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Developmental Apraxia of Speech: I. Descriptive and Theoretical Perspectives

Lawrence D. Shriberg
University of Wisconsin-Madison

Dorothy M. Aram
Emerson College
Boston, MA

Joan Kwiatkowski
University of Wisconsin-Madison

Developmental apraxia of speech (DAS) is a putative diagnostic category for children whose speech errors presumedly (a) differ from the errors of children with developmental *speech delay (SD)* and (b) resemble the errors of adults with acquired apraxia of speech. The studies reported in this series (Shriberg, Aram, & Kwiatkowski, 1997a, 1997b) concern both premises, with primary focus on the first—that children with DAS can be differentiated from children with SD on the basis of one or more reliable differences in their speech error profiles. Immediate goals are to identify a diagnostic marker for DAS and to consider implications for research and clinical practice. A long-term goal is to identify the phenotype marker for DAS, on the assumption that it may be a genetically transmitted disorder. This first paper reviews relevant descriptive and theoretical perspectives. Findings from a local ascertainment study support the clinical functionality of the term *suspected* DAS.

KEY WORDS: apraxia, phonology, speech, children, disorders

The validity of *developmental apraxia of speech (DAS)* (or alternative labels such as *developmental verbal dyspraxia [DVD]*) as a childhood speech disorder is one of the most controversial nosological issues in clinical speech pathology. However, unlike other continuously funded research areas within communicative disorders, there have been few programmatic efforts toward an explanatory account of the origin and nature of DAS. Many of the widely cited publications in the DAS literature are case studies, clinical reports, and small-sample cross-sectional studies. Chapter-length syntheses of the literature are nearly as prevalent as the empirical studies they critique. In their discussion of research needs in DAS, Marion, Sussman, and Marquardt (1993) make a trenchant comparison: "Despite the basic similarities between dyslexia and developmental apraxia, the former receives and benefits from a high level of universal attention and research focus, whereas the latter is virtually ignored" (p. 153).

In North America, widespread interest in DAS dates back only approximately 2 decades, with studies by Rosenbek and Wertz (1972) and Yoss and Darley (1974) frequently cited touchstones. More globally, the literature in apraxia of speech includes descriptive papers dating back to the 19th century (see reviews in Crary, 1993; Hall, Jordan, & Robin, 1993; Lebrun, 1989; Morley, 1972; Rosenbek, Kent, & LaPointe, 1984; Stackhouse, 1992). A widely cited critique of the concept and evidence for DAS was the detailed review by Guyette and Diedrich (1981) who

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concluded: "…No pathognomonic symptoms or necessary and sufficient conditions were found for the diagnosis…. The diagnosis 'developmental apraxia of speech' is neither appropriate nor useful" (p. 44). Notwithstanding the lack of scientific support for DAS before or since Guyette and Diedrich's careful review, perennial claims for the existence of some form of the disorder are apparently well motivated in clinical and research environments.

For clinical needs, DAS appears to provide a tentative explanatory label for children who have *severe*, *irregular*, and *persistent* speech disorders, in contrast to the *mild-to-severe*, *regular*, and typically *self-limiting* error patterns of the common form of developmental phonological disorders studied in detail internationally since the 1970s (cf. Bernthal & Bankson, 1993; Shriberg & Kwiatkowski, 1994). From a research perspective, the clinical entity of DAS continues to offer attractive potential for insights into developmental neurobiological processes underlying the acquisition of normal and nonnormal speech-language systems. Thus, strong clinical and research motivations—coupled with a certain mystique associated with rare disorders and the array of interesting characteristics imputed to children with suspected DAS—underlie continued interest in the possibility of validating at least some form of this putative clinical entity.

Descriptive Perspectives

Diagnostic Checklists for Children With Suspected DAS

Two diagnostic features are presumed to characterize children with suspected DAS: Their speech errors (a) differ from the errors of children with developmental *speech delay (SD)* and (b) resemble the errors of adults with acquired apraxia of speech. However, close examination of the DAS literature indicates there is little agreement on the error profiles that substantiate either of these claims. Rather, the state of the art is an approach wherein clinicians and researchers consult a number of diagnostic checklists that purport to characterize *probable* features of children with suspected DAS. For example, Hall et al.'s (1993, Table 2.1, pp. 28–32) comprehensive review organizes literature citations for checklist entries under the following headings: *errors in sound class and manner of production, addition errors, prolongation errors, repetition errors, nonphonemic productions, type of errors, voicing errors, vowel and diphthong errors, difficulties sequencing phonemes, metathetic errors, inconsistency and/or variability of errors, intelligibility, severity of the problem, nasality and/or nasal emissions, groping/silent posturing of articulators, prosodic disturbances, fluency, phonological characteristics, and prognosis*. For each of these 19 categories, Hall and colleagues discuss the relevant findings or viewpoints of researchers who proposed the value of the category for the diagnosis of DAS.

