DEVELOPMENTAL APRAXIA OF SPEECH

WITH PARTICULAR REFERENCE TO ASPECTS OF VOICING

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REFERENCE LIST OF ABBREVIATIONS

ASHA	American Speech & Hearing Association
C	Control group
CAI	Congenital auditory imperception
CP	Cerebral palsy/cerebral palsied
CST	College of Speech Therapists
DAD	Developmental articulatory dyspraxia
DAS	Developmental apraxia of speech
DVD	Developmental verbal dyspraxia
E	Experimental group
EAT	Edinburgh Articulation Test
IPA	International Phonetic Association/ International Phonetic Alphabet
IVOM	Isolated volitional oral movement(s)
ms	Milliseconds
NS	Nothing of significance reported
RHSC	Royal Hospital for Sick Children, Glasgow
SVOM	Sequenced volitional oral movements
VOT	Voice onset time

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ABSTRACT

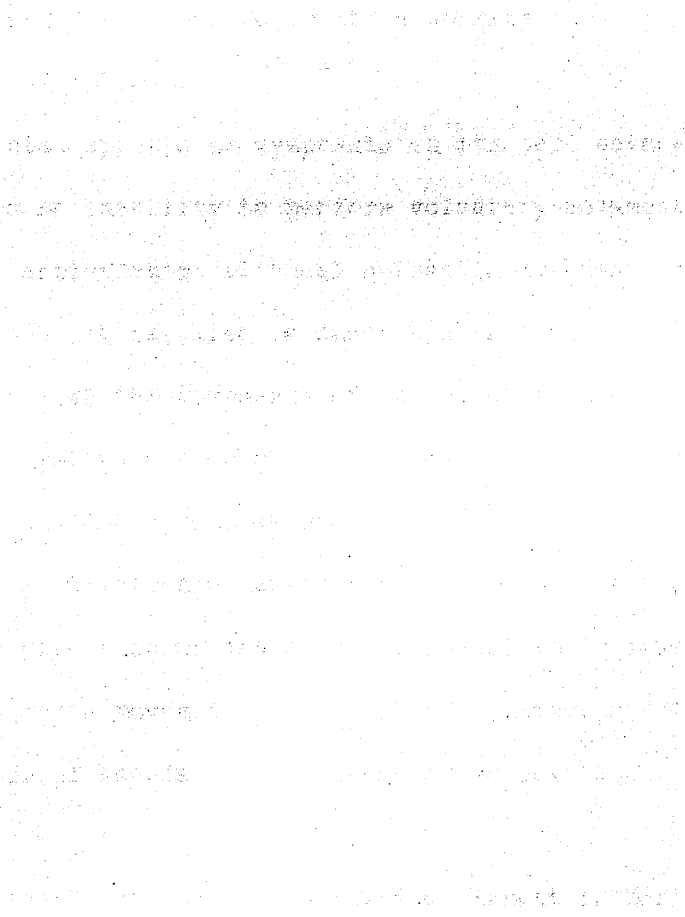
Developmental apraxia of speech is a disorder which has given rise to much controversy, both in terms of its etiology and its clinical management. It has traditionally remained an ill defined concept, with an associated terminology which at times lacks clarity and precision. In the absence of unanimity amongst clinicians as to its nature, therapeutic programmes for its alleviation have been developed slowly and not always effectively.

The aim of this thesis is to focus on one particular feature of the condition, namely the apraxic child's control of the timing mechanism for voicing. The experimental investigation is prefaced by a consideration of the varying approaches to developmental apraxia of speech from the 19th century onwards, noting the significance of studies of 'idioglossia' and, in the present century, the work of Orton in the United States and Morley in the United Kingdom. Notice is taken of the apparent inadequacies in the assessment and treatment programmes for the condition, which have culminated in some instances in practices which lack any firm theoretical foundation.

Auditory and instrumental phonetic techniques are employed to elucidate the nature of the laryngeal timing deficiency in the condition, and the conclusion is reached that a possible source of this deficiency may be found in the child's respiratory and laryngeal mechanisms.

It is postulated that developmental apraxia of speech should be viewed as part of a wider apraxic syndrome. By emphasizing, as a number of

researchers have done for nearly 20 years, the role that phonology, rather than phonetics, can play in describing speech disorders, the opportunity has been lost to examine the underlying physiological mechanisms of speech production. In this study, the focus is firmly on articulation as physiology rather than phonology.



Chapter 1

Approaches to the Study of the DAS Child

"....developmental apraxia of speech is a label in search of a definition" (Guyette & Diedrich 1981: 39)

1.1 In the study of developmental speech disorders, a group of children described as suffering from 'developmental articulatory dyspraxia' have elicited much discussion and controversy. The work of Morley and her associates in the Speech Clinic of the Royal Infirmary in Newcastle-upon-Tyne in the 1950s has formed the pivotal point in the investigation of such a disorder, and for many years her description, terminology and definition have been accepted as standard by those working in this field. Morley's definition is as follows:

> 'Developmental apraxia or dyspraxia in its less severe form has been described as an inability to perform voluntary movements of the muscles involved in articulation although automatic movements of the same muscles are preserved. It may also be described as a defect of articulation which occurs when the movements of the muscles used for speech, that is of tongue, lips, palate or cheeks, appear normal for involuntary or spontaneous movements such as smiling or licking the lips, or even for the voluntary imitation of movements carried out on request, but the control and direction of articulatory movements is inadequate for the complex and rapid movements used for articulation and the reproduction of the sequences of sounds used in speech' (Morley 1972 : 274).

1.2 In this thesis the basic descriptive element in Morley's definition will be accepted, but it will be extended to include not only the voluntary movement of the articulators within the oral cavity, but also laryngeal

and, by implication, respiratory activities (see further § 5.3). As a result, an investigation of the laryngeal, not just the articulatory, mechanism for speech has to be undertaken. I suggest that the disorder described as developmental articulatory dyspraxia (henceforth DAD) by Morley may encompass difficulties at the laryngeal and respiratory levels of speech production.

Perhaps a more accurate definition than Morley's - though less specific - which does allow for further descriptive components to be accepted would be that used by the Mayo Clinic, albeit with reference to adult acquired disorders, that 'apraxia of speech is a transmission problem, a difficulty with output and with motor programming' (Mayo Clinic & Mayo Foundation 1981 : 235).

It is further proposed in this thesis that the disorder should be described as 'developmental apraxia of speech' (henceforth DAS) : a term adopted by some recent workers (Blakely 1980, Guyette & Diedrich 1981, 1983). It has the virtue of allowing for more than exclusively articulatory features to be incorporated into the syndrome. The term 'apraxia' will be used in this context as synonymous with 'dyspraxia'.

1.3 The first chapter of this thesis will discuss terminology for developmental speech disorders with particular reference to the study of DAS and also the descriptions of the speech disorders covered by this terminology, taking note of the degree of similarity or divergence of opinion amongst researchers as to the nature of the concept.

There will be a review of the relevant literature in order to (i)investigate the weight of evidence regarding the characteristic voicing disorder and (ii) discuss assessment procedures to ensure that any valid way of assessing DAS is not omitted and (iii) evaluate assessment procedures in the light of the investigation of this thesis. Therapeutic procedures have also been summarized as an indication of the clinical understanding of the condition.

1.4 Although from the 1950s until recently there has been a period of relative stability in the use of the term 'developmental articulatory dyspraxia', this has not necessarily meant that the symptomatology which constitutes the condition has been interpreted in the same way by workers using the same terminology. This point is of crucial significance in an examination of the concept of DAS, since the definition given by investigators has tended to be descriptive in nature, yet different facets of language - and indeed of other behavioural aspects - have been taken into account. No indication is generally given as to how many of the descriptive features present are necessary before a diagnosis of DAS can be made. Amongst those authors who abide by the Morley definition (see above), there is agreement, but a number of the main contributors to the study of the subject define their own characteristics of DAS.

1.5 The central article by Morley and her colleagues in Newcastle-upon-Tyne, which was to form the basis for the acknowledgement and adoption of DAS as a clinical entity, derives from case presentations at meetings of the Section of Neurology of the Royal Society of Medicine in 1950 and a subsequent follow-up article in 1954.

At a meeting of the Royal Society of Medicine on 2 March 1950, Miller, Court and Morley led a discussion on 'speech defects in children'. They drew attention to certain specific groups of children. The first consisted of 'those cases which show a dysarthric defect in the absence of any detectable neurological lesion elsewhere' (Miller, Court & Morley 1950 : 581). A small proportion of the cases originally assigned to this group revealed on neurological examination a minimal diplegia; in some instances there was a history of feeding difficulty or late or abnormal motor development or clumsiness of the hands and a degree of spasticity. In other cases, however, 'a very similar dysarthria was found with no other evidence whatever of cerebral disease or maldevelopment' (ibid).

There seemed to be no clear cause of the 'dysarthria', but Miller and his colleagues believed that the explanation lay in physical clumsiness in the peripheral mechanism of speech. Further, on the basis of the small number of children examined at this stage, it was noted that a general characteristic was slow speech development and a very slow response to treatment. The condition affected mainly the movement of the lips, tongue, soft palate, pharynx or larynx, 'incoordination of which may [not] be evident on examination, but shows itself only when the muscles are used for the rapid and complex co-ordinated movements of speech.' For other purposes, muscular co-ordination appeared to be adequate: 'The difficulty may be most noticeable in joining a consonant to a vowel or in the co-ordination of phonation and articulation' (ibid). Fairly normal speech could be achieved at a slow deliberate rate, but neuromuscular control did not seem adequate for normal rates of speaking. The condition could be

mild or severe, with little spontaneous improvement; and a poor response to treatment allowed the condition to persist into adulthood.

In the discussion that followed the presentation of this paper, Critchley proposed that clinical features of developmental dysphasia must have been present in the children, and stated that 'Dysarthria is common, but differs from the form which accompanies aphasia in the adult, by reason of a dyslalia (amounting even to an idioglossia) representing an avoidance of difficult sounds and the substitution of easy ones' (Miller et al 1950 : 584). Thus the term 'dysarthria' was used for the child with abnormal articulation.

Four years later, in 1954, Morley, Court and Miller published their subsequent findings for the previously identified developmental dysarthric children. Eighteen cases in all had been studied, and in six of them 'movements of the lips, tongue and palate appeared normal on voluntary movements carried out at the examiner's request, but clumsy and awkward when the children attempted the more complex and rapid movements of articulation' (Morley et al 1954 : 9). Such cases were considered to be potential examples of 'dyspraxic dysarthria' or 'articulatory dyspraxia'. The condition could be associated or not with delayed development of language or reading difficulty. They thought that the prognosis varied according to the severity of the defect and the child's intelligence, and that 'response to consistent treatment' is usually slow, and occasionally the difficulty persists into adult life (op cit: 10).

1.6 This exposition of the nature of DAS became accepted as a standard by the majority of clinicians in the UK and USA (see further pp 17-18), and is regarded as essential for any understanding of DAS. It has, furthermore, acted as the basic reference-point in later studies of the condition.

1.7 A useful summary of the speech characteristics of DAS as described by a number of writers is given by Aram and Nation (1982 : 151-153). None of the writers specifies which particular combination of symptoms must be present for a positive diagnosis to be made, or if certain features represent varying degrees of severity of the condition.

1.8 Recent publications on articulation disorders (eg Guyette & Diedrich 1981, Sommers 1983, Edwards 1984) highlight this difficulty. Sommers, in his section on developmental articulatory dyspraxia, states that 'none of the characteristics is well enough researched to be a conclusive sign of this disorder, and it is likely that all are not required to support a diagnosis. Furthermore, assuming that developmental apraxia in children is a visible diagnostic entity, further studies may show that other symptomatologies are related to many of these and are perhaps better indices of the condition' (Sommers op cit : 28).

Guyette and Diedrich, in a very exhaustive discussion of the literature on DAS, come to an even more critical conclusion: that it is 'unclear as to how an apraxic child might be identified' and that there are 'no consistent symptoms associated with DAS' (Guyette & Diedrich 1981 : 32).

An 'official' British definition of developmental articulatory dyspraxia (henceforth DAD) has been recommended by the College of Speech Therapists in the past, but a revision is now perhaps overdue. The last recommendation from the CST was in 1959. There, under the heading of 'Articulation', 'articulatory apraxia (apraxic dysarthria)' was defined as 'a condition where there is inability to perform the movements required to reproduce sounds accurately (in isolation or combination) when hearing and perception are normal and the movements as far as swallowing and sucking are concerned are performed in a normal manner'. Secondly, 'articulatory dyspraxia (dyspraxic dysarthria)' was defined as 'varying degrees of failure to perform the movements to reproduce speech sounds accurately....Apraxia/dyspraxia may be associated with a wider syndrome of tongue and lip, or facial apraxia' (College of Speech Therapists 1959 : [2-4]). Not all workers have followed these guidelines, however. Connery et al (1982 : 10), for example, quote 'feeding problems' within their description of DAS.

(Since the terms DAD and DAS are now synonymous, but historically have been used in differing ways, they will be treated as equivalent to each other in what follows.)

In the original Morley work and in the CST definitions (as well as Yoss and Darley's investigations), all the children diagnosed with DAD had normal intelligence. Other workers, however, have not observed this limitation on the term, and have included children who were mentally handicapped (see, for example, Daly et al 1972, Rosenbek & Wertz 1972, Ferry et al 1975, McLaughlin & Kriegsmann 1980).

Under the heading 'Language' on the CST's terminology sheet, a further definition is of relevance to the description of DAS, viz 'developmental' : 'Failure or abnormally slow development of language in children when factors other than verbal ability such as learning and intelligence in general are normal. It may be executive only, or receptive-executive (auditory imperception). NB The term 'alalia' should be used until the diagnosis is assured.' The terminology sheet then goes on to define 'alalia' as 'absence of language and articulation in young children beyond the normal age range for the inception of speech'. Also under 'Language' one finds that apraxia (dyspraxia) is defined as 'an inability to perform purposive movements in the absence of paralysis'.

1.9 These various definitions encompass a range of clinical conditions such as apraxia, dysarthria, articulatory apraxia, apraxic dysarthria, and auditory imperception, none of which is well defined in its own right. As a result, a complex and vague classificatory system has emerged which is liable to cause confusion and lead to variation in usage in a clinical context.

1.10 Terminology associated with developmental speech disorders

1.10.1 Byers Brown has neatly summarized the confused state of terminology associated with speech disorders: '...there is now a fair degree of consensus among speech therapists as to the conditions requiring treatment. Unfortunately this consensus does not extend to the terms that should be used to depict the conditions. The need for a clear and comprehensive

terminology is everywhere expressed but not yet satisfied' (Byers Brown 1981 : 79).

1.10.2 The literature on childhood speech disorders amply illustrates Byers Brown's assertion. From a fairly restricted terminology up until the end of the 19th century, there developed, alongside the general interest in speech conditions, an increase in the number of diagnostic labels used to describe the speech difficulty. As a result, by the late 19th and early 20th centuries, more complex categorizations were in use. Until the 1950s, there was - in the UK at least - a fairly unified use of terminology in speech therapy, but at the present time there is again evidence that a new era of extensive terminology-making is upon us. The terms being devised are plentiful and comprehensive from some points of view, but not 'clear' according to Byers Brown's criterion. This is reflected in the present terminology for DAS. (For further details, see § 1.12.4.)

1.10.3 The aim of the following sections is to outline the terminology for childhood speech disorders used before 1954 and that adopted thereafter. If we accept the existence of a disorder of speech described by Morley and colleagues as DAD, then there is a strong likelihood of studies being in print, with possibly some hitherto unrecognized examples of the condition. This and the following sections will look at the literature prior to 1954 for such examples, and will proceed to outline the approach to speech disorders on which Morley based the work which led to her identification of a particular group of developmental articulatory disorders.

1.11 19th century terminology for developmental speech disorders

Childhood speech disorders were of interest to a number of clinicians during this period, although the range of terminology used until about 1890 was fairly restricted, considering the range of speech disorders covered. If we are justified in assuming that a DAS population must have existed at this time, it is likely that references to it and case reports would be found under the headings which were used in the description of articulatory disorders, namely (i) dyslalia (Hunt 1854), (ii) aphasia (Sainsbury 1889), (iii) disorders of speech (Bastian 1882), (iv) congenital aphasia (Gowers 1893), (v) defective articulation (Taylor 1890-91), (vi) defect of articulation (Hadden 1891), (vii) idioglossia (White & Golding-Bird 1891, Colman 1895), (viii) lalling (Wyllie 1894), (ix) dysarthria (Kerr 1900), (x) dumbness (Down 1882a), (xi) idiocy (Down 1882b), and (xii) stammering (Colman 1895).

Two items in this list require further comment. Idioglossia was a term recommended by Dr Edwin Cooper Perry, a distinguished classical scholar and Dean of the Medical School, Guy's Hospital, London (see White & Golding-Bird 1891.) The first clinicians to use the term were White and Golding-Bird (1891: 602). It was used with reference to a form of speech disorder characterized by articulatory deviations. The term stammering was used from the late 19th century onwards to describe not only stuttering but also articulatory disorders where no dysfluent element was present. It was still being used in this wider sense as late as 1937 - see McAllister 1937.

Throughout the latter part of the 19th century we find evidence of the borrowing of terms from the literature on acquired adult speech disorders to describe children's speech disorders: for example, 'aphasia', 'dysarthria' and 'word deafness' - the latter prefixed by the word 'congenital'.

Two other facets of a child's development were also being considered in relation to speech disorders at this period, namely mental ability (Down 1882b), and the relationship between the expression and the comprehension of speech (Hadden 1891). Thus, within the late 19th century discussion ondevelopmental speech disorders there began to appear an overt recognition of the importance of the perceptual requisites for speech development.

As far as specific references to dyspraxia at this time are concerned, Kussmaul (1878) defined 'apraxia' as the condition in which 'the memory for the uses of things is lost as well as the understanding for the signs by which the things are expressed' (Kussmaul 1878 : 748). In 1900, Liepmann, in what has come to be regarded as the classic statement of the nature of dyspraxia, described and discussed the symptoms of an adult dyspraxic (Liepmann 1900). He makes no reference, however, to a developmental form of the disorder.

1.12 20th century terminology

1.12.1 In the early part of this century (until about 1920), the pattern of terminology that was in use followed that of the 19th century: for

example, 'idioglossia' (Guthrie 1907, McCready 1910), 'congenital word deafness' (Syme 1904).

From these examples, we can note that, apart from idioglossia, a terminology appropriate to adult disorders was being used for the description of developmental ones.

1.12.2 During the decade 1920-1929, there were important developments in the study of developmental speech disorders; they were to influence future lines of enquiry and in particular the methods of classifying those cases which, in the light of Morley's 1972 definition, could be classified as DAD. In the study of adult acquired language disorders, the ideas of Henry Head were exerting a significant influence, with Worster-Drought and Allen in 1929 applying his principles to the study of childhood speech disorders, and publishing the results of an assessment of a child described as idioglossic on Head's criteria (Worster-Drought & Allen 1929a). In particular, they emphasized the importance of the receptive aspect of speech, and regarded the child's defective speech or 'idioglossia' as a direct result of faulty 'auditory reception'. The term 'congenital auditory imperception' was introduced by Worster-Drought. This concept could well have encompassed a group of children who would at the present day be described as having DAS.

In 1927, Wallin described the apraxias as referring to 'the loss of the ability (in the absence of paralysis or ataxia) to execute skilled movements' (Wallin 1927: 238). He explained that, in the main, knowledge of both the aphasias and the apraxias had derived from acquired forms, and

that practically nothing was known regarding the supposed congenital forms of many of the disturbances. In the subsequent discussion, he made no specific mention of an articulatory apraxia, although he did discuss 'aphemia' as referring to the loss of speech or the inability to combine articulatory movements into speech' (op. cit.: 378). The terms 'idioglossia', 'dysarthria' and 'dyslalia' are also used by him to describe articulatory difficulties. Recently, Rapin & Allen (1983) have related one of their developmental speech disorder categories to aphemia. (On aphemia, see further pp 20-21.)

1.12.3 1930-1939 During this period, in both the UK and the USA, there was a proliferation of terms describing childhood speech disorders, and the condition of DAS could have been listed under any number of them. Below is given a representative sample of terms, chosen on the basis of the categories under which DAS was likely to have been interpreted.

In 1931, a system of classification was suggested by the American Speech Correction Association's nomenclature committee (Robbins & Stinchfield 1931), and subsequently used by Stinchfield in her textbook in 1933. This included some extremely complex terminology with various categories of dyslalia. It is very likely that DAS was subsumed under the main heading of 'dyslalia' and the subcategory of 'idiolalia' (Robbins & Stinchfield 1931).

Also in the USA, in 1932, Allen discussed a group of children who had defective motor control of the peripheral articulatory apparatus, and also a second group with 'audiomutatas'. He implied that there could be an

impairment of speech in the presence of normal intelligence and hearing, but in the absence of a neurological lesion. Both of his groups could have contained DAS children.

Of major importance in tracing the development of the study of childhood speech disorders which led to the isolation of the concept of DAS was the meeting in 1937 of the American Academy of Pediatrics. It was here that Chesher related the views of Orton, and reported the latter's five categories of language disability:

(i) strephosymbolia
(ii) word deafness
(iii) motor speech delay
(iv) agraphia
(v) apraxia

Orton believed that on the basis of the extensive literature on adult acquired speech disorders as well as from his own clinical experience, certain facts could be selected from adult studies and applied to childhood learning problems. He therefore began using some of the terminology (including 'apraxia') for the classification of childhood speech disorders, prefixed by the word 'developmental'. Thus, 'developmental (congenital) apraxia (abnormal clumsiness)' was used with reference to speech as well as physical gait (Orton 1937 : 120). This citation would appear to be the first published reference to the extension of the term apraxia to describe a developmental speech disorder.

In the UK at this time, however, there was no evidence of such a term as 'developmental apraxia' being applied to speech disorders. In 1937, the same year of publication as Orton's book, McAllister, in her Clinical Studies in Speech Therapy, which dealt particularly with childhood disorders, stated that it was possible, even in view of the many varieties of speech defect, to divide speech disorders into two main groups. The first of these was 'stammering', described as those speech disorders which have 'consistent distortion or omission of certain speech sounds so that speech is unintelligible'. Within this category she included 'sigmatism (lisping)', 'idioglossia (jargon)' and 'lalling (babyish speech)' (McAllister 1937 : xv). The concept of DAS would very probably have been implied, together with other conditions, in the subcategory of idioglossia.

1.12.4 1940-1949 Attempts at standardizing the terminology for speech disorders became prominent in these years, in both the USA and the UK. In 1946, Wise proposed a revision of the 1930-31 American Speech Correction Association terminology, but there is nothing in the subsequent literature to indicate that his terminology gained acceptance, or that, for example, the term 'dysplasia', which he used to describe an impairment of articulation due to implication of the lower motor neurone (and which might have covered DAS), came into common usage.

