succession in time measuring the before, the now and the thereafter, whilst the eye simultaneously perceives in space.

Jakobson (1967) has also pointed out the strong tendency for auditory to be sequential, whereas visual tends to be rich in simultaneous components. The meaning from spoken language arises from sequential elements ordered in time and space, whereas in sign language meaning comes from simultaneously superimposed cheremes - the sig, dez and tab aspects of a single sign are simultaneously presented, and a sign may be differentiated only by a single aspect, the other two being identical. At this level then there is not the same succession in time, the eyes must take in information concerning meaning simultaneously. It is possible that these fairly basic differences in the perceptual requirements of sign language and vocal language might account for the disordered perception as reported by Fraser and Blockley. Different signs may also be produced simultaneously. Tervoort (1975) clearly illustrates this with an example he quotes of a deaf child who signed the following 'sentence' simultaneously 'mad you me not' - the signs for all the four words were presented simultaneously. This example shows that correct English word order has little, or no, reality for the child concerned. Tervoort even went on to observe that the effect of using SL which is so different, would probably create problems when it came to teaching English. He is regarding knowledge of sign language as a possible source of interference.

The non-standard written language of the majority of the deaf children encountered in the present study could equally well be explained by such cognitive and linguistic interference from knowledge and use of sign language - an alternative and rather different explanation to that put forward by Fraser and Blockley (1973). The results of Experiment 7 certainly suggest that sign language may be mediating between the deep structure and the generation of language at the level of the surface structure. A written form of sign language was not only more easily recognised, it was significantly better recalled than English was, and was frequently generated by the deaf children, even when they had been presented with English. This suggestion is similar to one made by Kates (1972), that since sign language is a different language, and does not, therefore, directly aid the learning of English, it detracts from concentration on the later learning of verbal language. The 'law of least effort' may also be operating, since sign language is most easily acquired by children during the normal language learning period of development, is easily discriminated, and easily perceived and produced. In addition to these advantages relating to 'least effort', sign language is also the <u>only</u> feasible method of spontaneous communication between deaf people. Psychologists cannot disregard its importance to the deaf community.

At the present time then, researchers appear to be more or less agreed on the nature of the language problems of deaf children, and the type of errors that are repeatedly generated, but are still at a speculative level regarding the actual reasons behind the mistakes - the origin of "deaf English". At present only possibilities can be outlined. In the past many of the studies were merely descriptive, without attempting reasons and explanations. The approach adopted by Fraser and Blockley (1973) was a very positive step in a new direction, that of explanation and treatment. Their ideas represent one possible explanation, another possibility has been presented for consideration and discussion here. But possibilities they must remain until more detailed data are available concerning the syntax of sign language and further studies of the 'deviant syntax' of deaf individuals are undertaken. Nothing more definite can emerge with the present state of the art.

The present study was not intended to further fuel the controversy over methods of communication. The findings should neither be used to support a manual or a verbal/oral approach, but should be interpreted in the intended context of an investigation of the cognitive functioning of a group of deaf children who are fluent users of sign language and two-handed fingerspelling.

# CHAPTER 8

## GENERAL DISCUSSION AND CONCLUDING REMARKS

The present study grew out of a general feeling of dissatisfaction with the current situation regarding research in the field of deafness. It seemed to the present writer that the majority of studies could be categorised into one of two major approaches. The first type of research has been carried out by concerned, involved individuals from within the field of deaf education, and who are therefore immersed in it, whilst the second has been carried out by a small number of psychologists and linguists who are interested in specific problems, but who lack the knowledge and insight into the deaf community necessary to work in an "applied" situation. The present investigation therefore differed from many of the earlier studies in that it was carried out with the firm belief that the experimenter needs to be very knowledgeable about the deaf community in which he or she is working, and be able to communicate directly, rather than via an interpreter, with the deaf individuals themselves. It was recognised that every deaf subject tested in an experimental setting brought to the situation the language and culture of the deaf community. Consequently it was felt to be vitally important that the experimenter should be fully aware of this background in order to be able to carry out a valid investigation and be able to interpret the findings both knowledgeably and usefully. It was felt to be all too easy for a hearing researcher to appear arrogant and, either consciously or unconsciously, to neglect the importance of vital information from outside the actual test situation.

Cognitive processes can never be directly observed, only inferred from outward behaviour. In the present study therefore experimental techniques were adopted which had been developed and successfully used by other psychologists in the area of visual information processing. It was found that techniques previously used with normally hearing subjects (who, for the most part, were adults) could be very profitably applied, with the occasional modification to suit the particular needs of younger subjects, to the study of the cognitive functioning of a sample of deaf children. Few psychologists appear to have realised the potential contribution of existing experimental techniques to an applied area such as the present one. There is particular need for detailed studies in which a whole series of experiments is undertaken with the same population of subjects, in direct contrast to the very many isolated studies that have been carried out by numerous researchers on differing groups of individuals merely, and insufficiently, labelled as "deaf". As a consequence, the findings from such studies are difficult to interpret, and impossible to integrate into much needed general theories relating to cognitive organisation.

## 8.1 The importance of individual variation within experimental groups.

Implicit in the above criticism of piecemeal studies lies a more fundamental criticism of the frequent assumption that the independent variable 'deafness' accounts for all observed behaviour differences between deaf and hearing subjects. It is clear from the present findings however that there are many other confounding variables and that individual differences within a group may be as great, if not greater than observed differences between the experimental and control groups. In the present investigatio considerable emphasis was placed on the importance of individual differences: throughout all nine experiments, but in the first few experiments in particular, the experimenter was aware of the importance of individual variation between deaf subjects - the differences becoming increasingly evident as the study progressed. Ability to articulate intelligibly was selected as one of the more obvious criteria by which to classify deaf individuals (as suggested by Conrad, 1971b) and was employed in Experiments 1 - 4 inclusive. It was however clear that other linguistic variables, such as knowledge of and proficiency in the use of verbal and/or sign language differentiated individuals within a single population. Yet the majority of researchers, with a few notable exceptions, fail to describe the characteristics of their deaf subjects in sufficient detail, despite attempts to increase awareness of the importance of such information. Over five years ago, Henderson and Henderson (1973) wrote:

> It is evident from previous studies that degree of deafness, age of onset of deafness, language ability, and the teaching method used in his school all influence the performance of the deaf, and that without information on these matters, data on the deaf are uninterpretable. (pp.510-11)

Until such time that inclusion of this kind of background information becomes standard practice, any evaluation of research findings and understanding of the effects of deafness must necessarily be limited, and will certainly not reflect the very striking upsurge of interest of the last five years and the associated flood of recent publications. Any study carried out on an ill-defined research population can only produce confusing results, and unfortunately this has frequently been the case in many of the studies in the past.

The importance of individual differences within a group is clearly illustrated by the notable exceptions, i.e. those studies in which an awareness of these differences is found. Group data may all too frequently mask individual differences as was clearly demonstrated by Experiments 3, 5, 6 and 7 of the present study and if overlooked, meaningful interpretation of the data becomes impossible. Other examples can be quoted from recent literature. Neville (1976) for example carried out a study of hemispheric specialisation in a group of deaf subjects. Using measures of evoked potentials, she found no significant differences between the left and right hemispheres. When however, in a subsequent more detailed analysis, she sub-divided her deaf subjects into two groups - 'signers' and 'non-signers' - she found that the former showed a significant right hemisphere dominance whilst the 'non-signers' did not. Similarly, Conrad (1971b) reported a significant difference between 'articulators' and 'non-articulators' in their ability to comprehend a passage of prose which they were required to read out aloud compared with their ability to understand similar passages read silently. In both of these studies the group data concealed significant individual differences within the group, with important psychological implications.

It is hardly a coincidence that in the examples cited in the preceding paragraph some feature of communication ability was found to be the important differentiating factor, in one case ability to articulate (in Experiments 1 to 4 inclusive; Conrad, 1971b) and in another instance use of sign language (Neville, 1976); deafness clearly does have a profound effect on language development. The importance of such differences in language ability within groups of deaf subjects cannot be overemphasised, particularly when so few studies have shown any kind of explicit awareness of possible differences within their experimental groups. Once again it should be reiterated that until such awareness becomes more generally the rule, it will remain virtually impossible to understand and interpret the findings from isolated investigations such as were described in the preceding two chapters. In short, an understanding of all the different explanatory theories relating to the kinds of errors that are characteristic of the written language of the majority of prelingually deaf individuals can only be gained through knowledge of communicative abilities and general linguistic background (cf. the results and conclusions of Davison (1977) and those of Experiment 7 in the present study).

The discussion and evidence of the preceding pages has clearly established that the communicative abilities of any sample of deaf individuals constitute an important experimental variable. This conclusion therefore challenges the use of deaf subjects as 'alinguistic controls' (e.g. Furth, 1964), and raises important questions as to the degree to which "the deaf" constitute a 'language-deficient' group, and the extent to which deaf individuals make "unique experimental subjects for clarifying the influence of language on cognition" (Furth, 1964, p.147). The widespread knowledge and use of sign language that one encounters within communities of deaf individuals such as the residential school in Newcastle also makes it appear quite inappropriate to regard deaf subjects as 'alinguistic', and to ignore their highly variable competence in English and their invariably fluent sign language. The speed with which the very youngest deaf children (aged between 2 and 5 years) entering the residential deaf school in Newcastle acquired sign language was particularly striking. A situation rapidly developed in which there were no discernible differences, in terms of sign language competence, between those deaf children with deaf parents who had been exposed to manual communication since birth and those children with hearing parents who knew no sign language before they entered school. Such a case may not however be typical; it certainly differs from the findings reported by Bornstein and Roy (1973) who commented on the lack of an early symbol system in a sample of 220 deaf children. They found that only 26% of their sample learned sign language before the age of 6. The explanation may however, lie in the earlier age of starting school in Newcastle.

The aims behind the complete series of nine experiments were, first, to discover the overall organisation of the cognitive structures which develop to compensate for prelingual deafness, and secondly, to investigate possible differences between the individual deaf subjects tested, and between the group of deaf subjects and their normally hearing counterparts. Well-tried techniques devised by Conrad, Posner and colleagues, and by Meyer and Schvaneveldt were used, so that the performance of the sample of deaf subjects tested could be compared with the previously established qualitative 'norms' of performance for 'normal' hearing subjects. In fact control subjects were only tested in 3 of the nine experiments (Experiments 5, 6 and 8) when experimental manipulations based on deaf norms were included (e.g. pairs of words with similar sign equivalents, and written forms of sign language), to investigate whether or not there was any evidence of a performance decrement for the hearing controls.

## 8.2 Towards a model of visual information processing in the deaf.

As a consequence of suffering from a severe or profound loss of hearing early in life (either congenitally or prelingually), an individual is largely debarred from interacting with his environment via his sense of hearing. Symbolic auditory behaviour therefore becomes difficult or impossible depending on the degree of deafness and amount of residual hearing. Such a handicap results in a shift of emphasis away from auditory symbolisation and towards visual symbolic behaviour. In short the entire information processing system is altered, thus reinforcing Myklebust's (1964) suggestion that when one sensory perception is missing, the function and integration of all the others is altered.

The results of Experiment 1 clearly demonstrate visual dominance in that the overriding source of confusability between the letters processed in memory was visual. Similarly shaped letters were frequently confused by the deaf subjects during memory processing, and this was reflected by lower memory span scores. These results certainly provide an answer to the question implied by Locke (1978, p.89), namely:"One encounters references to 'visual coding' in the memory literature but it is not clear whether visual coding exists, at least with reference to verbal materials". His findings were that most subjects encoded letters in terms of their phonemic representations, butit is the case that he tested only normally hearing subjects. In contrast the deaf subjects in the present study appear to have encoded the letters in terms of their visual representations, thus challenging Locke's conclusion that "While some letters physically resemble and are visually confused with others, once veridical perception has occurred the nature and rate of forgetting apparently are governed by extravisual processes" (p.92).

The cognitive system of the deaf children tested appears to be structurally different from that of normally hearing children, developing as it does primarily through visual input; one finds a visually oriented system which is backed up by additional articulatory and possibly also kinaesthetic information processing. Evidence for the latter was indirect in the form of observed use of fingerspelling, and those individuals able to articulate intelligibly also appeared to use some form of articulatory processing in memory.

The evidence from Experiments 2, 3 and 4 provides additional support for the importance of visual characteristics in the perceptual and memory processing of information in deaf subjects. Even when they were required to match by name pairs of letters presented successively with a 2-second interval between the letters, the degree of visual similarity between the letters of each pair affected the processing time (response latencies) required for name-matching. However, no such relationship has been reported by other researchers for normally hearing subjects who, having 'translated' the visual input into a name code, use this for subsequent matching responses in an otherwise identical experimental situation, there being no apparent influence of visual cues.

Since deaf individuals can only process information when it is presented visually, visual clarity of the input in terms of its potential confusability and lack of ambiguity is vitally important. The majority of deaf individuals are even forced to process speech visually, by observation of lip movements and other facial characteristics and non-verbal cues. The inherent ambiguity of these visual cues may well contribute to the problems generally associated with lip-reading (see Conrad, 1977a). Consequently, the visual input of information, if it is to be sufficient, must not be ambiguous.

The finding in Experiment 5 of a facilitation effect for graphemically similar pairs of words compared with the articulatorily similar and the control word-pairs, again supports the heavy reliance on visual cues, this time in the context of a lexical-decision task. Albeit limited to one individual, introspective evidence has also supported this finding: a deaf adult actually volunteered the information that he saw printed words in his dreams. Meanwhile, the results of Experiment 6 provide evidence that covert sign mediation is also employed in cognitive tasks even when the visual input is in the form of written words. It is generally accepted that internal speech is helpful to normally hearing subjects over a wide range of cognitive operations and here one finds evidence for the covert use of signs by the deaf subjects in a parallel siutation. Evans (1976a) put forward the suggestion that words might be used as 'signals' rather than as symbols by many deaf children. The preceding evidence regarding the apparent covert use of signs in a lexical-decision task would in fact support Evans' suggestion - words may in fact be merely used as 'signals', whilst the signs belonging to sign language, provide the symbols necessary for thinking. Some of the issues raised by the possibility that deaf people have an internal language, but a different one from hearing individuals, will be considered later. However, before

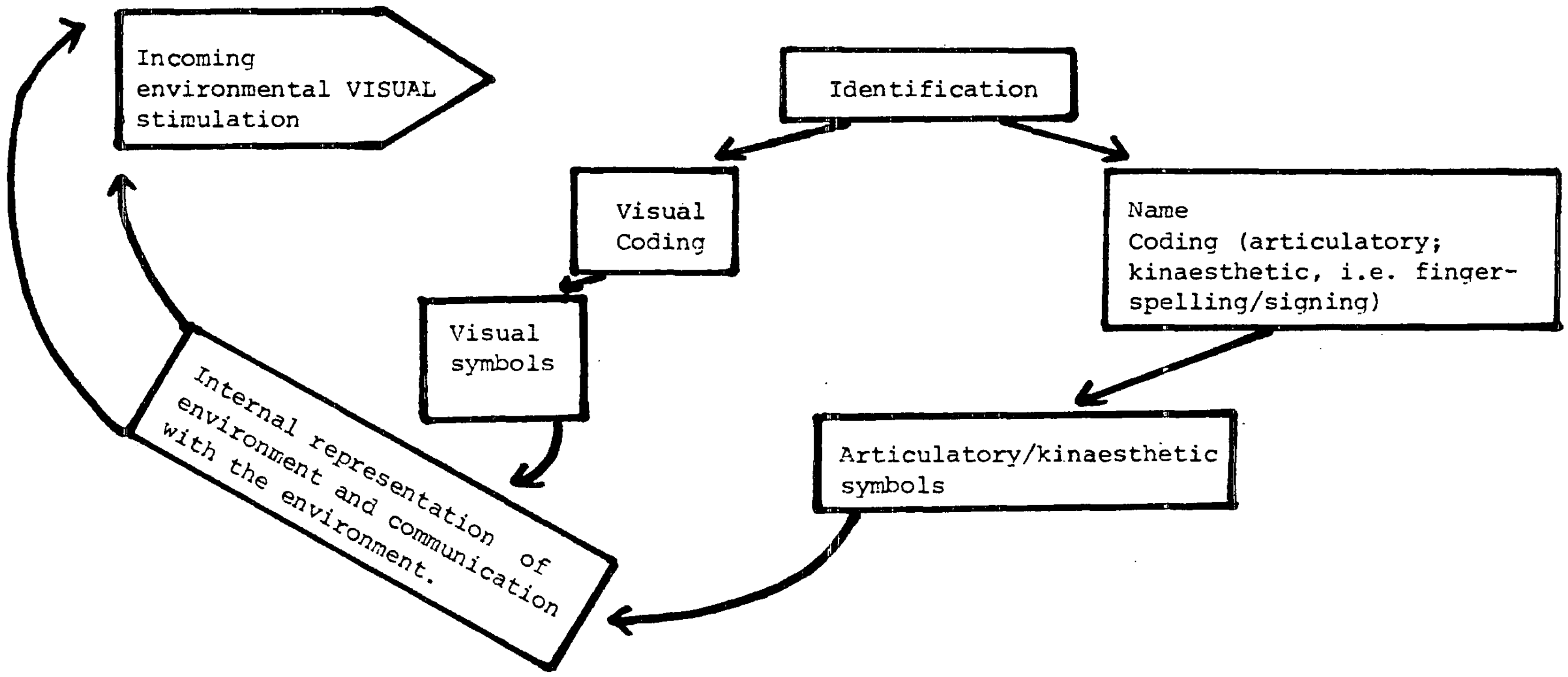


Figure 8-a. A model of visual information processing in prelingually deaf subjects.

discussing the results of the three final experiments, an attempt will be made to use the findings of the six initial experiments as a basis for a model of visual information processing.

Several theorists in the field of information processing have suggested thatprocessing items is akin to naming them, and have favoured a model which assumes that items from iconic memory (a visual sensory store) are represented in a more durable auditory coded form (e.g. Calfee, 1975; Conrad, 1964; Sperling, 1963, 1967). More recently, however, on the basis of a set of experiments investigating the effect of exposure duration (using masking techniques) on the number of items reported, Coltheart (1972, p.75) has created a tentative model which assumes that both a visual code and a name code can be developed in parallel from the fast decaying visual information in iconic memory. He suggests that the visual code has a flexible decay rate, whilst the name code decays negligibly over time. From Coltheart's model it can be assumed that the recall of a processed item can be based upon either a stored name or visual code. Such a model could account for the prelingually deaf subjects' ability, observed in Experiments 1 to 4 inclusive, to retain the visual characteristics of visually presented items over a substantially longer period of time than would be possible from iconic memory. Coltheart's (1972) hypothesis was therefore incorporated into the model of visual information processing shown in Figure 8-a which attempts to describe the ways in which the present sample of prelingually deaf individuals processed visual information.