The categorical descriptors used in the *Diagnostic and Statistical Manual of Mental Disorders (DSM-IV*, American Psychiatric Association, 1994) provide a useful framework to summarize diagnostic and epidemiologic findings for children with suspected DAS. Elsewhere, the *DSM-IV* system is used to classify DAS as one of five possible subtypes of *speech delay*, each associated with distal or more proximal etiologies (Shriberg, 1994). For efficiency in the following review, two of the descriptor headings in the *DSM-IV* (pp. 8–9), *Diagnostic Features* and *Associated Features [and Disorders]*, are used to subsume information in the other six major feature categories: *subtypes, age of onset, course, gender, familial pattern*, and *prevalence*. Discussion is limited to clinical-research issues that concern the studies to be reported in the other two papers in this series. Because there is no one characteristic validated as the necessary and sufficient diagnostic feature of DAS (i.e., the *pathognomonic marker*), it is not possible to evaluate the reliability of findings. Pending validated diagnostic criteria, we will continue to refer to the target children in this paper as children with *suspected DAS*, regardless of the nosological term used in the original citation (except for direct quotes).

Diagnostic Features

Subtypes

Given the extensive list of candidate behavioral markers for DAS, there has been surprisingly little discussion of the possibility of subtypes. Subtypes represent one of three possible classification perspectives on DAS that have been pursued: *unitary entity, syndrome*, or *subtypes*.

The *unitary entity* perspective is the most prevalent conceptual approach to DAS. The search for synthesis among the composite of behaviors associated with suspected DAS is illustrated in multivariate studies such as those reported by La Voi (1986) and Marlette and Deputy (1988). As above, the goal in such studies is to isolate the one characteristic that differentiates DAS from all other childhood speech problems. For example, Love (1992) states: "To retain [DAS] as a viable syndrome, one must first define the disorder in terms of an obvious, widely reported and constant physical sign, without which the diagnosis cannot be made, along with a set of less-fixed symptoms" (p. 98). Efforts to characterize the features of children with suspected DAS as reflecting a unitary entity have required researchers to propose broad-based theoretical perspectives. For example, Crary's (1984, 1993) influential studies have

conceptualized DAS symptomatology as reflecting a *motolinguistic continuum* embracing both motor and linguistic deficits.

The *syndrome* perspective on DAS does not require one necessary and sufficient diagnostic criterion (cf. Cohen, 1995; Gerber, 1990; Herrmann & Opitz, 1974; Jablonski, 1991; Jorgenson, 1989). Jaffe's (1986) recommendation for diagnosing DAS illustrates this perspective:

> Apraxia is defined by a symptom cluster….Not *all* symptoms must be present; no *one* characteristic or symptom *must* be present; and the typically reported symptoms are not *exclusive* to developmental apraxia of speech. Compounding the problem is the observation that children change over time. (pp. 166, 170)

The syndrome or symptom cluster perspective is also consistent with contemporary clinical-research procedures described previously, with DAS identified by some criterial number of "positives" on a behavioral checklist. What the diagnostician is seeking is sufficient evidence of a praxis deficit, ideally from findings in both speech and nonspeech domains. An illustrative list of diagnostic features used to support DAS by clinicians in a region of Australia is reported by Murdoch, Porter, Younger, and Ozanne (1984). The three most frequently reported diagnostic criteria in the complex of symptoms were: (a) struggle, groping, and trial and error behavior on production of some or all phonemes; (b) inability to volitionally produce an isolated phoneme or sequence of phonemes that has/have been produced correctly on other occasions; and (c) failure to achieve, on command, isolated and sequenced oral movements available at an automatic level. The four remaining, less frequent symptoms were (d) speech development shows a deviant pattern; (e) unable to produce, on a diadochokinetic task, sounds produced correctly in isolation; (f) increased number of articulation errors with increased length of utterance; and (g) inconsistent pattern of articulation errors.