A further attempt at producing a revised classificatory system was made in 1949, this time by Peacher. In connection with developmental disorders, he supported the view that 'congenital aphasia', for example, should be retained, one of his arguments being the fact that 'agnosia, apraxia and other signs of cerebral dysfunction may be present' (Peacher 1949 : 156).

Later in the same paper, he stated that factors which had previously applied to adult disorders should be used for childhood ones if preceded by the designation 'developmental'. From this it would seem reasonable, then, to assume that the term 'apraxia' could have been included in this list, and might indeed have been used by clinicians (op cit : 158). Morley, in her 1959 article on defects of articulation, refers to Peacher's paper. Although she makes no direct reference to DAD at this point, she was obviously aware of his recommendation.

In the UK at this time, recommendations for the standardization of terminology were also being put forward. Oldrey and Van Thal had begun an investigation into the usage of terminology for speech pathology in 1938; their proposals were published in 1947. It would seem, from their definitions, that DAS would have been implied by the general term 'congenital defect of speech' and thereafter, depending on the therapist's viewpoint, by 'multiple dyslalia', 'general dyslalia' or 'idioglossia' (Oldrey & Van Thal 1947 : 20). Their terminology makes no mention of developmental apraxia. In fact, the term 'apraxia' did not even appear under the classificatory system for acquired adult speech disorders.

1.12.5 1950-1985 In March 1950, Miller, Court and Morley described the classificatory system used by them in their work in the Speech Clinic in Newcastle-upon-Tyne, where over a ten year period 1500 cases of speech disorder had been seen. They stated that their attempt at classification had 'grown out of our day-to-day experience and is, as far as possible, conceived within the framework of accepted neurological terminology'

(Miller et al 1950 : 580). They identified a 'group of cases of dysarthria without abnormal neurological findings outside the speech mechanism' (op cit : 581); this was one of the three groups of children with speech difficulty to which they paid particular attention. In today's terminology, the group whose speech disorder appeared to be due to 'physical clumsiness in the principal mechanisms of speech' would most probably encompass the DAS group, which Miller and his colleagues classified at that time as 'dysarthria'.

This was a period when particular interest was being paid within the field of adult speech disorders to the question of articulatory defects in aphasia. For example, in January 1952, Critchley delivered the Semon lecture on this very subject (Critchley 1952), in which he referred to 'articulatory dyspraxia' as 'an independent entity, though it may co-exist with an aphasia and contribute to a defect of articulation' (op cit : 16). The term 'articulatory dyspraxia' was then in recognised usage with regard to adult speech disorders in the UK by the early 1950s. Morley (1959) refers expressly to Critchley's paper of 1952.

In 1954, Morley, Court and Miller provided further details of the group of children with 'developmental dysarthria', which they had previously discussed in 1950. Within this grouping they had found a number of children whose defect they felt would be better described as an 'articulatory dyspraxia'. Subsequent investigators such as Yoss and Darley (1974), Edwards (1974), Yoss (1974), Pritchard et al (1979) have referred to this as possibly the first use of the term and description of the condition. But, as has been noted above (pp 12, 14-16), there was

provision for such a concept some years earlier in the terminology devised by Wallin (1927), Orton (1937) and Peacher (1949).

With the publication of Morley's The Development and Disorders of Speech in Childhood (1st ed. 1957), which quickly established itself as the standard textbook on developmental speech disorders in the UK, the terms 'developmental articulatory apraxia' and 'developmental articulatory dyspraxia' for the less severe form gained ready acceptance, since she had devoted an entire chapter of the work to discussion of the syndrome.

In 1959, the College of Speech Therapists (London) produced an authorized Terminology for Speech Pathology. Since the College was the only examining body for speech therapists in the UK and Eire at that time, its recommendations had to be adopted by all training establishments. Thus a considerable degree of uniformity in terminology was achieved amongst clinicians and students-in-training. The following two terms relevant to DAS appear on this sheet of recommended terminology, both under the general heading of 'Articulation':

- articulatory apraxia (apraxic dysarthria)
- articulatory dyspraxia (dyspraxic dysarthria)

The term DAD would appear then to have been accepted by clinicians in the field of childhood speech disorders in the UK, but there was one notable exception. Ingram criticized the term DAD as used by Morley - even though he himself had used it in a paper he had co-authored with Reid in 1956. There were two aspects to his criticisms. One was that the use of the term

'apraxia' should be avoided 'until means of testing for apraxia of tongue, lips and palate during speech' were available (Ingram 1959 : 454). The other was that in Morley's investigation of 1954 a number of children described by her as suffering from DAD also had a language delay. Ingram therefore proposed that for classificatory purposes the two groupings should be combined, and he recommended that the expression 'specific developmental speech disorder syndrome' should be employed (ibid). He himself used it (see, for example, Ingram 1964, 1972), but it did not gain acceptance amongst other clinicians or figure in published reports of cases.

From the late 1950s until approximately 1970, the term DAD continued to be used in a fairly consistent manner by writers in the field of childhood speech disorders, albeit with some minor modifications: see. for example, Greene 1967, Hardy 1978, Nicolosi et al 1978, Pritchard et al 1979, McLaughlin & Kriegsmann 1980, Garvey 1980. Thus: 'articulatory dyspraxia' (Court & Harris 1965, Rosenthal 1971, Parry-Fielder 1971), 'developmental apraxia' (Yoss 1972). From these examples, it is clear that many researchers in the UK, Australia and the USA were, in effect, using very comparable terminology. Only Ingram was the exception; he continued to use 'specific developmental speech disorder syndrome' (Ingram 1964, 1972).

Alongside the use of DAD arose a convention of employing 'developmental verbal dyspraxia' (henceforth DVD), first used by Edwards (1973) as synonymous with DAD - although she provides no explanation for the apparently significant change from 'articulatory' to 'verbal'. Even so, one should note that Snowling and Stackhouse have recently employed it

(1983), but in a different sense from Edwards. Edwards' DVD was adopted by Hunter (1975), also by Ferry et al (1975). The latter described DVD as 'dilapidated speech' - a much quoted gloss on DAD. It was Edwards who was the first to use in print the phrase 'a dilapidation of speech' with reference to developmental dyspraxia (see Edwards 1973 : 65), which she attributed it to Critchley. He had indeed used these very words, in his Semon lecture of 1952 (see above, p 17), but with reference to adult aphasics, not children with developmental dyspraxia of speech.

Two further schools of thought on apraxia which have developed in the last 20 years or so have influenced other attempts at devising an appropriate terminology. One has been to regard the disorder as a 'programming' disorder, the other as a 'phonological' disorder. In Italy, in 1966, De Renzi and his colleagues described a particular aphasic disorder as being 'phonemic-articulatory' in nature (De Renzi et al 1966 : 55). In 1977, Dunlop and Marquardt argued that adult apraxia was 'impaired motor speech programming, which might be affected by linguistic articulatory variables' (Dunlop & Marquardt 1977 : 29). These differing terminologies soon found their way into published case reports in developmental studies: 'phonologic programming deficit syndrome (verbal apraxia)' (Rapin 1982 : 141) was one of them. In connection with the term, one notes that a year later Rapin and her co-author Allen had altered her position somewhat with the suggestion that 'severe expressive syndrome' should henceforth be used 'to describe those children labelled by Ferry et al (1975) as 'dilapidated speech'' (Rapin & Allen 1983 : 169). In other words, her concept equated exactly with DAS! They further suggested that their expressive syndrome might perhaps represent 'a more severe form of the phonologic-syntactic

syndrome', and related it to 'aphemia' (op cit : 169). Their 'phonologic-syntactic syndrome' was also used with reference to children with an articulatory disorder - possibly DAS.

At this point one may feel that the study of DAS has returned to an earlier era of investigation. Equally, that the re-labelling of the disorder in what may seem to be more up-to-date terminology (some of it rather unwieldy at times) is likely to obscure the admirable aim of Morley and her co-workers of providing classifications which derive from extensive clinical experience rather than abstract theorizing in the light of only a few isolated examples of the disorder.

A revision of the terminology authorized by the College of Speech Therapists has been in progress now for some years, but has not yet been completed. In consequence, there is in practice - at least in the UK and Eire - no generally accepted terminology : terms are used according to the therapist's personal inclinations or academic background or a working consensus reached amongst a group of therapists engaged in a common clinical setting.

In 1982, in the USA, the American Speech and Hearing Association (ASHA) produced a revised classification of speech disorders. Its categories are wide-ranging, and, depending on the individual clinician's point of view, the terminology surrounding DAS can be located under either one or the other of the two main headings : 'Speech' and 'Language'. For example, if DAS is seen as an articulatory disorder, and is therefore defined as 'the abnormal production of speech sounds', then it will be a 'speech' disorder.

If, on the other hand, it is regarded as a 'phonological' problem, then it will be a 'Language' disorder.

From the foregoing, it will be obvious that the terminology used to describe DAS is again in a state of confusion - primarily, one suspects, because the nature of the condition has still not yet been thoroughly explored and elaborated. And this state of affairs is likely to be aggravated further, at least in the short term, as researchers from various disciplines (eg linguistics, psychology, paediatric neurology, speech pathology) introduce their particular terminologies into the description and classification of DAS. There is a need, then, for criteria to be rigorously applied, and for a standardized terminology to be adopted in the study of the disorder. This, however, is probably not yet possible, given our limited understanding of developmental speech disorders, and indeed our knowledge of the processes of normal speech development.

1.13 Prior to the 1950s, which was the stage at which the term DAD was brought into common usage and defined by, for example, Morley and the College of Speech Therapists, there were a number of childhood speech disorders reported - the terminology is discussed above - which with hindsight may well have been examples of DAS. Some of these cases and descriptions will now be examined in chronological order in the light of those features of DAS which could be held to be characteristic of the condition, although, as has been previously mentioned, the isolating of such symptoms is problematical.

The following historical excursus on earlier cases of what may well have been examples of DAS will illustrate how various strands in the understanding of the nature of DAS have gradually woven themselves together into a more cohesive diagnostic pattern as more and more cases have been observed and discussed. Many of the features of DAS as currently understood are a direct development (conscious or not) of 19th century observations.

In 1836, Sir Charles Bell described a case of a six year old boy: 'all spirit and action. He is apparently capable of appropriate gesture with an intelligence and meaning'. He has 'hearing and all his faculties. He laughs, and gives the sound of cachination, and cries audibly in pain, but he cannot put out his tongue from his mouth: cannot articulate: and appears from birth to have been deprived of every motion which belongs to the ninth nerve.' (Bell 1836 : 396). Similarly, Brodie, in 1854, refers to the case of an eleven year old girl who had 'no faculty of speech, uttering merely some inarticulate sounds, which her parents in some degree understood but which were wholly unintelligible to others.' Her hearing was 'perfect', and there was 'no defect in the formation of the external organs'. She comprehended all that was said to her and could point out written letters to dictation. There was no history of fits or 'any indications of cerebral disease or other physical imperfection.' There were no behavioural problems and from her parents' report she had always been 'intelligent, but incapable of speech' (Brodie 1854 : 50,51).

These two cases illustrate a type of speech disorder in which comprehension is normal, but the speech produced is unintelligible. They could both have been examples of DAS.

Thus, there is evidence by the middle of the 19th century that features of developmental speech disorders were being recognized, and that behavioural problems could be associated with speech defects. Somewhat later, Hughlings Jackson stated that 'children who are speechless, presumably from disease of the hemisphere, who are not deaf, and have no difficulty in swallowing are in a far more distressing condition' than certain other types of speech defective children (Jackson 1867 : 499.500). Jackson's view may be compared with Brodie's. Jackson continues: 'They are often very viscious: they will bite and scratch their brothers and sisters, break the furniture, set fire to things, and seem quite regardless of punishment. The only thing some of them seem capable of learning is singing and humming' (ibid).

One could speculate that this description would apply to a child with a severe degree of DAS, who displayed intact swallowing and hearing, and who had behavioural difficulties secondary to his speech defect.

Standard medical dictionary definitions in the last century provide us with further insights into the nature of various types of developmental speech disorder. In Quain's Dictionary of Medicine , Down describes many physical attributes of the feeble-minded under the entry for Idiocy. He reports abnormality of motor functions with 'defective co-ordination, resulting in a deficiency of purposive acts'. 'Speech', he says,'is defective, partly

from want of co-ordination of the muscles of the tongue, partly owing to deformations of the mouth and palate, and partly to inability to convert ideas into words' (Down 1882 : 685). Undoubtedly, this statement adequately covers such conditions as developmental dysphasia, developmental dysarthria and DAS, according to modern classifications. Further, in his recommendations of certain treatment regimes for children diagnosed as 'idiots', he anticipates some of today's approaches to the treatment of DAS (see below, pp 48). Thus: 'The defective speech is best overcome by a well-arranged plan of tongue-gymnastics, followed by a cultivation of the purely imitative powers' (op cit : 687). For all feeble-minded children, physical training for all muscle groups is recommended (op cit : 686).

A further definition given by Down which is relevant to this thesis was that of dumbness: 'The condition of an individual incapable of articulating sounds' (op cit : 407). He considered 'intellectual disorders' to be the most common cause of true dumbness, and he also made reference to the existence of 'defective power of co-ordination of muscles of the tongue' and gave more specific ideas for treatment.

In 1889, Sainsbury reported a 'Case of difficulty of speech', which, he suggested, could be regarded as one of 'aphasia'. A girl, aged 5.6 yrs, was practically unintelligible to strangers and could not imitate sounds accurately. Her health and general behaviour were normal, and there was no family history of speech difficulty. She was not deaf, and the only physical abnormality recorded was that of a double right little toe (Sainsbury 1889 : 533-535).

In 1891, Hadden's much quoted article 'On certain aspects of articulation of children' appeared. He refers to Sainsbury's case as being similar to those he was interested in. He gives no more specific diagnostic label to his cases than 'defects of articulation', but does say that they show similarities to 'aphemia' as described by Bastian. (Bastian defines it thus: '... where the movements concerned in speech are more simply defective, we have that indistinctness of articulation and blurred utterance which, in various degrees, is so commonly associated with different forms of paralysis due to cerebral disease' (Bastian 1882b : 1448).) This remark does not seem to have been taken up or commented on by any of his contemporaries. A modern equivalent, however, to this observation can be found in the Mayo Clinic & Mayo Foundation's Clinical Examinations in Neurology (1981 : 235), where apraxia of speech is equated with Broca's aphemia. This latter idea is followed by Rapin (1982 : 150) in describing her child patients with a 'speech programming deficit syndrome' as resembling those with aphemia.

Hadden states that his cases are 'characterized by extreme defects of articulation in children of good mental capacity, which are associated neither with mechanical conditions in the mouth, nor with disease of the auditory apparatus, but are almost certainly dependent on some fault in the central nervous system' (Hadden 1891 : 103).

Certain aspects of the speech of these patients are reminiscent of what today be called DAS: features of inconsistency, a tendency to confuse voiced and voiceless consonants, and difficulty in sequencing sounds into intelligible speech.

At a meeting of the Royal Medical & Chirurgical Society in March 1891, White and Golding-Bird described two cases of what they called 'idioglossia'. They described it thus: 'They heard well, and expressed themselves in articulate sounds. The sounds were unlike those of any known language, but the same sound was always used by the same child to express the same word' (White & Golding-Bird 1891 : 601). In the discussion that followed the presentation of their paper, Hadden remarked that the cases of defective articulation which he himself had described earlier that year were in fact similar to those of White and Golding-Bird. In the published report of these cases, however, there is a potentially significant difference: the White and Golding-Bird children were said to use sounds consistently - 'the same sound was always used by the same child to express the same word' (ibid). Hadden, on the other hand - and perhaps more accurately - had noted inconsistencies in his patients' speech, both during the course of assessment and treatment: 'Some of these patients if speaking deliberately would pronounce well - but if they attempted to speak quicker, they would get confused' (Hadden op cit : 602).

A further description of a developmental speech defect, this time by Taylor (1890-91) was given at the same meeting in March 1891 at which White and Golding-Bird discussed idioglossia. There are similarities to the other cases, but it is difficult to equate them precisely, since there are notable discrepancies in the accuracy of the transcription of the patients' speech. Taylor made no attempt, for example, to use a phonetic notation to set out accurately what they had said. Hadden tended to describe the speech in greater detail than the others, and to be cognisant of the overall use of speech over a longer period of time.

The term 'idioglossia' does appear to have subsequently come into widespread usage, and, given the nature of the defect, it seems reasonable to assume that at least some cases of DAS must have been classified and described under this heading.

The work of Hadden, Taylor, White and Golding-Bird was to be followed by comparable studies by Wyllie (1894), Colman (1895) and Guthrie (1907). It was through them that the word 'idioglossia' became widely known. Colman, realising that traditional English orthography could not adequately set out the phonetic features of his patient's speech - he considered it to be 'both defective and redundant' (Colman 1895 : 1419) - advocated the use of Wyllie's 'Physiological Alphabet' instead. As a result, he was able to bring out clearly the characteristics of the speech pattern, including the distinction he considered to be of 'great importance in considering treatment, that of voiced and voiceless consonants' (ibid). Furthermore, in his estimation, cases of idioglossia were 'by no means uncommon' (op cit : 1421), and he himself described eight in detail. By following the method of phonetic analysis that Wyllie had taught him, he was able to differentiate between manner of articulation (voicing) and place of articulation, as well as to set out other features of idioglossia and to provide detailed descriptions of his patients. There can be no doubt that these descriptions contain examples of what today would be diagnosed as DAS.

Guthrie was to publish a few years later further descriptions of idioglossic speech in his well-known textbook Functional Nervous Disorders in Childhood (1907); he devoted an entire chapter to the condition. His

first case was that of a boy aged 7.6 yrs with inconsistencies in the use of sounds and the inability to sequence sounds into words. There was 'no defect in the motor apparatus of speech', and this led Guthrie to conclude that 'since there was no physical abnormality and the child appeared to be unable to monitor his speech, the defect was not in his motor vocal apparatus, but in his ear'. Furthermore, the child was not deaf, but he lacked 'the power of discriminating shades of difference between sounds' (Guthrie op cit: 274). (He also pointed out that asking a child to say the alphabet aloud - as was the practice at that time - was not the best indicator of speaking ability, 'because the sounds of the letters when uttered singly are not the same as when combined to form words (op cit : 271).)

This linking of idioglossia to a deficiency in auditory discrimination was a common procedure at this time, and culminated in Worster-Drought's concept of congenital auditory imperception (CAI) (see below, pp 31-32). Thus, the theoretical explanation of idioglossia in the earlier part of this century lay not as today in a motor disorder but in some form of sensory deficiency.

Guthrie, in defence of his explanation of idioglossia as an auditory defect, pointed to the statement by Hadden that 'evolution of speech depends on integrity of auditory perceptive centres' (Hadden 1891 : 102) and to the view of Spencer Watson at the discussion following the presentations by White and Golding-Bird and Taylor that idioglossia might be due to a 'defect of hearing short of deafness' (White & Golding-Bird

1891 : 602). Guthrie himself was of the opinion that 'some defect of auditory perceptive centres is probable' (Guthrie op cit : 289).

Textbooks of speech pathology published in the early part of the century were to adopt Guthrie's point of view. In 1927, for example, Greene described idioglossia as 'another form of mutilated or stammering speech particularly observed in young children....These people seem to speak a distinct language of their own. Parts of words or whole words may be slurred, disjointed or otherwise mutilated...[There is] no weakness of intellect although there is often a family history of insanity...[The cause of idioglossia is believed to be] a congenital deficient appreciation of musical tone (emphasis, JPHM) (Greene 1927 : 29).

By this time, methods of assessment and speech sampling had progressed beyond the repetition of the alphabet and the Lord's Prayer: Greene argued for having the patient 'repeat words, or sentences, or read a short selection in order to ascertain what form his stammering takes and just where the defect lies' (op cit : 36).

Stinchfield, in her Speech Disorders (1933), follows the Robbins and Stinchfield 1931 classification, and describes 'idiolalia' - what many refer to as 'idioglossia or invented language' - as 'a form of dyslalia characterized by the substitution of unusual and inaccurate consonants, so that the language appears to be unintelligible. The same sound or combination of sounds is always used to express the same idea, however' (Stinchfield 1933 : 51-52). She did not, then, admit inconsistency to be one of the defining criteria of idioglossia. DAS cases must have been

subsumed in the only other relevant classificatory category, namely idiolalia.

In the UK, Seth and Guthrie's Speech in Childhood: Its Development and Disorders (1935) also expressed the view that the child suffering from idioglossia had a 'fundamental deficiency of a perceptive kind' (op cit : 156), and McAllister, in her Clinical Studies in Speech Therapy (1937), regarded idioglossia as a form of stammering: a group of defects 'distinguished by consistent distortion or omission of certain speech sounds so that the speech is unintelligible' (op cit : xv). The book covers a wide range of speech disorders, but does not deal in great detail with articulatory cases. This is unfortunate from the point of view of identifying DAS cases since she uses IPA notation in the presentation of cases, and one has, therefore, examples of a more accurate analysis of defective speech data than are to be found in the work of her contemporaries. (Stinchfield, ironically, thanks Prof Lloyd James, professor of phonetics at SOAS, London, in the preface to her work, but never once uses phonetic notation!)

The hypothesis, mentioned above, that idioglossia is attributable to an auditory problem short of deafness (Down, Guthrie, Greene) was taken further in the work of Worster-Drought and Allen (1929a,b), with the proposal that a category of congenital auditory imperception (CAI) should be established. This category was to be seen as an extension of congenital word deafness. By considering cases of idioglossia already extant in the medical literature, they were led to the view that idioglossia was

secondary to a CAI, and the condition should more accurately be termed congenital auditory imperception.

It is interesting that a number of features which Worster-Drought considers symptomatic of CAI would now be included in DAS, and the two conditions would differ in only a minor respect, namely the interpretation of a child's response to sounds. A number of other non-idioglossic speech cases described by Worster-Drought and Allen would nevertheless be regarded as examples of DAS today. Of course, it could be said in criticism of this view that the existence of normal hearing in a child as a marker of CAI could have been difficult to establish unequivocally at that stage in a child's life, for, as Luchsinger and Arnold put it, 'the final demonstration of central hearing disorders is often delayed until juvenile or adult age' (Luchsinger & Arnold 1965 : 517, quoting Luchsinger 1947, 1952).