As Figure 8-a shows, visual information from the environment is first identified, and then it may subsequently be stored and maintained within the memory-system in either visual or name form. Visual coding, akin to that recently postulated by other researchers (e.g. Coltheart, 1972; Paivio, 1971; Phillips, 1979), seems to have been employed by many of the deaf subjects to process and store all kinds of exclusively verbal items. In contrast, normally hearing individuals seem only to use visual cues to process a fairly restricted sub-set of verbal items, namely concrete, imageable words (Paivio, 1971) as well as more non-verbal items such as scenes and faces. The alternative mode of coding - name coding - also assumed a quite different form since it is certain that verbal items could not be stored acoustically by the sample of deaf subjects under investigation. Some of the deaf adolescents were able to use articulatory coding, whilst they could all make use of kinaesthetic imagery and coding arising from fingerspelling and signing. It would appear therefore that the use of different forms of imagery and coding differentiated these prelingually deaf adolescents from a normally hearing population, that is to say they were unable to employ acoustic cues, and substituted visual, kinaesthetic and sometimes articulatory cues.

Following the discussion in Chapter 3 of the types of memory coding used during information processing, it should now be clear that the nature of the code is in fact a function of the type of cognitive operations that are both available and active, and is therefore largely dependent on the particular features of the items that are being attended to. It would appear reasonable to suggest that any salient feature (visual, acoustic, articulatory or kinaesthetic) may be used to process an item. Previous studies may have confused the situation by suggesting that the encoding system which is usually used by normally hearing individuals to process verbal items (i.e. acoustic/phonemic name coding) is in fact the system that is exclusively used. Such a confusion overlooks the important difference between optimal strategies and other, less satisfactory, yet workable coding systems. Clearly, the study of a population of individuals handicapped in one or more of their sensory systems, enables the psychologist to investigate the existence of alternative cognitive processing strategies.

Another of the goals of the present investigation was the production of a model of visual information processing based on the findings of the series of experiments undertaken with the prelingually deaf adolescents. It is recognised that the generalisability of these results and of this model is very limited, and that the findings cannot therefore, at least for the time being, apply beyond the context of the experimental population in question. Whilst one can be quite certain that this model would not be appropriate to adventitiously deaf individuals, whatever the degree of their hearing loss, it is not clear how it might apply to other populations of severely or profoundly prelingually deaf subjects. It would therefore be of considerable interest to undertake further studies of a similar kind using different deaf populations. Detailed background information regarding the experimental population of deaf subjects has been presented in the hope that the present findings and model of information processing will provide a framework within which future results can be both compared and contrasted. In this way our understanding of the deaf population in general should be extended beyond that which is possible at the present time.

The structurally different cognitive system of the deaf subjects does not necessarily imply any inherent inferiority of the system, but does raise the interesting question of whether a visual/kinaesthetic processing system is comparable to an auditory/visual system. Certainly the present data would seem to indicate that the central cognitive processes of deaf subjects can function effectively without acoustic mediators. Obviously, if teachers used the same approaches and teaching methods with deaf as with normally hearing children, regardless of their different learning procedures, then avoidable problems would almost certainly result. Any development of the curriculum which increases the focus of visual experiences, visual labels and visual transformations of information is desirable since this would maximise the potential of a visually orientated information processing system. At the same time one needs to be aware of possible sources of visual ambiguity and confusion, and avoid as much visual distraction as possible. The present author found to her cost, during one of the early pilot testing sessions,that the presence of visual distractors produced a similar effect (indeed it may even have been more dramatic) to auditory distractions with normally hearing children. One is therefore faced with the challenge of producing a stimulating, yet not visually distracting, environment.

## 8.3 The language ability of the deaf adolescents.

The first six experiments of the present study all concentrated on the visual processing of simple verbal items (letters and words), whilst the final experiments of the series were more concerned with the language ability of the sample of deaf adolescents. However, before disucssing the ability of members of the Upper School to produce, understand and process standard English, the results of the very last experiment, Experiment 9, will be discussed, since they relate most closely to the results of Experiment 6. The findings of both of these experiments suggested that there was a kinaesthetic basis to the perception of words, and those of Experiment 9 specifically indicated that active kinaesthetic rehearsal was a valuable aid to learning. It appears that these deaf children should be encouraged to establish a kinaesthetic basis to learning, given that they appear to make use of kinaesthetic imagery.

In contrast to the use of signs and fingerspelling as 'word-encoding' devices evidenced in the latter two experiments, Experiments 7 and 8 were both concerned with the use of signs within their own true linguistic context, i.e. sign language. As a group, the present population of deaf children were far more at home processing sign language, even a rather bizarre written version of it, than they were in English. It was found that not only could they both recognise and recall sentences written in sign language significantly better than those written in standard English, but that they also understood stories written in sign language significantly better than those written in standard English (as judged by the number of comprehension questions they were subsequently able to answer correctly). Should these results be found to be replicable in other deaf populations, they would have very important implications for the subtitling of television for the deaf. Many countries, including Britain, are currently concerning themselves with this problem (e.g. Schein, 1977; Sendelbaugh and Powell, 1978). One of the major issues raised by Carter and Southern (1977) who are involved with the problem in this country, concerns whether to use standard English sub-titles or a simpler alternative version. It is interesting to note that despite the fact that a deaf person actually pointed out that many deaf people cannot understand standard English (a view that is endorsed by the present study), Carter and Southern have decided that "it would be more appropriate in the initial stage to use full English grammar wherever possible" (p.119). Given that this important applied issue is currently being considered, it would seem all the more urgent that a widespread systematic study of the ability of the deaf community to read and understand standard English,of the kind that was attempted on a small scale in Experiments 7 and 8,be undertaken. This at least would provide factual information concerning the percentage of the deaf population in this country who could benefit from standard English sub-titles. Consideration of a problem such as that of sub-titling television for deaf people clearly illustrates the importance, discussed earlier in this chapter, of looking at, and being aware of the

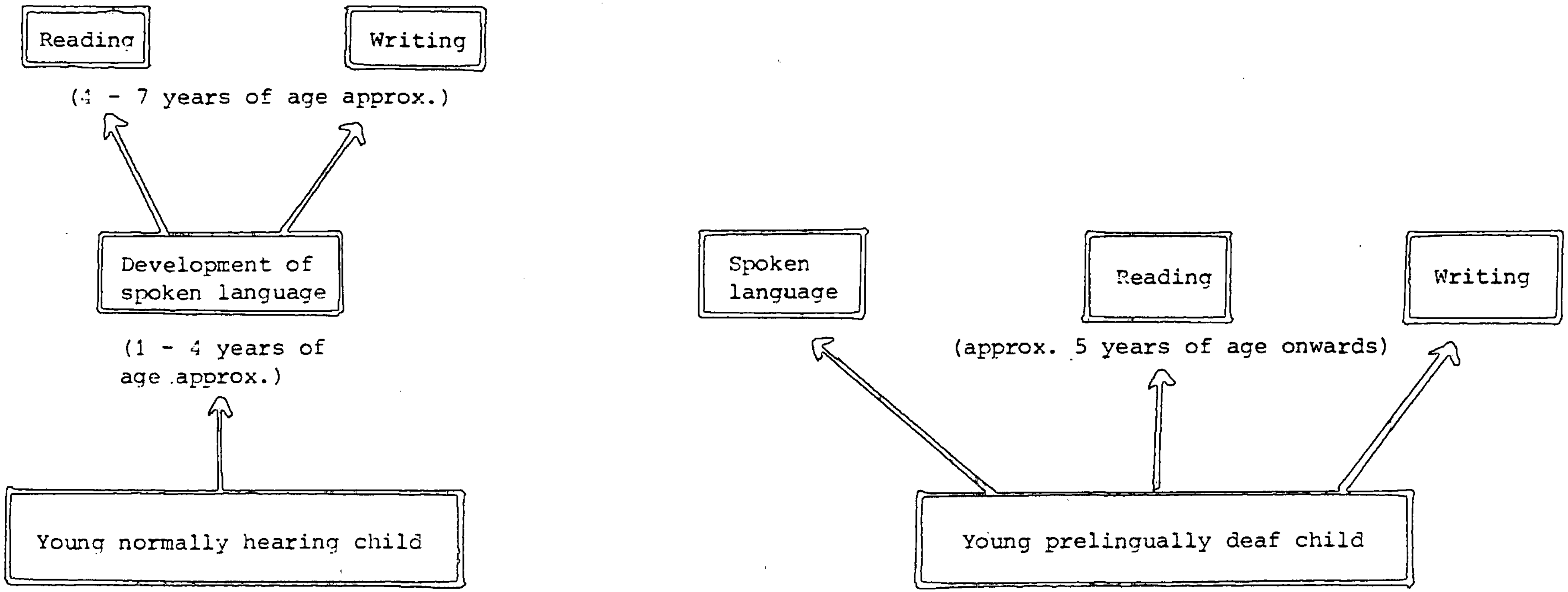


Figure 8-5. Schematic diagram to compare the development of verbal language in a young normally hearing child and a prelingually deaf child.

heterogeneity of the deaf community. It is precisely in this area of linguistic abilities that the crucial difference between prelingually and adventitiously deaf individuals is most striking.

Experiments 7 and 8 were also indirectly concerned with the deaf children's reading ability. It must be assumed that in order to read fluently a child must have access to the system of internal rules of language which are used to generate the material that is read. The results of Experiment 7 suggest that this was not in fact true of these deaf adolescents, thus providing some support for an idea put forward by Ivimey (1976): "It may be not so much that the deaf have deviant language skills and cannot read very well, but they cannot read very well because they have deviant skills" (p.105). It is clear that this is an important and challenging area into which researchers should move in the future: an attempt should be made to understand the mental processes required by the deaf child learning to read, since these appear to be very different from those required by normally hearing children. For whilst the hearing child is already familiar through spoken language with the language structures that he/she is learning to read, the deaf child is usually being taught concurrently to speak, to read and to write (see Figure 8-b).

It was never the intention of the present study to assess the effectiveness of any particular method of communication and thereby become involved in the ongoing methodology debate. Instead, the main interest of the present writer as a psychologist was with language as a source of symbols for cognitive development, and this has lead naturally to the question concerning the mode of thinking that was used by the deaf children to carry out the experimental tasks. The apparent covert use of sign language to process words, observed in Experiment 6, and the striking comparison between fluent communication in sign language and faltering expression in SE which is reflected in the findings of

Experiments 7 and 8, have important implications for the current status of sign language. As has been discussed earlier (see Section 1.2.5), there has for many decades been a good deal of simple mythologising with regard to sign language in the field of deaf education. In the following three paragraphs therefore, the present writer will attempt to assess the contribution of sign language to the overall cognitive development of the population of deaf subjects involved in the present study.

Although Evans (1976b),Headmaster of the N.C.S.D., recently said that "the present climate in Britain is one of growing recognition of the actual use of manual communication and acceptance of its need" (p.19), not everyone is quite as ready to recognise this, particularly teachers. Many are not yet ready to reject the Ewing's (1964) claim that sign language is not a good alternative to spoken language because it is not a verbal language. Indeed it is strange that it is largely the professionals (such as social workers) who encounter the deaf after they have left school, who recognise the need for, and the importance of, sign language. Meanwhile teachers, whilst few would deny the existence of sign language, are largely unaware of the extent to which signs can and do influence cognitive functioning. There is still a tendency to associate manual communication with the less able deaf child, and this is also reflected by the fact that one rarely, if ever, hears reference to 'manual successes', only 'oral successes'. Yet clearly the former do exist - in the Upper School of the N.C.S.D. there were two such individuals, both of whom had deaf parents, who were two of the very brightest pupils in the school. Psychologically speaking, it is the basic need and ability to communicate by whatever method that is important: the value of communication is clearly far more important than the specific method.

As a linguistic system, sign language fulfils the basic needs of sponteneous communication in that it is easily acquired (given an early linguistic model), and the signs themselves are easy to discriminate visually. Within a deaf residential school community only manual forms of communication are feasible between deaf peers, sign language, the living language of the deaf community at large being the preferred system. As a consequence, cognition and the initial structuring of the world is established through, and organised by, signs; early knowledge is structured using sign language. Just as Luria and Yudovich (1956) postulated a close connection between the acquisition of speech and organisation of a child's mental life, so for these deaf children acquisition of sign languge is of similar cognitive significance. There is a danger that forcing a deaf child to rely solely on the use of speech and lipreading (both of which they find difficult since neither is easily visually discriminable) might result in a loss of motivation to communicate, particularly if the speech were laboured and largely unintelligible as was the case for the majority of the present prelingually deaf population. Similarly, discouraging the early use of sign language might well reduce the child's intellectual curiosity, and thereby hinder cognitive development.

Even Alexander Graham Bell (1888), one of the greatest proponents of the oral method in the United States, admitted that deaf children respond most readily to signs:

> I think that if we have the mental condition of the child alone in view without reference to (English) language, no language will reach the mind like the language of signs; it is the quickest way of reaching the mind of a deaf child. (p.27)

The implications of such a statement for the psychologist who is interested in the cognitive development of young deaf children are self-evident. If teachers and researchers alike use only standard English (cf. Labov, 1972) as an indicator of language competence, then the psycholinguistic abilities and linguistic functioning of certain deaf children will surely be grossly underestimated. Hoemann, Andrews, Florian, Hoemann and Jensema (1976, p. 493) high-lighted this when they wrote:

> The same deaf children who are said to have a 'language deficit' because they lack competence in English have no difficulty at all acquiring native competence in A.S.L. when models of its use are available in their environments.

Stokoe (1976, p.26) quotes an example that clearly illustrates the point that is being made above - an example in which bad theory can be seen to corrupt the practice of a teacher of the deaf:

> A teacher may understand a complicated statement, an explanation, or a request presented in Sign and may respond appropriately. Yet this teacher is all too likely to tell an observer that the pupil who has just communicated in Sign "has no language"!

Before reacting critically to this surprising statement, one should perhaps first comment favourably on the fact that the hypothetical teacher referred to above could at least understand sign language (unfortunately this was not always the case in the N.C.S.D.) and could communicate with the deaf pupils on their terms. Yet at the same time the teacher was either unaware of, or denied, the important role of sign language in the spontaneous communication of the deaf and its implications for cognition, by suggesting that "language" can be equated solely with competence in standard English. It is clearly vitally important that such a misconception be eliminated. Every teacher of the deaf who encounters deaf children who have acquired sign language should be made aware of the status of this particular language, and the vital contribution that it almost certainly makes to the early development of cognitive functions, irrespective of any recognition of English as the 'official' classroom language.

### 8.4 "How do deaf persons think?" (Furth, 1964).

We shall now return to the question originally raised by Furth over a decade ago and try and assess in the light of the present findings what kind of symbols were used by the population of deaf adolescents in the Upper School of the N.C.S.D. In order to attempt to answer this question one is forced to go beyond observable evidence and infer the forms of symbolic representation that were employed. There was clear evidence of fairly general use of visual imagery by all of the deaf children tested (which Cohen (1977) would label 'first-order visual imagery'), and some evidence, restricted to certain individuals, of representation based on articulatory and kinaesthetic cues. This finding provides support for the suggestion made by William James (1890, Vol. I, p.266) that a deaf and dumb man could "weave his tactile and visual images" into a system of thought.

As cognitive processes become more complex however, and more abstracted from immediate sensory experience and 'first-order imagery', language must play an increasingly important role in cognitive processes. This then raises the question, with regard to deaf subjects, of which language is internalised: verbal language (as teachers of the deaf would hope, and many even assume) or sign language? The latter possibility certainly challenges the long-standing assumption concerning the relation between thinking and spoken language, and strongly suggests that other modes of language are just as adequate as speech for thought processes. Conrad (1976a, p.151), in addressing himself to the question of the development of internal language in deaf children, refers to "two modes of the same language - like speech and a sign mode". Yet in contrast, the evidence from the present study would suggest that these two different modes represent two different languages - sign language cannot simply be regarded as a manual version of standard English. It would seem plausible to suggest that deaf children will internalise the linguistic mode which is easiest for them, and clearly in the population which was studied all were more at home using sign language than English (spoken or written). On this basis alone it would seem very likely that they were thinking in sign language, which is also in accordance with the indirect evidence of sign language mediation in Experiments 6 and 7. The present author has become convinced of the possibility that the majority of the deaf adolescents were merely using verbal language on command (and even then not always very successfully) in the classroom but were thinking in signs: signs were the symbols necessary for complex thought processes. It would appear therefore that sign language functioned for the deaf adolescents as other verbal languages function for their hearing speakers, a conclusion which provides support for Cohen's (1977,p.42) speculation that the deaf could conceivably be "using a second-order imagery based on their manual sign language". One should perhaps also briefly mention those few deaf individuals who were also able to use verbal language, and who, it would appear, were able to think in both signs and words.

In sum the picture that has emerged is of a group of deaf adolescents who were all, without exception, fluent users of sign language, and consequently able to think in signs, with a few individuals in the group also able to think verbally. The majority of them clearly relied on sign language to process and communicate their thoughts and ideas in preference to the language of classroom instruction, i.e. English: sign language seemed to be their 'true' language (Furth, 1966a). There appeared to be no supportive evidence for the fear voiced by Dalziel (1976,p.8) that a "manual mode of internal language would prove to be a cumbersome tool and one that should not readily be handed over to all deaf children". One would clearly not conclude on the basis of the present findings that all deaf children should be taught sign language, and yet for those individuals who will never succeed in using verbal language adequately, there is no evidence for suggesting that sign language is more cumbersome a tool than any other language. In the United States, it has been reported by Quigley (1972), over 50 percent of the 'preparation programs' for teachers of the deaf offer training in manual communication, whilst in this country no such provision is made. If one assumes quite reasonably that the N.C.S.D. is not alone regarding the usage of sign language, then it would seem appropriate to suggest that at least some of the centres responsible for training future teachers of the deaf provide some initial training in sign language. Neither should deaf adults with fluent sign language be automatically barred from teaching in a deaf school on the basis of their lack of ability to teach speech alone (cf. British Association of Teachers of the Deaf, November 1978).

## 8.5 Future research.

It is obvious from the present study that the task of learning any verbal language such as English without functional hearing is very difficult - the "great blooming, buzzing confusion" (James, 1890, Vol. I, p.488) experienced by the normally hearing infant is yet more confusing for the child who is prelingually deaf. Many of the diverse and complicated problems associated with deafness do in fact stem from language and communication difficulties. A study of the kind undertaken here, which of necessity must be fairly restricted, may seem to raise more questions than can be answered at the present time. It would however appear that studies such as the present one are a necessary contribution to the identification of problems and questions which urgently need to be tackled. The past 50 years of research has been characterised by claims and accusations which have largely been based on subjective interpretation of individual experiences. Unquestionably what is needed, in order that progress may be made, are detailed objective studies on which theoretical models can be built and tested.