The *subtypes* perspective on DAS posits different behavioral characteristics associated with diagnostic criteria for each of two or more subtypes of the disorder. The possibility of subtypes of DAS was specifically raised by Williams, Ingham, and Rosenthal (1981) in a hallmark paper that reported a failure to replicate the findings of Yoss and Darley (1974). However, other than discussions of subtypes associated with differences in severity of involvement among children with suspected DAS, there have been no well-developed typologies. The systematic work of Hayden and colleagues (e.g., Hayden, 1994; Hayden & Square, 1993) represents a closely related approach. Hayden and colleagues divide children with motor speech disorders into four subgroups reflecting differing profiles of speech-motor and cognitive-linguistic function. The diagnosis of DAS is made by exclusion, wherein children with DAS have difficulty with sequenced oral movements and do not meet criteria for any of the other three subtypes.

Age of Onset and Course

Two characteristics of DAS on which there is apparent consensus are that its onset is early in the developmental period and that the disorder typically has a long-term course of normalization. Examined closely, however, several considerations limit the utility of these two presumedly secure diagnostic features.

First, the developmental period for speech acquisition extends from birth through the onset of adolescence. Exactly which age or stage of articulatory-phonological development marks the relevant *beginning* of speech varies by theoretical and applied research context. Because DAS emphasizes developmental motor-speech processes, it is particularly difficult to designate a delay or difference in the occurrence of a specific speech event as evidence of early onset. Similarly, exactly which temporal markers reflect the upper boundary of the developmental period are not widely agreed upon. Approximately 8.5 years has been suggested as the terminus point for both normal speech acquisition (cf. Locke, 1994) and normalization of speech delay (Shriberg, Gruber, & Kwiatkowski, 1994; Shriberg & Kwiatkowski, 1994). However, development and normalization of adult-like control of some allophones continue past this point until approximately 11-12 years (e.g., Kent, 1976; Shriberg et al., 1994).

Second, relative to the normalization of DAS, although most reports stress the persistence of the speech problem despite intervention, some researchers suggest that some children with suspected DAS have early spontaneous improvement. For example, Morley (1972) comments on several subjects who had early spontaneous improvement, which is consistent with presumed complete recoveries reported by many researchers (e.g., Ferry, Hall, & Hicks, 1975). Morley also describes the long-term normalization histories of many of her subjects with suspected DAS (e.g., one family had four children who remained unintelligible into late adulthood).

Thus, the DAS literature on age of onset and course of the disorder is constrained by a lack of consensus on the relevant temporal/linguistic markers. 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 or normalization of the disorder. Moreover, the literature is not clear on the temporal course of the disorder relative to primary and possibly compensatory phonological behaviors. Neither late onset of speech nor late normalization of speech are obligatory features of DAS and, if

either or both are present, they may reflect primary, secondary, or compensatory characteristics.

Associated Features of DAS

The focus in this section is only on epidemiological features, rather than on findings in such areas as nonspeech oral apraxia, manual apraxia, other praxis deficits, or cognitive-linguistic processes (cf. Crary, 1993; Hall et al., 1993).

Gender

Gender ratios expressing the incidence or prevalence of a disorder are important for explanatory theories, particularly for hypotheses about likely modes of genetic transmission. Reported gender ratios for developmental phonological disorders of unknown origin range from approximately 2:1 to 3:1 affected males to females (Ludlow & Dooman, 1992; Shriberg & Kwiatkowski, 1994). As with all estimates based on clinical referrals, the possibility of ascertainment bias in gender ratios is a methodological concern (e.g., Shaywitz, Shaywitz, Fletcher, & Escobar, 1990).

In the DAS literature, 24 group studies and 11 single subject studies reviewed by Hall et al. (1993) suggest an average boys:girls ratio of approximately 3:1, with individual studies indicating as high as 100% boys. Crary's several studies, reflecting some of the largest reported samples of children with suspected DAS, also suggest boys:girls ratios as high as 9:1 (cf. Crary, 1984). Severity of involvement is an important consideration when evaluating such data because girls may be likely to have more severe expression of X-linked or X-influenced disorders. Hall et al. comment on this possibility as an explanation for their approximately 1:1 gender ratio, noting that their known interest in DAS results in their seeing more severely involved children than seen in a typical caseload.