In their 1950 study of cases described as having 'developmental dysarthria', Miller, Morley and Court paid particular attention to the question of CAI, beginning their review and reclassification of cases 'with an open mind' and saying that initially they thought they had been able to locate some specific examples of the defect. Later, however, they concluded that on repeated audiometric testing every potential case of CAI proved to have 'a considerable degree of partial deafness' (Miller et al 1950 : 579).

The term 'congenital auditory imperception' is not one that has been retained up until the present in the terminology of speech pathology.

There are, however, obvious links between it and the current concept of DAS in view of the difficulty of determining the role of auditory perception in developmental articulatory cases.

Contemporary with the work of Worster-Drought was that of Orton in the USA: the latter differed from him in certain respects. In Orton we have what is probably the first published description of a developmental articulatory defect classified as an apraxia. In the context of his view that the speech disorder in developmental apraxia is part of a more widespread motor disorder, he states that 'the difficulty of learning complex movements which characterises the apraxias may extend to motor problems of both speech and writing...and hence lead to specific language disorders in the motor expressive field' (Orton 1937 : 121). This approach looks forward to the so-called 'clumsy child' studies of Gordon & McKinlay (1980), Gubbay (1975) and others, in which an apraxia of speech can be regarded as one of the features of the developmental apraxic.

Orton's work was of particular value in the study of childhood speech disorders, although recently it has, for the most part, gone unrecognized. In essence, he believed that a close similarity existed between acquired language deficits due to brain injury and certain developmental problems - hence the terminology he used. In the speech pathology literature in the USA, there was no evidence that Orton's ideas and terminology had gained credence, and so the term 'articulatory apraxia' did not pass into common clinical currency. And so it was that the first description of DAS is normally attributed to the work of Morley and her associates in the 1950s, but the author of the concept in their terms was undoubtedly Orton. Morley

was clearly aware of his writings on the subject, since she refers to one of his articles in Morley (1957), although not specifically in the context of dyspraxia.

Chapter 2

The Assessment of the DAS Child

2.1 Since in this study a group of children diagnosed as suffering from DAS will be investigated, it is in the interests of the investigation to discuss assessment procedures which are at present in operation, and to determine any which it might be necessary to follow in order to isolate a group of children exhibiting the syndrome.

2.2 Assessment procedures for DAS involve the use of a battery of standardized tests. These tend to be general tests for all developmental speech disorders. Two batteries of tests thought to be suitable to assess DAS have been published, namely that by the Tennessee Speech and Hearing Association (Smartt et al 1976) and Blakeley's Screening Test for Developmental Apraxia of Speech (1980). The Tennessee Speech & Hearing Association Test is a battery of tests for speech and language , and is a modification of the assessment procedures adopted by Yoss and Darley in 1974. The criticisms levelled at the Blakeley Test (see below) could be equally applied in this instance.

The Blakeley test is both a descriptive analysis of the speech of children with defects as well as a statement of those features thought to belong to the DAS syndrome. (It is worth emphasizing at this point that there has been severe criticism of the Blakeley test by Guyette and Diedrich (1983), on the grounds that the author of the test presupposes certain aspects of DAS speech to have been agreed, when this is patently not the case.

Further, it is suggested that the test construction shows serious defects. In addition, Blakeley makes use of general language tests which were never devised specifically to diagnose DAS - eg the Peabody Picture Vocabulary Test, by Dunn (1965).)

Items from the Tennessee Test will be adapted in the present study for use in the investigation of volitional oral movements in the children under investigation (see pp 83-93).

No precise pattern of assessment procedures emerges from the literature on DAS, and at times one finds no guidance given as to how to interpret the results of the tests, or indeed of their relationship to DAS.

In summary the following nine areas of investigation find support from a variety of clinicians.

1 Audiometric screening is advised by Yoss (1972), Yoss and Darley (1974), Rosenbek et al (1974), Pritchard et al 1979, Williams et al (1981). It is assumed from these studies that any hearing loss will be detected, but none of the authors indicates what the effect of a proved hearing loss should be in the diagnosis of DAS.

2 Intelligence testing is recommended by some investigators who have carried out the few group studies of DAS children. In the Yoss (1972) study, only children with normal intelligence were included. The duplication of Yoss's study by Williams and her colleagues was similar (Williams et al 1981); and Rosenbek et al (1974), whilst recommending the

use of IQ tests, give no indication of the expected level of intelligence which might form part of the diagnostic profile of DAS. Macaluso-Haynes (1978) recommends psychological investigation to identify any cognitive difficulty. Reef (1967), in a single case study, advises an intellectual assessment 'where indicated' (op cit: 43).

3 Language development and comprehension A number of investigators (eg Yoss 1972, Williams et al 1981) have examined DAS children of a specific language age. In Yoss's study, the language age band of the child had to be not less than six months behind the chronological age.

The assessment of language ability is also recommended for DAS by Macaluso-Haynes (op cit), but she gives no guidance as to which tests should be used, nor any indications as to the relative importance of the results.

4 Oral form discrimination Tests for orosensory perception and oral awareness have been recommended in the investigation of DAS: see Hunter (1975), Macaluso-Haynes (1978), Pritchard et al (1979). Various methods have been recommended, including the use of specially devised plastic shapes (Pritchard et al 1979).

Again, the interpretation of these tests proves difficult, and it would be necessary for controlled trials to be carried out to assess their validity and diagnostic value.

5 Oral apraxia Most investigators of DAS include a reference to, and some specific test for, the assessment of a possible oral apraxia. The majority

of the procedures are modifications of the test by De Renzi et al (1966), devised for adult dyspraxics (see eg Williams & Kools 1968, Yoss & Darley 1974, Pritchard et al 1979). The study by Kools and Tweedie (1975), which examines the normal acquisition of praxis and the relationship between oral praxic ability and the acquisition of speech, makes the point that by using the modified De Renzi et al test, only part of the speech mechanism is being assessed: palatal movement, itself an important feature of speech production, cannot be assessed unless one resorts to the use of radiographic techniques.

Yoss and Darley (1974) used as a diagnostic feature of DAS the fact that the children would have difficulty with isolated and sequenced volitional oral movements. In other studies this has not been used, and indeed it has been suggested that such a disorder does not have to be present for a diagnosis of DAS to be made (Aram & Nation 1982, Guyette & Diedrich 1981, Jaffe 1984).

The correlation between oral apraxia and DAS has been called into question, and it is now generally accepted, and stated as such, that DAS can exist with a concomitant oral apraxia, but the latter need not necessarily be an element in the syndrome. (Results of an oral apraxia test with the children in this study are set out on pp 89-93, together with suggestions regarding the underlying vocal tract activities. This thesis will take into account any aspects of an oral apraxia test which may be of particular value in the assessment of DAS.)

6 Articulation tests A variety of articulation tests have been used in an attempt to diagnose DAS and to study the condition in more depth. The following have been used, but no particular reason for choosing one test rather than another is generally given:

-Arizona Articulation Proficiency Scale (Fudala 1970, used by Pritchard et al 1979)

-Templin-Darley Test of Articulation (Templin & Darley 1960, used by Rosenbek et al 1974)

-Van Riper Predictive Screening Test of Articulation (Van Riper & Erickson 1968, used by Yoss 1972, Yoss & Darley 1974)

-McDonald Screening Deep Test of Articulation (McDonald 1968, used by Smartt et al 1976)

-Goldman-Fristoe Test of Articulation (Goldman & Fristoe 1969, used by Williams & Kools 1968, Williams et al 1981)

In none of them is any attempt made to isolate specific articulatory features for testing - eg the distinction between voiced and voiceless sounds, which has been suggested as a feature of DAS.

7 Diadochokinesis Investigation of oral diadochokinetic rates is included in a number of DAS investigations (Yoss 1972, Yoss & Darley 1974, Williams et al 1981), as well as in the Tennessee Speech & Hearing Association Test. A number of studies of diadochokinetic rates have been carried out, both for normal and abnormal speech, but Stoudt in his review of them (Stoudt 1967) has urged caution in transferring the values directly to a clinical setting because of the differing methods of assessment and evaluation of movement used in them.

8 Neurological examination A neurological examination was carried out for the children in the studies by Yoss (1972), Yoss & Darley (1974) and Williams et al (1981). Yoss reported a high incidence of 'soft' neurological signs , but this finding was not confirmed by Williams and her colleagues (1981), replicating the form of Yoss's study. Reef (1967), in his article on apraxic dysarthria - to use his term for DAS - concluded that if no organic lesion is evident from the clinical methods of investigations, then EEG examination for example may be necessary. He gives no information, however, as to what might be found by this method. As a result, it is impossible to judge the appropriateness of his suggestion.

9 Miscellaneous Slow response to certain forms of therapy does seem to be a clinical feature of the disorder, as a number of clinicians have emphasized (see eg Yoss & Darley 1974). Court and Harris (1965) also adopt this feature as a criterion for differentiating between DAS, dysarthria and 'continuing immaturity of speech'. This aspect of the differentiation of developmental dyspraxic assessment was indeed highlighted somewhat earlier by Morley et al (1954).

Certain investigators permit their diagnosis of DAS to derive primarily from a descriptive analysis of certain anticipated features, both linguistic and behavioural. Eisenson (1972) is perhaps the best known example of this approach. In addition to taking account of the child's background and developmental history, he examines for deficits in the following areas: responsiveness to environmental sound, early oral activity, articulatory activity and sequential activity (allied to

sequencing of sounds). He delineates the speech features which he believes to be indicative of a DAS child, but gives no indication of the relative importance of each factor.

2.3 Most other investigators use the analysis of speech as the conclusive diagnostic feature, even if they do claim to use a battery of tests. As has already been indicated, the tests have not been devised specifically for the DAS child, and it will be obvious from the summary of test procedures given above that assessment for DAS lacks as yet any definitive theoretical basis.

Since there is no real agreement amongst clinicians as to what should constitute the significant features of the disorder, it is perhaps inevitable that at the present time rigorous assessment procedures are not yet in existence. Further research may highlight aspects of speech which would be worth investigating. Indeed, a suggestion to be made in this study is that the phonatory and respiratory aspects of DAS are worthy of further investigation.

Chapter 3

Therapy for the DAS Child

3.1 The attempt to provide adequate therapy for children with DAS has generated considerable discussion for many years. This has arisen to a large extent because of the severity of the speech condition and the lack of response of such children to standard forms of therapy. Indeed, this lack of response is seen by many as a diagnostic feature of the condition (see p 40).

As with the lack of agreement on the number and type of features necessary for a positive diagnosis of DAS and thus a rigorous assessment procedure, so the therapy recommended by writers does not follow an identical pattern - nor do all writers recommend the same combinations of therapeutic procedures. It should be borne in mind, of course, that a researcher, as distinct from a clinician, has the luxury of being able to discuss the possible features of a condition, whereas the clinician is faced with the need to treat the condition, often on the basis of imperfectly understood data. For this reason, however much one may applaud the view of Rosenbek and his colleagues that 'the apraxic child is a rarity; knowledgeable therapies should not be' (Rosenbek et al 1974 : 21), the potential conflict between a research and a therapeutic context can lead to differing points of view - perhaps in some instances to the appearance of no secure point of view at all. As, then, with the lack of agreement on the number and type of features necessary for a positive diagnosis of DAS and thus a rigorous assessment procedure, so

the therapy recommended by writers does not follow an identical pattern - nor do all writers recommend the same combination of therapeutic procedures. Given the confused understanding of the condition, this is perhaps inevitable.

3.2 In the 19th century, there was a well regulated set of procedures to be followed in the treatment of children categorized as idioglossic - many of whom would be our present-day DAS population. It was recommended that the children be considered as deaf-mutes and treated accordingly (see the work of White and Golding-Bird 1891. However, with the development of more seemingly sophisticated views of the nature of DAS, therapeutic procedures have become more varied.

3.3 Since DAS is such a loosely defined concept, so far no comparative statement on the effectiveness of a particular therapy can be made. It is possible, however, to summarize five areas of therapeutic technique which have been recommended in the published literature. It is of value to discuss these, to consider any clues as to the nature of the condition which may have arisen from day-to-day clinical experience.

1	Verbal	(a) segmental
		(b) non-segmental
2	Non-verbal	(a) surrogate communication systems
		(b) kinesic (general)

3 Oro-motor functioning (a) oro-motor exercises

(b) tactile or kinaesthetic oral approach

4 Language therapy (a) syntax and semantics

5 Miscellaneous and use of modalities other than speech

1 Verbal

1a: Segmental -ie speech in terms of its component vowels and consonants.

Since DAS has for some time been viewed by the majority of speech therapists as a speech disorder (Eisenson 1972 :189-202, Morley 1972 : 275, Rosenbek et al 1974 : 13), it would be expected that well established and critically examined therapy along segmental lines would be available. No real evidence of a therapeutic programme dealing satisfactorily with the intricacies of the articulatory system which is disturbed in DAS has been described, although there is general agreement regarding broad articulatory approaches to therapy. Indeed, when summarized, the therapeutic programmes from a segmental point of view are almost identical to therapy for children with a functional articulation disorder. (See Morley 1972 : 305-351 for a detailed DAS therapy programme of this type.)

There is general agreement amongst writers that the segmental part of therapy should be covered in three phases as follows (see eg Yoss & Darley 1974, Macaluso-Haynes 1978, Connery et al 1982):

1 Individual phonemes

2 Phonemes in sequence

3 Individual words and key phrases, based on 2 above

There is no real agreement about the specific order in which phonemes should be taught (see Eisenson 1972, Chappell 1973, Rosenbek et al 1974, Yoss & Darley 1974, Smartt et al 1976, Connery et al 1982) for a variety of approaches). The most detailed segmental programme to date has been produced by Eisenson (1972).

1b: Non-segmental (This term covers features such as stress, intonation, rhythm, phonation types, speech tempo.)

This aspect of the verbal output of the DAS child has received some, albeit limited, attention in therapy programmes (Hunter 1975, Rowan 1983). The importance of an awareness of non-segmental features in therapy for DAS has been stressed by Hunter when she states that 'Stress, rhythm and intonation are introduced using any vocalization the child is able to make... Often, just using the correct prosodic features is enough to give some measure of intelligibility to the child's utterances' (Hunter 1975 : 138). This aspect of intelligibility of speech is referred to by Garvey in relation to clumsy children who can exhibit difficulty with prosodic features, thus reducing intelligibility (Garvey 1980 : 129). She gives specific exercises for stress, rhythm and intonation.

Singing is recommended as part of the therapeutic programme (Rosenbek et al 1974, Macaluso-Haynes 1978). A form of Melodic Intonation Therapy has also been advised (Weiss et al 1980, Helfrich-Miller 1984).

Control of speech tempo is a feature mentioned in some therapeutic programmes (see eg Eisenson 1972).

These measures are all reminiscent of the type of therapies used in the treatment of stammering, and in the main are in the nature of general guidelines.

An aspect which merits fuller investigation is the point in therapy at which rhythmic abnormalities become apparent. In practice it is noted that this seems to occur when the child begins to sequence phonemes. This clinical finding is a useful indicator of a descriptive feature of the condition. A factor which may be of significance in this connection is the suggestion to be made in this thesis that the DAS child may not have fine timing control of the airflow mechanism for speech.

One important development would be to see closer links developed between segmental and non-segmental features (as with Hunter's recommendations), thus avoiding the staccato type of so-called 'taught speech', which can result from intensive treatment concentrating on segmental features alone.

2 Non-verbal

2a Surrogate communication systems

A therapeutic procedure for the DAS child which is advocated by some researchers is to teach the child a non-speech communication system, for example signing (Larson 1971, Rapin 1982, Jaffe 1984). The most suitable system has not been specified, but of the communication systems in current use, it can be assumed that Makaton, Amerind and British Sign Language are the main possibilities. None of these, however, has been devised specifically for the DAS population, and to date no comparative study has been published reporting the results of such a method of treatment.

A currently expanding field of interest in speech pathology is the use of electronic communication aids, and in this area there are several possibilities for the management of the child with a severe DAS. It may be that the use of such an aid for communication purposes at certain stages of the child's development would help to relieve the frustration which is often evident in a child with DAS who is unintelligible to other people.

A note of caution should be entered when we consider alternative methods of communication. If we accept Kent's hypothesis that 'motor control for speech becomes highly ingrained at about eleven years, after which time new phonetic systems can be acquired only with considerable difficulty' (Kent 1976 : 442), perhaps we should concentrate therapy time on the training of speech motor movements and not on complex signing systems. Certainly there is today a body of opinion which

believes in 'drill and practice' in the articulatory field somewhat reminiscent of Down's plan of 'tongue gymnastics' (Down 1882a). It is crucial that the optimum developmental period for articulation therapy is not missed.

The use of a suitable communication aid for severe cases for use in emergency or very frustrating circumstances, however, should not adversely affect the therapeutic programme, in that the aid would be used as an augmentative device and not as an alternative communication system.

2b Kinesic - ie related to body movements.

The importance of controlled general body movements is mentioned in certain therapies for DAS as early as 1891. At that time, Hadden was recommending 'regular exercise and games out of doors' (Hadden 1891: 99) for his first reported case with defective articulation. In 1980, in her discussion of clumsy children with speech difficulties, Garvey speaks of the importance of the connection between language patterns and body activities and includes general body movements in her therapy for such children (Garvey 1980). Other examples of the attempt to link bodily movements with speech exercises for DAS can be found in the work of Rosenbek et al (1974), Hunter (1975) and Macaluso-Haynes (1978). This again may be an insight into another aspect of the DAS child's condition. In the group of children under study in this thesis, a high proportion were reported as having some degree of clumsiness, particularly of hand movements (see below, pp 71-72).

This is an area in which interdisciplinary cooperation is essential. Traditionally, in the treatment of a developmental disorder such as cerebral palsy there is close cooperation amongst the professionals involved in the management of the child. These include physiotherapists, occupational therapists, speech therapists and medical personnel. Perhaps the approach should be extended to the child with an apraxia which involves the speech musculature, since the speech disorder can be part of an overall movement disorder. (See further pp 117-118.)

A number of clinicians give specific recommendations for what could be termed the 'kinesic approach'. Weiss et al (1980) follow McDonald's sensory-motor theory (1964) and suggest what is essentially a form of Melodic Intonation Therapy, in which gross motor movements and speech are co-ordinated. This is an approach which Yoss and Darley also advocate (1974).

The 'kinesic approach' is thus an area of interest closely linked to the rhythm and stress of speech and thus to non-segmental features (see above).

3 Oro-motor functioning

Another feature of DAS therapy programmes is that of work on oro-motor functioning. By this is meant the attempt to train the child to move the speech organs adequately to command. In some instances, speech sounds are included, and thus this aspect of therapy is closely related to the previously described segmental approach.

3a Oro-motor exercises

Three main techniques for this area of therapy are evident in the published literature on DAS:

1 Positioning the articulators (eg Hardy 1978, Garvey 1980).
2 Teaching the ability to carry out basic motor movements either to verbal command or with additional visual stimulation (eg Smartt et al 1976, Hardy 1978, Macaluso-Haynes 1978, Garvey 1980).
3 Facilitating the combination of basic articulatory movements into sequences of movements with an awareness of speed and precision (eg Chappell 1973, Smartt et al 1976, Hardy 1978, Garvey 1980).

Often no connection is made in such therapy programmes between oral movement and oral sensation. Garvey, however, does recommend procedures to encourage 'oral awareness' in association with oral movement. Perhaps the two cannot be usefully dissociated in therapy.

In the area of therapy for DAS, the initial diagnostic features and theoretical viewpoint of the clinician are of significance (see pp 37-38 for a discussion of the presence of an oral apraxia in DAS). Further discussion and investigation of this feature will be found between pp 83 and 93 of this thesis.

3b Tactile and kinaesthetic oral perceptual approach

This is linked to oro-motor functioning, but some writers do place more emphasis on the perception of oral sensation than on positioning of the articulators (eg Hunter 1975).

Seiderman (1970) views DAS as a perceptual-motor dysfunction, and thus uses as the basic principle in therapy 'the enhancement of sensory input followed by the demands of a perceptual skilled motor task' (1970 : 850).

Edwards (quoted by Macaluso-Haynes 1978 : 246) has suggested the use of small acrylic plates with roughened surfaces placed in the mouth to assist oro-sensory awareness. No follow-up information or more specific details have been published, so it is not possible to comment on this possibility of treatment.

Further specific therapy techniques such as the Prompt System (see Chumpelik 1984) and the Touch Cue Method of Treatment (see Bashir et al 1984) have all been suggested. These will not be described here, but they do follow the principle of aiming therapy at a tactile oral perceptual approach, and have been specifically devised for DAS children.

4 Language component in therapy

The suggestion has been made that within the DAS syndrome there may be an element of language disorder (Edwards 1983, Ekelman & Aram 1983), ie that within the syndrome there is not just a disorder of phonetic features but also of syntactic and/or lexical ones. A sufficient body of opinion still exists, however, which would favour the statement by Rosenbek et al, based partly on the views of Yoss, that DAS 'is not a disorder of language, although it may co-exist with language deficits and learning disability' (Rosenbek et al 1974 : 13). This view is shared by Eisenson, who points out that the DAS child may, in addition, suffer from congenital aphasia (Eisenson 1972).

Aram and Nation, a decade later, take up the question of whether DAS is a 'speech' or a 'language' disorder, ie whether it is part of childhood aphasia or can be described as another speech disorder, when they say that 'since all the answers are far from conclusive, we maintain that a less than arbitrary position should be taken, including the theory that developmental apraxia may be part of rather than apart from a child's language disorder' (Aram & Nation 1982 : 151).

Dependent therefore on the theoretical position adopted by the clinician, and the results of assessment, a language component may or may not be included in the therapy plan.

5 Miscellaneous and use of modalities other than speech

Certain recommendations regarding the use of modalities other than speech and on general management in DAS therapy have been made. The following is a summary of such suggestions. It will be noted that the area is wide, and most agreement centres on the importance of making use of the visual sense in therapy procedures.

5a Visual emphasis

See Hadden 1891, Rosenthal 1971, Eisenson 1972, Yoss & Darley 1974, Rosenbek et al 1974. Recently, Hardcastle and Morgan (1982) have emphasized the use of visual feedback in their investigative instrumental work on articulation disorders (see below, p 64).

5b Auditory discrimination.

There is a lack of agreement on the necessity for auditory discrimination training to be given to DAS children, dependent on whether the clinician regards auditory perceptual difficulty to be a feature of DAS. Macaluso-Haynes (1978) states that there is a necessity for this aspect of therapy, whereas Weiss (quoting Rosenbek et al 1974) suggests that a check should be made to see if the child has auditory discrimination difficulties; only if this is present, should appropriate therapy be given (Weiss et al 1980). Eisenson (1972) and Garvey (1980) recommend auditory perceptual work.