In future more 'experts' such as psychologists and linguists should participate in classroom experiences before embarking on their own research studies. One idea that emerges from the present study is that it would be both interesting and informative to study in depth those individuals who are achieving either more or less than one would expect in the light of knowledge about their degree,and type,of deafness, their intellectual ability and their general background. In this way it might prove possible to understand what factors determine success or failure in academic achievement. A psychologist who is in close contact with the deaf community in which he or she is interested, and aware of the great individual variation within a single deaf population, is clearly better placed to offer practical suggestions concerning classroom management. Teachers and psychologists cooperating closely should succeed in producing well-adjusted non-hearing children who are able to manage the limitations of their auditory handicap. Simply ignoring the extent and effects of the handicap results in the production of a 'poor imitation' of a hearing child who fails for that very reason to achieve his full potential.

In conclusion, any shortcomings of the present research may largely be attributed to the chosen participant-observer approach, but the associated advantages undeniably far outweigh the disadvantages, in particular the possible danger, during one's initial contact, of submersion in the complexities of the field situation. The present study has attempted to establish certain basic principles regarding research methodology in the field of handicap, in particular the handicap of prelingual deafness. Since the validity of the approach is intimately connected with the validity of the findings, it is to be hoped that further work, based on the same principles, will be undertaken to establish the extent to which the present findings can be replicated in other prelingually deaf populations.

REFERENCES

Adams, J.A., Marshall, P.H. and Goetz, E.T. (1972) Response feedback and short-term motor retention. Journal of Experimental Psychology, 92, 92-5.

Alterman, A.J. (1970) Language and the education of children with early profound deafness. American Annals of the Deaf, 115, 514-21.

Arochová, O. and Halmiová, O. (1975) Continuous recognition in deaf adolescents under varying degrees of stimulus verbalisation. Studia Psychologica, 17 (4), 261-5.

Atkinson, R.C. and Shiffrin, R.M. (1968) Human learning: a proposed system and its control processes. In:K.W. Spence and J.T. Spence (Edsl) The psychology of learning and motivation: advances in research and theory, Vol. 2. New York:Academic Press.

Baddeley, A.D. (1966) S.T.M. for word sequences as a function of acoustic, semantic and formal similarity. Quarterly Journal of Experimental Psychology, 18, 362-5.

Baddeley, A.D. (1976) The psychology of memory. New York: Basic Books.

Baker, L. (1978) Processing temporal relationships in simple stories: effects of input sequence. Journal of Verbal Learning and Verbal Behaviour, 17, 559-72.

Bamber, D. (1969) Reaction times and error rates for "same" - "different" judgements of multidimensional stimuli. Perception and Psychophysics, 6 (3), 169-74.

Baron, J. (1973) Is the phonemic stage not necessary for reading? Quarterly Journal of Experimental Psychology, 25, 241-6.

Beck, K., Beck, C. and Gironella, O. (1977)Rehearsal and recall strategies of deaf and hearing individuals. American Annals of the Deaf, 122, 544-52.

Bell, A.G. (1888) Education of deaf children: evidence of Edward Miner Gallaudet and Alexander Graham Bell. Paper presented to the Royal Commission of the U.K. on the condition of the blind, the deaf and dumb, June 1888. (Ed.) J.C. Gordon, Washington D.C.:Volta Bureau, 1892 Part II, p.28. Cited in:R.Orin Cornett (1974) The learning of English by the deaf. Teaching English to the Deaf, 5 (2), 4-9.

Bellugi, U. (1971) The language of signs and signs of language. A paper presented at the Third Annual Michigan Conference on Applied Linguistics, Ann Arbor, Jan. 29-30, Cited in:H.W. Hoemann (1972) The development of communication skills in deaf and hearing children. Child Development, 43, 990-1003.

Bellugi, U. (1976) Attitudes towards sign language: is there need for a change? British Deaf News, 10 (11), 333-7.

Bellugi, U., Klima, E.S. and Siple, P. (1975) Remembering in signs. Cognition, 3 (2), 93-125.

Bellugi, U. and Siple, P. (1974) Remembering with and without words. In: F. Bresson (Ed.) Current problems in psycholinguistics. Paris: Centre Nationale de la Recherche Scientifique, pp. 215-36.

Blair, F.X. (1957) A study of the visual memory of deaf and hearing children. American Annals of the Deaf, 102 (2), 254-63.

Blank, M. (1965) Use of the deaf in language studies. Psychological Bulletin, 63 (6), 442-4.

Blanton, R.L. and Nunnally, J.C. (1967) Retention of trigrams by deaf and hearing subjects as a function of pronounceability. Journal of Verbal Learning and Verbal Behaviour, 6, 428-31.

Blanton, R.L., Nunnally, J.C. and Odom, P.B. (1967) Graphemic, phonetic and associative factors in the verbal behaviour of deaf and hearing subjects. Journal of Speech and Hearing Research, 10, 225-31.

Bloomfield, L. (1933) Language. New York: Holt.

Bonvillian, J.D., Charrow, V.R. and Nelson, K.E. (1973) Psycholinguistic and educational implications of deafness. Human Development, 16, 321-45.

Bonvillian, J.D., Nelson, K.E. and Charrow, V.R. (1976) Languages and language-related skills in deaf and hearing children. Sign Language Studies, 12, 211-50.

Boring, E.G. (1950) A history of experimental psychology. New York: Appleton-Century-Crofts.

Bornstein, H. (1974) Signed English:a manual approach to English language development. Journal of Speech and Hearing Disorders, 39 (3), 330-43.

Bornstein, H. and Roy, H.L. (1973) Comment on "Linguistic deficiency and thinking: research with deaf subjects 1964-69". Psychological Bulletin, 79 (3), 211-4.

Bower, T.G.R. (1970) Reading by eye. In: H.Levin and J.P. Williams (Eds.) Basic studies on reading. New York: Basic Books.

Brannon, J.B. (1968) Linguistic word classes in the spoken language of normal, hard-of-hearing and deaf children. Journal of Speech and Hearing Research, 11 (2), 279-87.

Brasel, K.E. and Quigley, S.P. (1977) Influence of certain language and communication environments in early childhood on the development of language in deaf individuals. Journal of Speech and Hearing Research, 20, 95-107.

Brennan, M. (1976) Can deaf children acquire language? Supplement to the British Deaf News, February 1976.

Brennan, M. (1977) The practical benefits of linguistic research. Paper presented at the B.D.A. Triennial Congress in Eastbourne, June 1977

Briggs, R. and Hocevar, D.J. (1975) A new distinctive feature theory for upper-case letters. Journal of General Psychology, 93, 87-93.

Brill, R.G. and Orman, J.N. (1953) An experiment in the training of deaf children in memory for sentences. American Annals of the Deaf, 98, 270-79.

Broadbent, D.E. (1958) Perception and communication. New York: Pergamon Press.

Brooks, N. (1964) Language and language learning: theory and practice. (2nd. ed.) New York: Harcourt, Brace and World, p.134.

Brown, J.C. and Mecham, M.J. (1961) The assessment of verbal language development in deaf children. Volta Review, 63, 228-30.

Brown, R. (1973) A first language. Harvard University Press.

Brown, R. and Bellugi, U. (1964) Three processes in the child's acquisition of syntax. Harvard Education Review, 34, 133-51.

Bruce, D. and Cofer, C.N. (1965) A comparison of recognition and recall in S.T.M. In: The Proceedings of the 73rd Annual Convention of the American Psychological Association. pp. 81-2. Cited in:J.A. Adams Human Memory. New York: McGraw Hill, 1967.

Bullock, A. (1975) A language for life. London: HMSO.

Calfee, R.C. (1975) Human experimental psychology. New York:Holt, Rinehart and Winston.

Carey, P. and Blake, J. (1974) Visual short-term memory in the hearing and the deaf. Canadian Journal of Psychology, 28 (1), 1-14.

Carter, K. and Southern, D. (1977) Television and the deaf. The British Deaf News, 11 (5), 147-9.

Charrow, V.R. (1975) A psycholinguistic analysis of "deaf English". Sign Language Studies, 7, 139-50.

Charrow, V.R. and Fletcher, J.D. (1974) English as the second language of deaf children. Developmental Psychology, 10 (4), 436-70.

Chase, W.G. and Posner, M.I. (1965) The effect of visual and auditory confusability on visual and memory search tasks. Paper presented to the Midwestern Psychological Association, Chicago. Cited by M.I. Posner, J.L. Lewis and C. Conrad In: Language by ear and by eye: the relationship between speech and reading. (Eds.) J.F. Kavanagh and I.G. Mattingly. Cambridge, Mass.:MIT Press, 1972.

Cimbalo, R.S. and Laughery, K.R. (1967) Short-term memory: effects of auditory and visual similarity. Psychonomic Science, 8 (2), 57-8.

Clark, H.H. (1973) The language-as-fixed-effect fallacy: a critique of language statistics in psychological research. Journal of Verbal Learning and Verbal Behaviour, 12, 335-59.

Clark, H.H. (1976) Reply to Wike and Church. Journal of Verbal Learning and Verbal Behaviour, 15, 257-61.

Claxton, G.L. (1975) Sources of information in word perception. Canadian Journal of Psychology, 29 (4), 292-301.

Cohen, G. (1969) Some evidence for parallel comparisons in a letter recognition task. Quarterly Journal of Experimental Psychology, 21, 272-9.

Cohen, G. (1972) Serial position effects in the recall of picture sequences. Quarterly Journal of Experimental Psychology, 24, 41-7.

Cohen, G. (1977) The psychology of cognition. London: Academic Press.

Cohen, J. (1976) Discussion of Wike and Church's comments:random means random. Journal of Verbal Learning and Verbal Behaviour, 15, 261-2.

Cole, R.A., Haber, R.N. and Sales, B.D. (1968) Mechanisms of aural encoding: I Distinctive features for consonants. Perception and Psychophysics, 3, 281-4.

Cole, R.A., Sales, B.D. and Haber, R.N. (1969) Mechanisms of aural encoding: II The role of distinctive features in articulation and rehearsal. Perception and Psychophysics, 6, 343-8.

Cole, R.A. and Young, M. (1975) Effect of subvocalisation on memory for speech sounds. Journal of Experimental Psychology: Human learning and memory, 1 (6), 772-9.

Coleman, E.B. (1964) Generalizing to a language population. Psychological Reports, 14, 219-26.

Coltheart, M. (1972) Visual information-processing. Chapter 3 in:New Horizons in Psychology 2. (Ed.) P.C. Dodwell. Harmondsworth, Middx.: Penguin Education.

Conlin, D. and Paivio, A. (1975) The associative learning of the deaf: the effects of word imagery and signability. Memory and Cognition, 3 (3), 335-40.

Conrad, R. (1959) Errors in immediate memory. British Journal of Psychology, 50, 349-59.

Conrad, R. (1962) An association between memory errors and errors due to acoustic masking of speech. Nature, 193, 1314-15.

Conrad, R. (1963) Acoustic confusions and memory span for words. Nature, 197, 1029-30.

Conrad, R. (1964) Acoustic confusions in immediate memory. British Journal of Psychology, 55 (1), 75-84.

Conrad, R. (1965) The role of the nature of the material in verbal learning. Acta Psychologica, 24, 244-52.

Conrad, R. (1967) Interference or decay over short retention intervals. Journal of Verbal Learning and Verbal Behaviour, 6, 49-54.

Conrad, R. (1970) S.T.M. processes in the deaf. British Journal of Psychology, 61 (2) 179-95.

Conrad, R. (1971a) The chronology of the development of covert speech in children. Developmental Psychology, 5 (5), 398-405.

Conrad, R. (1971b) The effect of vocalising on comprehension in the profoundly deaf. British Journal of Psychology, 62 (2), 147-50.

Conrad, R. (1972a) The developmental role of vocalising in short-term memory. Journal of Verbal Learning and Verbal Behaviour, 11, 521-33.

Conrad, R. (1972b) Short-term memory in the deaf:a test for speech coding. British Journal of Psychology, 63, 173-80.

Conrad, R. (1972c) Speech and reading. In: Language by ear and by eye: the relationship between speech and reading (Eds.) J.F. Kavanagh and I.G. Mattingly. Cambridge, Mass.:M.I.T. Press.

Conrad, R. (1973) Internal speech in profoundly deaf children. Teacher of the Deaf, 72, No. 422, 384-9.

Conrad, R. (1976a) Matters arising. Chapter 21 in:Methods of communication currently used in the education of deaf children. London:R.N.I.D.

Conrad, R. (1976b) Towards a definition of oral success. In: The Harrogate Papers. Four papers given at the R.N.I.D./N.C.T.D. Education Meeting at Harrogate on 30th October 1976. London: R.N.I.D.

Conrad, R. (1977a) Lip-reading by deaf and hearing children. British Journal of Educational Psychology, 47, 60-65.

Conrad, R. (1977b) The reading ability of deaf school-leavers. British Journal of Educational Psychology, 47, 138-48.

Conrad, R. and Hull, A.J. (1964) Information, acoustic confusion and memory span. British Journal of Psychology, 55 (4), 429-32.

Conrad, R. and Rush, M.L. (1965) On the nature of S.T.M. encoding by the deaf. Journal of Speech and Hearing Disorders, 30 (4), 336-43.

Corbett, A.T. and Dosher, B.A. (1978) Instrument inferences in sentence encoding. Journal of Verbal Learning and Verbal Behaviour, 17, 479-91.

Corcoran, D.W.J. and Besner, D. (1975) Application of the Posner technique to the study of size and brightness irrelevancies. In: Attention and Performance V. (Eds.) P.M.A. Rabbitt and S. Dornic. London: Academic Press.

Craig, E. (1973) The Paget-Gorman Sign System: A report of the research project 1970-73. Unpublished manuscript, Dept. of Linguistic Science, University of Reading.

Craig, E.M. (1973) Role of mental imagery in free recall of deaf, blind and normal subjects. Journal of Experimental Psychology, 97, 249-53.

Craik, F.I.M. and Jacoby, L.L. (1975) A process view of short-term retention. Chapter 9 in:Cognitive Theory Vol. 1. Proceedings of the seventh Indiana Cognitive Mathematical Psychology Conference, 1974. (Eds.) F. Restle, R.M. Shiffrin, N.J. Castellan, H.R. Lindman and D.B. Pisoni. Hillsdale, New Jersey: Lawrence Erlbaum Associates.

Craik, F.I.M. and Lockhart, R.S. (1972) Levels of processing:a framework for memory research. Journal of Verbal Learning and Verbal Behaviour, 11, 671-84.

Dainoff, M. and Haber, R.N. (1967) How much help do repeated presentations give to recognition processes? Perception and Psychophysics, 2, 131-6.

Dainoff, M. and Haber, R.N. (1970) Effect of acoustic confusability on levels of information processing. Canadian Journal of Psychology, 24 (2), 98-108.

Dalziel, G.H. (1976) Paper 2 in: The Harrogate Papers: Four papers given at the R.N.I.D./N.C.T.D. Education Meeting at Harrogate on 30th October 1976. London: R.N.I.D.

Darlington, R.B. (1973) Comparing two groups by simple graphs. Psychological Bulletin, 79 (2), 110-16.

Davison, F.M. (1977) The written language of deaf children. Unpublished manuscript, Department of Linguistic Science, University of Reading.

Dawson, E.H. (1973) A study of recognition memory in deaf children using visually presented material. Unpublished manuscript, Department of Psychology, University of Durham.

Denton, D.M. (1976) The philosophy of total communication. Supplement to the British Deaf News, August 1976.

Dewey, J. (1897) My pedagogic creed. Reprinted in: John Dewey selected educational writings. (Ed.) F.W. Garforth. London:Heinemann, 1966.

DiCarlo, L.M. (1966) Much ado about the obvious: the relationship between early manual communication and later achievement of the deaf. Volta Review, 68, 269-73.

Diewart, G.L. (1975) Retention and coding in motor short-term memory:a comparison of storage codes for distance and location information. Journal of Motor Behaviour, 7 (3), 183-90.

Doehring, D.G. and Rosenstein, J. (1960) Visual word recognition by deaf and hearing children. Journal of Speech and Hearing Research, 3, 320-6.

Donders, F.C. (1868) Over de snelheid van psychische processen Onderzoekingen gedaan in het Physiologish Laboratorium der Utrechtsche Hoogeschool 1868-69. Tweede voor genees-en Natuurkunde, 4, 117-45. Translated by W.G. Koster (1969) On the speed of mental processes. Acta Psychologica, 30, 412-31.

Dornic, S., Hagdahl, R. and Hanson, G. (1973) Visual search and S.T.M. in the deaf. Report No. 38, Institute of Applied Psychology, University of Stockholm.

Dunn, O.J and Clark, V.A. (1974) Applied statistics:analysis of variance and regression. New York:Wiley.

Eimas, P.D. (1975) Distinctive feature codes in the S.T.M. of children. Journal of Experimental Child Psychology, 19,241-51.

Erber, N.P. (1974) Visual perception of speech by deaf children:recent developments and continuing needs. Journal of Speech and Hearing Disorders, 39 (2), 178-85.

Espeseth, V.K. (1969) An investigation of visual-sequential memory in deaf children. American Annals of the Deaf, 114, 786-9.

Evans, L. (1976) Communication in question. In: The Harrogate Papers: Four papers given at the R.N.I.D./N.C.T.D. Education Meeting at Harrogate on 30th October 1976, pp. 15-24. London: R.N.I.D.

Ewing, A.W.G. and Ewing, E.C. (1964) Teaching deaf children to talk. Manchester University Press.

Ewing, I.R. and Ewing A.W.G. (1950) Opportunity and the deaf child (2nd ed.) University of London Press.

Faarborg-Andersen, K. (1957) Electromyographic laryngeal muscles in humans. Acta Physiologia Scandinavica, 41, Supplement 140, 1-149.

Faarborg-Andersen, K. and Edfeldt, A.W. (1958) Electromyography of intrinsic and extrinsic laryngeal muscles during silent speech:correlation with reading activity. Acta-oto-laryngologica, 49, 478-82.

Fisher, C.G. (1968) Confusions among visually perceived consonants. Journal of Speech and Hearing Research, 11, 796-804.

Fisher, D.F., Monty, R.A. and Glucksberg, S. (1969) Visual confusion matrices:fact or artefact? Journal of Psychology, 71, 111-25.

Forster, K.I. and Chambers, S.M. (1973) Lexical access and naming time. Journal of Verbal Learning and Verbal Behaviour, 12, 627-35.

Fowler, R. (1974) Understanding language:an introduction to linguistics. London:Routledge and Kegan Paul.

Fraser, G.M. and Blockley, J. (1973) The language disordered child:a new look at theory and treatment. London:National Foundation for Educational Research.

Freeman, N.H. (1975) Temporal and spatial ordering in recall by five-to eight-year-old children. Child Development, 46, 237-9.

Friedman, A. (1978) Memorial comparisons without the "mind's eye". Journal of Verbal Learning and Verbal Behaviour, 17, 165-74.

