Issues Contrasting Adult Acquired Versus Developmental Apraxia of Speech

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ABSTRACT

Acquired and developmental apraxia of speech (AOS and DAS) are defined as disorders of the transition from an abstract phonological code into motor commands. However, the natural course of these disorders differs substantially because of the fundamental difference in the developmental stage at which the apraxia expresses itself. In normal and pathological development alike, development of language and speech is an interactive process, involving speech motor control, perception, and psycholinguistic processes. Infant speech develops from random babbling and sensomotoric learning, followed by more abstract phonological acquisition. Supposing that the core deficit of DAS comprises a reduced sensomotoric learning capacity explains a large part of the symptomatology of DAS in the psycholinguistic domain because of the impact on phonological, perceptual, and higher-level processes. This contrasts with adults with AOS, who already have acquired stable top-down processes. Implications for clinical management are discussed.

KEYWORDS: Speech motor disorders, speech development, psycholinguistics, child neuropsychology

Learning Outcomes: As a result of this activity, the reader will be able to (1) outline the developmental aspects of speech disorders in children and the manifestations of developmental apraxia of speech as compared to acquired apraxia of speech and (2) list corresponding differences in symptomatology and clinical management of the two disorders.

Clinical views, as well as the understanding of underlying deficits of AOS, have gained tremendously from cognitive neuropsychological and psycholinguistic models of speech production and perception. Three processing stages are particularly involved in the speech output disorder AOS: lexical retrieval, phonological encoding, and articulation (Fig. 1A).

Disentangling these processes requires complicated experimentation and experimen-

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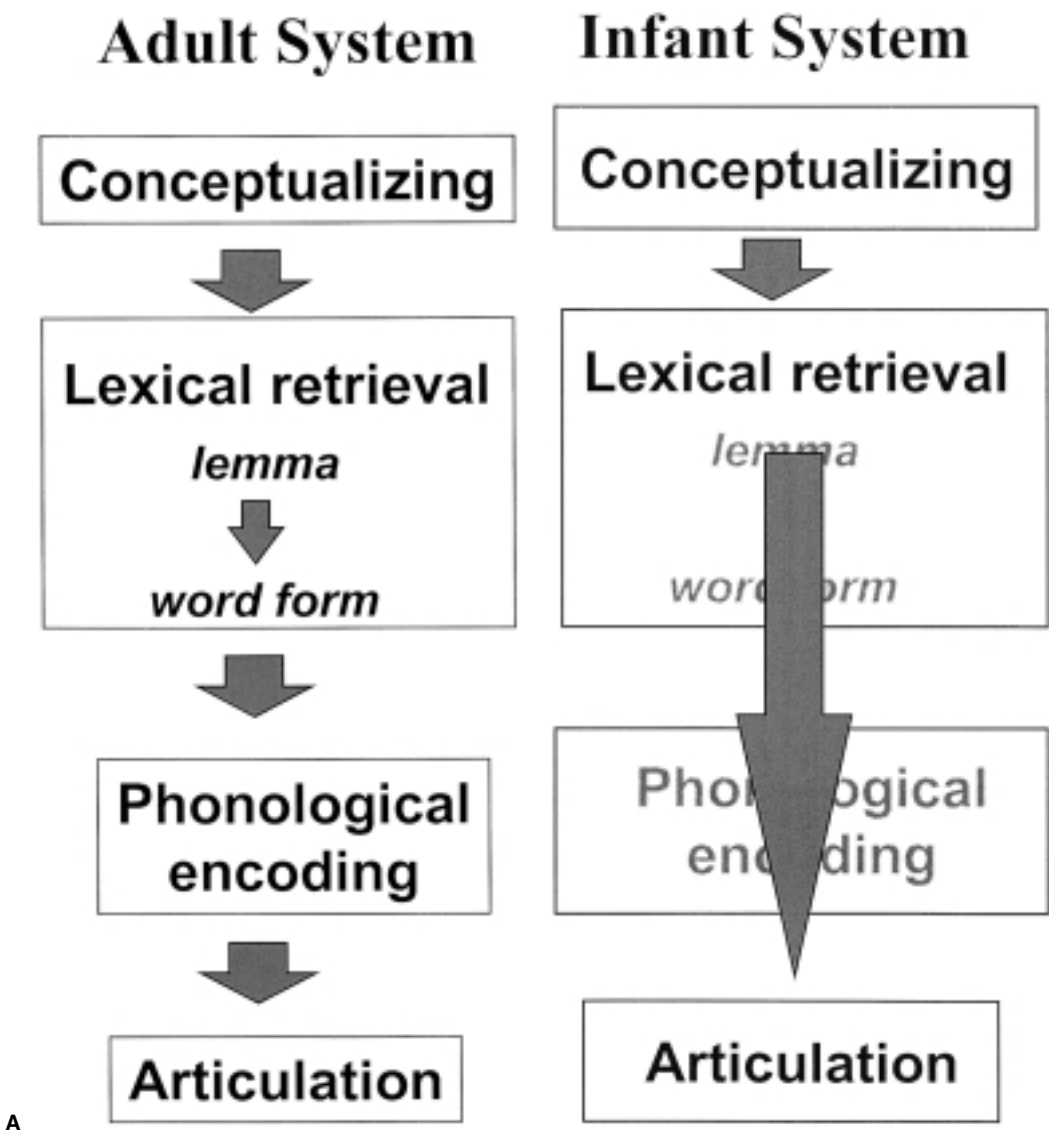