Prevalence

Prevalence estimates are also central statistics in epidemiologic, genetic, and other frameworks for description and explanation of disorders. The classification problems described above constrain the ability to obtain point-prevalence estimates for the prevalence of DAS. Morley's (1972) classic study of 944 children in 1,000 Newcastle-Upon-Tyne, England, families yielded 12 children (1.3%) with suspected DAS. An influential study by Yoss (1975) reported a 1% prevalence rate, based on a finding of 10 of 1,000 available children in Rochester, Minnesota, meeting Yoss's widely cited criteria for suspected DAS. Based on the proportion of children referred to one university clinic, a convenience sample that is likely to underestimate population prevalence, Shriberg (1994) estimated the prevalence of suspected DAS at 1–2 children per thousand. Using a population estimate that 2.5% of preschool children have developmental phonological disorders of unknown origin (cf. Shriberg & Kwiatkowski, 1994), the 5% proportion of clinical referrals representing children with suspected DAS yielded a population estimate of 0.125% (.05 × .025 × 100) or 1–2 children per thousand.

Familial Aggregation

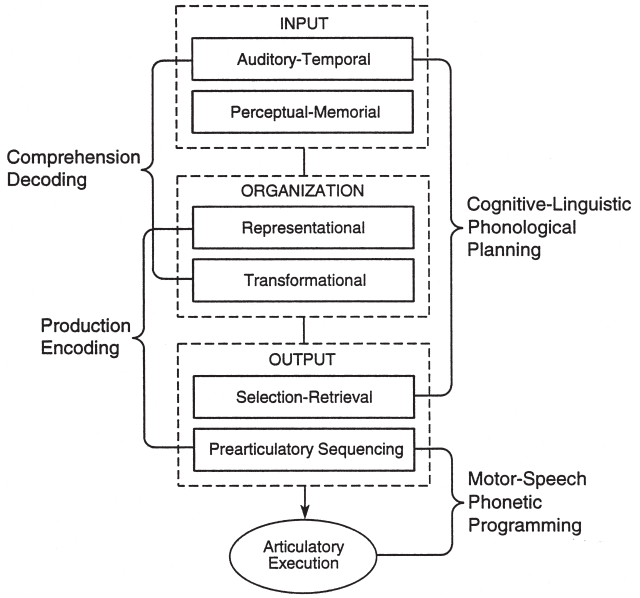
Data on the occurrence of suspected DAS in families strongly suggest that at least some form of DAS is familial, and hence likely heritable (e.g., Aram & Glasson, 1979; Aram & Nation, 1982; Crary, 1993; Hall et al., 1993; Lewis, Ekelman, & Aram, 1989; Milloy & Summers, 1989; Morley, 1972; Riley, 1984). These sample citations describe or review a variety of communication deficits in families of children with suspected DAS. The patterns of involvement are consistent with several possible modes of genetic transmission. As with other current research in developmental speech and language disorders, identifying a valid and reliable phenotype marker (Pennington, 1986; see later discussion) is a crucial need for productive genetic research. Until a phenotype marker for DAS is available, it cannot be studied with the powerful new tools in behavioral and molecular genetics that are increasingly being used with other developmental disabilities.

Theoretical Perspectives

An Organizational Schema

Figure 1 is a rudimentary schema that provides a framework for brief review of theoretical perspectives on DAS. The schema divides possible proximal origins of faulty speech production in DAS into six linguistic processing stages within the three traditional domains labeled *Input, Organization*, and *Output*. Input processes include a stage reflecting the integrity of *auditory-temporal* processes and a stage reflecting the *perceptual-memorial* processes necessary to acquire the phonology of the ambient language. *Organizational* processes include a *representational* stage, reflecting the segmental and suprasegmental primitives of underlying forms, and a *transformational* stage, which adjusts underlying forms for appropriate morphophonemic, allophonic, and sociolinguistic detail (Edwards & Shriberg, 1982). In some theoretical schemes, these two levels of processing represent a speaker's phonological knowledge (cf. Elbert, Dinnsen, & Weismer, 1984). *Output* processes include a level for *selection-retrieval* of the phonological elements and a level for *prearticulatory sequencing*. As shown in Figure 1, the final stage of *articulatory execution* adds any deficits in the integrity of the motor-speech

Figure 1. Alternative loci of speech production deficits in children with suspected developmental apraxia of speech (DAS).



mechanism to the product of the previous stages. The schema in Figure 1 attempts to use the least theoretically dedicated terms and concepts to organize the array of cognitive-linguistic and motor-speech loci implicated in the pathogenesis of suspected DAS. The schema is deliberately underdeveloped relative to classical speech and speech/language processing proposals (e.g., Bock, 1982; Dell, 1986; Garrett, 1980; Levelt, 1989; Shattuck-Huffnagel, 1983), but is more allied with them than with parallel-processing models (cf. Goldsmith, 1993; Smolensky, 1988). It is also underdeveloped relative to contemporary theories of motor-speech control (cf. Kent, Adams, & Turner, 1996). Its heuristic function is useful only if granted the potential productivity of viewing speech processing at discrete "stages" or "levels."