Frumkin, B. and Anisfeld, M. (1977) Semantic and surface codes in memory of deaf children. Cognitive Psychology, 9, 475-93.

Furth, H.G. (1964) Research with the deaf:implications for language and cognition. Psychological Bulletin, 62 (3), 145-64.

Furth, H.G. (1966a) Thinking without language: psychological implications of deafness. London: Collier-Macmillan Ltd.

Furth, H.G. (1966b) A comparison of reading test norms of deaf and hearing children. American Annals of the Deaf, 111, 461-2.

Furth, H.G. (1970) Piaget for teachers. Englewood Cliffs, New Jersey: Prentice Hall.

Furth, H.G. (1971) Linguistic deficiency and thinking: research with deaf subjects 1964-9. Psychological Bulletin, 76 (1), 58-72.

Furth, H.G. (1973) Deafness and hearing: a psychosocial approach. Belmont, California: Wadsworth Publishing Company.

Furth, H.G. and Pufall, P.B. (1966) Visual and auditory sequence learning in hearing-impaired children. Journal of Speech and Hearing Research, 9, 441-9.

Fusfeld, I.S. (1955) The academic program of schools for the deaf. Volta Review, 57, 63-70.

Fusfeld, I.S. (1958) How the deaf communicate - written language. American Annals of the Deaf, 103, 255-63.

Garner, W.R. (1970) The stimulus in information processing. American Psychologist, 25, 350-8.

Gates, A.I. and Chase, E.H. (1926) Methods and theories of learning to spell tested by studies of deaf children. Journal of Educational Psychology, 17, 289-300.

Gates, R. (1971) The reception of verbal information by deaf students through a television medium - a comparison of speech reading, manual communication and reading. In: The Proceedings of the Convention of American Instructors of the Deaf. Washington D.C.: American Annals of the Deaf, pp. 513-22.

Gellatly, A.R.H. and Gregg, V.H. (1977) Intercategory distance and categorisation times: effects of negative-probe relatedness. Journal of Verbal Learning and Verbal Behaviour, 16, 505-18.

Gemmill, J.E. and John, J.E.J. (1977) A study of samples of spontaneous spoken language from hearing-impaired children. Teacher of the Deaf, 1 (6), 193-201.

Gibson, E.J. (1969) Principles of perceptual learning. New York:Prentice Hall.

Gibson, E.J. (1971) Perceptual learning and the theory of word perception. Journal of Cognitive Psychology, 2, 351-68.

Gibson, E.J. and Levin, H. The psychology of reading. Cambridge, Mass.: M.I.T. Press.

Gibson, E.J., Shurcliff, A. and Yonas, A. (1968) Utilisation of spelling patterns by deaf and hearing subjects. In: H. Levin, E.J. Gibson and J.J. Gibson (Eds.) The analysis of reading skill: a program of basic and applied research. Washington: U.S. Office of Education Bureau of Research.

Goda, S. (1959) Lanugage skills of profoundly deaf adolescent children. Journal of Speech and Hearing Research, 2, 369-76.

Goodnow, J.G. (1972) Rules and repertories, rituals and tricks of the trade: social and informational aspects to cognitive and representational development. Chapter 5 in: S. Farnham-Diggory (Ed.) Information processing in children. New York: Academic Press, pp. 83-102.

Greenwald, A.G. (1976) Within-subjects designs:to use or not to use? Psychological Bulletin, 83 (2), 314-20.

Haber, R.N. (1970) How we remember what we see. Scientific American, 220, 104-12.

Hawkins, H.L., Reicher, G., Rogers, M. and Peterson, L. (1976) Flexible coding in word recognition. Journal of Experimental Psychology: Human Perception and Performance, 2, 380-5.

Hays, W.L. (1963) Statistics. New York: Holt, Rinehart and Winston.

Healy, A.F. (1975) Short-term retention of temporal and spatial order. Bulletin of the Psychonomic Society, 5, 57-8.

Heider, F. and Heider, G.M. (1940) A comparison of sentence structure of deaf and hearing children. Psychological Monographs, 52 (1), whole no. 232, 42-103.

Henderson, L. (1972) Visual and verbal codes: spatial information survives the icon. Quarterly Journal of Experimental Psychology, 24, 439-47.

Henderson, S.E. and Henderson, L. (1973) Levels of visual-information processing in deaf and hearing children. American Journal of Psychology, 86 (3), 507-21.

Hermelin, B. and O'Connor, N. (1973) Ordering in recognition memory after ambiguous initial and recognition displays. Canadian Journal of Psychology, 27, 191-9.

Hintzman, D.L. (1967) Articulation coding in short-term memory. Journal of Verbal Learning and Verbal Behaviour, 6, 312-16.

Hockett, C.D. (1960) The origin of speech. Scientific American, 203 (3) 88-96.

Hodge, D.C. (1962) Legibility of a uniform-strokewidth alphabet: I Relative intelligibility of upper and lower case letters. Journal of Engineering Psychology, 1, 34-46.

Hoemann, H.W. (1974) Deaf children's use of fingerspelling to label pictures of common objects: a follow-up study. Exceptional Children, 40, 519-20.

Hoemann, H.W., Andrews, C.E., Florian, V.A., Hoemann, S.A. and Jensema, C.J. (1976) The spelling proficiency of deaf children. American Annals of the Deaf, 121, 489-93.

Hofmarksrichter, K. (1931) Visuelle Kompensation und Eidetik bei Taubstummen: vergleichende Untersuchungen an Taubstummen und Vollsinnigen. Archiv für die gesamte Psychologie, 82, 329-402.

Howarth, C.I. and Wood, D.J. (1977) A research programme on the intellectual development of deaf children. Teacher of the Deaf, 1 (1), 5-12.

Humphreys, M.S. (1978) Item and relational information: a case for context independent retrieval. Journal of Verbal Learning and Verbal Behaviour, 17, 175-89.

Ingram, R.M. (1977) Principles and procedures of teaching sign language. Carlisle: British Deaf Association.

Isaacs, S. (1965) The children we teach: 7 to 11 years. (2nd ed.) University of London Press.

Ivimey, G.P. (1973) Teach your child to be deaf and dumb. Talk, No. 68, 22-3.

Ivimey, G.P. (1976) The written syntax of an English deaf child: an exploration in method. British Journal of Disorders of Communication, 11, (2), 103-20.

Ivimey, G.P. (1977) The perception of speech: an information-processing approach, part 3 - lip-reading and the deaf. Teacher of the Deaf, 1 (3), 90-100.

Jacobson, E. (1932) Electrophysiology of mental activities. American Journal of Psychology, 44, 677-91.

Jakobson, R. (1967) On the relations between visual and auditory signs. In: Selected writings II. The Hague:Mouton

Jakobson, R., Fant, C.G.M. and Halle, M. (1963) Preliminaries to speech analysis: the distinctive features and their correlates. (2nd ed.) Cambridge, Mass.:M.I.T. Press

Jakobson, R. and Halle, M. (1956) Fundamentals of language. The Hague: Mouton.

James, W. (1890) The principles of Psychology, Vol. 1. New York: Holt.

Johnson, E.H. (1948) The ability of pupils in a school for the deaf to understand various methods of communication. American Annals of the Deaf, 93, 194-213 and 258-314.

Jonckheere, A.R. (1954) A distribution-free k-sample test against ordered alternatives. Biometrika, 41, 133-45.

Kaplan, G.A., Yonas, A. and Shurcliff, A. (1966) Visual and acoustic confusability in a visual search task. Perception and Psychophysics, 1, 172-4.

Kates, S. (1972) Language development in deaf and hearing adolescents. Northampton, Mass.:Clarke School for the Deaf.

Kendall, M.G. (1970) Rank correlation methods. (4th ed.) London: Charles Griffin and Company Ltd.

Keppel, G. (1976) Discussion of Wike and Church's comments: words as random variables. Journal of Verbal Learning and Verbal Behaviour, 15, 263-65.

Kieras, D.E. (1978) Good and bad structure in simple paragraphs: effects on apparent theme, reading and recall. Journal of Verbal Learning and Verbal Behaviour, 17, 13-28.

Kirk, R.E. (1968) Experimental design: procedures for the behavioural sciences. Belmont, California: Brooks-Cole Publishing Company.

Kleiman, G.M. (1975) Speech recoding in reading. Journal of Verbal Learning and Verbal Behaviour, 14, 323-39.

Kolers, P.A. (1972) Some problems of classification. In: Language by ear and by eye: the relationships between speech and reading. (Eds.) J.F. Kavanagh and I.G. Mattingly. Cambridge, Mass.: M.I.T. Press.

Koplin, J.H., Odom, P.B., Blanton, R.L. and Nunnally, J.C. (1967) Word association test performance of deaf subjects. Journal of Speech and Hearing Research, 10, 126-32.

Kroll, N.E.A., Parks, T., Parkinson, S.R., Bieber, S.L. and Johnson, A.L. (1970) S.T.M. while shadowing: recall of visually and aurally presented letters. Journal of Experimental Psychology, 85, 220-24.

Kuennapas, T. (1966) Visual perception of capital letters. Scandinavian Journal of Psychology, 7, 189-96.

Kuennapas, T. (1967) Visual memory of capital letters: multidimensional ratio scaling and similarity. Perceptual and Motor Skills, 25, 345-50.

Kuennapas, T. and Janson, A.J. (1969) Multidimensional similarity of letters. Perceptual and Motor Skills, 28, 3-12.

Laberge, D. and Samuels, S.J. (1974) Towards a theory of automatic information processing and reading. Cognitive Psychology, 6, 293-323.

Labov, W. (1972) Language in the Inner City: studies in Black English Vernacular. Philadelphia: University of Pennsylvania Press.

Landauer, T.K. (1962) Rate of implicit speech. Perceptual and Motor Skills, 15, p.646.

Lane, H.S. (1976) The profoundly deaf: has all education succeeded? Volta Review, 78, 329-40.

Lane, H., Boyes-Braem, P. and Bellugi, U. (1976) Preliminaries to a distinctive feature analysis of handshapes in A.S.L. Cognitive Psychology, 8, 263-89.

Laughery, K.R. and Harris, G.J. (1970) Visual and auditory intrusion errors in S.T.M. Journal of Experimental Psychology, 83 (1), 101-6.

Laughery, K.R., Welte, J.W. and Spector, A. (1973) Acoustic and visual coding in primary and secondary memory. Journal of Experimental Psychology, 99 (3), 323-9.

Levine, E.S. (1976) Psychological contributions. Chapter 4 in:A Bicentennial Monograph on hearing impairment:trends in the U.S.A. (Ed.) R. Frisina. Volta Review, 78, (4).

Levy, B.A. (1971) Role of articulation in auditory and visual S.T.M. Journal of Verbal Learning and Verbal Behaviour, 10, 123-32.

Lewis, M.M. (1968) Language and personality in deaf children. London: National Foundation for Educational Research.

The Lewis Report (1968) The education of deaf children: the possible place of fingerspelling and signing. Report of the Committee appointed by the Secretary of State for Education and Science. London: HMSO.

Liben, L.S. and Drury, A.M. (1977) S.T.M. in deaf and hearing children in relation to stimulus characteristics. Journal of Experimental Child Psychology, 24, 60-73.

Locke, J.L. (1970a) Sub-vocal speech and speech. Journal of the American Speech and Hearing Association, 12 (1), 7-14.

Locke, J.L. (1970b) S.T.M. encoding strategies in the deaf. Psychonomic Science, 18, 233-4.

Locke, J.L. (1973) Children's language coding in S.T.M. Language and Speech, 16, 271-8.

Locke, J.L. (1978) Large auditory and small visual effects in the recall of consonant letters. American Journal of Psychology, 91 (1), 89-92.

Locke, J.L. and Fehr, F.S. (1970) Subvocal rehearsal as a form of speech. Journal of Verbal Learning and Verbal Behaviour, 9, 495-8.

Locke, J.L. and Locke, V.L. (1971) Deaf children's phonetic, visual and dactylic coding in a graphemic recall task. Journal of Experimental Psychology, 89 (1), 142-6.

Luria, A.R. and Yudovich, F.I. (1956) Speech and the development of mental processes in the child. English translation published by Harmondsworth Middsx.: Penguin Education, 1971.

MacGinitie, W.H. (1964) Ability of deaf children to use different word classes. Journal of Speech and Hearing Research, 7, 141-50.

Mandler, G. and Anderson, R.E. (1971) Temporal and spatial cues in seriation. Journal of Experimental Psychology, 90 (1), 128-35.

Max, L.W. (1937) An experimental study of the motor theory of consciousness IV. Action-current responses in the deaf during awakening, kinaesthetic imagery and abstract thinking. Journal of Comparative Psychology, 24, 301-44.

McDougall, R. (1904) Recognition and recall. Journal of Philosophy, 11, 229-33.

McFarland, C.E., Duncan, E.M. and Kellas, G. (1978) Isolating the typicality effect in semantic memory. Quarterly Journal of Experimental Psychology 30, 251-62.

McGuigan, F.J. (1967) Feedback of speech muscle activity during silent reading. Science, 175, 579-80.

McGuigan, F.J. (1970) Covert oral behaviour during the silent performance of language tasks. Psychological Bulletin, 74, 309-26.

McGuigan, F.J. (1971) Covert linguistic behaviour in deaf subjects during thinking. Journal of Comparative and Physiological Psychology, 75 (3), 417-20.

McNeill, D. (1966a) The capacity for language acquisition. Volta Review, 68, 17-33.

McNeill, D. (1966b) Developmental psycholinguistics. In: The genesis of language: a psycholinguistic approach. (Eds.) F. Smith and G.A. Miller. Cambridge, Mass: M.I.T. Press, pp. 15-84.

McNeill, D. (1970) The acquisition of language: the study of developmental psycholinguistics. New York: Harper & Row.

Meadow, K.P. (1968) Early manual communication in relation to the deaf child's intellectual, social and communicative functioning. American Annals of the Deaf, 113, 29-41.

Menyuk, P. (1971) The acquisition and development of language. Englewood Cliffs, N.J.: Prentice-Hall.

Meyer, D.E. and Schvaneveldt, R.W. (1971) Facilitation in recognising pairs of words: evidence of a dependence between retrieval operations. Journal of Experimental Psychology, 90 (2), 227-34.

Meyer, D.E., Schvaneveldt, R.W. and Ruddy, M.G. (1973) Loci of contextual effects of visual word-recognition. In: P.Rabbitt (Ed.) Attention and Performance V, New York: Academic Press.

Meyer, D.E., Schvaneveldt, R.W. and Ruddy, M.G. (1974) Functions of graphemic and phonemic codes in visual word-recognition. Memory and Cognition, 2 (2), 309-21.

Miller, G.A. (1956) The magical number seven plus or minus two: some limits on our capacity for processing information. Psychological Review, 63, (2), 81-96.

Miller, G.A., Bruner, J.S. and Postman, L. (1954) Familiarity of letter sequences and tachistoscopic identification. Journal of General Psychology, 50, 129-39.

Miller, G.A., Heise, G.A. and Lichten, W. (1951) The intelligibility of speech as a function of the context of the test materials. Journal of Experimental Psychology, 41, 329-35.

Miller, G.A. and Nicely, P.E. (1955) An analysis of perceptual confusions among some English consonants. Journal of Acoustical Society of America, 27 (2), 338-52.

Montgomery, G.W. (1966) The relationship of oral skills to manual communication in profoundly deaf students. American Annals of the Deaf, 111, 557-65.

Moores, D.F. (1970a) An investigation of the psycholinguistic functioning of deaf adolescents. Exceptional Children, 36, 645-52.

Moores, D.F. (1970b) Psycholinguistics and deafness. American Annals of the Deaf, 115, 37-48.

Moores, D. (1971) Recent research on manual communication. Occasional Paper No 7, University of Minnesota: Research, Development and Demonstration Centre in the education of handicapped children.

Moores, D.F. (1974) Non-vocal systems of verbal behaviour. Chapter 15 in: Language perspectives - acquisition, retardation and intervention. (Eds.) R.L. Schiefelbusch and L.L. Lloyd. London:Macmillan.

Morkovin, B.V. (1960) Experiment in teaching deaf preschool children in the Soviet Union. Volta Review, 62, 260-8.

Moulton, R.D. and Beasley, D.S. (1975) Verbal coding strategies used by hearing-impaired individuals. Journal of Speech and Hearing Research, 18 (3), 559-70.

Moyle, D. et al. (1973) Readability of newspapers. Edge Hill College of Education. Cited in: A language for life. London:H.M.S.O., 1975.

Murray, D.J. (1968) Acoustic confusability in S.T.M. Journal of Experimental Psychology, 78 (4), 679-84.

Myklebust, H.R. (1964) The psychology of deafness: sensory deprivation, learning and adjustment. (2nd ed.) New York: Grune and Stratton.

Myklebust H.R. and Brutten, M. (1953) A study of the visual perception of deaf children, Acta-oto-laryngologica, Stockholm supplement no. 105.

Neisser, U. (1967) Cognitive psychology. New York: Academic Press.

Neville, H. (1976) The functional significance of cerebral specialisation. Chapter 9 in: The neuropsychology of language: essays in honour of Eric Lenneberg (Ed.) R.W. Rieber. London:Plenum Press.

Nickerson, R.S. (1965) Response times for 'same'-'different' judgements. Perceptual and Motor Skills, 20, 15-18.

Nickerson, R.S. (1968) Note on 'same'-'different' response times. Perceptual and Motor Skills, 27, 565-6.

Norman, D.A. and Bobrow, D.G. (1975) On data-limited and resource-limited processes. Cognitive Psychology, 7, 44-64.

Novikova, L.A. (1961) Electrophysiological investigation of speech. In: Recent Soviet Psychology. (Ed.) N. O'Connor. New York: Liveright Publishing.

Nunnally, J.C. and Blanton, R.L. (1966) Patterns of word association in the deaf. Psychological Reports, 18 (1), 87-92

O'Connor, J.D. (1973) Phonetics. Harmondsworth, Middsx.:Penguin.

O'Connor, N. and Hermelin, B. (1972) Seeing and hearing and space and time. Perception and Psychophysics, 11, 46-8.

O'Connor, N. and Hermelin, B. (1973) The spatial or temporal organisation of S.T.M. Quarterly Journal of Experimental Psychology, 25, 335-43.

O'Connor, N. and Hermelin, B. (1976) Backward and forward recall by deaf and hearing children. Quarterly Journal of Experimental Psychology, 28, 83-92.

Odom, P.B. and Blanton, R.L. (1967) Phrase-learning in deaf and hearing subjects. Journal of Speech and Hearing Research, 10, 600-5.

Odom, P.B. and Blanton, R.L. (1970) Implicit and explicit grammatical factors and reading achievement in the deaf. Journal of Reading Behaviour, 2 (1), 47-55.

Odom, P.B., Blanton, R.L. and McIntyre, C.K. (1970) Coding medium and word recall by deaf and hearing subjects. Journal of Speech and Hearing Research, 13 (1), 54-8.