Figure 1 Schematic diagram of the speech production mechanism of adults (A) and children (B) after Levelt et al.[1] For an explanation, please refer to the text.

tal techniques (for a research update, see Levelt and colleagues[1]) that, as a rule, are not available during clinical examinations. Typically, in clinical examinations all the information-processing steps potentially involved in the speech-output disorder are tested simultaneously. For instance, in a confrontation picture-naming task, the subject goes through all three processing levels (taking visual analysis and object recognition for granted): retrieval of lexical concept (lemma) and of word form (lexeme), followed by phonological encoding and articulation. Deriving the underlying deficit from performances on this complex task is by no means undisputed; faulty interpretations or low inter-rater agreement on the diagnosis are serious risks.

The previously sketched clinical interpretational uncertainty is one of the main obstacles to resolving the debate as to whether AOS is a syndrome or a specific function disorder, whether it can be distinguished from other speech-output disorders, and whether the adult and childhood forms (DAS) are essentially the

same or are different disorders.[2,3] Research on adult patients seems to converge on the conclusion that AOS is a disorder of motor planning and motor programming in the cognitive architecture particularly localized after the phonological encoding stage.[4]

The author contends that there are two major differences between DAS in children and AOS in adults. The first difference relates to the speech model used. Recent research suggests that speech and language production during infancy and early childhood can be characterized by a more simplified model, consisting of fewer processing stages than what is seen with the full-fledged adult system. Figure 1B schematically presents the model underlying studies such as those by Levelt et al,[5] showing that at the earliest stage of speech development children have at their disposition a restricted set of articulatory forms the size of a syllable. At a later developmental stage, under the communicative pressure of the growing vocabulary, the phonological system expands and takes advantage of the more productive phonological combination rules of the adult system. As a result, a word form lexicon and a phonological encoding system develop.