5c Behaviour modification and other psychological procedures are used in some therapy programmes:

behaviour modification (Ferry et al 1975)

reinforcement management devices (Daly et al 1972)

token reinforcement programme (Rosenthal 1971)

operant conditioning (Edwards 1973)

3.4 Conclusion

It will be obvious from the therapeutic suggestions in this section that there is a wide variation in recommendations and there are no definitive answers. All therapy programmes for DAS are based on rather uncertain theoretical foundations, since the character of the disorder is still not fully understood, but they may in themselves provide pointers to aspects of the disorder.

No specific work on respiratory or phonatory features is evident, but is contained, albeit unwittingly, in some of the non-segmental therapies, and in a specific therapy such as Melodic Intonation Therapy.

There is a need for present research into the condition of DAS to be introduced into clinical therapy, and for the clinician to use the therapeutic programmes with discrimination, aware that in a number of cases there is, as yet, no proper theoretical justification for their employment.

Chapter 4

Voicing and Voice Onset Time in Children: Auditory and Instrumental Perspectives

4.1 In any study of abnormal speech development, cognizance must be taken of the normal pattern of speech acquisition, in order that a distinction may be drawn between deviant and delayed speech and that a standard for comparison may be available. As this thesis is concerned with the use of a particular phonetic feature in DAS, it is interesting to note that although a body of descriptive material of children's articulatory patterns exists (see eg the summaries in Winitz 1969, Cruttenden 1979) few specific chronologically ordered conclusions have been reached which could serve as norms of acquisition from the point of view of this thesis. It should in any case be noted that many of these studies refer to American forms of English, and that no comparable large-scale studies exist for any accents of British English, with the exception of Eastern Scottish (see Anthony et al 1971). A further lacuna is information on another aspect of phonetic development relevant for this study, namely children's phonation types (whisper, creak etc).

4.2 Auditory-based studies of articulatory acquisition

Traditional large-scale population studies of the acquisition of speech sounds (of the sort that Winitz. for example, summarizes) have aimed to provide a statement of a chronological age at which a child should articulate a sound 'correctly' (cf Wellman et al 1931, Poole 1934, Templin 1957). Within these studies, no distinction is drawn between so-called phonemic acquisition and the acquisition of specific articulatory configurations, ie allophonic realizations of phonemes.

Thus, sounds produced by a child such as [t tʰ tˢ] would be included as a single [t] sound. By using a phonemic transcription, data such as the presence of palatalization or affrication will not be recorded. In this connection, we should note the view expressed by Carney that 'assessment of speech based on data recorded in terms of phonemes or distinctive features is shown to be unsafe, because the levels of abstraction can obscure the phonetic facts' (Carney 1979 : 123).

As early as 1934, Voegelin and Adams discussed the method of recording children's speech data. They stated that 'phonetic transcription is so flexible that more than the significant sounds may be recorded if desired', and found that 'the variation within a phoneme is greater for children than for standard adult speech' (Voegelin & Adams 1934 : 108). They adopted, however, a phonemic approach which 'did not take into account variations within the phoneme, such as the lack of aspiration, glottalization, retroflex formation, and relative forward and backward position'. They were able to justify a phonemic transcription on the grounds that the variations occurring within the phoneme were 'so slight that they would probably not even be observed by parents and teachers in general'. This decision , taken on the grounds of practicality, can now be seen to have been an incorrect one, since the ensuing widespread decision to use a phonemic rather than a narrower phonetic transcription means that workers in speech pathology who require finer, more detailed information on speech development (as for example in a disorder like DAS) are not able to find a comprehensive and reliable core of data on phonetic aspects of speech development. Such information is necessary not just for diagnostic and assessment purposes, but for the use of

'goals' in planning appropriate therapy. Over the years, much phonetic data could have been accumulated if narrower transcriptions had been attempted, and thus more detailed chronological information might now be available. Admittedly, in recent years certain articulation tests such as the Edinburgh Articulation Test (EAT) (Anthony et al 1971) have attempted to remedy the situation, but list only a single phoneme examination of single utterances of specific test words. No overall impression of the total range of allophones in a child's speech is obtained.

4.3 Instrumental studies of speech acquisition

One of the main aims of the experimental section of this thesis is to investigate, by instrumental means, one aspect of voicing in the DAS child, namely voice onset time (VOT), the time-lag between the noise-burst in the production of a stop sound and the onset of voice, either in the stop itself or in the following vowel. It is apposite, therefore, to consider at this stage instrumental investigations of speech disorders with particular reference to childhood articulatory speech disorders, and in particular to any which refer to VOT.

Various techniques (electromyographic, acoustic, aerodynamic) can be used to collect data on individual aspects of speech production. The collection of simultaneous data is more difficult, mainly because of technical problems, but advances are now being made in this field (see eg the discussion in Baer & Alfonso 1982). A considerable amount of information requires to be amassed on developmental changes in the speech mechanism, and to date no large scale studies of, for example,

respiratory or laryngeal functioning in speech, even for normal children, has been carried out.

From the point of view of the speech pathologist, the application of such techniques as electropalatography, pneumotachography and the acoustic measurement of features such as VOT (see below pp 59 and 67) should provide more reliable data on speech disordered children than the subjective auditory assessment of speech has done. A difficulty, however, lies in assessing the relative value of data of this type, since reliable comparative norms do not, as yet, exist.

Certain phonetic aspects of normal speech development have been investigated in recent years using instrumental techniques. These studies, comprehensively reviewed by Kent (1980), are still in many respects in the preliminary stages, but the overwhelming conclusion from them is that the age at which a child can be said to have a stable adult-like speech system is much later than has hitherto been assumed from non-instrumental work (eg that of Templin - see p 55 above). In Kent's survey of acoustical studies, which provide information on the 'anatomical and neuromuscular maturation of the speech mechanism', the conclusion is reached that 'the accuracy of motor control improves with age until adult-like performance is achieved at about 11 or 12 years' (Kent 1976 : 421). A corollary to this, unnoticed by Kent, must be that he is considering articulatory aspects of speech production: by the age of 11 or 12 the phonatory patterns of a girl and, more obviously of a boy, still do not match those of adults.

4.4 Voicing and voice onset time

Confusion exists in some quarters over the use of the terms 'voicing' and 'voice onset time (VOT)' (see below p 65). In the experimental section of this thesis, both voicing and VOT will be investigated: it is therefore essential that the distinction between the two terms is recognized.

To a normal adult speaker of English, the word PIN sounds different from the word BIN: on the basis of this perceptible difference which signals a difference of meaning, we can say that there is a phonemic contrast between /p/ and /b/. The phonetic factors which create the difference in the first place are three in number: (1) the strength of the sounds in question - /p/ is stronger in terms of articulatory effort than /b/, (2) the length of the sounds - /p/ is longer than /b/, and (3) the time interval between the release of air after the total obstruction to airflow at the lips for the two stop sounds and the beginnings of vocal fold vibration for the vowel. This latter is the voice onset time. To create the recognizable phonemic contrast between /p/ and /b/ in this context, it is the VOT that is critical. The longer the VOT, the greater the likelihood that the sound will be perceived as a voiceless stop, ie /p/; and the converse applies. Measurements of the VOT in my own pronunciation of the two words will serve as an example:

PIN : VOT 60 milliseconds (ms)

BIN : VOT 11 milliseconds (ms)

If the two phonemes /p/ and /b/ are used in a different context, then the VOT values may vary. Thus in the words LOPPING and LOBBING, the VOT values in my speech are: for /p/ 38 ms, for /b/ 21 ms. In word-final position, there can be an even greater alteration, with no voicing at all being present in a so-called voiced phoneme :

NIP : VOT -15 ms, NIB : VOT 0 ms.

It will be clear that sometimes the onset of voicing follows the release of the stop, sometimes it is simultaneous with it, and sometimes it precedes it. The terminology used by phoneticians will be adopted here: voicing following the burst of air is a positive VOT, voicing preceding it is a negative VOT.

The term voicing refers to a particular activity of the vocal folds: the periodic cycle of abduction and adduction. Sometimes other so-called phonation types are used in speaking, such as creak (the irregular vibration of part of the vocal folds, usually towards the thyroid end) and whisper (the narrowing of the space between the folds (the glottis) without actually causing full abduction) and so on. Both creak and whisper can operate simultaneously with voice: in creaky voice, there is irregular vibration towards the thyroid end, but regular vibration towards the arytenoid end of the vocal folds. In whispery voice, part of the glottis remains apart - hence the turbulent effect - but the remainder of the glottis is in regular vibration. Any discussion of 'voice' or 'voicing' in dyspraxic children ought to draw a distinction between any deviance in terms of phonation type and deviance in terms of VOT.

Two further terms require to be explained. Aspiration is the traditional phonetic term for the perceptible positive VOT, ie the time-lag between the release of the stop and the onset of voicing. Most productions of /p/ in a word like PIN involve a degree of aspiration, ie if the positive VOT is greater than about 40ms, then the sound is perceived and described as aspirated; if the positive VOT is less than this figure, then the sound is unaspirated. It will be shown that some dyspraxic children fail to signal a voiceless sound because their positive VOT is less than about 40ms, and the adult listener hears instead a 'voiced' sound. The child's production, then, is unaspirated, and from the point of view of the adult listener deviant.

It is not unusual in a word like NIB, or any word ending in a so-called voiced stop phoneme, when silence follows, for the voicing in the stop to cease well before the end of the consonant: the sound is described as devoiced. (VOT data for NIB and NIP are given above, p 60.) In the absence of vocal fold vibration to help signal a /b/ rather than a /p/, the distinction between the two sounds is carried by a mixture of inherent strength of the two stop sounds, their length, and the length of the preceding vowel (cf Fry 1979).

When speaking in phonemic rather than phonetic terms, it is traditional to use a term such as 'voiced stop' as a shorthand label for two features of the phoneme: one, that the sound is a stop, the other that there is some phonatory activity taking place, even if the actual phonetic values for the VOT would seem to put the sound into the 'voiceless stop' category. Thus in NIB said before silence, there may

be virtually the same negative VOT in the /b/ as there is in the /p/ of NIP, but the phonemes remain distinct - on the basis primarily of the length and the strength of the sounds; voicing, strictly speaking, may not be relevant, but the term 'voiced' is still used.

In the context of this thesis, it is important to appreciate that the factors which underpin normal adult productions of /p/ and /b/ may not *a priori* be applicable to the question of how the dyspraxic child realises the distinction - if indeed he can be said to have the distinction. Furthermore, it must be borne in mind that VOT values for *normal* children are not the same as for *normal* adults, and that an adult observer's perception of which phoneme a child is attempting to reproduce (the voiced or the voiceless one) may differ in some way from what a normally functioning member of the DAS child's peer group might perceive. This is a question which has so far not been studied.

4.5 Voicing in DAS

Disorders of voicing are one aspect of DAS which Yoss (1972) found to be a significant feature. The DAS children under investigation had twice as many errors of voicing as the comparative group of children with delayed articulation. This study and the subsequent article by Yoss and Darley (1974) have frequently been quoted as a major development in the study of DAS. It should not go unnoticed, however, that Morley (1959) had also pointed out the possible substitution of voiced for voiceless consonants in DAS.

There is, nevertheless, no unanimity of opinion on the use of voicing in DAS amongst clinicians who have investigated the condition. The duplication of the Yoss and Darley study by Williams et al (1981) does not concur with the finding in respect of voicing. (There were, however, significant differences in the method of selecting the subjects for the investigation, and these could, conceivably, have affected the results.)

A previous study by Williams et al (1980) in which clinicians were asked to answer a questionnaire related to the assessment of DAS found that the voicing disorder was not one which was deemed to be of definite significance. This study was, however, very dependent on the knowledge and experience of the therapists who acted as assessors and on their phonetic ability.

Since both the studies by Williams and her colleagues which contradict the conclusions reached by Yoss are on Australian populations, one wonders whether DAS in British, American and Australian English can be said to be exactly comparable. Similarly, it could be questioned whether the DAS children studied by Morley, Court and Miller in Newcastle-upon-Tyne could be equated directly with a West of Scotland population, since differences in regional accent would cause differences in the phonetic realization of phonemes. A recent Australian study of normal speech acquisition shows some surprisingly differing results for children from various parts of Australia and from American children (Chirlian & Sharpley 1982).

A close look at possible DAS cases in the literature before Morley as well as cases that have been described since her work in the 1950s does reveal some evidence for the thesis that in DAS there is a difficulty in the development of the correct voicing contrasts. There is, of course, a diversity in the accuracy and detail of the phonetic analysis employed by the various authors which makes definite conclusions impossible. However, there are indications of such a feature in, for example, Hadden's cases of defective articulation (Hadden 1891) and in Sainsbury's 'case of difficulty of speech' (Sainsbury 1889).

The instrumental study of children with articulation disorders by Hardcastle and Morgan (1982) found voicing errors in the two DAS children who were included in the study. One had 'no apparent distinction between voiced and voiceless plosives and fricatives' (op cit: 48). (This particular child also had auditory discrimination problems, with noticeable difficulty in distinguishing voiced/voiceless stops and fricatives (op cit: 48). The other child had 'little distinction between voiced and voiceless fricatives' (op cit: 49).)

Further related evidence of a possible problem with voicing contrasts in a DAS syndrome is to be found in Snowling and Stackhouse's work on the spelling performance of 4 such children (Snowling & Stackhouse 1983). Two of the 4 cases had a significant number of spelling mistakes which could be attributed to voicing errors.

Before this type of evidence can be taken to signal an underlying problem in the development of voicing contrasts, information on the

development of the normal child's ability to operate the voicing contrast in spelling would have to be taken into consideration. A normal child just beginning to read was examined by Snowling and Stackhouse using the same methods as that for the DAS children, and it was found that all of his spelling errors were due to 'voicing changes in final consonants' (op cit: 432). This was accepted as a normal feature of spelling development, but such a conclusion is perhaps rather premature in view of the fact that only one child was examined.

A particular example of the confusion which exists between VOT and voicing is illustrated in Edwards (1984) where she states that in dyspraxia - both developmental and acquired studies are equated, with no reference to their differences - voicing is 'one of the most frequently cited errors (op cit : 87). In defence of this statement, Hardcastle and Morgan's study (1982) is quoted - this actually measures VOT in instrumental terms - as is that by Yoss and Darley (1974), which describes voicing in traditional auditory terms as a voiced/voiceless distinction. (See pp 59-62 of this thesis for a discussion of VOT contrasted with that of voicing.) The distinction is a crucial one, and it is vital for any future studies of DAS that it be understood, otherwise, as in the case of Edwards (op cit), unjustified conclusions can be made.

4.6 Voicing and VOT in aphasia

Within the literature on adult aphasia, instrumental investigations such as those on VOT have been published, as have comments on voicing (see eg

Shankweiler & Harris 1966, Freeman et al 1978). Blumstein et al (1977, 1980) have differentiated between types of aphasia on the basis of measurements of VOT. The latter study has been criticized by Walsh (1983) who recommends glottographic observations in addition to VOT measurements.

With regard to voicing errors, in 1966 Shankweiler and Harris studied the phonetic characteristics of a number of expressive aphasic patients who had residual articulatory defects. It was found that a number of errors occurred in manner of articulation chiefly that of voicing: in particular, a voiceless sound was replaced with a voiced one.

Sands et al (1978) followed one of Shankweiler and Harris' patients over a 10 year period, and found that, although improvement in certain articulatory features was evident, there was a significant percentage of voicing errors in the patient's residual difficulties.

Chapter 5

Voicing and VOT in the DAS Child
Design and Results of the Investigation

5.1 Since speech involves the coordination of respiration, phonation and articulation - and thereby the activities of over a hundred muscles - a full instrumental study of the voicing contrast in DAS along the lines of that described in Hewlett and Anthony's 1982 report of voicing characteristics in a normal male speaker would be of particular value. The technical and staffing requirements involved in this are beyond the scope of this exploratory study. Nevertheless, taking into account the possibility of an incoordination in respiration, phonation and articulation in DAS, a full study of these factors would be of considerable interest : not only as an academic exercise in describing the totality of features present at the aerodynamic and physiological levels, but also as a potential means of gaining new insights into the nature of DAS, which could be of practical benefit in the assessment and remediation of the condition.

5.2 The present exploratory investigation of the voicing contrast in DAS will consider voice onset time (VOT) values for a group of DAS children, assessing the results in the light of other features of voicing obtained by traditional phonetic analyses and relating the conclusions to results obtained from a test of volitional oral movements.

5.3 The study will confine itself to a compilation of spectrographic data from which will be obtained information on VOT values, and to the administration of a slightly modified standard test of volitional oral movements. Of particular interest in the latter will be any items which

require responses of the laryngeal and respiratory mechanisms. Most important would be movements requiring coordination of respiratory, laryngeal and supralaryngeal mechanisms. There will in addition be a discussion of the assessment of voicing described in traditional phonetic terms.

5.4 Thus, the aim of this thesis is to investigate further the hypothesis that a disorder of the voicing contrast is a characteristic feature of DAS. It will involve the following analyses:

1 the isolation of the voicing contrast in the speech of the DAS group under study by conventional phonetic analysis;

2 the investigation of a specific aspect of voicing, namely VOT, by instrumental means, and the comparison of the experimental group with a group of normal children;

3 the examination of isolated volitional oral movements (IVOM) and sequenced volitional oral movements (SVOM) as assessed by a standard test, subdividing the test items so that specific articulatory features are isolated. In this connection, the laryngeal and respiratory features are of particular interest.

The experimental DAS group will be matched with a group of normal children.

5.5 It was originally intended that an additional instrumental investigation using the laryngograph would be included. The children under study were all asked to produce their 'normal' voice on certain sounds, and then to try to demonstrate another kind of voice quality (in this case that of the film character ET - ie a severely creaky, breathy ventricular

voice). The investigator was interested in the children's ability to vary voice quality in a volitional manner. Laryngograms were made, but an effective objective interpretation of them was hindered by the lack of published normative data as well as by the complex computer assessment of the waveform which would have been necessary to derive maximum benefit from the data. It was therefore felt that the analysis of such data would go beyond the scope of the thesis.

Some tentative comments on this area of investigation have been made (see below pp 110-112), and some data have been included.

One feature, however, which did emerge from the data was that the DAS children exhibited a difficulty in changing voice quality at will, and this would be an interesting area for future research, particularly if descriptions of voice quality were made by, for example, a system such as the Vocal Profile Analysis (Laver et al 1981).

5.6 From the point of view of an examination and comparison of the VOT results with a pathological paediatric condition which was well defined, the speech of two children with cerebral palsy was analysed for VOT. One child (CP1) was described as having mixed cerebral palsy, and had unintelligible speech. The other child (CP2) was described as having 'spastic quadriplegia', and her speech was intelligible.

5.7 Subjects

5.7.1 Criteria for selection of DAS children

The subjects were selected according to the following criteria:

1 All had had a neurodevelopmental assessment at the Royal Hospital for Sick Children, Glasgow (RHSC). The majority had been referred there because of concern about their speech development.

2 In all cases it had been felt by the hospital assessment unit staff that there was a dyspraxic element in their speech. There was, in effect, a double diagnosis of dyspraxia of speech ie that of the referring therapist, or therapist giving regular treatment in addition to that of the hospital staff. This diagnosis had in all cases been arrived at by traditional speech therapy practice and in the absence of a definitive assessment procedure for DAS (see above Chapter 2) was accepted for the purposes of this study. In the event, only one child was excluded as being unsuitable since she had developed a normal speech pattern by the time the study took place and was thus probably wrongly diagnosed initially. In all other cases, I considered that an element of varying degrees of DAS could well be present.

3 All the children had a West of Scotland accent.

4 The children had to have enough usable speech to enable a sufficient sample of verbal material to be obtained.

5 All had normal hearing and had been assessed by audiometric testing.

6 All had intelligence within normal limits except one child (the oldest) who was considered to have a mild degree of global retardation. All had been assessed by a psychologist.

5.7.2 Developmental history The developmental history of each child was obtained from medical records and the relevant data are recorded below. Note that 8 out of 10 of the children were reported to have a degree of clumsiness, predominantly of hand movement (cf Orton 1937), and 5 out of 10 had a familial history of a developmental speech disorder.

Table 1

EXPERIMENTAL GROUP

Subj	Sex	Age at time of interview in yr	Family history of speech defect	Significant neurological/ medical history	Motor milestones and ability
1	M	5,5	N,S,	N,S,	Normal, Slight clumsiness with gross motor tasks
2	F	5,6	N,S,	Post Reye's syndrome	Normal
3	M	5,11	Father and mother; delayed speech, Two cousins (male) on paternal side have speech difficulty	N,S,	Normal, Slight clumsiness in fine and gross motor tasks

4	M	6,0	Older brother; stammer	N,S,	Slight clumsiness with hands
5	M	7,2	Older sister; articulatory disorder	N,S,	Normal, Difficulty with pencil control, Clumsiness in gross motor movements
6	F	10,1	N,S,	N,S,	Normal, Clumsy hand movements
7	M	10,11	Younger sister; articulatory disorder	Developmental Gerstmann Syndrome	Motor difficulties, No firm grasp in right hand
8	F	11,6	Father; delayed speech	Macrocephaly	Normal
9	F	12,3	N,S,	N,S,	Normal, Poor fine motor co-ordination,
10	M	14,5	N,S,	Microcephaly, Mild degree of global retardation, Convulsions	Normal, Slight clumsiness in manipulating small objects

5.7.3 Criteria for selection of control group

A group of children with normal speech development was matched with the experimental group for age, sex and regional accent.

5.7.4 Criteria for selection of Cerebral Palsied children

Two children within the same age range and with West of Scotland accents were selected for VOT analyses (CP1 and CP2). Their developmental and medical histories were different from the experimental DAS group and the control group. The details are therefore summarized below:

CP1 Sex M Age at administration of test battery: 7.4 yrs
Relevant personal history: Mixed cerebral palsy due to central birth injury affecting right leg with left leg affected to a lesser degree. Feeding difficulty. Motor milestones delayed. Intelligence: normal. Hearing: normal

CP2 Sex F Age at administration of test battery: 6.9 yrs
Relevant personal history: Cerebral palsy. Spastic quadriplegia. Birth: Caesarean section. 29 week pregnancy. Birth weight: 2 lb 11 oz. Motor milestones delayed. Intelligence: normal. Hearing: normal.

5.8 Statement of the research questions

1 In auditory phonetic terms, is the voicing distinction disturbed?

2 What categories of voicing are represented in the group under study in the test administered?

3 Are there any particular items on the IVOM and SVOM tests which are significantly deviant in the DAS group?

4 What is the status of items which include laryngeal and respiratory components?

5 For VOT values, is the profile presented by the DAS child significantly different from the normal child?

6 Do the CP children differ in any significant way from the DAS and control groups?

These questions divide into three main areas of investigation:

1 The phonetic description of the voicing distinction

2 The investigation of IVOM and SVOM

3 The voice onset time analysis of initial stops.

The investigative procedures adopted, data and results obtained will be organized under three main headings.