Olsson, J.E. and Furth, H.G. (1966) Visual memory-span in the deaf. American Journal of Psychology, 79, 480-4.

Paivio, A. (1971) Imagery and verbal processes. New York: Holt, Rinehart and Winston.

Paivio, A. and Csapo, K. (1969) Concrete image and verbal memory codes. Journal of Experimental Psychology, 80 (2), 279-85.

Parks, T.E., Kroll, N.E.A., Salzberg, P.M. and Parkinson, S.R. (1972) Persistence of visual memory as indicated by decision time in a matching task. Journal of Experimental Psychology, 92 (3), 437-8.

Perry, F.R. (1968) The psycholinguistic abilities of deaf children - an exploratory investigation. Australian Teacher of the Deaf, 9 (3), 153-60.

Peterson, L.R. and Johnson, S.T. (1971) Some effects of minimising articulation on short-term retention. Journal of Verbal Learning and Verbal Behaviour, 10, 346-54.

Phillips, R.J. (1979) Recognition, recall and imagery of faces. The Proceedings of the International Symposium on practical aspects of memory. (Eds.) M.M. Gruneberg, R.N. Sykes and P.E. Morris. London: Academic Press.

Phillips, W.A. (1974) On the distinction between sensory storage and short-term visual memory. Perception and Psychophysics, 16 (2), 283-90.

Phillips, W.A. and Baddeley, A.D. (1971) Reaction time and short-term visual memory. Psychonomic Science, 22 (2), 73-4.

Pinkus, A.L. and Laughery, K.R. (1967) Short-term memory:effects of acoustic similarity, presentation rate and presentation mode. Psychonomic Science, 6 (6), 285-6.

Pintner, R. and Paterson, D.G. (1915) The Binet Scale and the deaf child. Journal of Educational Psychology, 6, 201-10.

Pintner, R. and Paterson, D.G. (1916) A measurement of the language of deaf children. Psychological Review, 23, 413-36.

Pintner, R. and Paterson, D.G. (1917) Psychological tests for deaf children. Volta Review, 19, 661-7.

Pintner, R. and Paterson, D.G. (1918) Some conclusions from psychological tests of the deaf, Volta Review, 20 (1), 10-14.

Pit Corder, S. (1973) Introducing applied linguistics. Harmondsworth, Middsx.: Penguin Education, pp.115-16.

Posner, M.I. (1967) Characteristics of visual and kinaesthetic memory codes Journal of Experimental Psychology, 75 (1), 103-7.

Posner, M.I. (1969) Abstraction and the process of recognition. In:The psychology of learning and motivation: advances in research and theory, vol. III. (Eds.) G.H. Bower and J.T. Spence. New York: Academic Press.

Posner, M.I. (1970) On the relationship between letter names and superordinate categories. Quarterly Journal of Experimental Psychology, 22, 279-87.

Posner, M.I. (1974) Coordination of internal codes. In: Visual information processing. (Ed.) W.G. Chase. NewYork: Academic Press.

Posner, M.I., Boies, S.J., Eichelman, W.H. and Taylor, R.L. (1969) Retention of visual and name codes of single letters. Journal of Experimental Psychology Monograph, 79, no.1 (2), 1-16.

Posner, M.I. and Keele, S.W. (1967) Decay of visual information from a single letter. Science, 158, 137-9.

Posner, M.I., Lewis, J.L. and Conrad, C. (1972) Component processes in reading: a performance analysis. In: Language by ear and by eye: the relationship between speech and reading. (Eds.) J.F. Kavanagh and I.G. Mattingly. Cambridge, Mass.: M.I.T. Press.

Posner, M.I. and Mitchell, R.F. (1967) Chronometric analysis of classification. Psychological Review, 74 (5), 392-409.

Posner, M.I. and Taylor, R.L. (1969) Subtractive method applied to separation of visual and name components of multi-letter arrays. Acta Psychologica, 30, 104-14.

Postman, L. and Rau, L. (1957) Retention as a function of the method of presentation. Berkeley: University of California Publication in Psychology. Cited in: J.A. Adams. Human Memory. New York: McGraw Hill, 1967.

Poulton, E.C. (1973) Unwanted range effects from using within-subject experimental designs. Psychological Bulletin, 80 (2), 113-21.

Pressnell, L.M. (1973) Hearing-impaired children's comprehension and production of syntax in oral language. Journal of Speech and Hearing Research, 16, 12-21.

Putnam, V., Iscoe, I. and Young, R.K. (1962) Verbal learning in the deaf. Journal of Comparative and Physiological Psychology, 55 (5), 843-6.

Pufall, P.B. and Furth, H.G. (1966) Recognition and learning of visual sequences in young children. Child Development, 37, 827-36.

Quigley, S.P. (1972) Educational implications of research on manual communication. Division for Children with Communication Disorders Newsletter (Spring) 8:2, 4-12.

Quigley, S.P., Montanelli, D.S. and Wilbur, R.B. (1976) Some aspects of the verb system in the language of deaf students. Journal of Speech and Hearing Research, 19 (3), 536-50.

Rabbitt, P.M.A. (1968) Repetition effects and signal classification strategies in serial choice-response tasks. Quarterly Journal of Experimental Psychology, 20, 232-40.

Ross, B. (1969) Sequential visual memory and the limited magic of the number seven. Journal of Experimental Psychology, 80 (2), 339-47.

Rothstein, L.D. (1974) Reply to Poulton. Psychological Bulletin, 81 (3) 199-200.

Rozanova, T.V. (1970) Memory of words in deaf children (article written in Russian) Defectologia, 3, 8-15.

Rubenstein, H., Lewis, S.S. and Rubenstein, M.A. (1971a) Homographic entries in the internal lexicon: effects of systematicity and relative frequency of meanings. Journal of Verbal Learning and Verbal Behaviour, 10, 57-62.

Rubenstein, H., Lewis, S.S. and Rubenstein, M.A. (1971b) Evidence for phonemic recoding in visual word-recognition. Journal of Verbal Learning and Verbal Behaviour, 10, 645-7.

Rubenstein, H., Richter, M.L. and Kay, E.J. (1975) Pronounceability and the visual recognition of nonsense words. Journal of Verbal Learning and Verbal Behaviour, 14, 651-57.

Sarachan-Deily, A.B. and Love, R.J. (1974) Underlying grammatical rule structure in the deaf. Journal of Speech and Hearing Research, 17 (4), 689-98.

Schein, J.D. (1977) Current priorities in deafness. Volta Review, 79 (3) 162-74.

Schlesinger, H.S. and Meadow, K.P. (1972) Sound and sign:childhood deafness and mental health. University of California Press.

Schulman, H.G. (1971) Similarity effects in S.T.M. Psychological Bulletin, 75 (6), 399-415.

Sendelbaugh, J. and Powell, J.T. (1978) Television for the deaf: a comparative study of eleven nations. American Annals of the Deaf, 123, 31-4.

Shallice, T. and Warrington, E.K. (1970) Independent functioning of verbal memory stores: a neuropsychological study. Quarterly Journal of Experimental Psychology, 22, 261-73.

Siegel, S. (1956) Nonparametric statistics for the behavioural sciences. Tokyo: McGraw-Hill.

Simmons, H.A. (1962) A comparison of the type-token ratio of spoken and written language of deaf and hearing children. Volta Review, 64, 417-21.

Siple, P., Fischer, S.D. and Bellugi, U. (1977) Memory for non-semantic attributes of ASL signs and English words. Journal of Verbal Learning and Verbal Behaviour, 16, 561-74.

Smith, F. and Carey, P. (1966) Temporal factors in visual information processing. Canadian Journal of Psychology, 20 (3), 337-42.

Snodgrass, J.G. and Jarvella, R.J. (1972) Some linguistic determinants of word classification times. Psychonomic Science, 27 (4), 220-2.

Sperling, G. (1960) The information available in brief visual presentations. Psychological Monograph 74, No. 11.

Sperling, G. (1963) A model for visual memory tasks. Human Factors, 5, 19-31.

Sperling, G. (1967) Successive approximations to a model for short-term memory. Acta Psychologica, 27, 285-92.

Spoehr, K.T. (1978) Phonological encoding in visual word recognition. Journal of Verbal Learning and Verbal Behaviour, 17 (2), 127-42.

Stanners, R.F., Forbach, G.B. and Headley, D.B. (1971) Decision and search processes in word - nonword classification. Journal of Experimental Psychology, 90, 45-50.

Stein, B.S. (1978) Depth of processing re-examined: the effects of the precision of encoding and test appropriateness. Journal of Verbal Learning and Verbal Behaviour, 17, 165-74.

Sternberg, S. (1969) Memory scanning: mental processes revealed by reaction-time experiments. American Scientist, 57, 421-57.

Stokoe, W.C. (1960) Sign language structure: an outline of the visual communication systems of the American deaf. Studies in Linguistics, Occasional Paper No. 8, New York: University of Buffalo.

Stokoe, W.C. (1974) The study of sign language. Educational Resources Information Centre, Clearing House for Linguistics, Centre for Applied Linguistics, Office of Education Department of Health, Education and Welfare, Washington D.C.

Stokoe, W.C. (1975) The use of sign language in teaching English. American Annals of the Deaf, 120, 417-21.

Stokoe, W.C. (1976) The study and use of sign language. Sign Language Studies, 10, 1 - 36.

Stokoe, W.C., Casterline, D.C. and Croneberg, C.G. (1965) A dictionary of American Sign Language on linguistic principles. Washington D.C.: Gallaudet College Press.

Stuckless, E.R. and Birch, J.W. (1966) The influence of early manual communication on the linguistic development of deaf children. American Annals of the Deaf, 111, 452-60 and 499 - 504.

Stuckless, E.R. and Pollard, G. (1977) Processing of fingerspelling and print by deaf students. American Annals of the Deaf, 122, 475-9.

Templin, M. (1948) A comparison of the spelling achievement of normal and defective hearing subjects. Journal of Educational Psychology, 39, 337-46.

Tervoort, B.T. (1961) Esoteric symbolism inthe communication behaviour of young deaf children. American Annals of the Deaf, 106, 436-80.

Tervoort, B.T. (1975) Bilingual interference between acoustic and visual communication. In: The Proceedings of the International Congress on Education of the Deaf, Tokyo, August 25 - 28, 1975, pp. 319-22.

Thomassen, A.J.W.M. (1970) On the representation of verbal items in short-term memory. Nijmegen, Drukkerij Schippers.

Thompson, W.H. (1936) An analysis of errors in written composition by deaf children. American Annals of the Deaf, 81, 95-9.

Tinker, M.A. (1928) The relative legibility of the letters, the digits and of certain mathematical signs. Journal of General Psychology, 1, 87-96.

Tversky, B. (1969) Pictorial and verbal encoding in a short-term memory task. Perception and Psychophysics, 6, 225-33.

Underwood, B.J. (1964) Articulation in verbal learning. Journal of Verbal Learning and Verbal Behaviour, 3, 146-9.

Van Uden, A. (1970) A world of language for deaf children. Rotterdam University Press.

Vernon, M. (1968) 50 years of research on the intelligence of deaf and hard of hearing children: a review of the literature and discussion of implications. Journal of Rehabilitation of the Deaf, 1 (4), 1-12.

Vernon, M. (1969) Sociological and psychological factors with profound hearing loss. Journal of Speech and Hearing Research, 12, 541-63.

Vernon, M. (1974) Total communication. In: Spotlight on Communication, pp. 2-7. Carlisle: British Deaf Association.

Vernon, M. and Koh, S.D. (1970) Effects of early manual communication on achievement of deaf children. American Annals of the Deaf, 115, 527-36.

Vernon, M. and Koh, S.D. (1971) Effects of oral pre-school compared to early manual communication on education and communication in deaf children. American Annals of the Deaf, 116, 569-74.

Walker, J.H. (1973) Pronounceability effects on word-nonword encoding in categorisation and recognition tasks. Journal of Experimental Psychology, 99, 318-22.

Wallace, G. and Corballis, M.C. (1973) Short-term memory and coding strategies of the deaf. Journal of Experimental Psychology, 99 (3) 349-55.

Walter, J. (1955) A study of the written sentence construction of a group of profoundly deaf children. American Annals of the Deaf, 100, 335-52.

Walter, J. (1959) Some further observations on the written sentence construction of profoundly deaf children. American Annals of the Deaf 104, 282-5.

Warrington, E.K. and Shallice, T. (1972) Neuropsychological evidence of visual storage in S.T.M. tasks. Quarterly Journal of Experimental Psychology, 24, 30-40.

Whaley, C.P. (1978) Word-nonword classification time. Journal of Verbal Learning and Verbal Behaviour, 17, 143-54.

Wickelgren, W.A. (1965) Distinctive features and errors in short-term memory for English vowels. Journal of the Acoustical Society of America, 38, 583-88.

Wickelgren, W.A. (1966) Distinctive features and errors for English consonants. Journal of the Acoustical Society of America, 39, 388-98.

Wickelgren, W.A. (1969) Auditory or articulatory coding in verbal short-term memory. Psychological Review, 76 (2), 232-5.

Wike, E.L. and Church, J.D. (1976) Comments onClark's "The language-as-fixed-effect-fallacy". Journal of Verbal Learning and Verbal Behaviour, 15, 249-55.

Wilbur, R.B. (1977) An explanation of deaf children's difficulty with certain syntactic structures of English. Volta Review, 79 (2), 85-92.

Winer, B.J. (1971) Statistical principles in experimental design. (2nd ed.) New York: McGraw-Hill.

Withrow, F.B. (1968) Immediate memory span of deaf and normally hearing children. Exceptional Children, 35, 33-41.

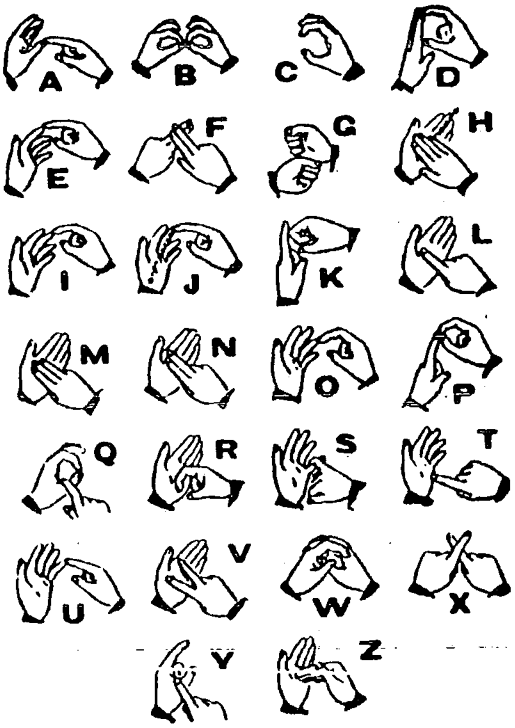
Wollman, D.C. and Hickmott, J. (1976) Language development for deaf pupils. Dialogue (Schools Council) No. 23, 6-7.

Woodford, D.E. (1973) Some aspects of fingerspelling as seen in schools for the deaf at the present time. Teacher of the Deaf, 74, 188-201.

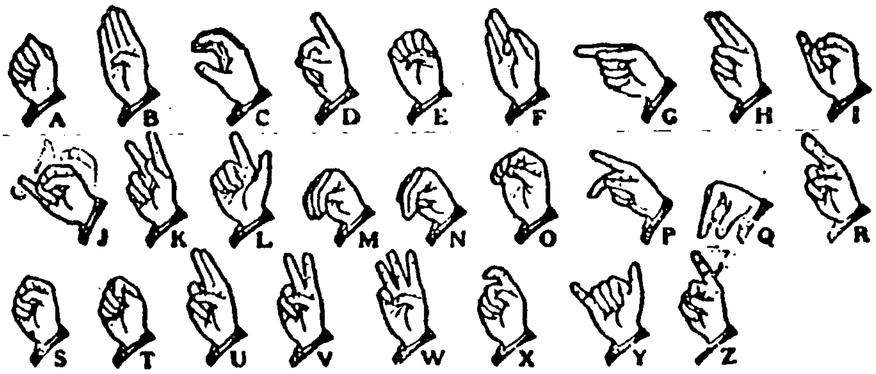
Wrightstone, J.W., Aronow, M.S. and Moskowitz, S. (1963) Developing reading test norms for deaf children. American Annals of the Deaf, 108, 311-6.

Zakia, R.D. and Haber, R.N. (1971) Sequential letter and word recognition in deaf and hearing subjects. Perception and Psychophysics, 9 (1B), 110-14.

## Appendix A : Manual Alphabets

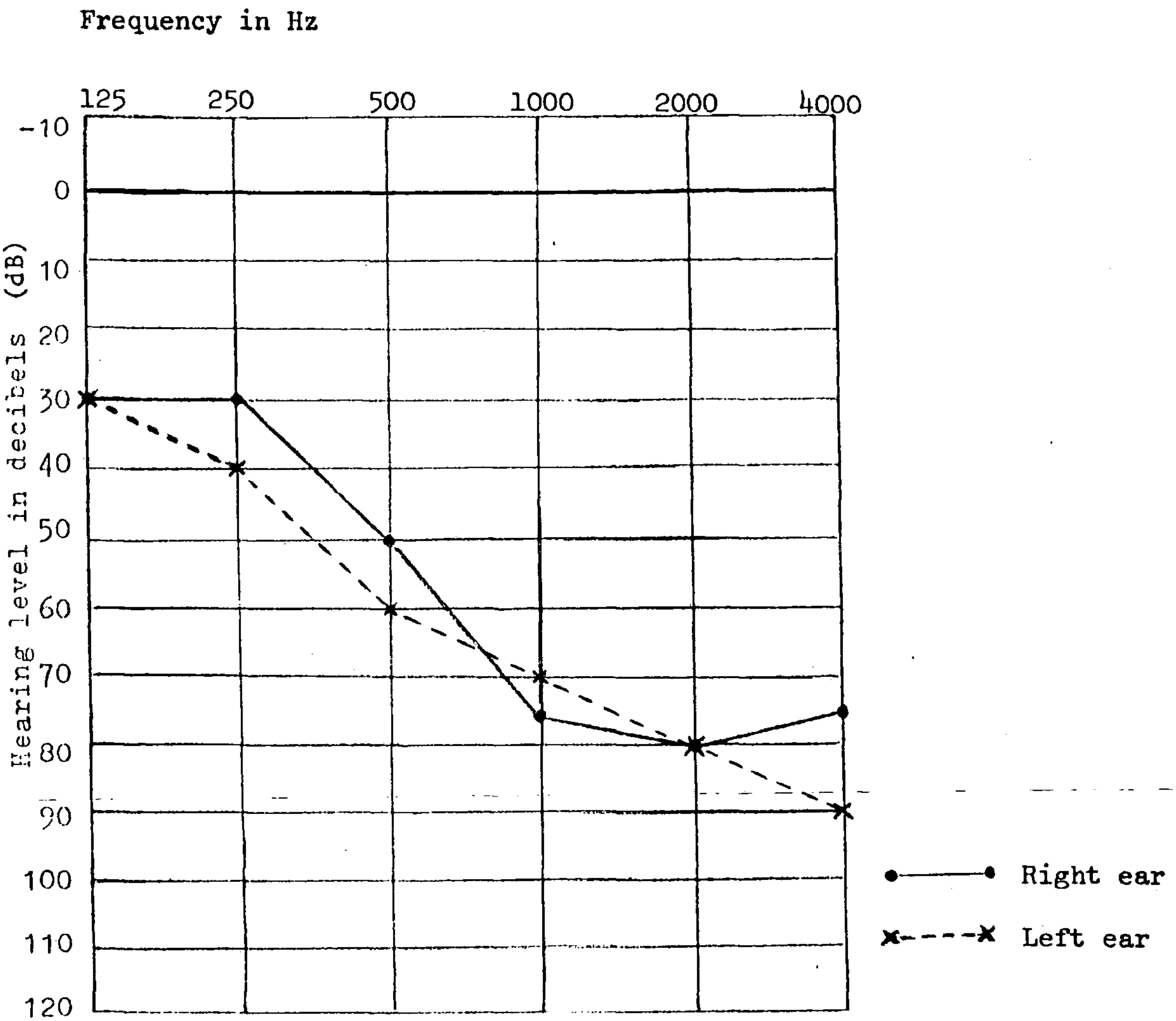


The two-handed manual alphabet that is most widely used in Britain.