The terms indicated by brackets in Figure 1 demarcate four sets of dichotomies that recur in theoretical treatments of apraxia of speech. Beginning with *Comprehension* or *Decoding* versus *Production* or *Encoding* processes, note that Organizational processes are necessarily invoked in both activities. The primary dichotomies deliberated in the adult apraxia of speech (AOS) and DAS literatures are represented by the right brackets in Figure 1: Are the speech deficits in apraxia reflecting *Cognitive-Linguistic* or *Phonological* or *Planning* processes versus *Motor-Speech* or *Phonetic* or *Programming* processes? As shown, the former constructs may invoke any one or more of the top five speech processing stages, whereas the latter constructs usually refer to only the lowest output stage as well as to Articulatory Execution. The following discussion referenced to Figure 1 illustrates the diversity of theoretical positions on the nature and origins of DAS.

DAS as a Deficit in Input Processes

Auditory-Temporal Processes

Tallal and colleagues have long suggested that a deficit in auditory-temporal processing—specifically in the ability to process rapidly changing information—is a reliable correlate, if not the source, of speech-language delay (e.g., Tallal, 1976; Tallal & Piercy, 1973a, 1973b, 1978; however, see Rapin, 1988; Tomblin, Abbas, Records, & Brenneman, 1995). Robin, Hall, and Jordan (1986) found that 5 children with suspected DAS showed markedly poorer performance than controls in analyzing auditory temporal patterns as stimuli increased in rate. Robin et al. noted that each of the children had disordered speech prosody, suggesting that "impaired temporal perception could impact on their ability to gain information about durational aspects of prosody and add to the observed prosodic difficulties" (p.11).

Perceptual-Memorial Processes

Jaffe (1980) found that 17 children with suspected DAS performed more poorly than matched normals and children with articulation disorders on each of three standardized perceptual tests to assess recognition, discrimination, and sequence of sounds. Because the children with suspected DAS also had statistically lower performance on oral stereognostic tests, intelligence tests, and a series of language comprehension tests, Jaffe concluded: "The apraxic children performed poorly on all of the perceptual tasks, demonstrating that they have not only the very obvious deficit in their motor, or output, system, but also in these particular sensory, or input, systems" (p. 1). Bridgeman and Snowling (1988) reported that children with suspected DAS had more difficulty than controls in discriminating sequences of phonemes when they occurred in nonsense words. More recently, Groenen, Crul, Maassen, and Thoonen (1993) concluded that, although their subjects with suspected DAS had normal phonemic-stage processing, the auditory stage of speech processing was affected and they had "weaker auditory memory traces." These authors suggested that perceptual discrimination tasks have significant diagnostic value, concluding that "the degree of dysfunctionality in speech production in children with [DAS] is related to the degree of dysfunctionality in speech perception" (p. 3).

DAS as a Deficit in Organizational Processes

The claim that the speech deficits in DAS originate at the level of organizational processes, as depicted in

Figure 1, has been proposed by researchers taking two general perspectives: across-the-board deficits in language processes, or specific deficits in either the formation of appropriate phonological representations or transformational processes.

The across-the-board linguistic explanatory perspective is reflected by the findings and conclusions of several research groups who emphasize that, unlike children with some other motor speech disorders, children with suspected DAS invariably have language deficits. Arguing against DAS as a clinical entity, Panagos and Bobkoff (1984) proposed that DAS is "a phonological disorder of cognitive origins" (p. 39). A series of studies by Aram and colleagues (e.g., Aram & Glasson, 1979; Ekelman & Aram, 1983) reported that children with suspected DAS have problems with multiple components of expressive grammar: "Apraxia of speech is not confined to the articulatory or motor control aspects of speech. Rather, all levels of expressive language are affected including the lexical, syntactic, and phonemic aspects" (Aram & Glasson, 1979, p. 15). Smith, Marquardt, Cannito, and Davis (1994) also proposed that "DAS typically is included within a broader syndrome marked by delayed expressive language, impaired nonverbal oral movements, and reduced performance on tests of verbal intelligence" (p. 81).