The second major difference between adults and children is between dissociation and association.[6] In adult neuropsychology, the specificity of a disorder is demonstrated by double dissociation. In order to conclude that two functions A and B (e.g., phonological encoding and articulomotor planning) are distinct, one must find patients with impaired function A and intact function B (e.g., phonemic paraphasia) and also patients with intact function A and impaired function B (e.g., AOS[2]). In children, however, there is ample evidence for interaction between levels of representation, with modularity not emerging until later in the course of development. The best-known example is the effect of severe hearing loss or deafness on language and speech development. Although deafness is only a disorder of the *perception* of speech sounds, it has devastating effects on both receptive and productive language and speech skills. Thus, a disorder in the auditory domain can have effects across linguistic and motor domains. Note that hearing loss has totally different effects when it is congenital than when it is acquired in adulthood, after language and speech have had a chance to develop. Even 2 years of normal development, as compared with no sound experience whatsoever, are a big advantage for further developing of oral language skills. In a review article, Bishop[6] drew particular attention to the clinical problem that changes in the nature of representations and in the relationships between components of a developing system may be misleading with respect to the primary deficit, in particular because top-down influences also can occur. For instance, a deficit in lexical development puts the child at a disadvantage with respect to analyzing similarities and differences between words and therefore may be a hindrance for phonological development. In its turn, a delayed phonological development can, like deprivation, cause poorer articulomotor or auditory-perceptual skills. Similarly, Locke[7] assigns a crucial role to the storage of linguistic material (words and short phrases), that is the raw linguistic data for the system to work on for the development of syntax and phonology.

The author will first elucidate some qualitative differences in the phases of speech development of children with DAS that lead to the continuously changing symptom complex and growing diversity in developmental histories. Next, the consequences of this developmental perspective for differential diagnostic classification will be discussed. Because of changes in expression of the underlying deficit in DAS, the diagnostic criteria to differentiate DAS from other speech disorders in children are also changing continuously. Finally, implications for clinical management are discussed.

DEVELOPMENT ASPECTS

Speech Motor Learning

The term "infant speech development" is really a "contradictio in terminus," because infant literally means nonspeaking. Infant speech development consists of vocal play and babbling. Studies on the relation between babbling and early speech in normal development show that there is a continuous developmental progression from oral motor behavior during the 1st

year of life to early speech in the 2nd year.[8–12] Although overall speech and language development is strongly influenced by environment, vocal development in the 1st year of life appears to be robust with respect to conditions of rearing, in particular socioeconomic status and bilingual or monolingual environment.[13] Factors other than ambient language affect infant speech development. For example, severe hearing impairment, or mild and variable hearing loss because of episodes of otitis media, have been shown to affect babbling.[14] This supports the view that the 1st year of speech development is dominated by motor learning, which remains important during the years to follow but in normal development is gradually replaced by a more phonological orientation. Many studies have demonstrated the prognostic value of both early hearing loss and babbling in normal development and also in distinct delayed or pathological conditions.[15] For instance, Oller and colleagues[16] demonstrated that infants who showed late onset of canonical babbling, assessed at the age of 10 months, had smaller production vocabularies at 18, 24, and 30 months than did infants in a comparison group.

Modeling Speech Motor Learning

Recently, Guenther et al[17] presented a model for speech production in which, during the early babbling stages of speech motor development, the infant learns *systemic mappings* between articulatory movements and auditory consequences. During this acquisition stage, the more or less randomly generated babbling movements of the articulatory organs form the opportunity for the child to discover the auditory effects of the articulatory system. Thus, vocal play can be considered as the first speech motor drill. The model proposes that this learning process is neurologically mediated by so-called "mirror neurons." These mirror neurons are capable of using tactile, proprioceptive, and auditory feedback signals to train neural mappings that are later used for phoneme production.

At a somewhat later stage in development, typically during the 2nd year of life, the child learns to imitate speech sounds spoken by others. *Phoneme-specific* mappings are formed in which auditory—and via auditory also articulatory—representations are organized and grouped together into the phonemic categories of the native language. Callan et al[18] addressed the issue of how the speech production system is capable of this developmental process, thereby adapting to continuous changes in size and shape of the articulatory system. The account they put forward is a neural network model based on auditory feedback that is capable of motor-equivalent speech production despite changes in the acoustical properties of the vocal tract that occur during growth. Thus, the model gives a solid account for the perceptuomotor aspects of the developmental and clinical observations with respect to babbling and the role of audition described earlier.