The one-handed manual alphabet that is used in the United States, and which was introduced experimentally into the N.C.S.D. between 1973 and 1976.

## Appendix B : An example of a pure-tone audiogram



With a hearing loss such as is shown in the audiogram above, the individual would be aware of speech sounds, and would hear the low frequency components of speech at approximately normal levels, yet would be unable to interpret the speech because mainly vowel sounds would be heard, but only a few consonant sounds. This is an example of high-frequency deafness.

## Appendix C

### A descriptive analysis of the articulation of the 16 letters used in Experiment 1

O'Connor (1973) provided the linguistic basis to the articulatory phonetics necessary for the production of the two tables below (Tables C-1 and C-2).

Table C-1 The articulatory features possessed in common between the letter-pairs from List A.

| | ei | di: | ef | dzei | kei | es | ti: | eks |
|---|---|---|---|---|---|---|---|---|
| ei | I | | | | | | | |
| di: | - | I | | | | | | |
| ef | - | - | I | | | | | |
| dzei | b | VP | - | I | | | | |
| kei | b | M | V | b | I | | | |
| es | - | V | aVM* | P | V | I | | |
| ti: | - | bMP* | V | p | VM | VP | I | |
| eks | - | MP | aVM* | P | V | aVc* | MV | I |

*High articulatory similarity
dt, fs, fx, sx.

Key:

I = Identity

Vowel sounds:

a = identical vowel beginning

b = identical vowel ending

Consonant sounds:

c = identical consonant

V = same voicing

P = same place of articulatio

M = same mode of articulation

Table C-2 The articulatory features possessed in common between the letter pairs from List B.

| | bi: | eitʃ | em | en | kju: | vi: | dʌblju: | wai |
|---|---|---|---|---|---|---|---|---|
| bi: | I | | | | | | | |
| eitʃ | - | I | | | | | | |
| em | VP | - | I | | | | | |
| en | V | P | aMV* | I | | | | |
| kju: | M | V | - | - | I | | | |
| vi: | bVP* | - | VP | V | - | I | | |
| dʌblju: | - | - | - | - | b | - | I | |
| wai | P | - | P | - | - | P | - | I |

*High articulatory similarity:
bv, mn.

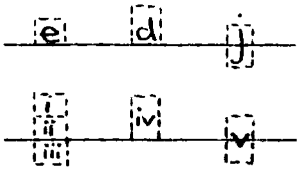
Key as above.

## Appendix D

## A descriptive analysis of the shape attributes of the 16 alphabet letters used in Experiment 1.

| The descriptive code used: | | Code | Feature |
|---|---|---|---|
| a) Linearity | - vertical | 1 | \| |
| | - horizontal | 2 | — |
| b) Angularity | | 3 | / |
| | | 4 | \ |
| c) Curvature | | 5 | C |
| | | 6 | Ↄ |
| | | 7 | ‿ |
| | | 8 | ⌒ |
| | | 9 | • |

Feature positions:



Code used for feature positions:

$1 \rightarrow 2$ = feature 2 occurs to the right of feature 1 (i.e. └ )

$1 \leftarrow 2$ = feature 2 occurs to the left of feature 1 (i.e. ┘ )

$1 \uparrow 2$ = feature 2 occurs above feature 1 (i.e. ⊤ )

$1 \downarrow 2$ = feature 2 occurs below feature 1 (i.e. ⊥ )

1;2 = features 1 and 2 are superimposed one upon the other (i.e. + ).

### The descriptive shape analysis of each of the letters in Lists A and B.

Letter-list A:

| | |
|---|---|
| a | $5^{ii} \rightarrow 1^{ii}$ |
| d | $5^{ii} \rightarrow 1^{iv}$ |
| f | $1^{iv} ; 2^{ii}{}_{\rightarrow}\uparrow 8^{i}$ |
| j | $7^{iii}{}_{\longrightarrow}\uparrow \; 1^{v} \uparrow 9^{i}$ |
| k | $1^{iv}{}_{\rightarrow} 3^{ii} \downarrow 4^{ii}$ |
| s | $5^{ii} \downarrow 6^{ii}$ |
| t | $1^{iv} ; 2^{ii} \downarrow_{\rightarrow} 7^{ii}$ |
| x | $3^{ii} ; 4^{ii}$ |

Letter-list B:

| | |
|---|---|
| b | $1^{iv}{}_{\rightarrow} 6^{ii}$ |
| h | $1^{iv} \rightarrow 8^{ii} \downarrow^{\rightarrow} 1^{ii}$ |
| m | $1^{ii} \rightarrow 8^{ii} \longrightarrow 1^{ii} \longrightarrow 8^{ii} \longrightarrow 1^{ii}$ |
| n | $1^{ii} \rightarrow 8^{ii} \longrightarrow 1^{ii}$ |
| q | $5^{ii} \rightarrow 1^{v} \rightarrow 3^{iii}$ |
| v | $4^{ii} \rightarrow 3^{ii}$ |
| w | $4^{ii} \rightarrow 3^{ii} \longrightarrow 4^{ii} \longrightarrow 3^{ii}$ |
| y | $4^{ii} \rightarrow 3^{v} \downarrow_{\leftarrow} 7^{iii}$ |

The two matrices below (Tables D-1 and D-2) show the degree of visual similarity between the possible pairing of the letters used in Experiment 1. The similarity coefficients are based on the number of shape attributes possessed in common, their relative positions, and membership of the three main categories of features, i.e. linearity, angularity and curvature.

Table D-1 Visual similarity coefficients for all the letter-pairs from List A.

| | a | d | f | j | k | s | t | x |
|---|---|---|---|---|---|---|---|---|
| a | - | | | | | | | |
| d | .75* | - | | | | | | |
| f | .2 | .4 | - | | | | | |
| j | .3 | .3 | .17 | - | | | | |
| k | .2 | .4 | .33 | .17 | - | | | |
| s | .5 | .3 | .2 | .1 | .2 | - | | |
| t | .4 | .4 | .75* | .33 | .67* | .2 | - | |
| x | .25 | .2 | .2 | 0 | .8* | .25 | .2 | - |

*High visual similarity
⩾.6: tk, ad, tf, kx.

Table D-2 Visual similarity coefficients for all the letter-pairs from List B.

| | b | h | m | n | q | v | w | y |
|---|---|---|---|---|---|---|---|---|
| b | - | | | | | | | |
| h | .7* | - | | | | | | |
| m | .36 | .75* | - | | | | | |
| n | .5 | .83* | .75* | - | | | | |
| q | .5 | .33 | .13 | .17 | - | | | |
| v | .25 | .2 | .29 | .4 | .4 | - | | |
| w | .17 | .14 | .44 | .29 | .22 | .67* | - | |
| y | .1 | 0 | .13 | .17 | .5 | .6* | .45 | - |

*High visual similarity
⩾.6: vy, wv, bh, hm, mn, hn.

Appendix E

The raw scores for the 11 factors used for the correlation coefficients and the mulitple regression analysis (Experiment 1)

Older age group:

|  |  | Memory span scores |  | (List A-ListB) | Age in | W.I.S.C. | Hearing Loss (better ear)** |  |  | Single letter-confusions from Lists A and B together. |  |  |  |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| S | AI score | List A | List B | Difference(d) | months | performance grade* | High Frequency | Low Frequency | Reading age in months | Visual (VS) | Articulatory (AS) | Distinctive (D) | Total |
| 1 | 0 | 3.4 | 3.1 | .3 | 190 | 2 | 3 | 4 | 84 | 3 | 0 | 6 | 9 |
| 2 | 0 | 3.1 | 2.9 | .2 | 151 | 2 | 4 | 4 | 90 | 4 | 1 | 7 | 12 |
| 3 | 0 | 6.4 | 5.0 | 1.4 | 151 | 5 | 4 | 4 | 96 | 5 | 1 | 7 | 13 |
| 4 | 1 | 3.5 | 3.1 | .4 | 160 | 2 | 4 | 4 | 87 | 8 | 0 | 10 | 18 |
| 5 | 1 | 3.6 | 3.0 | .6 | 160 | 4 | 4 | 4 | 81 | 6 | 1 | 8 | 15 |
| 6 | 1 | 3.5 | 3.8 | - .3 | 190 | 2 | 4 | 4 | 86 | 4 | 0 | 10 | 14 |
| 7 | 2 | 3.8 | 3.9 | - .1 | 182 | 3 | 3 | 4 | 84 | 5 | 3 | 8 | 16 |
| 8 | 2 | 2.9 | 2.8 | .1 | 175 | 1 | 3 | 4 | 90 | 6 | 1 | 9 | 16 |
| 9 | 3 | 3.5 | 3.3 | .2 | 163 | 3 | 4 | 4 | 91 | 8 | 1 | 3 | 12 |
| 10 | 3 | 3.5 | 3.4 | .1 | 173 | 3 | 3 | 4 | 90 | 7 | 0 | 5 | 12 |
| 11 | 4 | 4.3 | 4.3 | 0 | 185 | 5 | 3 | 4 | 96 | 1 | 3 | 5 | 9 |
| 12 | 4 | 4.0 | 4.0 | 0 | 186 | 5 | 4 | 4 | 93 | 4 | 2 | 4 | 10 |
| 13 | 5 | 3.7 | 3.6 | .1 | 159 | 4 | 3 | 4 | 91 | 4 | 1 | 1 | 6 |
| 14 | 5 | 2.6 | 2.6 | 0 | 196 | 3 | 4 | 4 | 100 | 4 | 3 | 5 | 12 |
| 15 | 5 | 3.8 | 3.6 | .2 | 169 | 3 | 3 | 3 | 91 | 1 | 0 | 6 | 7 |
| 16 | 6 | 3.6 | 3.5 | .1 | 194 | 2 | 3 | 4 | 90 | 4 | 0 | 8 | 12 |
| 17 | 6 | 3.4 | 3.5 | - .1 | 184 | 2 | 4 | 4 | 91 | 2 | 2 | 6 | 10 |
| 18 | 6 | 3.8 | 3.3 | .5 | 180 | 3 | 4 | 4 | 97 | 4 | 3 | 5 | 12 |
| 19 | 6 | 3.6 | 4.1 | - .5 | 174 | 5 | 4 | 4 | 89 | 6 | 1 | 4 | 11 |
| 20 | 7 | 3.4 | 3.1 | .3 | 178 | 2 | 4 | 4 | 92 | 4 | 2 | 6 | 12 |
| 21 | 7 | 4.5 | 4.5 | 0 | 153 | 5 | 3 | 4 | 96 | 2 | 1 | 7 | 10 |
| 22 | 7 | 4.1 | 4.3 | - .2 | 191 | 3 | 3 | 4 | 93 | 2 | 3 | 6 | 11 |
| 23 | 8 | 5.6 | 4.6 | 1.0 | 177 | 5 | 4 | 4 | 115 | 3 | 2 | 4 | 9 |
| 24 | 8 | 3.1 | 2.6 | .5 | 182 | 1 | 3 | 3 | 88 | 3 | 1 | 8 | 12 |
| 25 | 10 | 4.4 | 4.5 | - .1 | 200 | 3 | 3 | 4 | 109 | 1 | 2 | 2 | 5 |
| 26 | 10 | 3.3 | 3.9 | - .6 | 154 | 2 | 3 | 3 | 88 | 2 | 3 | 5 | 10 |
| 27 | 11 | 3.0 | 2.8 | .2 | 165 | 3 | 3 | 3 | 87 | 5 | 5 | 3 | 13 |
| 28 | 11 | 2.9 | 2.9 | 0 | 175 | 2 | 2 | 3 | 86 | 5 | 3 | 3 | 11 |
| 29 | 11 | 4.1 | 4.6 | - .5 | 189 | 5 | 2 | 3 | 84 | 1 | 10 | 4 | 15 |
| 30 | 11 | 2.8 | 3.3 | - .5 | 153 | 2 | 2 | 3 | 91 | 0 | 8 | 2 | 10 |
| 31 | 11 | 4.0 | 4.0 | 0 | 200 | 4 | 2 | 3 | 96 | 5 | 2 | 3 | 10 |
| 32 | 11 | 3.6 | 4.5 | - .9 | 199 | 2 | 2 | 3 | 102 | 2 | 3 | 2 | 7 |
| 33 | 12 | 3.5 | 3.3 | .2 | 195 | 3 | 2 | 3 | 87 | 3 | 6 | 8 | 17 |
| 34 | 12 | 4.6 | 4.4 | .2 | 190 | 5 | 2 | 3 | 100 | 4 | 2 | 4 | 10 |
| 35 | 13 | 4.0 | 3.9 | .1 | 172 | 4 | 3 | 3 | 102 | 1 | 4 | 2 | 7 |
| 36 | 13 | 2.9 | 3.0 | - .1 | 157 | 2 | 2 | 3 | 89 | 2 | 6 | 5 | 13 |

Note: * 5 > 120
4 111-120
3 101-110
2 91-100
1 80- 90

Note: ** 2 moderate (45 - 60dB)
3 severe (61 - 89dB)
4 profound ( ≥ 90dB)

Younger age group:

| S | AI score | Memory span scores<br>List A | Memory span scores<br>List B | (List A-List B) Difference(d) | Age in months | W.I.S.C. performance grade | Hearing Loss (better ear)<br>High Frequency | Hearing Loss (better ear)<br>Low Frequency | Reading age in months | Single letter-confusions from Lists A and B together<br>Visual (VS) | Articulatory (AS) | Distinctive (D) | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0 | 2.8 | 2.2 | .6 | 135 | 2 | 4 | 4 | 81 | 6 | 3 | 3 | 12 |
| 2 | 0 | 2.8 | 2.3 | .5 | 102 | 5 | 3 | 4 | 80 | 5 | 3 | 8 | 16 |
| 3 | 1 | 2.5 | 2.4 | .1 | 102 | 1 | 4 | 4 | 73 | 4 | 1 | 4 | 9 |
| 4 | 2 | 2.6 | 2.4 | .2 | 121 | 2 | 4 | 4 | 80 | 5 | 0 | 8 | 13 |
| 5 | 2 | 2.5 | 2.4 | .1 | 132 | 1 | 4 | 4 | 84 | 6 | 2 | 2 | 10 |
| 6 | 3 | 2.6 | 2.6 | 0 | 101 | 4 | 4 | 4 | 80 | 5 | 1 | 8 | 14 |
| 7 | 3 | 3.3 | 2.9 | .4 | 123 | 4 | 3 | 4 | 86 | 5 | 1 | 5 | 11 |
| 8 | 4 | 2.8 | 2.6 | .2 | 122 | 2 | 3 | 4 | 88 | 5 | 1 | 4 | 10 |
| 9 | 5 | 3.3 | 3.1 | .2 | 115 | 3 | 3 | 4 | 85 | 0 | 2 | 5 | 7 |
| 10 | 5 | 2.6 | 2.9 | -.3 | 131 | 1 | 3 | 3 | 78 | 3 | 1 | 2 | 6 |
| 11 | 5 | 3.1 | 2.8 | .3 | 145 | 3 | 3 | 4 | 87 | 1 | 5 | 7 | 13 |
| 12 | 6 | 2.8 | 2.8 | 0 | 145 | 3 | 3 | 4 | 89 | 7 | 1 | 7 | 15 |
| 13 | 6 | 3.4 | 3.1 | .3 | 130 | 3 | 4 | 4 | 88 | 3 | 1 | 7 | 11 |
| 14 | 6 | 2.8 | 2.6 | .2 | 107 | 3 | 3 | 4 | 84 | 2 | 3 | 6 | 11 |
| 15 | 8 | 3.0 | 2.9 | .1 | 104 | 4 | 4 | 4 | 84 | 5 | 0 | 6 | 11 |
| 16 | 8 | 3.3 | 3.8 | -.5 | 139 | 2 | 3 | 3 | 92 | 0 | 1 | 4 | 5 |
| 17 | 10 | 3.5 | 3.5 | 0 | 147 | 4 | 3 | 3 | 86 | 5 | 5 | 2 | 12 |
| 18 | 10 | 2.4 | 3.3 | -.9 | 127 | 3 | 3 | 3 | 85 | 1 | 4 | 6 | 11 |
| 19 | 10 | 3.5 | 3.6 | -.1 | 145 | 2 | 3 | 3 | 91 | 3 | 2 | 2 | 7 |
| 20 | 11 | 2.2 | 2.6 | -.4 | 133 | 3 | 3 | 3 | 85 | 3 | 3 | 3 | 9 |
| 21 | 12 | 2.8 | 3.1 | -.3 | 116 | 2 | 3 | 4 | 92 | 5 | 2 | 5 | 12 |
| 22 | 12 | 2.3 | 2.6 | -.3 | 147 | 2 | 3 | 3 | 80 | 3 | 1 | 6 | 10 |
| 23 | 13 | 2.8 | 3.1 | -.3 | 129 | 3 | 2 | 3 | 88 | 3 | 4 | 5 | 12 |
| 24 | 14 | 2.4 | 2.8 | -.4 | 144 | 3 | 3 | 3 | 85 | 3 | 5 | 5 | 13 |