Representational Processes

Emerging views in both acquired AOS and DAS are that the deficits associated with apraxia are within the representations of morphemes or words. Using nonlinear and feature geometry frameworks, Dogil, Mayer, and Vollmer (1994) propose that adults with AOS have overspecified speech sounds, rather than underspecified speech sounds as posited in several theoretical approaches (cf. Steriade, 1995). Based on the speech errors of 11 children with suspected DAS, which were linguistically similar to those made in normal speech acquisition, Maassen, Thoonen, and Gabreëls (1993) concluded that the deficit is consistent with a "phonological encoding disorder." Based on rhyming deficits in children with suspected DAS, Marion et al. (1993) also proposed that the source of these children's linguistic deficits is within phonological representations. In critique of positions described below and above, they suggest:

> The child with DAS may be operating with an impoverished phonological representation system that severely precludes both selection and access to phonological forms guiding motor performance. Such a deficit would also be expected to adversely impact all higher-order language functions predicated on operational and well-formed phonological representations. (p. 3)

Velleman and Strand (1994) also implicate representational level processing, using formalisms from nonlinear phonology and from McNeilage and Davis's (1990) frame-content model of phonological organization and development to characterize the deficits in phonological representations. Velleman and Strand suggest that children with suspected DAS "could be seen as impaired in their ability to generate and utilize frames, which would otherwise provide the mechanisms for analyzing, organizing, and utilizing information from their motor, sensory, and linguistic systems for the production of spoken language" (pp. 119–120). Snow, Marquardt, and Davis (1993) also suggest representational problems at the core of the behaviors associated with DAS, concluding that children with DAS "demonstrate an apparent breakdown in the ability to perceive 'syllableness' and to access and compare syllable representations with regard to position and structure" (p. 5).

Transformational Processes

As indicated in the next section, morphophonemic, allophonic, and sociolinguistic rules appear to be intact in both adults with AOS and children with suspected DAS. For example, McNeil and Kent (1990) report that adults with AOS make suitable adjustments in relative lengths of consonants and vowels, observing appropriate allophone transformation rules. Thus, to date, this speech processing stage has not been implicated as the proximal origin of DAS.

DAS as a Deficit in Output Processes

Selection-Retrieval Processes

Buckingham's (1983) perspective on adult AOS as an "apraxia of language" places the loci of adult AOS at the level of selection-retrieval of phonemes:

> Language apraxia errors occur at a level of selection and ordering of phonemes that is prior to the articulatory implementation of vocal tract shapes. That is to say, they are committed above the level of phonetic execution. For this reason, errors at the phonological level are more appropriately language errors as opposed to speech errors. Consequently, they are further away from anything directly motoric. (p. 3)

A number of instrumental analyses, however, have failed to support selection-retrieval errors as the loci of adult AOS and DAS. In a widely cited study of an adult with AOS, Itoh, Sasanuma, and Ushijima (1979) tracked velar movements during repeated tokens of target sounds that were produced with variable phonetic precision. Because velar movements for the target sound had a consistent successional pattern of gestures, the

authors concluded that the apractic adult speaker was reliably selecting and retrieving the target phoneme. They argued, therefore, that the phonetic variability observed in apraxia involves a lower-level deficit in movement programming, rather than in retrieval of phonemic units.

Negative findings for apraxia as a selection-retrieval deficit have also been reached in several studies of children. In an acoustic study of vowels in children with suspected DAS, Walton and Pollock (1991) supported a "motor theory" noting that: "Although one could argue that there is a phonemic confusion in the speech of these children, one could also argue that their ability to demonstrate these contrasts is lost when their motor systems are taxed or challenged" (p. 5). In an acoustic study of consonants, Maassen, Lamers, Thoonen, and Gabreëls (1993) concluded that because the variability in voice-onset-time (VOT) values observed in their DAS subjects observed phoneme boundaries, the deficit was not at the level of phoneme selection. Relative to theoretical and methodological caveats, it is important to note here the reservations expressed by several investigators when structuralist constructs like *phoneme substitutions* or *phoneme distortions* based on acoustic analysis and/or narrow phonetic transcription are used to infer a speaker's phonological planning or goals (e.g., Allen, 1975; Buckingham, 1983; Liss & Weismer, 1992; McNeil, 1988; McNeil & Kent 1990; Odell, McNeil, Rosenbek, & Hunter, 1990; Pollock & Hall, 1991; Wertz & Rosenbek, 1992).