Speech Motor Learning in DAS

What does such a model of perceptuomotor development offer for the understanding of developmental apraxia of speech? Among the first signs of a dyspraxic development, often assessed in retrospect, is reduced babbling in combination with a delayed or deviant oral motor development. As we saw earlier, this is not a very specific symptom of DAS because reduced babbling has also been described in other developmental speech disorders and even hearing impairment. In a review of the literature, Shriberg and collaborators[19] concluded that "DAS may be suspected in a child's earliest attempts at talking, but there are no phonological or phonetic parameters of talking that unambiguously document the onset . . . of the disorder." The literature is not clear on the temporal course of the disorder, and not all children with DAS show late onset of speech.

Still, although this is not an exclusive characteristic, there is strong evidence that delayed or deviant motor development and perceptual motor learning play a role in many children with DAS. The first clinical evidence, reduced babbling, has already been mentioned. The second piece of clinical evidence is the high incidence of concomitant dysarthria and oral motor dyspraxia, already noted in the early studies by Rosenbek and Wertz[20] and Yoss and Darley.[21] Apparently, many children with DAS suffer

from a more generalized deficiency in motor control of the speech mechanisms. As we will discuss more fully later, reduced diadochokinetic rate of both simple and more complex syllable sequences, often found in DAS, is a sign of motor involvement.[22] Also, poor oral-sensory perception is a frequently mentioned feature of DAS.[23]

The third type of clinical evidence is the high comorbidity rate of DAS, especially with regard to fine and gross motor impairment. Clumsiness is frequently reported for children with DAS[23] and also children with mild motor retardation[24] or difficulty with coordinating alternating hand movements.[21] Finally, various studies have reported production as well as perception errors. A study of Hoit-Dalgaard et al,[25] for example, showed that children with DAS demonstrated problems in both the production and the perception of the voicing feature of phonemes. A similar relation between production and perception problems was found in children with DAS with respect to the feature "place of articulation"[26] and in rhyming abilities.[27]

The studies mentioned earlier were all conducted during childhood, but from a developmental perspective it can be argued that the poor phonetic and phonological capabilities found at that later age, at least in part, reflect poor motoric and perceptual-motor capacities during infancy. Therefore, it seems reasonable to hypothesize that a reduced capacity to form *systemic mappings* might underlie the oral motor and early speech learning difficulties in DAS and put the child at a disadvantage for the acquisition of the motor aspects of phonology, that is, the *phoneme-specific* mappings. It requires specific experimentation to confirm that indeed poor perceptual-motor control lies at the basis of the phonetic and phonemic phenomena found in children with DAS. Pioneering experiments to collect evidence are presented below.

Phonological Development in Relation to Speech Motor Development

The development of articulomotor control plays a persisting role in speech development. A first observation is that at the stage at which children produce intelligible speech, the maturation of speech motor control also continues. Clear indices of continuing maturation have been demonstrated until the age of 7 years, possibly continuing up to the age of 12 years.[28] During this developmental period, the variability of speech production decreases, resulting in stabilization of speech patterns increasingly similar to the adult patterns. Also, qualitative changes in coarticulation have been demonstrated in the direction of adult patterns. The speech of infants and young children is organized around the syllable as the production unit. Thus, Levelt et al[5] showed that in early speech, place of articulation is not varied phoneme by phoneme but syllable by syllable, with the result that back consonants are combined with back vowels (in syllables such as /go/), front consonants with front vowels (/di/), and labial consonants with low central vowels (/ba/). Only at a later stage of development, place of articulation is varied within the syllable, which yields a tremendous increase in the combinatorial possibilities, and thus the productive power of the speech mechanism needed to express the growing vocabulary.

EXPERIMENTAL EVIDENCE

Details of this developmental process were offered by Nittrouer and collaborators,[29–31] who provided evidence that the unit in children's speech develops from the syllable to the phoneme. The evidence comes from acoustic analyses of coarticulation in speech production and coarticulatory effects in perception. As an example of production studies, Nittrouer[30] asked 10 adults and 30 children ranging in age from 3 to 7 years to produce utterance, such as "It's a CV Bob," in which C stand for one of the consonants /s, ʃ, t, d, k/ and V for one of the vowels /a, i, u/. Acoustical analyses were conducted on the fragment [↔]-CV. It was shown that, for instance, in the word set "she" (/ʃi/), "shoe" (/ʃu/), "see" (/si/), and "Sue" (/su/) children produced more coarticulation between vowel and consonant than adults did and less distinction in spectral characteristics of the fricative. Nittrouer et al[31] drew a parallel with motor development in newborns, in that global movements of the infant are refined into more precise and more differentiated coordinative structure and that at the same time these in-

creasingly differentiated movements are assembled into large functional units.