5.9 Test procedures

All testing was carried out by the same investigator.

5.9.1 Experimental Group

Testing was conducted in clinic rooms at RHSC Glasgow at a time when there was as little background noise as possible.

The following tests were used:

1 Word Test (see p 79)

2 IVOM and SVOM Tests (see pp 84-85)

5.9.2 Control Group

Testing was conducted in a quiet room in the school which the children attended.

The following tests were used:

1 Word Test

2 IVOM and SVOM Tests

5.9.3 CP Children

Testing was conducted in the homes of the children concerned.

The following test was used:

Word Test

5.10 Instrumentation

1 Uher 4000 Report L tape-recorder and microphone, Uher Werke, München.

2 7029A Sound Spectrum Analyser, Kay Elemetrics Inc, New Jersey.

The Sound Spectrum Analyser (also known as the Sonagraph or Sound Spectrograph) provides a visual display in a permanent form of the spectral characteristics of sound. The display, a sound spectrogram, shows time on the X-axis - in this case 2.4 seconds - and frequency on the Y-axis. The frequency range chosen for the purposes of this investigation was 85Hz to 8kHz. Amplitude is shown in relative terms by the degree of blackening on the spectrogram. Two frequency resolutions are available, 300 Hz and 45 Hz. Both possibilities were employed according to the aim of the analysis at that particular point in the investigation. For measurements of VOT, the 300 Hz filter was used, because of the relatively fast time response of the filter. Conversely, the 45 Hz filter was employed in order to reveal more accurately than is possible with the 300 Hz filter the harmonic structure of particular segments and to assist where necessary in the segmentation of the signal.

3 Gould Advance 0S400 Digital Storage Oscilloscope, Gould Instruments Ltd, Hainault, Essex.

4 Voiscope, Laryngograph Ltd, London.

5 Sony Betamax Video Recorder SL-C7UB, Sony (UK) Ltd, Sunbury on Thames, Middlesex.

6 Polaroid CP Land camera, Polaroid (UK) Ltd, St Albans, Hertfordshire.

5.11 Test Battery : nature, construction and administration

5.11.1 Word Test

There can be artificial constraints on a child's speech production if he or she is tested in a very formal manner so as to meet the requirements of certain psychometric standards. Hardcastle and Morgan, for example, in order to achieve sufficient data for later statistical analysis were compelled to resort to this approach (Hardcastle & Morgan 1982), as was Zlatin (1972). The effect is that the data to be obtained from the child are rigorously controlled and often lead to the child 'performing' rather than speaking in as natural and normal a manner as possible. All of Hardcastle and Morgan's subjects were asked to say the words TEAR, DEER, PIN, BIN, CURL and GIRL six times!

In the present study, the aim has been to obtain as natural a set of data as possible, even at the expense of limiting the type of statistical analysis that can be performed on it afterwards. It was accepted that children do not perform to command and that there was a likelihood of there being some omissions in the data recorded.

A Word Test was drawn up according to phonetic principles to sample the child's voicing contrasts and a picture stimulus was given (see below p 79). The choice of words was limited by the possibility of children of the age range of the sample (5.5 - 14.5 yrs) knowing the words and by the ability to illustrate them.

Articulation tests have traditionally covered a wide range of articulatory items, giving an indication of a child's developmental speech 'age' but little specific detail of fine articulatory features. For the purposes of the present study, a specific word test was devised to sample the contrast between phonemically voiced and voiceless stop phonemes. See below for the full word list. A picture book was compiled for the administration of the test, and the interview with the child was tape-recorded.

This section of the test battery was recorded by means of standard high quality recording procedures, using a Uher 4000 Report-L portable taperecorder and microphone.

The Test was devised in the following manner. A list of words of the segmental structure (C)CV(C) was drawn up to allow contrasts to be noted between the three sets of stop phoneme pairs in a Western Scottish accent of English : /p:b/, /t:d/, /k:g/. Ideally the contrasts should have been assessed in as many environments as possible, ie prevocalically, intervocalically, postvocalically, and, in certain instances, postconsonantally. With a 14 vowel system to take into account in setting up such a test inventory, the final form of the test would have been both extensive and completely unwieldy in the context of this particular study. Thus, as well as testing a child's use of the /p:b/ contrast in words like PEA and BEE, one would also have to test them in POISE and BOYS; and if environments which involved crossing syllable boundaries were included as well, then in forms such as MISS PRICE and MISS BRYCE. It was therefore decided that the stop phoneme pairs should be examined in word-initial position only.

Initially an extensive set of items was considered for inclusion, but this was gradually reduced according to two criteria : each word should be of a simple segmental form, and each child should be aware of the words if they were presented in a picture-book form.

Table 2

WORD TEST

1 PIN	2 TART	3 COAL	4 DOWN	5 TRAIN
6 PIE	7 TOY	8 CUP	9 TEA	10 PRICES
11 TOOTHPASTE	12 TOOTHBRUSH	13 TEETH	14 GAME	15 CLASS
16 DIRTY	17 PEA	18 PEAS	19 BEAR	20 CUB
21 COAT	22 COLD	23 BRICK	24 COT	25 TRIP
26 BUN	27 TORCH	28 DUCK	29 PIG	30 KILT
31 BIN	32 DART	33 GOAL	34 PRIZES	35 GLASS
36 BEE	37 PEAR	38 GOAT	39 GOLD	40 DRIP
41 BIG	42 GROW	43 KILLED	44 PEG	45 PEN
46 POST	47 KEY	48 BIG BEN	49 POOH	50 TIN
51 BOW	52 BACK	53 PENS	54 BIT	55 TOE
56 POT	57 KATE	58 POUR	59 GLUE	60 TEN
61 PENCE	62 POOR	63 BUY	64 TOWN	65 CREW
66 BAG	67 TWO	68 BED	69 GUM	70 GATE

5.11.2 The phonetic description of the voicing distinction

A narrow phonetic transcription using the conventions of the International Phonetic Alphabet (IPA) was made of each utterance from the taperecordings, with particular care being taken over the analysis and notation of the stop phonemes, ie /p b t d k g/. The child's realization of the stop was analysed according to 10 possibilities:

(1)	normal voiceless aspirated	eg	[pʰ]	PIN
(2)	normal devoiced	eg	[b̥]	BALL
(3)	normal voiced	eg	[b]	BALL
(4)	deviant unaspirated	eg	[p]	PIN
(5)	deviant glottalized	eg	[ʔp]	PIN
(6)	deviant affricated or fricative articulation	eg	[tˢ]	TEN
(7)	deviant voiced	eg	[b]	PIN
(8)	deviant devoiced	eg	[b̥]	BIG BEN
(9)	deviant voiceless	eg	[p]	BIN
(10)	deviant air-stream mechanism	eg	[tʾ]	TIN

In previous DAS studies, a simple distinction has been drawn between voiced and voiceless sounds. For the purposes of this thesis it was decided to make a finer analysis of the timing factors that contribute in part to the realization of the phonemic contrast between voiced and voiceless sounds.

5.12 Results

5.12.1 Profile of Voicing Parameters

The data below are not numerical, ie they do not represent the number of occurrences of each category, but the fact that at least one example of the category marked was found on testing using the Word Test.

Parameters

1 = Normal voiceless aspirated

2 = Normal devoiced

3 = Normal voiced

4 = Deviant unaspirated

5 = Deviant glottalized

6 = Deviant affricated or fricative articulation

7 = Deviant voiced

8 = Deviant devoiced

9 = Deviant voiceless

10 = Deviant air stream mechansim

Table 3

SUBJECTS AND RESULTS

Subject → / Parameter ↓	1	2	3	4	5	6	7	8	9	10
1	+	+	+	+	+	+	+	+	+	+
2	+	+	+		+		+	+	+	+
3	+	+	+	+	+	+	+	+	+	+
4		+	+	+	+	+			+	+
5	+	+	+	+	+	+	+			+
6		+	+	+	+	+	+			+
7	+	+	+	+	+	+	+	+	+	+
8		+		+			+	+		+
9	+		+	+	+	+	+		+	+
10					+					

Categories of disturbance:	Subject No:	Total
(4) deviant unaspirated	2 3 4 5 6 7 9 10	8
(5) deviant glottalized	1 2 3 4 5 6 7 10	8
(6) deviant affricated or fricative articulation	2 3 4 5 6 7 10	7
(7) deviant voiced	2 3 4 5 7 9 10	7
(8) deviant devoiced	2 4 7	3
(9) deviant voiceless	1 3 4 5 6 7 9	7
(10) deviant air-stream mechanism	5 7 8 10	4

In all the children there is evidence of abnormalities of voicing, and these are spread across the categories of voicing analysed.

5.13 The investigation of volitional oral movements

5.13.1 Isolated volitional oral movement (IVOM) and sequenced volitional oral movement (SVOM) were investigated using a modified version of the DAS assessment recommended by the Tennessee Speech and Hearing Association (Smartt et al 1976). The items selected were subdivided into the component vocal tract movements (see pp 86-88), and a Pass/Fail system of scoring was adopted.

The response to the items was recorded on videotape for later analysis. The results are set out below, pp 89-93.

It was of interest to the investigator to note the number and composition of the activities tested. It will be obvious from the analysis of the vocal tract movement test subdivisions (see pp 86-88) that there is an inequality in the test items. In the two-item sequencing tests, for example, there are 3 items which involve lip movement, but only one for air-flow, and none involving the laryngeal mechanism.

Table 4

5.13.2 TEST OF ISOLATED VOLITIONAL ORAL MOVEMENTS (IVOM)

Modification of Smartt, J et al (1976) Developmental apraxia of speech : a TSHA Subcommittee report. J Tennessee Speech & Hearing Association 20, 21-31.

The modifications are: Replacement of 7 Snap your tongue with
7 Blow your nose (In order to introduce a more normal command and an additional test of the airflow mechanism.)

Addition of 14 Spit
15 Swallow

Directions: The following verbal instructions are given to the child

1 Stick out your tongue

2 Show how you would whistle

3 Show how you would kiss a baby

4 Show how your teeth chatter when you are cold

5 Touch your chin with your tongue

6 Wag your tongue from side to side

7 Blow your nose

8 Puff out your cheeks

9 Touch the tip of your nose with your tongue

10 Blow

11 Clear your throat

12 Lick your lips all the way round

13 Bite your lower lip

14 Spit

15 Swallow

Table 5

5.13.3 TEST OF SEQUENCED VOLITIONAL ORAL MOVEMENTS (SVOM)

Modification of Smartt, J et al (1976) - see above

The modifications are: Rewording of 1 Protrude tongue, put lips in smile
to 1 Stick out your tongue, put lips...

Directions: Now we are going to do some of these movements together. Watch me and do just what I do, but wait until I tell you.

TWO-ITEM SEQUENCING TASKS:

1a Stick out your tongue
1b Put lips in smile

2a Pucker lips
2b Wag tongue from side to side

3a Teeth bite lower lip
3b Blow air

THREE-ITEM SEQUENCING TASKS:

1a Click teeth and chatter
1b Lick lips
1c Clear throat

2a Put tip of tongue to nose
2b Blow air
2c Puff cheeks

3a Kiss
3b Click tongue
3c Stick out tongue

Table 6

5.13.4 ANALYSIS OF VOLUNTARY VOCAL TRACT ACTIVITIES DURING IVOM

Instruction to subject	Vocal Tract Activities
1 Stick out your tongue	Tongue
2 Show how you would whistle	Pulmonic egressive airflow Tongue Lips
3 Show how you would kiss a baby	Velaric ingressive airflow Lips
4 Show how your teeth chatter when you are cold	Percussive airflow Teeth
5 Touch your chin with your tongue	Tongue
6 Wag your tongue from side to side	Tongue
7 Blow your nose	Pulmonic egressive airflow
8 Puff out your cheeks	Pulmonic egressive airflow Cheeks
9 Touch the tip of your nose with your tongue	Tongue
10 Blow	Pulmonic egressive airflow Lips
11 Clear your throat	Pulmonic egressive airflow Vocal fold adduction/abduction
12 Lick your lips all the way round	Tongue
13 Bite your lower lip	Teeth
14 Spit	Velaric egressive airflow
15 Swallow	Tongue

Table 7

5.13.5 ANALYSIS OF VOLUNTARY VOCAL TRACT ACTIVITIES DURING SVOM

Instruction to Subject	Vocal Tract Activities
TWO-ITEM SEQUENCING TASKS:	
1a Stick out your tongue	Tongue
1b Put lips in smile	Lips
2a Pucker lips	Lips
2b Wag tongue from side to side	Tongue
3a Teeth bite lower lip	Teeth
3b Blow air	Lips Pulmonic egressive airflow
THREE-ITEM SEQUENCING TASKS:	
1a Click teeth and chatter,	Teeth
1b Lick lips	Tongue
1c Clear throat	Pulmonic egressive airflow Vocal fold adduction/ abduction
2a Put tip of tongue to nose	Tongue
2b Blow air	Pulmonic egressive airflow Lips
2c Puff cheeks	Pulmonic egressive airflow Lips Cheeks
3a Kiss	Velaric ingressive airflow Lips
3b Click tongue	Tongue Velaric ingressive airflow
3c Stick out tongue	Tongue

Table 8

5.13.6 INVOLVEMENT OF VOCAL TRACT MECHANISM IN IVOM AND SVOM

IVOM

Structure	Number of Item on List
Tongue	1 2 5 6 9 12 15
Teeth	4 13
Lips	2 3 10 14
Airflow	2 3 7 8 10 11 14
Vocal fold adduction/abduction	11
Cheeks	8

SVOM

Structure	Number of Item on List
TWO-ITEM SEQUENCING TASK	
Tongue	1a 2b
Teeth	3a
Lips	1b 2a 3b
Airflow	3b
Vocal fold adduction/abduction	
THREE-ITEM SEQUENCING TASK	
Tongue	2a 3b 3c
Teeth	1a
Lips	1b 2b 2c 3a
Airflow	1c 2b 2c 3a 3b
Vocal fold adduction/abduction	1c
Cheeks	2c

Table 9

5.13.7 RESULTS OF TESTING OF VOLITIONAL ORAL MOVEMENTS DIVIDED INTO CONSTITUENT FEATURES, WITH EXPERIMENTAL GROUP MARKED AGAINST CONTROL GROUP

E = Experimental C = Control

\+ Positive Response - Negative Response

IVOM	Item	1:E	C	2:E	C	3:E	C	4:E	C	5:E	C
Tongue	1	+	+	+	+	+	+	+	+	+	+
	2	-	+	+	+	-	+	+	+	+	+
	5	+	+	+	+	+	+	+	+	+	+
	6	+	+	-	+	+	+	+	+	+	+
	9	-	+	+	+	-	+	+	+	+	+
	12	-	+	-	+	-	+	+	+	+	+
	15	+	+	-	+	-	+	+	+	+	+
Teeth	4	-	+	+	+	-	+	-	+	+	+
	13	-	+	+	+	-	+	+	+	+	+
Lips	2	-	+	+	+	-	+	+	+	+	+
	3	+	+	+	+	+	+	-	+	+	+
	10	-	+	-	+	+	+	+	+	+	+
	14	+	+	+	+	+	-	+	+	+	+
Airflow	2	-	+	+	+	-	+	+	+	+	+
	3	+	+	+	+	+	+	-	+	+	+
	7	-	+	-	+	-	+	-	+	-	+
	8	-	+	+	+	-	+	+	+	+	+
	10	-	+	-	+	+	+	+	+	+	+
	11	-	+	+	+	-	+	-	+	-	+
	14	+	+	+	+	+	-	+	+	+	+
Larynx	11	-	+	+	+	-	+	-	+	-	+
Cheeks	8	-	+	+	+	-	+	+	+	+	+

IVOM	Item	6:E	C	7:E	C	8:E	C	9:E	C	10:E	C
Tongue	1	+	+	+	+	+	+	+	+	+	+
	2	-	+	-	+	+	+	+	+	-	+
	5	-	+	+	+	+	+	+	+	-	+
	6	-	+	+	+	+	+	+	+	-	+
	9	+	+	+	+	+	+	+	+	+	+
	12	-	+	+	+	+	+	+	+	-	+
	15	-	+	+	+	+	+	+	+	+	+
Teeth	4	+	+	+	+	+	+	+	+	-	+
	13	-	+	+	+	+	+	+	+	+	+
Lips	2	-	+	-	+	+	+	+	+	-	+
	3	+	+	-	+	-	+	+	+	+	+
	10	+	+	+	+	+	+	+	+	+	+
	14	+	+	+	+	+	+	+	+	+	+
Airflow	2	-	+	-	+	+	+	+	+	-	+
	3	+	+	-	+	-	+	+	+	+	+
	7	-	+	+	+	+	+	+	+	+	+
	8	-	+	+	+	+	+	+	+	+	+
	10	+	+	+	+	+	+	+	+	+	+
	11	+	+	-	+	+	+	-	+	+	+
	14	+	+	+	+	+	+	+	+	+	+
Larynx	11	+	+	-	+	+	+	-	+	+	+
Cheeks	8	-	+	+	+	+	+	+	+	+	+

		1:E	C	2:E	C	3:E	C	4:E	C	5:E	C
SVOM	2-item										
Tongue	1a	+	+	+	+	+	+	+	+	+	+
	2b	+	+	−	+	+	+	+	+	+	+
Teeth	3a	+	+	−	+	−	+	+	+	+	+
Lips	1b	+	+	+	+	+	+	+	+	+	+
	2a	+	+	+	+	+	+	+	+	+	+
	3b	−	+	+	+	+	+	+	+	+	+
Airflow	3b	−	+	+	+	+	+	+	+	+	+
SVOM	3-item										
Tongue	2a	+	+	−	+	−	+	−	+	+	+
	3b	−	+	−	+	−	−	−	+	−	+
	3c	+	+	+	+	+	+	+	−	+	+
Teeth	1a	+	+	−	+	−	+	−	+	+	+
Lips	1b	+	+	−	+	+	+	+	+	+	+
	2b	+	+	−	+	+	+	+	+	+	+
	2c	−	+	−	+	−	+	−	−	−	+
	3a	+	+	−	+	+	+	−	+	+	+
Airflow	1c	−	+	+	+	−	+	−	+	−	+
	2b	−	+	−	+	+	+	+	+	+	+
	2c	−	+	+	−	−	+	−	−	−	+
	3a	+	+	−	+	+	+	−	+	+	+
	3b	−	+	−	+	−	−	−	+	−	+
Larynx	1c	−	+	+	+	−	+	−	+	−	+
Cheeks	2c	+	+	+	−	+	+	+	−	+	+

		6:E C	7:E C	8:E C	9:E C	10:E C
SVOM	2-item					
Tongue	1a	+ +	+ +	+ +	+ +	+ +
	2b	- +	+ +	+ +	+ +	+ +
Teeth	3a	- +	+ +	+ +	+ +	- +
Lips	1b	+ +	+ +	+ +	+ +	+ +
	2a	- +	+ +	+ +	+ +	+ +
	3b	+ +	+ +	+ +	+ +	+ +
Airflow	3b	+ +	+ +	+ +	+ +	+ +
SVOM	3-item					
Tongue	2a	- +	+ +	+ +	- +	+ +
	3b	- +	- +	+ +	- -	- +
	3c	- +	+ -	+ +	+ +	+ +
Teeth	1a	+ +	+ +	+ +	+ +	+ +
Lips	1b	- +	+ +	+ +	+ +	+ +
	2b	- +	+ +	+ +	- +	+ +
	2c	- +	+ +	+ +	- +	+ +
	3a	- +	- +	+ +	+ +	- +
Airflow	1c	- +	+ +	- +	+ +	+ +
	2b	- +	+ +	+ +	- +	+ +
	2c	- +	+ +	+ +	- +	+ +
	3a	- +	- +	+ +	+ +	- +
	3b	- +	- +	+ +	- -	- +
Larynx	1c	- +	+ +	- +	+ +	+ +
Cheeks	2c	- +	+ +	+ +	+ +	+ +

Results

The IVOM and SVOM group results (ie experimental group matched with control group) were analysed by means of the Fisher Exact Probability Test (Finney 1948), and yielded the following significant results - all others were non-significant.

Item	Level of Significance
IVOM 2	.05 <p> .025
IVOM 7	.025 <p> .01
IVOM 11	.025 <p> .01
IVOM 12	.05 <p> .025

SVOM	2 item	3a	$p < .05$
SVOM	3 item	1c	$.025 < p > .01$
SVOM	3 item	2a	$.05 < p > .025$
SVOM	3 item	2b	$.025 < p > .01$
SVOM	3 item	3a	$.05 < p > .025$
SVOM	3 item	3b	$p < .005$

When the items were divided into constituent vocal tract activities, the following levels of significance were obtained:

Vocal Tract Mechanism	Item	Level of Significance
Tongue	IVOM 2	$.05 < p > .025$
	IVOM 12	$.05 < p > .025$
	SVOM 3 item 2a	$.05 < p > .025$
	SVOM 3 item 3b	$p < .005$
Lips	IVOM 2	$.05 < p > .025$
	SVOM 3 item 2b	$.025 < p > .01$
	SVOM 3 item 3a	$.05 < p > .025$
Airflow	IVOM 2	$.05 < p > .025$
	IVOM 7	$.025 < p > .01$
	IVOM 11	$.025 < p > .01$
	SVOM 3 item 1c	$.025 < p > .01$
	SVOM 3 item 2b	$.025 < p > .01$
	SVOM 3 item 3a	$.05 < p > .025$
	SVOM 3 item 3b	$p < .005$
Laryngeal	IVOM 11	$.025 < p > .01$
	SVOM 3 item 1c	$.025 < p > .01$

5.14 Voice onset time analysis of initial stops

5.14.1 The Word Test (p 79) was used as the basis of the VOT analysis of initial stops in both the Experimental and Control groups. Each taperecorded utterance was then analysed spectrographically in the Phonetics Laboratory of the Department of English Language, University of Glasgow. Altogether, a total of 738 spectrograms was made.

Using the formula that 319mm of spectrogram paper represents 2400ms of speech signal, a calculation was made of the duration of each VOT. Figures

were rounded to the nearest whole number. The full results are set out in the Appendix (pp 119-132), and examples of spectrograms for both the Experimental and Control groups are given below (pp 96-98).