DAS as a Deficit in Motor Programming

The alternative to the several cognitive-linguistic *planning* perspectives of DAS is that it is a disorder of motor *programming*. Notice in Figure 1 the demarcation point between planning processes and programming processes, with the latter marking the initiation of output processes. Here is where the simplifications inherent in Figure 1 may be troublesome to motor speech theorists who assign cognitive-linguistic, representational processing to this level as well. Several reviewers of childhood and adult apraxia research have noted problems with the use of the concept of motor *programming* as an explanatory concept. Formally, Panagos and Bobkoff (1984) note that any attempt to assign explanatory status to the products of description is a "first-order isomorphism fallacy." An extended quote from Buckingham (1979) also argues against the reification of programming as an explanatory concept:

> When we are told that an apraxia of speech involves disorders in the "programming" of motor speech, we need to know immediately what the units of speech are that are involved and precisely where in the encoding process we are. It is not clear that the phonemic level is motor in any sense whatsoever. Is the motor level allophonic? Are the allophones specified within broadly defined syllabic units which may straddle lexical boundaries? One should not lose sight of the fact that "program" is a metaphor and may be used as a descriptor at any level of abstraction whatsoever and therefore may be used at the earliest ideational levels or the latest output levels. (p. 218)

Such concerns about the term programming notwithstanding, there is more consensus in the adult AOS literature than in the DAS literature that the type and variability of errors observed in apraxia implicate a programming deficit in motor-speech processing, rather than a planning deficit.

Prearticulatory Sequencing Deficit

As suggested in several places to this point, the most prevalent theoretical position in acquired and developmental apraxia of speech attributes the variability observed in speech output to deficits in prearticulatory sequencing of the spatiotemporal movements for speech sounds. Following is a sample of definitions of apraxia of speech, each of which proposes deficits at the prearticulatory level of speech-motor control: "an impairment in the mechanisms for programming movements for speech production" (McNeil & Kent, 1990, p. 350); "a breakdown in the spatial/temporal properties of movements which cannot be explained by direct sensory-motor pathology nor comprehension deficits" (Crary, 1984, p. 33, paraphrasing Geschwind, 1975); "a neurologically based disorder in the ability to program movements for speech volitionally in the absence of impaired neuromuscular function" (Smith et al., 1994, p. 81). Grunwell and Yavas (1988) proposed a prearticulatory sequencing rather than a representational deficit in DAS, finding discrepancies between well-developed segmental phonetic repertoire and restricted phonetic structures.

A widely cited definition of apraxia of speech, also locating the deficit in a prearticulatory level of speech-motor control, is that proposed by Darley (1969) (Rosenbek et al., 1984, referencing the citation by Deal & Darley, 1972, p. 639):

> …an articulatory disorder resulting from impairment, as a result of brain damage, of the capacity to program the positioning of speech musculature and the sequencing of muscle movements for the volitional production of phonemes….The speech musculature does not show significant weakness, slowness, or incoordination when used for reflex and automatic acts. Prosodic alterations

> may be associated with the articulatory problem, perhaps in compensation for it. (p. 12)

In the present context, the observation about prosodic alterations in Darley's and other definitions of apraxia of speech is particularly important. As explored in the second and third papers in this series, a question is whether abnormal prosody is an optional correlate of acquired AOS, or whether it is a central feature of the disorder. Theoretically, this issue depends upon one's view of how prosodic and articulatory processes are represented at the prearticulatory level of motor control. Kent and McNeil's (1987) position is that there is dissociation between the prosodic and segmental levels in motor-speech programming. They develop the following description of prearticulatory programming in relation to the dysprosody observed in acquired AOS:

> Slots-fillers and frames-contents are similar ideas about speech organization motivated largely by the conclusion that the explanation of normal speech sequencing errors, especially exchange errors, requires a separate specification of syllable structure and phonetic (or phonemic) segments. We believe that, at the least, the prearticulatory representation contains information on syllable structure and segment composition. Because these two bodies of information are held separately, they are susceptible to separate loss or error. Furthermore, the syllabic and segmental specifications only gradually lose their separateness in motor control. Syllabic organization is a primary level of cohesion in which (1) suprasegmental information is given form in the prosodic envelope of a syllabic sequence; and (2) segmental information is converted to movements (preferably compound trajectories defined by compatible sequential goals [Shaffer, 1982]). Finally, the prosodic envelope based on syllabic sequences guides output monitoring and is a first line of linkage between the monitored acoustics output and the slot-filler specifications in the prearticulatory representation. When phonetic-motoric coding is vulnerable to error, as in the neurologic disorders studied here, speakers may allocate more resources to the slot-filler specifications of individual syllables and the motoric realization. Syllable lengthening and long intersyllabic pauses may result. (p. 213)

Thus, as with other descriptions of apraxia that view dysprosodies as secondary characteristics, Kent and McNeil propose that the dysprosody observed in acquired AOS may be due to resource allocation limitations.