## Appendix F

### Mean correct response latencies (msec) for shape-matching task (Experiment 2):

| | Type of letter-pair: | Same shape and size: | Same shape, different size: |
|---|---|---|---|
| AI Group 1 | S1 | 452 | 482 |
| | 2 | 358 | 422 |
| | 3 | 404 | 425 |
| | 4 | 437 | 468 |
| | 5 | 402 | 471 |
| | 6 | 538 | 585 |
| | 7 | 439 | 501 |
| | 8 | 412 | 499 |
| | 9 | 416 | 430 |
| | 10 | 467 | 519 |
| | 11 | 414 | 454 |
| | 12 | 477 | 489 |
| AI Group 2 | S1 | 469 | 507 |
| | 2 | 410 | 523 |
| | 3 | 410 | 484 |
| | 4 | 462 | 497 |
| | 5 | 519 | 538 |
| | 6 | 488 | 556 |
| | 7 | 416 | 444 |
| | 8 | 467 | 519 |
| | 9 | 424 | 469 |
| | 10 | 373 | 385 |
| | 11 | 449 | 516 |
| | 12 | 456 | 486 |
| AI Group 3 | S1 | 432 | 470 |
| | 2 | 432 | 463 |
| | 3 | 408 | 453 |
| | 4 | 454 | 486 |
| | 5 | 423 | 479 |
| | 6 | 408 | 436 |
| | 7 | 416 | 502 |
| | 8 | 416 | 458 |
| | 9 | 441 | 505 |
| | 10 | 450 | 506 |
| | 11 | 428 | 472 |
| | 12 | 532 | 569 |

Mean correct response latencies (msec) for name-matching task (Experiment 2):

| | Type of letter-pair: | Same name, shape & size: | Same name & shape, different size: | Same name, different shape and size: |
|---|---|---|---|---|
| AI Group 1 | S1 | 543 | 577 | 713 |
| | 2 | 397 | 422 | 510 |
| | 3 | 373 | 400 | 506 |
| | 4 | 475 | 493 | 629 |
| | 5 | 433 | 469 | 596 |
| | 6 | 647 | 644 | 778 |
| | 7 | 508 | 595 | 805 |
| | 8 | 461 | 505 | 641 |
| | 9 | 492 | 512 | 629 |
| | 10 | 586 | 635 | 669 |
| | 11 | 471 | 484 | 607 |
| | 12 | 529 | 566 | 852 |
| AI Group 2 | S1 | 488 | 528 | 680 |
| | 2 | 498 | 553 | 589 |
| | 3 | 393 | 472 | 537 |
| | 4 | 444 | 473 | 594 |
| | 5 | 559 | 629 | 780 |
| | 6 | 511 | 565 | 805 |
| | 7 | 428 | 474 | 566 |
| | 8 | 512 | 557 | 678 |
| | 9 | 438 | 458 | 590 |
| | 10 | 379 | 385 | 487 |
| | 11 | 430 | 485 | 606 |
| | 12 | 463 | 484 | 603 |
| AI Group 3 | S1 | 414 | 466 | 566 |
| | 2 | 409 | 467 | 582 |
| | 3 | 387 | 479 | 580 |
| | 4 | 483 | 534 | 651 |
| | 5 | 403 | 450 | 485 |
| | 6 | 349 | 382 | 473 |
| | 7 | 415 | 461 | 579 |
| | 8 | 399 | 444 | 519 |
| | 9 | 464 | 488 | 630 |
| | 10 | 535 | 528 | 892 |
| | 11 | 401 | 448 | 567 |
| | 12 | 538 | 625 | 660 |

Mean difference scores (msec) between speed of name-matching different types of letter-pair differing in their degree of visual similarity (Experiment 2):

| | Type of letter-pair: | Letters with same name but different shape and size - letters with same name, shape and size. | Letters with same name and shape different size - letters with same name, shape and size. |
|---|---|---|---|
| AI Group 1 | S1 | 170 | 34 |
| | 2 | 113 | 25 |
| | 3 | 133 | 27 |
| | 4 | 154 | 18 |
| | 5 | 163 | 36 |
| | 6 | 131 | -3 |
| | 7 | 297 | 87 |
| | 8 | 180 | 44 |
| | 9 | 137 | 20 |
| | 10 | 83 | 49 |
| | 11 | 136 | 13 |
| | 12 | 323 | 37 |
| AI Group 2 | S1 | 192 | 40 |
| | 2 | 91 | 55 |
| | 3 | 144 | 79 |
| | 4 | 150 | 29 |
| | 5 | 221 | 70 |
| | 6 | 294 | 54 |
| | 7 | 138 | 46 |
| | 8 | 166 | 45 |
| | 9 | 152 | 20 |
| | 10 | 108 | 6 |
| | 11 | 176 | 55 |
| | 12 | 140 | 21 |
| AI Group 3 | S1 | 152 | 52 |
| | 2 | 173 | 58 |
| | 3 | 193 | 92 |
| | 4 | 168 | 51 |
| | 5 | 32 | 47 |
| | 6 | 124 | 33 |
| | 7 | 164 | 46 |
| | 8 | 120 | 45 |
| | 9 | 166 | 24 |
| | 10 | 357 | -7 |
| | 11 | 166 | 47 |
| | 12 | 122 | 87 |

Mean difference scores (msec) between speed of name- and shape-matching identical letter-pairs (Experiment 2).

| Letters with same name shape and size | | | | Letters with the same name and shape but differing in size. | | | |
|---|---|---|---|---|---|---|---|
| AI Group | 1 | 2 | 3 | AI Group | 1 | 2 | 3 |
| | 91 | 19 | -18 | | 95 | 21 | - 4 |
| | 39 | 88 | -23 | | 0 | 30 | 4 |
| | -31 | -17 | -21 | | -25 | -12 | 26 |
| | 38 | -18 | 29 | | 25 | -24 | 48 |
| | 31 | 40 | -20 | | - 2 | 91 | -29 |
| | 109 | 23 | -59 | | 59 | 9 | -54 |
| | 69 | 12 | - 1 | | 94 | 30 | -41 |
| | 49 | 45 | -17 | | 6 | 38 | -14 |
| | 76 | 14 | 23 | | 82 | -11 | -17 |
| | 119 | 6 | 85 | | 116 | 0 | 22 |
| | 57 | -19 | -27 | | 30 | -31 | -24 |
| | 52 | 7 | 6 | | 70 | - 2 | 56 |

## Appendix G

Mean correct response latencies (msec) for the name-matching task with a 2-second interval between presentation of $L_1$ and $L_2$ (Experiment 3).

| | Type of letter-pair: | Same-name, shape and size. | Same name and shape, different size. | Same name, different shape and size. |
|---|---|---|---|---|
| AI Group 1 | S1 | 270 | 302 | 359 |
| | 2 | 213 | 254 | 285 |
| | 3 | 220 | 219 | 217 |
| | 4 | 287 | 282 | 347 |
| | 5 | 248 | 269 | 299 |
| | 6 | 319 | 360 | 374 |
| | 7 | 298 | 331 | 365 |
| | 8 | 293 | 299 | 334 |
| | 9 | 264 | 288 | 315 |
| | 10 | 286 | 301 | 339 |
| | 11 | 407 | 481 | 483 |
| | 12 | 332 | 383 | 391 |
| AI Group 3 | S1 | 357 | 321 | 434 |
| | 2 | 303 | 304 | 317 |
| | 3 | 225 | 248 | 265 |
| | 4 | 268 | 295 | 377 |
| | 5 | 277 | 288 | 320 |
| | 6 | 286 | 276 | 334 |
| | 7 | 225 | 245 | 276 |
| | 8 | 300 | 320 | 330 |
| | 9 | 284 | 274 | 319 |
| | 10 | 326 | 331 | 379 |
| | 11 | 276 | 295 | 322 |
| | 12 | 244 | 265 | 304 |

Mean difference scores (msec) between speed of name-matching different types of letter-pair differing in their degree of visual similarity (Experiment 3).

| | | Letter-pairs with same name, but different shape and size - letter-pairs with same name, shape and size. | Letter-pairs with same name and shape, different size - letter-pairs with same name, shape and size. |
|---|---|---|---|
| AI Group 1 | S1 | 89 | 32 |
| | 2 | 72 | 41 |
| | 3 | - 3 | - 1 |
| | 4 | 60 | - 5 |
| | 5 | 51 | 21 |
| | 6 | 55 | 41 |
| | 7 | 67 | 33 |
| | 8 | 41 | 6 |
| | 9 | 51 | 24 |
| | 10 | 53 | 15 |
| | 11 | 76 | 74 |
| | 12 | 59 | 51 |
| AI Group 3 | S1 | 77 | -36 |
| | 2 | 14 | 1 |
| | 3 | 10 | 23 |
| | 4 | 109 | 27 |
| | 5 | 43 | 11 |
| | 6 | 48 | -10 |
| | 7 | 51 | 20 |
| | 8 | 30 | 20 |
| | 9 | 35 | -10 |
| | 10 | 53 | 5 |
| | 11 | 46 | 19 |
| | 12 | 60 | 21 |

## Appendix II

Mean correct response latencies (msec) for the name-matching responses in an experiment in which visual and articulatory confusability of letter-pairs was manipulated (Experiment 4).

| Response categories: | | 'Same name' | 'Different name' | | 'Distinctive' |
|---|---|---|---|---|---|
| | | | Visually confusable | Articulatory confusable | |
| AI Group 1 | S1 | 231 | 436 | 401 | 324 |
| | 2 | 255 | 321 | 311 | 257 |
| | 3 | 336 | 602 | 505 | 504 |
| | 4 | 374 | 515 | 441 | 430 |
| | 5 | 395 | 529 | 510 | 473 |
| | 6 | 312 | 422 | 434 | 374 |
| | 7 | 320 | 584 | 622 | 505 |
| | 8 | 341 | 488 | 389 | 389 |
| | 9 | 373 | 434 | 513 | 413 |
| | 10 | 309 | 451 | 413 | 350 |
| | 11 | 398 | 551 | 534 | 485 |
| | 12 | 348 | 553 | 455 | 399 |
| AI Group 3 | S1 | 280 | 457 | 365 | 367 |
| | 2 | 301 | 567 | 523 | 492 |
| | 3 | 290 | 445 | 355 | 330 |
| | 4 | 371 | 584 | 526 | 478 |
| | 5 | 384 | 544 | 489 | 468 |
| | 6 | 275 | 590 | 468 | 441 |
| | 7 | 248 | 335 | 298 | 303 |
| | 8 | 411 | 522 | 454 | 460 |
| | 9 | 286 | 392 | 355 | 356 |
| | 10 | 239 | 343 | 299 | 298 |
| | 11 | 279 | 409 | 335 | 348 |
| | 12 | 359 | 525 | 439 | 446 |

Mean difference scores (msec) for speed of name-matching visually confusable and articulatory confusable letter-pairs (Experiment 4).

| | | Visually confusable letter-pairs - 'distinctive' letter-pairs | Articulatory confusable letter-pairs - 'distinctive' letter-pairs |
|---|---|---|---|
| AI Group 1 | S1 | 112 | 77 |
| | 2 | 64 | 54 |
| | 3 | 98 | 1 |
| | 4 | 85 | 11 |
| | 5 | 56 | 37 |
| | 6 | 48 | 60 |
| | 7 | 79 | 117 |
| | 8 | 99 | 0 |
| | 9 | 21 | 100 |
| | 10 | 101 | 63 |
| | 11 | 66 | 49 |
| | 12 | 154 | 56 |
| | | | |
| | S1 | 90 | - 2 |
| | 2 | 75 | 31 |
| | 3 | 115 | 25 |
| | 4 | 106 | 48 |
| | 5 | 76 | 21 |
| | 6 | 149 | 27 |
| | 7 | 32 | - 5 |
| | 8 | 62 | - 6 |
| | 9 | 36 | - 1 |
| | 10 | 45 | 1 |
| | 11 | 61 | -13 |
| | 12 | 79 | - 7 |

## Appendix I

### The "language-as-fixed-effect fallacy" : a controversial issue.

Coleman (1964) published a methodological paper criticising some of the procedures adopted by psychologists to analyse their data from language samples. He wrote: "It has not been customary to perform significance tests that permit generalisation beyond these specific materials" (p.219). These criticisms put forward by Coleman were not immediately taken up until Clark (1973) wrote a critique of the statistics used in language research in psychology. Clark argued that the conclusions drawn from studies in verbal language, memory and psycholinguistics were open to serious doubts because researchers had generalised beyond the specific samples of language materials used in the experiment - the 'language-as-fixed-effect fallacy'. He suggested that experimenters should treat both subjects and language items as random effects. Clark wrote:

> When should the investigator treat language as a random effect? The answer is, whenever the language stimuli used do not deplete the population from which they were drawn. Note that the answer is not, whenever the language stimuli used were chosen at random from this population. The latter requirement is, in a sense, secondary to whether or not language should be treated as a random effect. (p.348)

In short, this prescriptive paper tells researchers how to analyse their data and has led to considerable controversial discussion, much of which has been focussed on the above quotation.

Substantial criticisms of Clark's (1973) paper have subsequently appeared (e.g. Cohen, 1976; Keppel, 1976; Wike and Church, 1976). In the light of these criticisms neither quasi F ratios nor min F' were used in the data analyses of Experiments 5, 6 and 7, all of which employed linguistic stimuli which did not deplete the population of items from which they were drawn.

It is clear, despite Clark's attempt to treat this as a secondary issue, that in order that a random effects model be appropriate, a sample of words and sample of subjects must be drawn at random from the respective populations in which one is interested. With regard to the selection of subjects for the three experiments in question, subjects were randomly chosen from the population which is defined,for the purposes of the present study, as all prelingually deaf pupils in the Upper School of the N.C.S.D. Treatment of subjects as a random effect is therefore clearly appropriate. However, when one considers the selection of words (in Experiments 5 and 6) and sentences (Experiment 7), it is equally clear that these linguistic items were not randomly selected.For although one may assume that the word-pairs selected were representative of the word-pairs of the same type that were not included, there is no sense in which the items were randomly selected from the entire population of word-pairs of a particular type. There can be no notion of randomisation implicit in the intuitive, intelligent manipulation of linguistic variables that was carried out. Since this was the case, only a fixed effects model is appropriate to analyse the data from these three experiments.

However, the issue does in fact extend beyond these particular instances in that it is questionable whether words can ever be selected truly at random from the entire population of items conforming to the specified criteria (e.g. Keppel, 1976). It is difficult to envisage how a researcher could draw up a complete population from which to select a sample at random, particularly when linguistic variables such as word length and word frequency etc. are usually manipulated within the category of words that the experimenter is interested in. Thus in the case of Experiments 5 and 6, the experimenter would be faced with the task of drawing up populations of all graphemically similar and all phonemically similar words, and all words with similar sign equivalents and those with no sign equivalents that are known by all the pupils in the Upper School. It is not clear whether it is possible even given unlimited time, to carry such an exercise.

There are,however, further reasons why the use of a random effects model way be undesirable. The use of both a random effects model (Model II) or a mixed model (Model III) relies on the basic assumption that the main effects and the interactions are statistically independent (see for example Dunn and Clark, 1974; Hays, 1963; Kirk, 1968). Since this basic assumption is not readily testable, and since little is known about the consequences of failing to meet the above assumption, the suggestion made by Wike and Church that investigators should continue to use fixed factor designs "..: about which more is known" (p.254) might seem to be sound advice.

Clark himself (1973, pp.351-2) makes clear what penalties are involved when sampling biases are present, and such penalties must surely also apply when one treats a non-random selection of linguistic items as if they were a random sample by applying a random effects model. Clark points out that sampling biases generally: (i) "spuriously increase the differences between the treatments of interest", and (ii) "spuriously reduce the error term for the treatments effect". The consequence of such occurrences would be to enlarge the treatment F-ratio and thereby increase the likelihood of a Type I error, and yet one of Clark's prime objectives for suggesting the statistical procedures was to reduce the likelihood of such errors.

It should be quite apparent by now that the issue originally raised by Coleman (1964) continues to be a very controversial subject as is reflected in current volumes of certain journals. A paper recently submitted to 'Neuropsychologica' was rejected on the grounds that the use of min F' was statistically inappropriate, with the comment that 'random means random'. Meanwhile other journals continue to publish both papers where Clark's proposals are followed (e.g. Baker, 1978; Corbett and Dasher, 1978; Spoehr, 1978), and those where his proposals are not followed (e.g. Friedman, 1978; Humphreys, 1978; Kieras, 1978, 1978, p.18; McFarland, Duncan and Kellas, 1978, p.256; Stein, 1978). There is however one disturbing feature apparent in some of the studies in which min F' is calculated and that is when min F'is found not to be significant at the .05 level whilst $F_1$ and $F_2$ are, the conservatism of the test is drawn upon to justify the subsequent rejection of the null hypothesis (e.g. Gellatly and Gregg, 1977, p.514). To pay mere lip-service to Clark's proposals would seem to clearly indicate a failure to appreciate the basis of what Clark was advocating.

In applying a fixed effects model in Experiments 5 - 7 inclusive, the author is aware of the consequent lack of statistical generalisability. There is however, no obvious reason to believe that the particular selection of items in each of the stimulus categories was in any way peculiar, and that the results are not consequently replicable. Both Keppel (1976) and Wike and Church (1976) advocate that researchers seek non-statistical generality and make use of scientific inference, by means of replication, rather than rely solely, as is common practice, on statistical generality. Wike and Church go on to point out that the findings of any single experiment that are generalised on the basis of statistical analyses must always be regarded as tentative. (Surely this criticism applies to the majority of all published research papers.) They go on to state that an experimenter should utilise "... the cumulative knowledge of his field and his intuition. Generality is not obtained simply by selecting p levels randomly" (p.253). It was not possible, due to time constraints, nor was it deemed desirable to replicate (thereby trading breadth of the study against depth) the three experiments of the present study that are in question. Since all three experiments were carried out in the context of a wider investigation designed to examine the use of articulatory, visual and kinaesthetic coding and using a range of differing cognitive tasks (converging operations), scientific generality may be drawn upon.

## Appendix J

Raw data from Experiment 5.

Mean response latencies for each subject and each word-word stimulus category.

| | | Graphemically similar W-W pairs | Phonemically similar W-W pairs | Control W-W pairs |
|---|---|---|---|---|
| Deaf subjects | S1 | 729 | 951 | 888 |
| | 2 | 627 | 827 | 842 |
| | 3 | 702 | 820 | 749 |
| | 4 | 757 | 798 | 843 |
| | 5 | 810 | 888 | 920 |
| | 6 | 704 | 777 | 843 |
| | 7 | 660 | 741 | 752 |
| | 8 | 917 | 1021 | 1032 |
| | 9 | 731 | 824 | 778 |
| | 10 | 692 | 806 | 879 |
| | 11 | 623 | 680 | 756 |
| | 12 | 664 | 681 | 741 |
| | 13 | 559 | 582 | 688 |
| | 14 | 543 | 619 | 604 |
| | 15 | 553 | 602 | 627 |
| | 16 | 619 | 636 | 661 |
| | 17 | 868 | 927 | 879 |
| | 18 | 572 | 583 | 576 |
| | 19 | 568 | 579 | 497 |
| | 20 | 550 | 574 | 593 |
| | 21 | 678 | 681 | 723 |
| | 22 | 622 | 627 | 644 |
| | 23 | 603 | 583 | 631 |
| | 24 | 591 | 839 | 842 |
| | 25 | 685 | 641 | 571 |
| | 26 | 535 | 629 | 612 |
| Hearing subjects | S1 | 735 | 751 | 718 |
| | 2 | 670 | 694 | 727 |
| | 3 | 703 | 735 | 724 |
| | 4 | 849 | 781 | 775 |
| | 5 | 961 | 817 | 844 |
| | 6 | 724 | 660 | 674 |
| | 7 | 644 | 638 | 648 |
| | 8 | 635 | 563 | 612 |
| | 9 | 638 | 625 | 664 |
| | 10 | 795 | 795 | 804 |
| | 11 | 653 | 630 | 676 |
| | 12 | 615 | 558 | 567 |

## Appendix K

Raw data from Experiment 6.