5.14.2 General conclusions from the VOT values

Only a limited set of conclusions can be drawn from the statistics for VOT values for the Experimental and the Control groups. These are:

1 There is a range of variation, expressed in ms, within both the Control and the Experimental groups. The variation is greater in the latter:
(a) A calculation of the distance between the highest and lowest figures when expressed as an average across all segmental contexts shows the following:

/p/ before	Exper	79	ms
	Control	56	ms
/b/ before	Exper	73	ms
	Control	41	ms
/t/ before	Exper	93	ms
	Control	51	ms
/d/ before	Exper	56	ms
	Control	44	ms
/k/ before	Exper	111	ms
	Control	44	ms
/g/ before	Exper	69	ms
	Control	42	ms

If these figures are then averaged, we can conclude that there will be a range of variation amongst the Experimental group of 80ms, whereas with the Control group it will be 46ms.

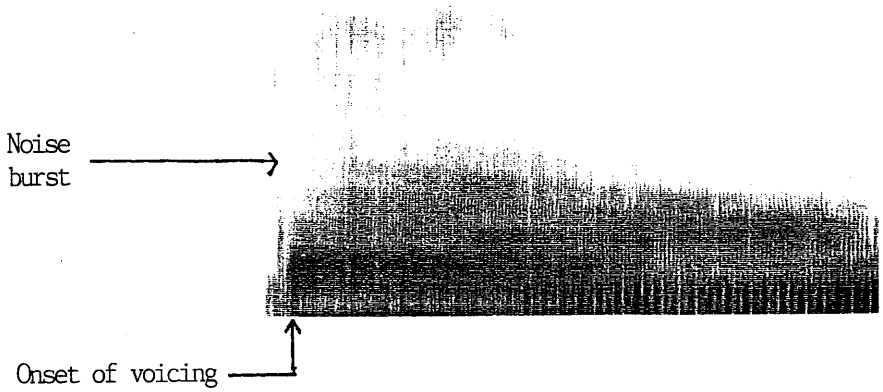
~~(b)~~ As the data in the Appendix show, the variation is dependent also on the segmental context in which the stop is being used.

2 A calculation of the average VOT for a specific consonant in different segmental contexts shows an interesting similarity within each type of Group:

/p/ before ↓	Control Group	Experimental Group	
/i/	59 ms	54 ms	
/I/	55 ms	27 ms	([I] is equivalent to IPA [ɪ])
/e/	64 ms	37 ms	
/ɛ/	57 ms	46 ms	
/ø/	60 ms	56 ms	([ø] is equivalent to IPA [ɔ])
/o/	56 ms	47 ms	
/u/	75 ms	40 ms	
/ae/	63 ms	35 ms	
/r/	65 ms	25 ms	

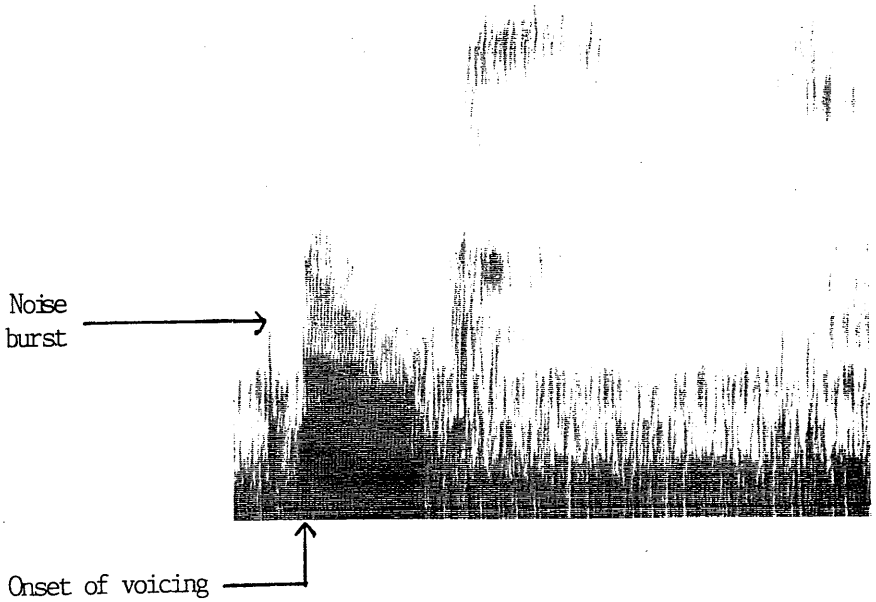
[Text continues p 99]

FIGURE 1



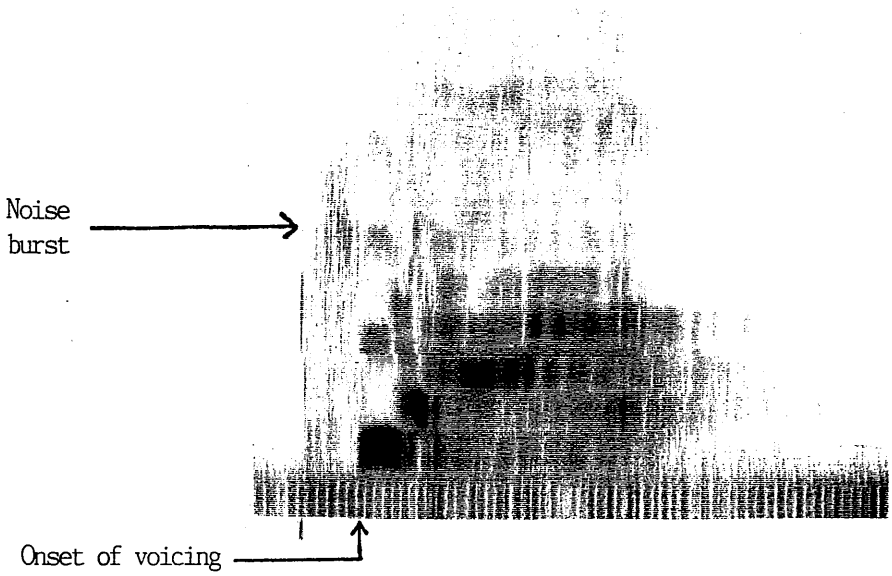
Spectrogram of BEAR, Experimental Subject 1, aged 5.5 yrs: VOT 17 ms

FIGURE 2



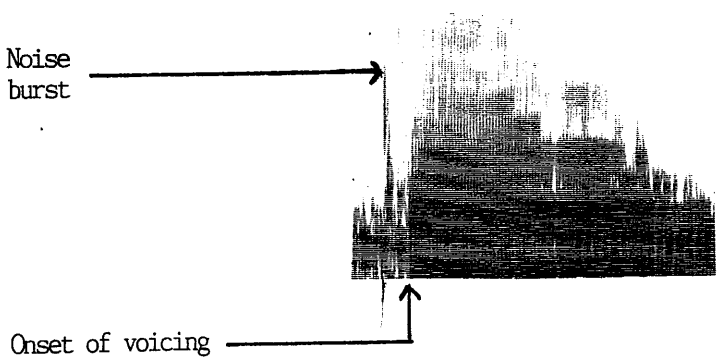
Spectrogram of POST, Experimental Subject 5, aged 7.2 yrs: VOT 30 ms

FIGURE 3



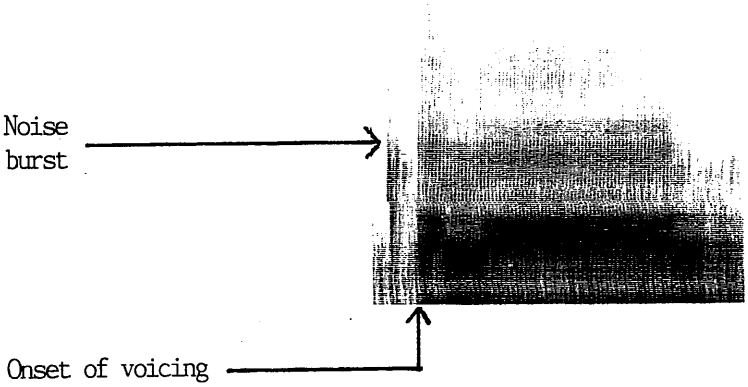
Spectrogram of CUP, Experimental Subject 6, aged 10.1 yrs: VOT 56 ms

FIGURE 4



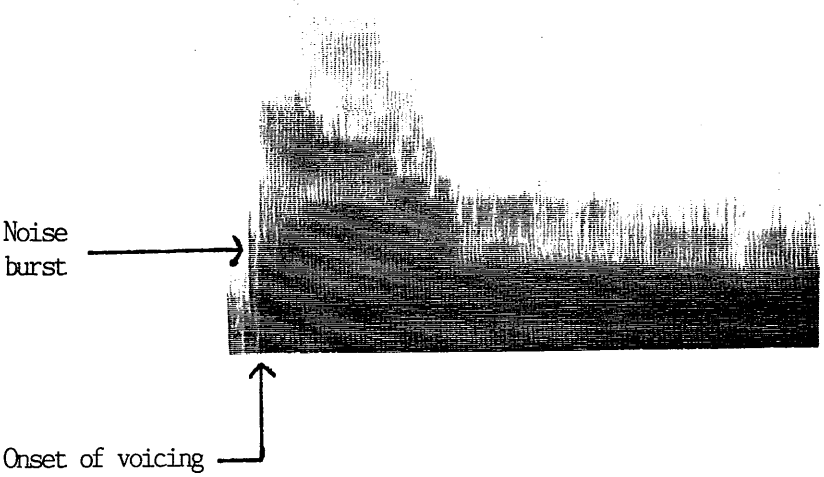
Spectrogram of TIN, Experimental Subject 7, aged 10.11 yrs: VOT 26 ms

FIGURE 5



Spectrogram of GOAL, Experimental Subject 8, aged 11.6 yrs: VOT 32 ms

FIGURE 6



Spectrogram of DOWN, Experimental Subject 9, aged 12.3 yrs: VOT 15 ms

3 Comments on comparative values of VOT for specific consonants for Matched Pairs:

/p/ In the majority of cases from MP1 to MP6, and also in MP9, the Experimental subjects have a lower VOT than the Control subjects.

/b/ The results are more erratic than for /p/

/t/ From MP1 to MP6 there is almost always too low a VOT compared with the values for the Control subjects. The figures for MP7 to MP10 are closer together.

/d/ As with /b/, there is a greater amount of variation, which in itself suggests that /p/ and /t/ are patterning differently from /b/ and /d/. Sometimes the Experimental subjects have a higher figure, sometimes a lower compared with the Control subjects.

/k/ Compared with the figures for /p/ and /t/ there is more variability here. The relation between the values for the Experimental group and the Control group is not as consistent as for /p/ and /t/.

/g/ The results for both subjects lie within a narrower range. This in itself would suggest that /g/ + Segment does not present the same difficulties of timing of the VOT as the other stop consonants.

4 The graphs on pp 102-107 for the highest and lowest figures for both groups (ExH, ExL, CoH, CoL), which disregard the division into matched pairs, show:

(a) The Control group have a narrower range of VOTs than the Experimental group.

(b) In most cases, the Control ranges lie within those for the Experimental group; sometimes they straddle them; they never lie outside them.

5 If we take the Control group to represent normal articulatory values, then the VOT problem experienced by the Experimental group relates more to the voiceless stops /p t k/ than the voiced ones. The Experimental group are tending to shorten the duration of the VOT to the point at which some of the pronunciations are perceived as those for the equivalent voiced stops.

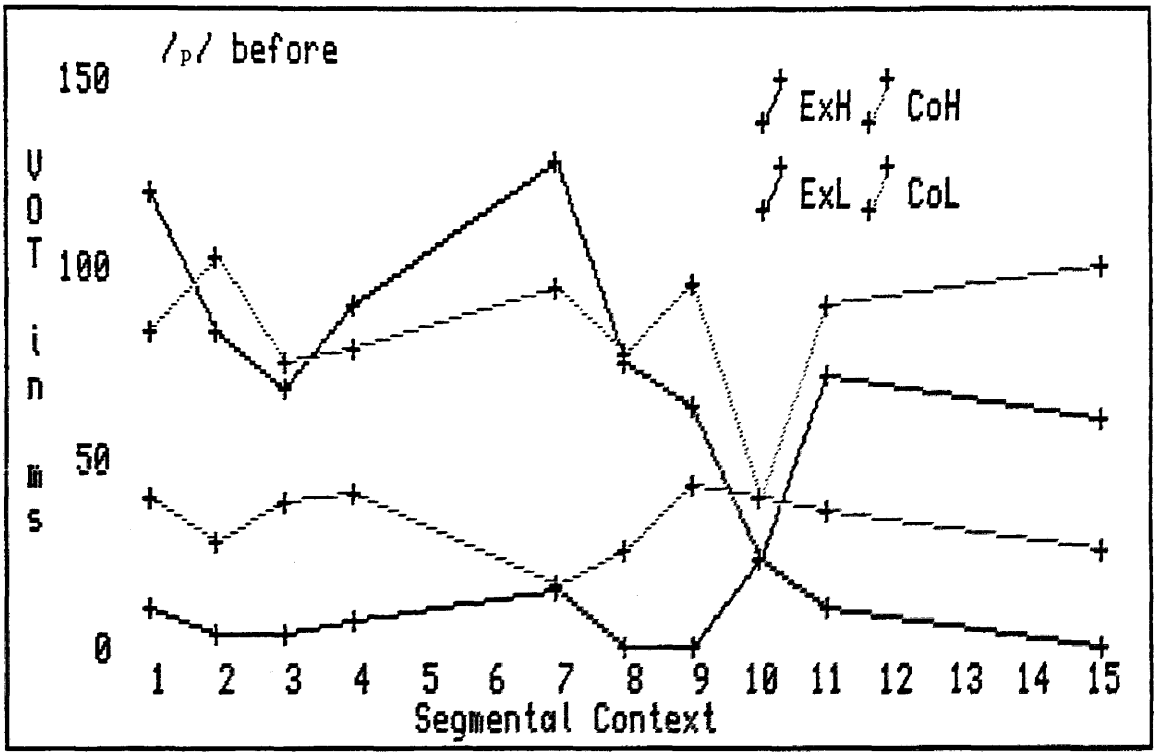
5.14.3 In summary, it was found that (i) there was a greater degree of variation in VOT values demonstrated in the DAS group's results; (ii) the VOT difficulties which were found in the DAS children affected voiceless stops more than voiced stops.

[Text continues p 108]

The graphs on the following 6 pages represent the highest and lowest VOT figures for the Experimental and Control groups. They are included to give an indication of the relationship between the performance of the 2 groups.

The data are taken from the Appendix, pp 119-122.

FIGURE 7



Consonant /p/ before various segments

Segmental Context

1	i	as in TEETH	2	I	as in PIN
3	e	as in BEAR	4	ϵ	as in BED
5	a	as in BAG	6	æ	as in GUM
7	ø	as in COT	8	o	as in COAL
9	u	as in POOR	10	æi	as in PRICES
11	ae	as in BUY	12	øe	as in TOY
13	æu	as in DOWN	14	l	as in GLASS
15	r	as in BRICK			

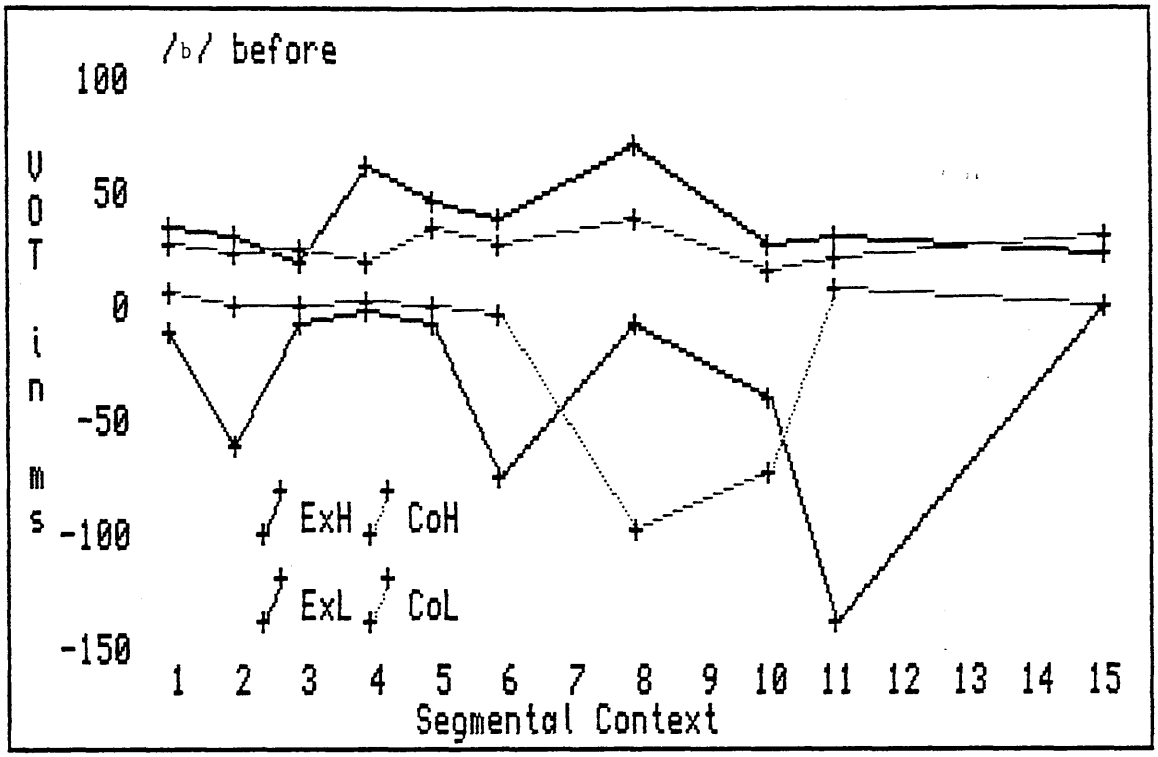
ExH = highest value amongst the Experimental Group

CoH = highest value amongst the Control Group

ExL = lowest value amongst the Experimental Group

CoL = lowest value amongst the Control Group

FIGURE 8



Consonant /b/ before various segments

Segmental Context

1	i	as in TEETH	2	I	as in PIN
3	e	as in BEAR	4	ϵ	as in BED
5	a	as in BAG	6	æ	as in GUM
7	ø	as in COT	8	o	as in COAL
9	u	as in POOR	10	æi	as in PRICES
11	ae	as in BUY	12	øe	as in TOY
13	æu	as in DOWN	14	l	as in GLASS
15	r	as in BRICK			

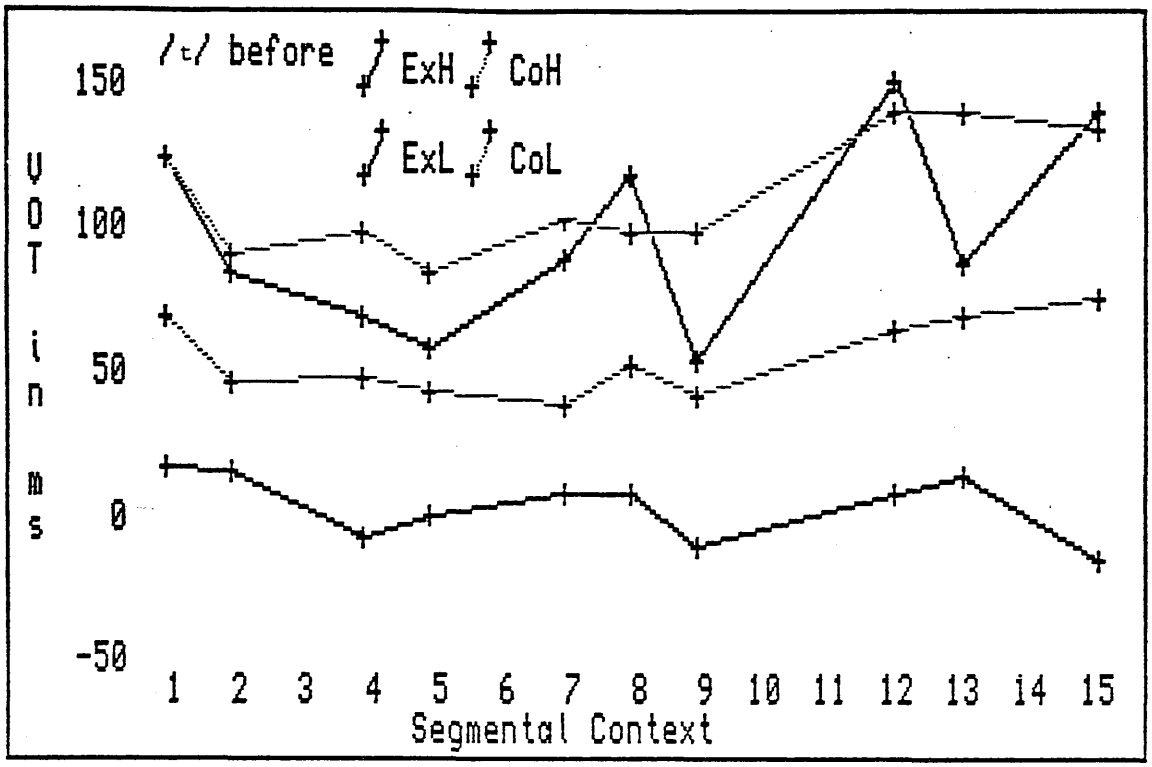
ExH = highest value amongst the Experimental Group

CoH = highest value amongst the Control Group

ExL = lowest value amongst the Experimental Group

CoL = lowest value amongst the Control Group

FIGURE 9



Consonant /t/ before various segments

Segmental Context

1	i	as in TEETH	2	I	as in PIN
3	e	as in BEAR	4	ɛ	as in BED
5	a	as in BAG	6	æ	as in GUM
7	ø	as in COT	8	o	as in COAL
9	u	as in POOR	10	æi	as in PRICES
11	ae	as in BUY	12	øe	as in TOY
13	æu	as in DOWN	14	l	as in GLASS
15	r	as in BRICK			