McCune and Vihman[32] investigated the influence of phonetic skills on early phonological and lexical progress. In particular, these authors emphasized the qualitative aspect of vocabulary acquisition and growth, rather than the quantitative aspect referred to as the "vocabulary spurt" and demonstrated that vocabulary acquisition is made possible by emerging phonology, which in its turn depends on phonetic development. The evidence consists of developmental data showing that symbolic or referential, as opposed to context-bound, word use goes hand in hand with the phonetic development of "vocal motor schemes" (VMS), which allows the child to produce phonemes consistently. Thus, children gradually build and enlarge their phonemic repertoire on the basis of these vocal motor schemes, which opens the way for the child to distinguish among the increasing number of lexical items in the growing vocabulary. Thus, phonetic development fosters lexical development via phonological development.

To conclude, there is converging evidence that early speech develops on the basis of infant babbling. Acoustic studies have demonstrated continuity in the development from babbling to speech, even to the point that individual differences during babbling are found again in early speech.[12]

Phonological Development in DAS

The one consistent characteristic of the speech of children with DAS is its *inconsistency*. The low intelligibility of DAS speech is caused by a large number of consonantal errors, especially (contextual) substitutions and omissions. The phonemic repertoire is limited, and some studies conclude that the phonological system can be characterized as deviant rather than delayed. There is a tendency to make predominant use of simple syllable shapes, but the distribution of phonemic errors across syllable positions is not different from speech errors in speech delay or even normal development. Furthermore, error rate increases with increasing length and complexity of the utterance. In contrast with normal children, who produce fewer errors in words than they do in nonsense words, the error rate in children with DAS is much less sensitive to wordlikeness. Not only consonants but also vowels are frequently substituted or distorted. There is a tendency to neutralize vowels and a tendency *not* to neutralize, namely to stress unstressed syllables, resulting in staccato speech, or to mark phonologically unmarked consonants. To date, of all these characteristics, inappropriate stress might stand out as the first candidate to serve as diagnostic marker for DAS.[2,33–36] A typical phonological development, or a phonological system characteristic for DAS, has not been found. Shriberg et al[19] calculated the profiles on large samples of spontaneous speech from children with DAS as compared with children with speech delay. Not only were consonant, vowel, and diphthong profiles determined, but consistency analyses were also conducted by comparing word types that occurred at least twice in the sample. Of the statistical comparisons made, only one appeared significant, just as many as one would expect by chance on the basis of the applied alpha. The conclusion is that apart from a late-onset and protracted development, DAS has no specific phonological characteristics.

CLINICAL MANAGEMENT OF DAS AND AOS: CONTRASTIVE ISSUES

Diagnosis

In the previous section, speech development was described as a complex process that depends on the timely interplay of perceptual, motor, and higher cognitive functions. Infants and children go through stages in which the focus is on development of functions that are typically impaired in DAS. Thus, normal infants go through a babbling stage, during which they practice the particular aspect of speech motor control that gives children with DAS great difficulty up to a much later age. The result in normal development is systemic mappings, according to Guenther's model.[17] During the 2nd and 3rd year of life, development proceeds, in that children learn to use their articulatomotor skills to produce adult-like speech sounds and speech sound sequences; *phoneme-*

specific mappings are acquired built on the systemic mappings. Up to at least the age of 7 years, perceptuomotor control gradually becomes less important as a determiner of speech development, whereas phonological learning (phonological encoding and decoding) gains weight.