Mean response latencies for each subject and each word-word stimulus category.

| | | W-W pairs with similar sign equivalents | W-W pairs with no sign equivalents | W-W pairs with non-similar sign equivalents |
|---|---|---|---|---|
| Deaf Subjects | S1 | 675 | 583 | 610 |
| | 2 | 723 | 876 | 796 |
| | 3 | 636 | 669 | 618 |
| | 4 | 821 | 897 | 848 |
| | 5 | 829 | 1045 | 859 |
| | 6 | 873 | 1039 | 899 |
| | 7 | 741 | 848 | 752 |
| | 8 | 684 | 773 | 700 |
| | 9 | 636 | 708 | 640 |
| | 10 | 637 | 651 | 653 |
| | 11 | 785 | 804 | 867 |
| | 12 | 632 | 738 | 609 |
| | 13 | 718 | 808 | 790 |
| | 14 | 750 | 762 | 747 |
| | 15 | 545 | 684 | 547 |
| | 16 | 862 | 944 | 863 |
| | 17 | 635 | 736 | 660 |
| | 18 | 901 | 1008 | 892 |
| | 19 | 721 | 744 | 712 |
| | 20 | 886 | 968 | 868 |
| | 21 | 761 | 795 | 780 |
| | 22 | 629 | 670 | 648 |
| | 23 | 619 | 596 | 624 |
| | 24 | 739 | 819 | 750 |
| | 25 | 719 | 799 | 739 |
| | 26 | 724 | 799 | 737 |
| Hearing subjects | S1 | 736 | 795 | 718 |
| | 2 | 717 | 756 | 723 |
| | 3 | 775 | 823 | 728 |
| | 4 | 799 | 829 | 775 |
| | 5 | 930 | 960 | 844 |
| | 6 | 684 | 683 | 674 |
| | 7 | 661 | 647 | 648 |
| | 8 | 583 | 620 | 612 |
| | 9 | 658 | 683 | 664 |
| | 10 | 813 | 832 | 804 |
| | 11 | 694 | 671 | 676 |
| | 12 | 596 | 593 | 567 |

## Appendix L

Raw data from Experiment 7.

| | | RECOGNITION GROUP | | | | RECALL GROUP | | | |
|---|---|---|---|---|---|---|---|---|---|
| Language form: | | SE | DE | SL | Total | SE | DE | SL | Total |
| Subjects | 1 | 6 | 3 | 7 | 16 | 2 | 5 | 5 | 12 |
| | 2 | 7 | 7 | $\boxed{8}$ | 22 | 3 | 2 | 5 | 10 |
| | 3 | 7 | 5 | 6 | 18 | 4 | 5 | 6 | 15 |
| | 4 | 5 | 7 | $\boxed{8}$ | 20 | 7 | 2 | $\boxed{8}$ | 17 |
| | 5 | 4 | 7 | $\boxed{8}$ | 19 | 6 | 3 | 5 | 14 |
| | 6 | $\boxed{8}$ | 5 | $\boxed{8}$ | 21 | 2 | 3 | 4 | 9 |
| | 7 | 6 | 6 | $\boxed{8}$ | 20 | 1 | 1 | 4 | 6 |
| | 8 | 5 | 6 | 7 | 18 | 4 | 1 | 4 | 9 |
| | 9 | 5 | 7 | $\boxed{8}$ | 20 | 5 | 2 | 7 | 14 |
| | 10 | 5 | 6 | 6 | 17 | 4 | 2 | 3 | 9 |
| | 11 | 5 | 6 | $\boxed{8}$ | 19 | 1 | 1 | 5 | 7 |
| | 12 | 6 | $\boxed{8}$ | $\boxed{8}$ | 22 | 4 | 6 | 4 | 14 |
| | 13 | 7 | 7 | 7 | 21 | 0 | 3 | 5 | 8 |
| | 14 | $\boxed{8}$ | 7 | $\boxed{8}$ | 23 | $\boxed{8}$ | 6 | 6 | 22 |
| | 15 | 5 | 6 | $\boxed{8}$ | 19 | 2 | 4 | 5 | 11 |
| | 16 | 6 | 4 | $\boxed{8}$ | 18 | 3 | 3 | $\boxed{8}$ | 14 |
| | 17 | 5 | 7 | 6 | 18 | 0 | 3 | 4 | 7 |
| | 18 | 7 | $\boxed{8}$ | 7 | 22 | 0 | 1 | 5 | 6 |
| | 19 | 7 | 6 | 6 | 19 | 0 | 3 | 7 | 10 |
| | 20 | 6 | 6 | 6 | 18 | 0 | 3 | 5 | 8 |
| | 21 | $\boxed{8}$ | 7 | 7 | 22 | 1 | 2 | 7 | 10 |
| | 22 | 5 | 5 | $\boxed{8}$ | 18 | 7 | 2 | 5 | 14 |
| | 23 | 7 | 4 | 7 | 18 | 2 | 4 | 4 | 10 |
| | 24 | 7 | 4 | 6 | 17 | 0 | 3 | 6 | 9 |

Note: Max. score = $\boxed{8}$

Orthogonal comparisons: (i) SL v SE and DE
(ii) SE v DE

Recognition group: SS comparison (i) = 3,497.74
SS comparison (ii) = 24.28

Recall group: SS comparison (i) = 7,424.41
SS comparison (ii) = 211.43

The spelling mistakes made by the 24 deaf children in the Recall group of Experiment 7.

S1 arries (arrive)
kich (kick)
Something (sometimes)
brithday* (birthday)

S2 later (late)
monters* (monster)
aboard*(abroad)
cookery (cooking)
tack (took)
faveite (favourite)

S3 brithday* (birthday)
fater (father)
unle (uncle)
broard (abroad)
monate (monster)
favouriste (favourite)
piece (pence)
firend* (friend)
visie (visit)

S4 ucnle* (uncle)
enyoyed (enjoyed)
obed (obey)
sort (short)
chrip (chips)

S5 fid-op (fed-up)
wint (want)
litter (little)
werk (went)
loik (like)
bed (bad)
Lonod (London)
lant (late)
beg (boy)
king (kick)
firdn (friend)
penak (park)
birther (birthday)
bohther (brother)
ship (chips)
livn (live)

S6 oeple (obey)
paned (pence)
lept (late)
lessea (lesson)
feworite (favourite)
wathod (watched)
cate (cats)
birthad (birthday)

S6 chile (child)
lekis* (likes)
wicht (with)
friand (friend)
mony (money)
munt (much)
brithar (brother)
leve (live)
day (boy)
kist (kick)
yestasday (yesterday)
abared (abroad)
monter (monster)
frther (father)

S7 rainning (raining)

S8 pair (paid)
favooratie (favourite)
killin (kitten)
few (fed)
obleyng (obeying)
enjoe (enjoy)
brothe (brother)
freind* (friend)

S9 yestrday (yesterday)
flim* (film)

S10 went (wear)

S11 peence (pence)
eejoyed (enjoyed)
founiete (favourite)
sweing* (sewing)

S12 borther* (brother)
aboard*(abroad)
do (so)

S13 somethin (sometimes)

S14 arried (arrived)
something (sometimes)
wail (want)
monter (monster)

S15 arraived (arrived)
wacthed* (watched)
flim* (film)
lasson (lesson)
went (want)

S16 hat (got)
abroand (abroad)
injoy (enjoy)
tack (took)
lette (little)

S17 favoite (favourite)
monters* (monster)
visiot (visit)
over (oven)
libiray (library)
brothre* (brother)

S18 lessen (lesson)
pot (got)
broard (abroad)

S19 watter (water)

S20 monter (monster)
libary (library)
brithday* (birthday)

S21 stoh (short)
chrip (chips)
monter (monster)
unler (uncle)
mather (mother)
librart (library)
must (much)
brithar (brother)
few-up (fed-up)

S22 uncel* (uncle)
something (sometimes)
enoyant (enjoyed)
libray (library)
flim* (film)
frind (friend)

S23 lirbray* (library)
birthay (birthday)
englot (enjoy)
arrievn (arrive)
borther* (brother)
monye*(money)
mothe (mother)
fried (friend)
aborke (abroad)
monter (monster)
dree (dress)

S24 was* (saw)
lats* (last)
monther (monster)
firend* (friend)

S24 pack (park)
enjiy (enjoy)
borther* (brother)
yesterdy (yesterday)

Note: * = letter transpositions within a word.

## Appendix M

Raw data from Experiment 8:

Comprehension scores of the deaf subjects (matched pairs).

| | Group $D_E$ (read both stories in SE) | | | | Group $D_S$ (read both stories in SL) | | |
|---|---|---|---|---|---|---|---|
| | Story A | Story B | Total | | Story A | Story B | Total |
| S1 | $\boxed{9}$ | 8 | 17 | S1 | $\boxed{9}$ | $\boxed{9}$ | $\boxed{18}$ |
| 2 | 8 | 8 | 16 | 2 | $\boxed{9}$ | $\boxed{9}$ | $\boxed{18}$ |
| 3 | 8 | 8 | 16 | 3 | 8 | 7 | 15 |
| 4 | 6 | 4 | 10 | 4 | 6 | 7 | 13 |
| 5 | 8 | 7 | 15 | 5 | $\boxed{9}$ | $\boxed{9}$ | $\boxed{18}$ |
| 6 | 8 | $\boxed{9}$ | 17 | 6 | $\boxed{9}$ | 7 | 16 |
| 7 | 8 | 8 | 16 | 7 | 8 | 6 | 14 |
| 8 | 7 | 8 | 15 | 8 | 8 | 8 | 16 |
| 9 | 8 | 8 | 16 | 9 | $\boxed{9}$ | $\boxed{9}$ | $\boxed{18}$ |
| 10 | 8 | 5 | 13 | 10 | 7 | 7 | 14 |
| 11 | 7 | 8 | 15 | 11 | 8 | 8 | 16 |
| 12 | 8 | 6 | 14 | 12 | 8 | 8 | 16 |
| 13 | 6 | 5 | 11 | 13 | 7 | 5 | 12 |
| 14 | 8 | 6 | 14 | 14 | 7 | 7 | 14 |
| 15 | 6 | 7 | 13 | 15 | 7 | 7 | 14 |
| 16 | 6 | 7 | 13 | 16 | 6 | 8 | 14 |
| 17 | 5 | 5 | 10 | 17 | 7 | 6 | 13 |

Note: ☐ = maximum comprehension score possible.

Comprehension scores of the hearing control subjects in Experiment 8:

| | Story read in SE ($A_E$ or $B_E$) | Story read in SL ($B_S$ or $A_S$) |
|---|---|---|
| S1 | $\boxed{9}$ | 8 |
| 2 | $\boxed{9}$ | 5 |
| 3 | 8 | 7 |
| 4 | $\boxed{9}$ | 6 |
| 5 | $\boxed{9}$ | 8 |
| 6 | $\boxed{9}$ | 8 |
| 7 | 8 | 8 |
| 8 | $\boxed{9}$ | 8 |
| 9 | 8 | 7 |
| 10 | $\boxed{9}$ | $\boxed{9}$ |
| 11 | $\boxed{9}$ | 8 |
| 12 | $\boxed{9}$ | 6 |
| 13 | 8 | 7 |
| 14 | 7 | 5 |
| 15 | 7 | 7 |
| 16 | $\boxed{9}$ | 8 |
| 17 | $\boxed{9}$ | 6 |
| 18 | $\boxed{9}$ | 8 |
| 19 | 8 | 8 |
| 20 | $\boxed{9}$ | 4 |
| 21 | 8 | 6 |
| 22 | 8 | 7 |
| 23 | 8 | 6 |
| 24 | 8 | 8 |
| 25 | $\boxed{9}$ | 8 |
| 26 | $\boxed{9}$ | 6 |
| 27 | 7 | 7 |
| 28 | $\boxed{9}$ | 6 |
| 29 | 7 | 6 |
| 30 | 8 | 6 |
| 31 | $\boxed{9}$ | 7 |
| 32 | $\boxed{9}$ | 6 |
| 33 | $\boxed{9}$ | 8 |
| 34 | 8 | 7 |

Note: ☐ = maximum comprehension score possible.

## Appendix N

Raw data from Experiment 9:

Group F$\bar{F}$: (fingerspelling presentation)

Length of French words (in letters)

| | 3 | | 4 | | 5 | | 6 | |
|---|---|---|---|---|---|---|---|---|
| | 1st | 1&2 | 1st | 1&2 | 1st | 1&2 | 1st | 1&2 |
| S1 | 7 | 7 | 5 | 6 | 3 | 5 | 0 | 0 |
| 2 | 8 | 8 | 4 | 8 | 3 | 6 | 0 | 5 |
| 3 | 5 | 6 | 1 | 2 | 0 | 0 | 0 | 0 |
| 4 | 7 | 8 | 6 | 7 | 3 | 3 | 3 | 3 |
| 5 | 8 | 8 | 5 | 7 | 4 | 6 | 1 | 4 |
| 6 | 7 | 8 | 3 | 5 | 2 | 3 | 0 | 0 |
| 7 | 7 | 8 | 5 | 7 | 4 | 6 | 2 | 4 |
| 8 | 7 | 8 | 4 | 7 | 4 | 5 | 1 | 3 |
| 9 | 5 | 7 | 2 | 5 | 2 | 4 | 0 | 3 |
| 10 | 8 | 8 | 2 | 6 | 2 | 3 | 0 | 0 |
| 11 | 8 | 8 | 8 | 8 | 6 | 8 | 4 | 7 |
| 12 | 8 | 8 | 7 | 8 | 5 | 7 | 3 | 7 |
| 13 | 7 | 8 | 7 | 8 | 6 | 8 | 2 | 7 |

Group FF: (fingerspelling presentation and production)

Length of French words (in letters)

| | 3 | | 4 | | 5 | | 6 | |
|---|---|---|---|---|---|---|---|---|
| | 1st | 1&2 | 1st | 1&2 | 1st | 1&2 | 1st | 1&2 |
| S1 | 8 | 8 | 8 | 8 | 7 | 8 | 2 | 3 |
| 2 | 8 | 8 | 5 | 6 | 3 | 5 | 1 | 2 |
| 3 | 8 | 8 | 8 | 8 | 5 | 7 | 4 | 7 |
| 4 | 7 | 7 | 5 | 7 | 6 | 6 | 4 | 5 |
| 5 | 8 | 8 | 6 | 7 | 4 | 5 | 2 | 3 |
| 6 | 8 | 8 | 6 | 7 | 5 | 6 | 3 | 4 |
| 7 | 8 | 8 | 6 | 7 | 6 | 7 | 2 | 5 |
| 8 | 8 | 8 | 5 | 8 | 2 | 6 | 2 | 2 |
| 9 | 8 | 8 | 6 | 7 | 5 | 7 | 4 | 6 |
| 10 | 8 | 8 | 8 | 8 | 6 | 7 | 3 | 5 |
| 11 | 8 | 8 | 8 | 8 | 8 | 8 | 4 | 8 |
| 12 | 8 | 8 | 7 | 8 | 6 | 8 | 6 | 7 |
| 13 | 7 | 8 | 7 | 7 | 4 | 7 | 3 | 7 |

Group W$\bar{F}$: (written presentation)

Length of French words (in letters)

| | 3 | | 4 | | 5 | | 6 | |
|---|---|---|---|---|---|---|---|---|
| | 1st | 1&2 | 1st | 1&2 | 1st | 1&2 | 1st | 1&2 |
| S1 | 8 | 8 | 6 | 8 | 5 | 6 | 4 | 5 |
| 2 | 7 | 8 | 6 | 7 | 5 | 6 | 1 | 3 |
| 3 | 8 | 8 | 8 | 8 | 8 | 8 | 6 | 8 |
| 4 | 8 | 8 | 7 | 7 | 3 | 5 | 2 | 4 |
| 5 | 8 | 8 | 6 | 7 | 6 | 7 | 6 | 7 |
| 6 | 7 | 8 | 5 | 7 | 5 | 5 | 0 | 1 |
| 7 | 8 | 8 | 7 | 8 | 5 | 7 | 5 | 6 |
| 8 | 8 | 8 | 6 | 7 | 5 | 6 | 1 | 5 |
| 9 | 5 | 7 | 6 | 8 | 6 | 7 | 3 | 5 |
| 10 | 7 | 8 | 5 | 7 | 4 | 5 | 1 | 3 |
| 11 | 8 | 8 | 7 | 7 | 7 | 8 | 7 | 7 |
| 12 | 8 | 8 | 7 | 8 | 3 | 6 | 4 | 5 |
| 13 | 8 | 8 | 8 | 8 | 8 | 8 | 7 | 7 |

Group WF: (written presentation and production of fingerspelling)

Length of French words (in letters)

| | 3 | | 4 | | 5 | | 6 | |
|---|---|---|---|---|---|---|---|---|
| | 1st | 1&2 | 1st | 1&2 | 1st | 1&2 | 1st | 1&2 |
| S1 | 8 | 8 | 8 | 8 | 8 | 8 | 7 | 8 |
| 2 | 8 | 8 | 8 | 8 | 6 | 8 | 4 | 7 |
| 3 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 |
| 4 | 8 | 8 | 8 | 8 | 7 | 8 | 8 | 8 |
| 5 | 8 | 8 | 6 | 7 | 6 | 7 | 5 | 6 |
| 6 | 8 | 8 | 8 | 8 | 8 | 8 | 6 | 8 |
| 7 | 8 | 8 | 7 | 8 | 6 | 8 | 6 | 7 |
| 8 | 8 | 8 | 6 | 7 | 5 | 5 | 4 | 6 |
| 9 | 8 | 8 | 8 | 8 | 7 | 8 | 5 | 6 |
| 10 | 7 | 8 | 7 | 8 | 4 | 6 | 3 | 5 |
| 11 | 8 | 8 | 8 | 8 | 6 | 7 | 6 | 6 |
| 12 | 8 | 8 | 8 | 8 | 8 | 8 | 7 | 7 |
| 13 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 |

Note: Maximum score = 8.