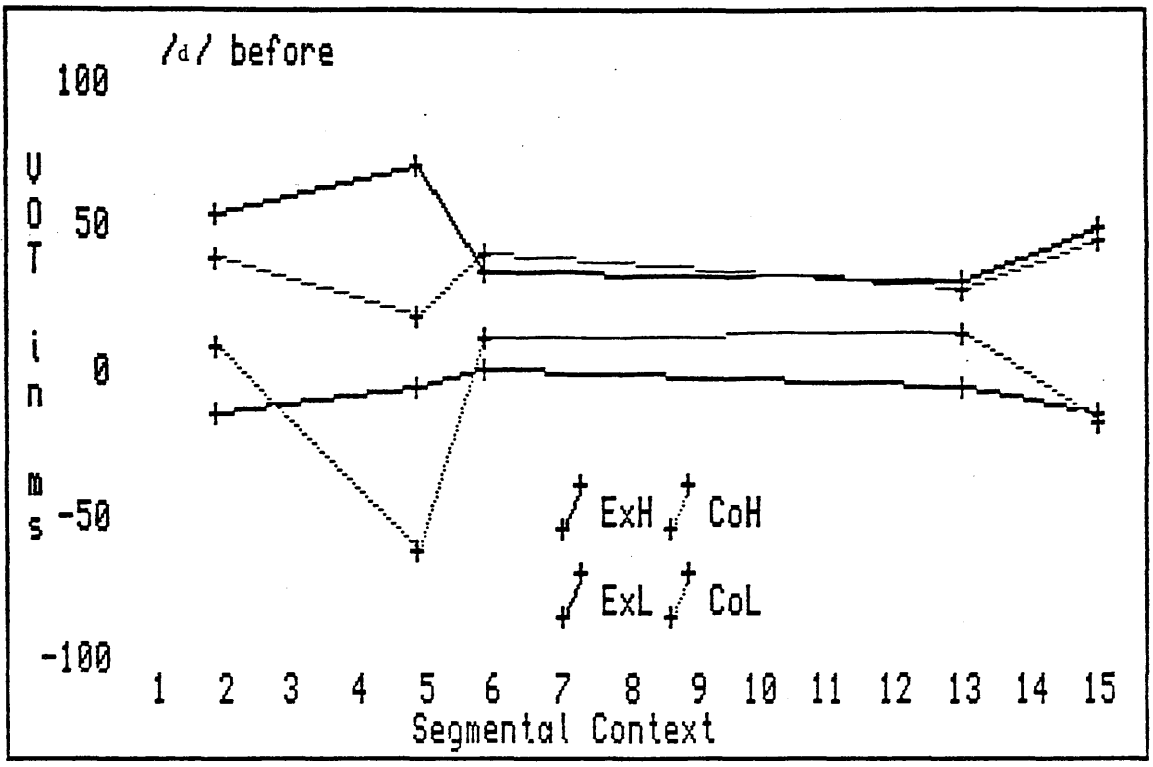
ExH = highest value amongst the Experimental Group

CoH = highest value amongst the Control Group

ExL = lowest value amongst the Experimental Group

CoL = lowest value amongst the Control Group

FIGURE 10



Consonant /d/ before various segments

Segmental Context

1	i	as in TEETH	2	I	as in PIN
3	e	as in BEAR	4	ɛ	as in BED
5	a	as in BAG	6	æ	as in GUM
7	ø	as in COT	8	o	as in COAL
9	u	as in POOR	10	æi	as in PRICES
11	ae	as in BUY	12	øe	as in TOY
13	æu	as in DOWN	14	l	as in GLASS
15	r`	as in BRICK			

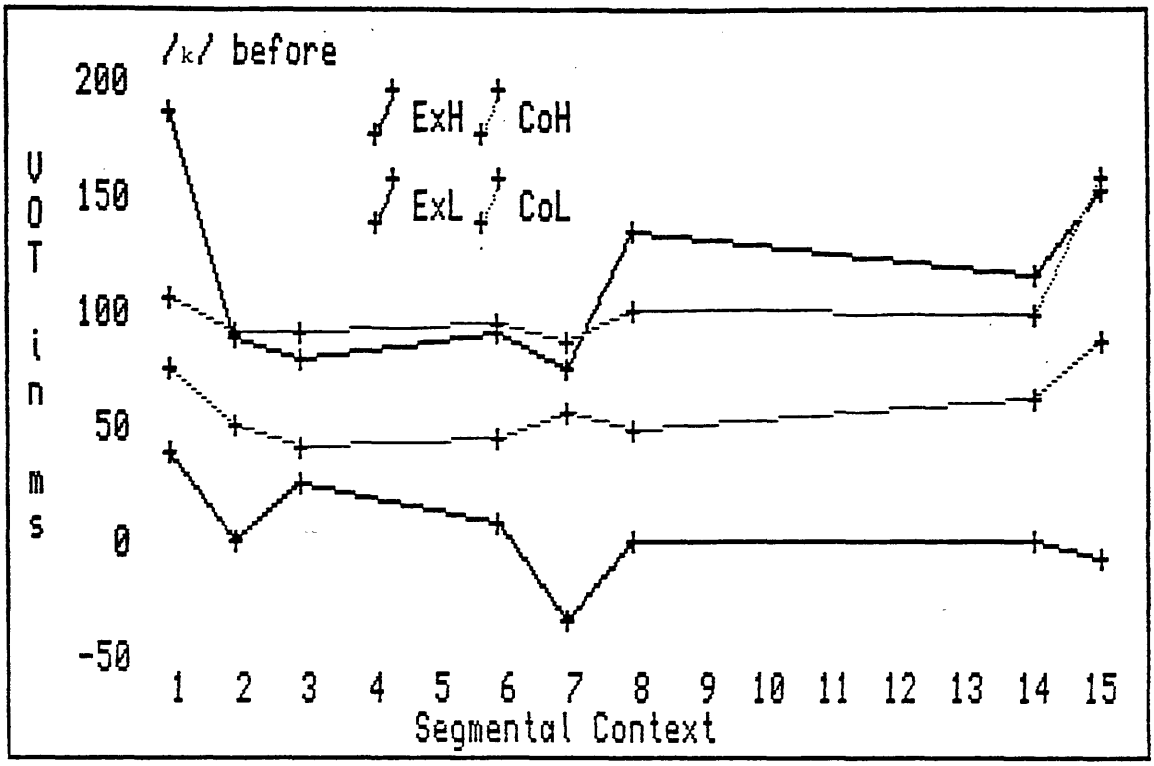
ExH = highest value amongst the Experimental Group

CoH = highest value amongst the Control Group

ExL = lowest value amongst the Experimental Group

CoL = lowest value amongst the Control Group

FIGURE 11



Consonant /k/ before various segments

Segmental Context

1	i	as in TEETH	2	I	as in PIN
3	e	as in BEAR	4	ɛ	as in BED
5	a	as in BAG	6	æ	as in GUM
7	ø	as in COT	8	o	as in COAL
9	u	as in POOR	10	æi	as in PRICES
11	ae	as in BUY	12	øe	as in TOY
13	æu	as in DOWN	14	l	as in GLASS
15	r	as in BRICK			

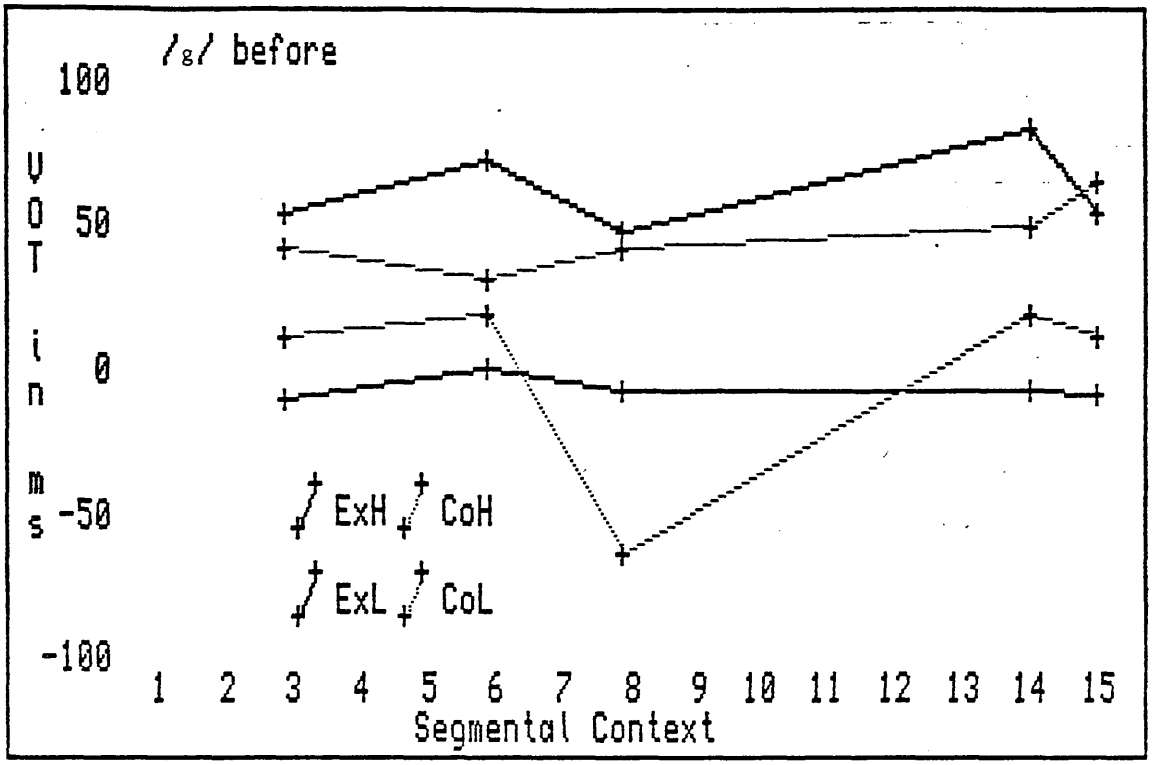
ExH = highest value amongst the Experimental Group

CoH = highest value amongst the Control Group

ExL = lowest value amongst the Experimental Group

CoL = lowest value amongst the Control Group

FIGURE 12



Consonant /g/ before various segments

Segmental Context

1	i	as in TEETH	2	I	as in PIN
3	e	as in BEAR	4	ɛ	as in BED
5	a	as in BAG	6	æ	as in GUM
7	ø	as in COT	8	ɒ	as in COAL
9	u	as in POOR	10	æi	as in PRICES
11	ae	as in BUY	12	øe	as in TOY
13	æu	as in DOWN	14	l	as in GLASS
15	r	as in BRICK			

ExH = highest value amongst the Experimental Group

CoH = highest value amongst the Control Group

ExL = lowest value amongst the Experimental Group

CoL = lowest value amongst the Control Group

5.14.4 VOT analysis of two cerebral palsied children

There were considerably differing results for both CP children, illustrating the range of speech ability which occurs within the group covered by this term. CP1 had what would traditionally be described as dysarthric speech, and the VOT values for him were severely abnormal. They differed considerably from the DAS children as well as from the Control children.

CP2 was a child whose speech appeared auditorily to be within a normal developmental range and accordingly her results fitted into a normal pattern.

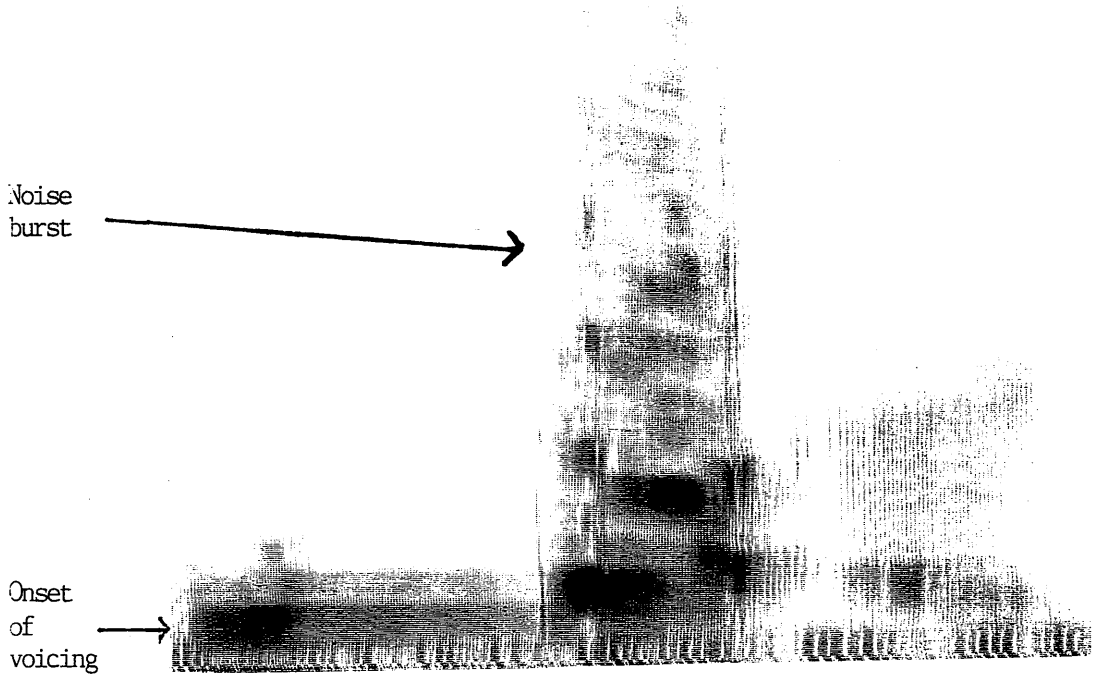
Sound spectrograms were made of the children's pronunciations of the items in the Word Test. Two sample spectrograms are shown in Figures 13 and 14 on p 109.

5.14.5 The figures for the cerebral palsied children show the following:

(a) CP2 has VOT values that lie close to the range for the DAS control group children. Using the data, to begin with, for all the controls and comparing them with those for CP2, one finds that exactly 50% of the values lie within the extremes of the range for each stop in each segmental context; the remainder are fairly close to either end of the ranges.

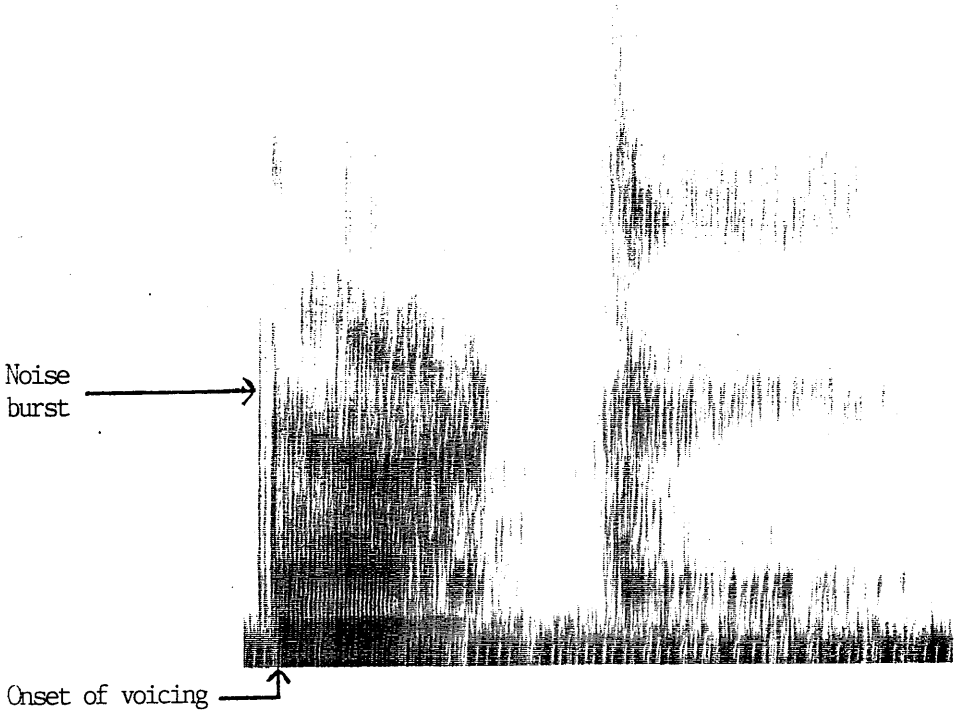
(b) CP1 has VOT values that lie far beyond the ranges for either the controls or the experimentals. For the voiceless stops /p t k/, all the

FIGURE 13



Spectrogram of DIRTY, Cerebral Palsied Child 1, aged 7.4 yrs: VOT -356 ms

FIGURE 14



Spectrogram of DIRTY, Cerebral Palsied Child 2, aged 6.9 yrs: VOT 23 ms

control values were positive - as were almost all the experimental values. But for CP1 all the VOT values for /p t k/ were negative, many of an order that placed them a considerable distance from the controls . For example:

/p/ before /æi/: -816 ms ([æi] is equivalent to IPA [ʌi])

/t/ before /a/ : -519 ms

/k/ before /o/ : -611 ms

The nearest figures for any of the controls were:

C1 /p/ before /æi/: 40 ms

C3 /t/ before /a/ : 43 ms

C2 /k/ before /o/ : 49 ms

The control subject nearest in age to CP1 (aged 7.4) is C5 (aged 7.2). The comparative data are as follows:

CP1 /p/ before /æi/: -816 ms C5 : No data available

CP1 /t/ before /a/ : -519 ms C5 : 56 ms

CP1 /k/ before /o/ : -611 ms C5 : 100 ms

For the voiced stops /b d g/, the ranges of VOT values were greater than anticipated, but not as much as for /p t k/. In this respect, there was a closer approximation to 'normality' than for /p t k/. This situation parallels that for the DAS children.

In summary, then, one can conclude that the greater problem for CP1, as for the DAS Experimental group, lies in the timing of vocal fold activity

following the release of voiceless stops; there is less difficulty with voiced stops.

5.15 Laryngographic assessment

5.15.1 A Laryngographic investigation of normal voice and of a different type of voice quality, namely that of creaky voice, was carried out with the Experimental Group children. The latter part of this investigation also served as an indicator of their ability to alter voice quality in a voluntary manner. Each child was asked to say OH (in some cases the /o/ of GOAL was used) in his or her normal voice, then to make a voluntary change to a breathy, creaky, ventricular voice by saying 'ET' in the manner of the film character popular at the time of the investigation. Laryngographic traces, using a portable Voiscope and oscilloscope, were made of the normal and the attempted 'ET' voices. It was not possible to video the wavepattern because of the unavailability of the appropriate equipment, which would have required a degree of technical sophistication considerably beyond the resources of the Medical Illustrations Department of a hospital, and instead photographic stills of appropriate 'frozen' sections on the waveform were taken and matched with the simultaneous sound recording. As indicated above (§5.5), no further analysis was made of the data because of the necessity to store the data in a digital form prior to computerized analysis. Within the limitations of this study, such a procedure was not possible.

5.15.2 All of the children had difficulty in imitating a voice quality other than their own, and it would be of value to set up a controlled study of this aspect of speech.

5.15.3 An auditory analysis of each child's normal voice quality was made from the taperecordings and is detailed below. Note the prevalence of whisperiness/breathiness and creak in a number of children.

Table 10

Subject	Sex	Voice quality features
1	M	Slightly whispery Palatalized 'Girlish' voice quality
2	F	Slightly creaky Very high pitch range at times Unable to keep pitch movements constant
3	M	Slightly harsh voice Creaky
4	M	Creaky and ventricular Slightly velarized Young 'girlish' voice quality
5	M	Slightly whispery
6	F	Slightly creaky Very low pitch
7	M	Slightly breathy Slightly whispery
8	F	Moderately whispery
9	F	Slightly creaky at the end of vocalization Noticeable creak in spontaneous speech
10	M	Slightly creaky Slightly breathy

Chapter 6

Present and Future Perspectives for the Study of DAS

In the course of this study, three approaches to the investigation of aspects of DAS have been made, and the main area of voicing has been considered in different ways. Laryngeal and respiratory constituents of articulation have been regarded as part of speech (which is viewed as not simply oral articulation). Thus by looking at any significant difficulties in IVOM and SVOM the possibility of an underlying disorder of the laryngeal and respiratory mechanism has been investigated.

The use of appropriate voicing in articulation (ie the ability to use what is perceived as a 'voiced' or 'voiceless' sound) has been investigated by two methods, auditory analysis and instrumental investigation.

Since it is very difficult to make an immediate visual assessment and written record of IVOM and SVOM, the use of the video equipment was found to be invaluable for assessment purposes. If possible, this method should be used in speech clinics. Unfortunately, the quality of audio recording on a video machine is not good enough for detailed auditory and instrumental analysis, and so the advantages which could be gained by being able to assess auditorily with the simultaneous visual clue is not yet available to the researcher.

In tests of volitional oral movement, there has been a tendency to mark only the oral superficial elements of articulatory activity - eg tongue and lips - and not to look at other components of the vocal tract involved in

speech movements, such as the respiratory and laryngeal mechanisms. Kissing, for example, is regarded as a test of lip movements, whereas it also involves a degree of control over the airflow mechanism. Indeed, the importance of being aware of airflow mechanisms underlying certain activities (eg kissing) has not been emphasized or even recognised in the interpretation of tests of IVOM and SVOM. Items including this mechanism have been found to be significantly defective for the DAS group under study in this thesis, and it is recommended that any assessment of DAS should investigate this feature and interpret the test results accordingly.

The way in which the assessment procedures in this thesis have been devised and interpreted (Chapter 2) is an attempt to remedy this situation, and in view of the possible phonatory problem which may exist in DAS children to elicit evidence of an underlying difficulty at the respiratory and laryngeal levels.

As a group, items which appeared to be significantly defective were those involving airflow and tongue movement, and, to a lesser degree, those involving lip and laryngeal activities. It is important to mention that only one test item (throat clearing) involved laryngeal activity, and this was found to be significantly defective in the DAS group under study. It would therefore be wise to include such an item in assessments and to be aware of the bias of tests towards certain selective articulatory activities, thus giving a false picture of overall ability of voluntary movements of the speech musculature.

The phonetic analysis of speech can be managed in two ways: auditory analysis and instrumental analysis. In this thesis, both methods have been employed to provide details of one of the features of speech, namely voicing. The instrumental analysis has used expensive, sophisticated equipment not normally available to clinical therapists in the UK.

From the traditional method of IPA transcription of the speech responses, abnormalities in the use of appropriate voicing were detected. These were present in all cases. Normally, the speech therapist would view sounds as being categorized as either voiced or voiceless, but as has been discussed (see above, pp 59-62), the understanding of voicing is a much more complex matter. In this thesis, categories of voicing have been set up and the data examined accordingly. The indications are that a more detailed examination of the voicing process in DAS children is a useful insight into the condition and may give pointers to appropriate therapy leading in turn to greater intelligibility in the child. From the limited laryngographic test and the indications of difficulties in changing voice quality experienced by the DAS children, it would seem that a detailed study to test the DAS child's ability to change phonation types at will would yield further insights into the condition.

The instrumental study of stop consonants has further underlined the inadequacies of the voicing process in the DAS child. Research in this field is to some extent hindered by the type of equipment required and by the lack of normative data. In this study, comparative data were collected from West of Scotland children - information which was not obtainable from any published source. In fact, the data presented here are probably the

first normative VOT data on children to be collected in this geographical area. It was necessary that children with the same accent be compared, since VOT values can vary according to the regional accent (see above, p 63).