If we start from the hypothesis that DAS is an impairment in perceptuomotor control and perceptuomotor learning, then there is a long developmental trajectory in which this underlying impairment can show its effects. These effects can be diverse: some children do not start speaking or stop speaking once started, whereas others speak a great deal but unintelligibly; some children come up with a disrupted phonological system, or word-form lexicon, or morphemic and thus grammatical development. Thus, even if one assumes a single perceptuomotor deficit underlying DAS, the symptomatology at the age the children are referred for a speech-language examination (typically not before age 2.6 to 3 years) can be quite diverse. It is not until about 1 year later that the differential diagnosis DAS can be confirmed with some certainty. It is at this age that we pick up our story: contrastive issues in DAS versus AOS.

Definition and Differential Diagnosis

Starting from the earliest definition of AOS by Darley et al,[37] most authors agree that AOS is a speech-motor disorder. McNeil[38] noted that "it is not a lack of theory or the inability to select the correct theory from the known alternatives that limits understanding of AOS. . . . It *is* the lack of a definition and an agreed-upon set of criteria for subject selection that is the single most important impediment to theoretical and clinical advancement in AOS." Similarly, Ballard and colleagues[4] conclude that "while the notion of AOS as a phonetic-motoric disorder is now generally accepted, . . . differentiating between the respective phonetic-motoric and linguistic impairments has proven difficult." Thus, according to both McNeil[38] and Ballard et al,[4] the problem lies not so much in defining the underlying impairment of AOS as in a lack of clear *operational definitions* or *procedural criteria* for the differential diagnosis of AOS. This problem, however, not only has an impact on clinical diagnosis but also influences more theoretical research, in which uncontroversial subject selection is a prerequisite for characterization of the disorder.

For DAS, the situation is much more controversial at both the theoretical and the operational levels. In a critical evaluation, Guyette and Diedrich[3] concluded that researchers do not agree with respect to the two proposed defining criteria to distinguish DAS from other communicative disorders in children, the so-called pathognomonic symptoms, which are valid for AOS. The prevailing theoretical account for DAS stresses as first criterion the underlying inability to perform volitional speech movements, which should be a primary symptom (i.e., not because of a phonological or higher-order language deficit on the one hand or dysarthria on the other). No unequivocal procedures are available, however, to diagnose volitional speech impairment in children that are not confounded by other psycholinguistic task aspects (e.g., lexical retrieval in a picture-naming task and auditory perception in a repetition task). This procedural problem is similar but more extreme as compared with the AOS literature. A fundamental difference between AOS and DAS, however, is that in DAS a specific underlying speech motor impairment has an impact on the development of higher phonological and linguistic processing levels, as was argued earlier. This has inspired other theoretical accounts of DAS. Thus, Marion et al[27] proposed "a conceptualization of DAS as a fundamental disorder of the segmental phonological level of language that *impacts on all hierarchically relevant language components*" (author's emphasis). Dogil and collaborators[39] posited that the disorder can be explained as a purely linguistic, or phonological, impairment, comprising overspecification of phonetic representations, which leads to reduced coarticulation, impaired production of underspecified speech sounds, and staccato speech containing no unstressed syllables.

Given that the primary deficit in DAS is still controversial (one reason being that pure forms of DAS without comorbidity are extremely rare), Shriberg et al[19] concluded that the

situation is still such that the clinical diagnosis DAS is made by exclusion. In recent years, series of studies have been started in search for a "diagnostic marker" for DAS; there is not sufficient space to review these studies here.

Neurological Evidence

The second controversial issue in the definition of DAS relates to the brain damage. For a neurogenic disorder to be classified as developmental, it is presupposed that the brain damage is there before the first symptoms appear. The alternative, that the speech is impaired only after a period of normal development, suggests an acquired disorder because of some neurological accident causing the impairment. In child neurology and child neuropsychology, this line of reasoning is tremendously complicated by the diagnostic option of postponed expression. In the child neuropsychological domain, the examples from Locke[7] and Bishop[6] support the argument that developmental stages are sequentially dependent and show that particular impairments in information processing can become manifest only at a later age. Dyslexia is the most obvious example in the psycholinguistic domain. Currently, in both Finland and the Netherlands, longitudinal studies are conducted that aim to find precursors in auditory and speech development from age 2 months to 5 years for dyslexia at the age of 7 to 9 years. It is very likely that developmental disorders such as specific language impairment (SLI) and DAS, both disorders having a genetic component, have an underlying neurological determiner that waits to be found once sophisticated brain imaging techniques are sensitive enough to detect them.