An ideal arrangement would be the simultaneous recording of respiratory, phonatory, aerodynamic and acoustic features of speech production in a DAS child in relation to developmental vocal tract geometries. One anticipates that answers might be found to some of the questions raised by the results of this VOT study : why, for example, is the VOT value for [p] seemingly the most aberrant of all the stop consonants for a DAS child; what effect do changes in vocal fold vibratory patterns have, as a child's vocal tract matures, on the supralaryngeal resonances - in short, what is the exact relationship between phonatory and articulatory activities in DAS children?

The data presented in this thesis for VOT values indicate that it is impossible to set up a single figure to represent a VOT value for a particular stop consonant - cf one particular normal child's 17ms VOT for /p/ before /ø/ with the 75ms VOT before /u/. Yet there is a tradition in studies of children's VOT values, both normal and pathological, to establish a single value for each stop consonant (cf Simon 1976 : 147). An exception hitherto to this tradition is Zlatin (1972), but she deals only with values for the same stop before 4 different vowels. This study has shown that the data are much more complex than other researchers have admitted, and whatever the implications of such figures for statistical analysis, if we are to gain an accurate picture of the timing factors in

normal as well as abnormal speech, we must be prepared to accept the need for a detailed enquiry rather than a superficial statement.

In the experimental group of children studied, it was found that in a high proportion (8 out of 10) there was a report of a degree of clumsiness in their developmental history. In 5 of the children, there was a specific reference to clumsiness of hand movements. This observation is in keeping with the findings of Orton (1937), McAllister (1937), and with later work by Walton, Ellis and Court (1962). In fact, it was found that the apraxia was not confined to speech, but extended to other movement synergies as part of a generalized apraxia. No individual case was found in which apraxia was solely confined to speech.

In Glasgow, almost 50 years ago, McAllister emphasized the importance of considering the speech mechanism in relation to other body movements. Referring to her observations on handedness and speech disorders in the group which she defined as 'stammerers' (ie in today's terminology, articulatory cases including DAS) she said 'the co-ordinations of speech in children whose other muscular movements lack distinctness are generally clumsy and badly controlled...Their common characteristic was clumsy hand movements...Their poor speech movements meagre to the point of rendering speech unintelligible, were a parallel to clumsy hand movements...These stammerers made their first attempt towards speech improvement by learning to refine, strengthen and quicken their hand movements...A satisfactory therapeutics of speech disabilities will not be established until the physiological problems suggested by the various disorders have been elucidated' (McAllister 1937 : xix-xx).

In this thesis, the recognition of the underlying physiological problems in DAS has been of primary importance. It has been postulated that speech apraxia is part of a wider apraxic syndrome, and thus an instrumental investigation of the speech pattern has been made involving phonetic techniques aimed at providing data on one aspect of speech physiology, namely the fine timing of vocal fold vibratory patterns - an aspect of relevance in a disorder such as DAS.

In the study of volitional oral movements, it has been pointed out that mechanisms other than oral ones are involved in the movement patterns under examination.

Thus, the conclusion reached in this thesis is that developmental apraxia of speech is but part of a generalized apraxia and that the investigation, assessment and treatment of the disorder cannot be carried out satisfactorily without due recognition of the involvement of other movement synergies.

Appendix

VOT VALUES IN ms FOR STOP PHONEMES FOLLOWED BY VOWEL OR CONSONANT : VOT VALUES FOR EXPERIMENTAL GROUP

The left-most column represents the numbers of the Experimental Group in each Matched Pair. IPA notation is used, with the following exceptions;

ɪ ≡ I æ ≡ ʌ ø ≡ ɔ æi ≡ ʌi øe ≡ ɔe æu ≡ ʌu

/p/ before

	i	I	e	ɛ	a	æ	ø	o	u	æi	ae	øe	æu	l	r
1	11	17	8	30			26	49	56	23					8
2	11	11		11					0						
3		15	56	23				47	38		19				19
4	11	8	4	8			15	0			15				8
5	34	4	15	68				30							0
6		32		68					49		45				26
7	79	23	40	38				64	43		25				34
8	120	83	68	90			128	75	64		72				60
9	69	38	64	53			38	58	17		11				23
10	100	38	38	73			71	51	53		58				47

/b/ before

	i	I	e	ɛ	a	æ	ø	o	u	æi	ae	øe	æu	l	r
1	5	15	17	15	15	5		16		21	0				13
2	-11	6	17	11	26	8									
3	19	23	11		45	0		70							23
4		-62	15	-2	0	-17					-13				
5	-8	0	0			8		-8		0	0				
6		20	19					23							
7	-11	0	-8	11	-8	0		-8		13	-137				0
8	34	15	26	0	6	0		4		26					26
9	15	15	0			-75		0		-41					19
10	15	30	11	60	26	38		30		9	30				19

/t/ before

	i	I	e	ɛ	a	æ	ø	o	u	æi	ae	øe	æu	l	r
1	17	15		15			38	19	4				34		
2				34	0			11					45		
3	41				49		60	49	34			45			98
4	90			-8	15		8	8	-11			8	13		-15
5	17			68	9		88	8	15			15	87		139
6	41			23	53		53	26	34						41
7	98	26		30	45		38	53	45			149	45		56
8	124	83			58		68	117	53			79	75		90
9	120	45		60	41		77	58	43			79			105
10	75	60		49	45		60	88	49			87	79		58

/d/ before

	i	I	e	ɛ	a	æ	ø	o	u	æi	ae	øe	æu	l	r
1		53			30	32							19		30
2													19		0
3		38			70								13		
4		-15													0
5		0			0	0							0		-15
6						34							30		
7		0			-6	0							-6		0
8		26			45	21							15		9
9		-8			2	0							15		41
10		23			26	25							11		49

/k/ before

	i	I	e	ɛ	a	æ	ø	o	u	æi	ae	øe	æu	l	r
1	38	38	26			11	32	19							-8
2						41		23							
3		75	40			79	53	23							
4		8					15	19							
5	186	0	79			9	68	0							151
6	49	49				56	68	135							
7	90	38	53			56	-34	94							98
8	109	88	72			90	53	92						87	143
9	83	68	62			64	75	102						115	
10	109	75				38	53	81						0	83

/g/ before

	i	I	e	ɛ	a	æ	ø	o	u	æi	ae	øe	æu	l	r
1			30			15		19						19	25
2								15							
3			17					30						83	53
4			11					9						0	-9
5			0			0		-8						-8	
6			38					9							
7			0					0						0	0
8			30			22		32						41	49
9			-11					13						23	26
10			53			72		47						26	49

VOT VALUES FOR CONTROL GROUP

/p/ before

	i	I	e	ɛ	a	æ	ø	o	u	æi	ae	øe	æu	l	r
1	56	32	60	64			17	47	75	40					94
2	49	28		41					43						
3		60	70	53				26	66		36				41
4	40	53	64	60			68	77			68				64
5	64	60	62	41				60							56
6		103		79					90		90				100
7	75	34	38	60				45	72		58				56
8	53	58	71	60			53	77	75		53				66
9	53	75	75	68			94	68	96		60				26
10	83	45	75	41			68	49	79		77				79

/b/ before

	i	I	e	ɛ	a	æ	ø	o	u	æi	ae	øe	æu	l	r
1	15	11	15	19	34	8		38		0	19				
2	13	8	0	8	15	-4									
3	6	6	0		0	0		8							0
4		8	0	2	15	0					8				
5	15	0	9			0		8		8	8				
6		23	11					26							
7	11	8	23	15	8	17		-98		-72	11				26
8	11	8	0	13	11	11		13		8					30
9	23	15	15			15		24		15					19
10	26	15	24	15	29	26		23		15	21				23

/t/ before

	i	I	e	ɛ	a	æ	ø	o	u	æi	ae	øe	æu	l	r
1	124			83			94	87	53				138		
2				83	60			83					102		
3	105				43		102	87	68			94			75
4	83			90	75		41	94	41			68	83		75
5	105			98	56		87	90	75			139	120		128
6	105			60	72		64	98	98						132
7	68	56		47	49		53	64	56			64	113		90
8	68	75			64		85	79	55			64	68		94
9	75	90		64	56		38	98	49			88			102
10	105	45		49	83		62	51	51			87	75		113

/d/ before

	i	I	e	ɛ	a	æ	ø	o	u	æi	ae	øe	æu	l	r
1		15			15	40							26		34
2													28		-19
3		13			11								15		
4		8													45
5		11			0	11							15		23
6						17							26		
7		15			-62	13							13		23
8		15			15	17							19		32
9		23			15	17							19		45
10		38			19	19							17		26

/k/ before

	i	I	e	ɛ	a	æ	ø	o	u	æi	ae	øe	æu	l	r
1	75	75	55			75	85	92							158
2						72		49							
3		60	40			45	87	87							
4		79					87	75							
5	101	90	90			83	60	100							90
6	105	72				75	55	90							
7	83	51	56			53	62	75							98
8	83	60	72			45	62	72						74	92
9	90	55	75			88	72	88						62	
10	87	87				94	77	90						98	87

/g/ before

	i	I	e	ɛ	a	æ	ø	o	u	æi	ae	øe	æu	l	r
1			32			26		38						43	38
2								15							
3			11					30						30	21
4			26					19						49	11
5			15			23		30						34	
6			36					41							
7			19					-64						19	11
8			19			19		23						36	64
9			19					30						23	33
10			41			30		23						41	23

COMPARISON OF VOT VALUES FOR EXPERIMENTAL AND CONTROL GROUPS

Matched Pair 1 ;

/p/ before

	i	I	e	ɛ	a	æ	ø	o	u	æi	ae	øe	æu	l	r
E	11	17	8	30			26	49	56	23					8
C	56	32	60	64			17	47	75	40					94

/b/ before

	i	I	e	ɛ	a	æ	ø	o	u	æi	ae	øe	æu	l	r
E	5	15	17	15	15	5		16		21	0				13
C	15	11	15	19	34	8		38		0	19				

/t/ before

	i	I	e	ɛ	a	æ	ø	o	u	æi	ae	øe	æu	l	r
E	17	15		15			38	19	4				34		
C	124			83			94	87	53				138		

/d/ before

	i	I	e	ɛ	a	æ	ø	o	u	æi	ae	øe	æu	l	r
E		53			30	32							19		30
C		15			15	40							26		34

/k/ before

	i	I	e	ɛ	a	æ	ø	o	u	æi	ae	øe	æu	l	r
E	38	38	26			11	32	19							-8
C	75	75	55			75	85	92							158

/g/ before

	i	I	e	ɛ	a	æ	ø	o	u	æi	ae	øe	æu	l	r
E			30			15		19						19	25
C			32			26		38						43	38

Matched Pair 2 :

/p/ before

	i	I	e	ɛ	a	æ	ø	o	u	æi	ae	øe	æu	l	r
E	11	11		11					0						
C	49	28		41					43						

/b/ before

	i	I	e	ɛ	a	æ	ø	o	u	æi	ae	øe	æu	l	r
E	-11	6	17	11	26	8									
C	13	8	0	8	15	-4									

/t/ before

	i	I	e	ɛ	a	æ	ø	o	u	æi	ae	øe	æu	l	r
E				34	0			11					45		
C				83	60			83					102		

/d/ before

	i	I	e	ɛ	a	æ	ø	o	u	æi	ae	øe	æu	l	r
E													19		0
C													28		-19

/k/ before

	i	I	e	ɛ	a	æ	ø	o	u	æi	ae	øe	æu	l	r
E						41		23							
C						72		49							

/g/ before

	i	I	e	ɛ	a	æ	ø	o	u	æi	ae	øe	æu	l	r
E								15							
C								15							

Matched Pair 3 :

/p/ before

	i	I	e	ɛ	a	æ	ø	o	u	æi	ae	øe	æu	l	r
E		15	56	23				47	38		19				19
C		60	70	53				26	66		36				41

/b/ before

	i	I	e	ɛ	a	æ	ø	o	u	æi	ae	øe	æu	l	r
E	19	23	11		45	0		70							23
C	6	6	0		0	0		8							0

/t/ before

	i	I	e	ɛ	a	æ	ø	o	u	æi	ae	øe	æu	l	r
E	41				49		60	49	34			45			98
C	105				43		102	87	68			94			75

/d/ before

	i	I	e	ɛ	a	æ	ø	o	u	æi	ae	øe	æu	l	r
E		38			70								13		
C		13			11								15		

/k/ before

	i	I	e	ɛ	a	æ	ø	o	u	æi	ae	øe	æu	l	r
E		75	40			79	53	23							
C		60	40			45	87	87							

/g/ before

	i	I	e	ɛ	a	æ	ø	o	u	æi	ae	øe	æu	l	r
E			17					30						83	53
C			11					30						30	21

Matched Pair 4 ;

/p/ before

	i	I	e	ɛ	a	æ	ø	o	u	æi	ae	øe	æu	l	r
E	11	8	4	8			15	0			15				8
C	40	53	64	60			68	77			68				64

/b/ before

	i	I	e	ɛ	a	æ	ø	o	u	æi	ae	øe	æu	l	r
E		-62	15	-2	0	-17					-13				
C		8	0	2	15	0					8				

/t/ before

	i	I	e	ɛ	a	æ	ø	o	u	æi	ae	øe	æu	l	r
E	90			-8	15		8	8	-11			8	13		-15
C	83			90	75		41	94	41			68	83		75

/d/ before

	i	I	e	ɛ	a	æ	ø	o	u	æi	ae	øe	æu	l	r
E		-15													0
C		8													45

/k/ before

	i	I	e	ɛ	a	æ	ø	o	u	æi	ae	øe	æu	l	r
E		8					15	19							
C		79					87	75							

/g/ before

	i	I	e	ɛ	a	æ	ø	o	u	æi	ae	øe	æu	l	r
E			11					9						0	-9
C			26					19						49	11

Matched Pair 5 :

/p/ before

	i	I	e	ɛ	a	æ	ø	o	u	æi	ae	øe	æu	l	r
E	34	4	15	68				30							0
C	64	60	62	41				60							56

/b/ before

	i	I	e	ɛ	a	æ	ø	o	u	æi	ae	øe	æu	l	r
E	-8	0	0			8		-8		0	0				
C	15	0	9			0		8		8	8				

/t/ before

	i	I	e	ɛ	a	æ	ø	o	u	æi	ae	øe	æu	l	r
E	17			68	9		88	8	15			15	87		139
C	105			98	56		87	90	75			139	120		128

/d/ before

	i	I	e	ɛ	a	æ	ø	o	u	æi	ae	øe	æu	l	r
E		0			0	0							0		-15
C		11			0	11							15		23

/k/ before

	i	I	e	ɛ	a	æ	ø	o	u	æi	ae	øe	æu	l	r
E	186	0	79			9	68	0							151
C	101	90	90			83	60	100							90

/g/ before

	i	I	e	ɛ	a	æ	ø	o	u	æi	ae	øe	æu	l	r
E			0			0		-8						-8	
C			15			23		30						34	

Matched Pair 6 :

/p/ before

	i	I	e	ɛ	a	æ	ø	o	u	æi	ae	øe	æu	l	r
E		32		68					49		45				26
C		103		79					90		90				100

/b/ before

	i	I	e	ɛ	a	æ	ø	o	u	æi	ae	øe	æu	l	r
E		20	19					23							
C		23	11					26							

/t/ before

	i	I	e	ɛ	a	æ	ø	o	u	æi	ae	øe	æu	l	r
E	41			23	53		53	26	34						41
C	105			60	72		64	98	98						132

/d/ before

	i	I	e	ɛ	a	æ	ø	o	u	æi	ae	øe	æu	l	r
E						34							30		
C						17							26		

/k/ before

	i	I	e	ɛ	a	æ	ø	o	u	æi	ae	øe	æu	l	r
E	49	49				56	68	135							
C	105	72				75	55	90							

/g/ before

	i	I	e	ɛ	a	æ	ø	o	u	æi	ae	øe	æu	l	r
E			38					9							
C			36					41							

Matched Pair 7 ;

/p/ before

	i	I	e	ɛ	a	æ	ø	o	u	æi	ae	øe	æu	l	r
E	79	23	40	38				64	43		25				34
C	75	34	38	60				45	72		58				56

/b/ before

	i	I	e	ɛ	a	æ	ø	o	u	æi	ae	øe	æu	l	r
E	-11	0	-8	11	-8	0		-8		13	-137				0
C	11	8	23	15	8	17		-98		-72	11				26

/t/ before

	i	I	e	ɛ	a	æ	ø	o	u	æi	ae	øe	æu	l	r
E	98	26		30	45		38	53	45			149	45		56
C	68	56		47	49		53	64	56			64	113		90

/d/ before

	i	I	e	ɛ	a	æ	ø	o	u	æi	ae	øe	æu	l	r
E		0			-6	0							-6		0
C		15			-62	13							13		23

/k/ before

	i	I	e	ɛ	a	æ	ø	o	u	æi	ae	øe	æu	l	r
E	90	38	53			56	-34	94							98
C	83	51	56			53	62	75							98

/g/ before

	i	I	e	ɛ	a	æ	ø	o	u	æi	ae	øe	æu	l	r
E			0					0						0	0
C			19					-64						19	11

Matched Pair 8 :

/p/ before

	i	I	e	ɛ	a	æ	ø	o	u	æi	ae	øe	æu	l	r
E	120	83	68	90			128	75	64		72				60
C	53	58	71	60			53	77	75		53				66

/b/ before

	i	I	e	ɛ	a	æ	ø	o	u	æi	ae	øe	æu	l	r
E	34	15	26	0	6	0		4		26					26
C	11	8	0	13	11	11		13		8					30

/t/ before

	i	I	e	ɛ	a	æ	ø	o	u	æi	ae	øe	æu	l	r
E	124	83			58		68	117	53			79	75		90
C	68	75			64		85	79	55			64	68		94

/d/ before

	i	I	e	ɛ	a	æ	ø	o	u	æi	ae	øe	æu	l	r
E		26			45	21							15		9
C		15			15	17							19		32

/k/ before

	i	I	e	ɛ	a	æ	ø	o	u	æi	ae	øe	æu	l	r
E	109	88	72			90	53	92						87	143
C	83	60	72			45	62	72						74	92

/g/ before

	i	I	e	ɛ	a	æ	ø	o	u	æi	ae	øe	æu	l	r
E			30			22		32						41	49
C			19			19		23						36	64

Matched Pair 9 ;
/p/ before

	i	I	e	ɛ	a	æ	ø	o	u	æi	ae	øe	æu	l	r
E	69	38	64	53			38	58	17		11				23
C	53	75	75	68			94	68	96		60				26

/b/ before

	i	I	e	ɛ	a	æ	ø	o	u	æi	ae	øe	æu	l	r
E	15	15	0			-75		0		-41					19
C	23	15	15			15		24		15					19

/t/ before

	i	I	e	ɛ	a	æ	ø	o	u	æi	ae	øe	æu	l	r
E	120	45		60	41		77	58	43			79			105
C	75	90		64	56		38	98	49			88			102

/d/ before

	i	I	e	ɛ	a	æ	ø	o	u	æi	ae	øe	æu	l	r
E		-8			2	0							15		41
C		23			15	17							19		45

/k/ before

	i	I	e	ɛ	a	æ	ø	o	u	æi	ae	øe	æu	l	r
E	83	68	62			64	75	102						115	
C	90	55	75			88	72	88						62	

/g/ before

	i	I	e	ɛ	a	æ	ø	o	u	æi	ae	øe	æu	l	r
E			-11					13						23	26
C			19					30						23	33

Matched Pair 10 ;
/p/ before

	i	I	e	ɛ	a	æ	ø	o	u	æi	ae	øe	æu	l	r
E	100	38	38	73			71	51	53		58				47
C	83	45	75	41			68	49	79		77				79

/b/ before

	i	I	e	ɛ	a	æ	ø	o	u	æi	ae	øe	æu	l	r
E	15	30	11	60	26	38		30		9	30				19
C	26	15	24	15	29	26		23		15	21				23

/t/ before

	i	I	e	ɛ	a	æ	ø	o	u	æi	ae	øe	æu	l	r
E	75	60		49	45		60	88	49			87	79		58
C	105	45		49	83		62	51	51			87	75		113

/d/ before

	i	I	e	ɛ	a	æ	ø	o	u	æi	ae	øe	æu	l	r
E		23			26	25							11		49
C		38			19	19							17		26

/k/ before

	i	I	e	ɛ	a	æ	ø	o	u	æi	ae	øe	æu	l	r
E	109	75				38	53	81						0	83
C	87	87				94	77	90						98	87

/g/ before

	i	I	e	ɛ	a	æ	ø	o	u	æi	ae	øe	æu	l	r
E			53			72		47						26	49
C			41			30		23						41	23

VOT VALUES FOR TWO CEREBRAL PALSIED CHILDREN ACCORDING TO TYPE OF STOP CONSONANT AND SEGMENTAL CONTEXT

CerP1

	i	I	e	ɛ	a	æ	ø	o	u	æi	ae	øe	æu	l	r
p		-241		-254				-346	-231	-816					-56
b	-86	-348	-525	-132	-316	-436		-166			-530	-357			-271
t		-196		-98	-519		-128	-391	-87				-120		-85
d		-356			-169	-143							-214		-226
k		-211				-376		-611							-278
g			-369			-542		-609						-361	-127

CerP2

	i	I	e	ɛ	a	æ	ø	o	u	æi	ae	øe	æu	l	r
p		85		53			113	105	83	62					105
b	38	0	45	-49	23	23		19		23	23				25
t	60			90	103		79	67	83			135	166		147
d		23			49	22							23		60
k	139	88				70		85							
g			36			60		15						23	34

COMPARISON OF VOT VALUES FOR TWO CEREBRAL PALSIED CHILDREN

/p/ before

	i	I	e	ɛ	a	æ	ø	o	u	æi	ae	øe	æu	l	r
1		-241		-254				-346	-231	-816					-56
2		85		53			113	105	83	62					105

/b/ before

	i	I	e	ɛ	a	æ	ø	o	u	æi	ae	øe	æu	l	r
1	-86	-348	-525	-132	-316	-436		-166			-530	-357			-271
2	38	0	45	-49	23	23		19		23	23				25

/t/ before

	i	I	e	ɛ	a	æ	ø	o	u	æi	ae	øe	æu	l	r
1		-196		-98	-519		-128	-391	-87				-120		-85
2	60			90	103		79	67	83			135	166		147

/d/ before

	i	I	e	ɛ	a	æ	ø	o	u	æi	ae	øe	æu	l	r
1		-356			-169	-143							-214		-226
2		23			49	22							23		60

/k/ before

	i	I	e	ɛ	a	æ	ø	o	u	æi	ae	øe	æu	l	r
1		-211				-376		-611							-278
2	139	88				70		85							

/g/ before

	i	I	e	ɛ	a	æ	ø	o	u	æi	ae	øe	æu	l	r
1			-369			-542		-609						-361	-127
2			36			60		15						23	34

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