Clinical evidence for neurological involvement in DAS is weak. In 1981, Guyette and Diedrich[3] qualified DAS as a behavioral concept with neurological implications, analogous to the then-prevailing concept of minimal brain dysfunction (MBD). The term soft neurological signs does not capture the complex relationship between brain structure and neurophysiological functioning on the one hand and complex behavioral disorders on the other. A complicating factor is that in many studies brain damage serves as an exclusion criterion for "pure" DAS. Furthermore, in the definition of DAS, the clearest neurological speech symptom (i.e., dysarthria) is explicitly excluded in all diagnostic classifications. (See also the section on dysarthria as comorbidity later.)

In a brief literature review, Marion et al[27] concluded that "some form of brain dysfunction is implicitly assumed in DAS despite a lack of documented neurological deficits in the majority of children diagnosed as having DAS." This, in fact, was the same conclusion as that of Horwitz,[40] who nine years earlier ". . . failed to demonstrate consistent neurological findings or a specific localizing anatomical basis for the clinical manifestations of DAS." This is a very unsatisfactory state of affairs. As in developmental dysphasia or dyslexia, disorders with very similar behavioral characteristics as their acquired counterparts, neurological involvement is often assumed also in DAS. For developmental dysphasia and dyslexia, postmortem microscopic examination of cerebral tissue and magnetic resonance imaging have shown cortical anomalies (see Marion et al[27]) and symmetric plana temporalis, as compared with asymmetric plana in normally developing peers (see review by Locke[41]).

In acquired AOS, as in most aphasias for that matter, the critical site of pathology as a rule can be delineated. For AOS, that site is in the perisylvian and anterior insular regions. The difference between DAS and AOS might arise in part because children are seriously impaired in speech and language only if the pathology is bilateral. Recently, a three-generation family was investigated and half of the family members were affected by a pronounced AOS. Functional abnormalities in both cortical and subcortical motor-related areas of the frontal lobe were demonstrated with positron emission tomography; quantitative analyses of magnetic resonance imaging scans revealed structural abnormalities in several of these same areas, particularly the caudate nucleus, which was found to be abnormally small bilaterally (Vargha-Kadem et al[42]).

To date, the evidence supporting the epithet neurogenic for DAS consists of the genetic

aspect (DAS runs in families), the preponderance in men (in fact also a genetic factor), and the elevated incidence of comorbidities.

Implications for Therapy

The most complete published program for training children with DAS is the Nuffield Dyspraxia Program,[43] which has been translated and modified for Dutch (Erlings-van Deurse et al[44]). The starting point of this program is the critical developmental speech motor learning phases, in which the young child acquires motor schemes for separate oral motor gestures, learns to combine these into syllable-sized units, and develops further differentiation and motor automation. The program starts at the oral motor Level 0, goes through five levels of sound production and four levels of word production, ending in sentence Level 10. At each level, first conscious control of basic movements is acquired, including awareness of sensory feedback, immediately followed by an automation and differentiation phase, during which particular contrasts are practiced and repeated.

The major difference in this approach as compared with therapy for AOS is that higher-level psycholinguistic, in particular phonological, skills are not taken for granted. In therapy with adults, use can be made of their linguistic knowledge, of written material for instance, and the treatment can appeal to available syntactic, lexical, and phonological skills. In therapy with children, no or less-stable higher-level knowledge is available and, more importantly, must be acquired by the child via the problematic speech production and perception skills. This implies that more explicit attention during therapy must be devoted to these higher-level skills, which otherwise do not emerge.

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