What is important to underscore for the studies in this three-part report is that the presumed apractic difficulties at the prearticulatory stage of speech-motor control are centered on segmental, not suprasegmental, difficulties. Research support for such deficits are marshaled from studies such as those cited above that reject an explanation of phonemic and allophonic variability observed in apraxia as evidence of "linguistic" selection-retrieval processes. Rather, most theoretical explications of acquired apraxia of speech invoke deficits in prearticulatory sequencing of articulatory segments. However, as reviewed above, among theorists in developmental apraxia of speech, there is an emerging interest in representational processes as the loci that may more adequately explain the segmental, suprasegmental, and other linguistic deficits observed in children with suspected DAS.

A Local Ascertainment Study of Suspected DAS

If there currently is no descriptive, diagnostic, or theoretical consensus on the nature and origin of DAS, why does "suspected DAS" persist as a tentative classification label in clinical contexts? As suggested in the brief literature review and in most others, suspected DAS appears to provide a functional solution to the puzzle of children who are not making good progress despite early, frequent, and competent speech services.

To assess the validity and explore the implications of this thesis we conducted a records search of a local database. The goal was to gain a perspective on the reasons why some children are referred to a university phonology clinic for assessment and possible management of suspected DAS. Findings from this retrospective study would be used to interpret individual differences in the three studies to be reported in the following papers.

Method

Subjects

Table 1 is a summary of information for 148 children under the age of 16 who were referred to the university Phonology Clinic in Madison, Wisconsin, over a 5-year period. The first group of entries in Table 1 are children referred only for assessment and the second group of entries describe children referred for assessment and intervention. The assessment only group (n = 27) includes 20 children (74%) who were referred by speech-language pathologists from the local public schools or surrounding community and 7 children (26%) referred by professionals from a multidisciplinary diagnostic team that is a part of the clinical service unit at the center housing the Phonology Clinic (the Harry A.

Table 1. Descriptive statistics for 148 children referred to the university Phonology Clinic in Madison, Wisconsin.

	Assessment only			Assessment and intervention				All
Suspected DAS	Speech-language pathologists	Multidisciplinary team	Total	Speech-language pathologists	Early childhood screening team	Parents	Total	Total
No	12	5	17	14	97	7	117	134
Yes	8	2	10	4	0	0	4	14
Total	20	7	27	18	97	7	121	148
Percentage of referrals with suspected DAS	40%	29%	37%	22%	0%	0%	3%	10%

Waisman Center on Mental Retardation and Human Development). The assessment and intervention group (n = 121) includes children referred from three sources: 18 children were referred by speech-language pathologists from the local public schools; 97 children were referred by an early childhood screening team from the local public schools; and 7 children were referred directly by their parents.

Ascertainment Information

Referrals by the Early Childhood Screening Team

The early childhood screening team referenced in Table 1 consisted of a teacher with a background in special education and a speech-language pathologist, both of whom had over 10 years experience screening children. The screening procedure begins with the caregivers contacting the schools to arrange for the screening because they have concerns or someone—usually a preschool teacher—has raised questions about the child's functional abilities in the area of learning, speech, or language. The team conducts a home visit to assess the child using a standard assessment protocol. Children referred to the Phonology Clinic meet two criteria: (a) The team determines that their needs are determined to be specific for speech, rather than an early childhood placement, and (b) caregivers elect to bring their child for twice-weekly, 50-minute sessions at the Phonology Clinic, rather than having their child enrolled for services by a speech-language pathologist in the neighborhood school. It should be noted that parental choice of service provider is not associated with severity of involvement, because children enrolled in the Phonology Clinic reflect all levels of severity, many fairly mild.

Referrals by Speech-Language Pathologists in Schools

Referrals to the university Phonology Clinic by speech-language pathologists in the schools were typically made for one of three reasons. For most of the referred children, the goal was to maintain programming over the summer so that a child would not regress. The next most frequent reason for referral was concern about a child's slow progress, with the hope that additional speech services in the Phonology Clinic would help. The other reason for referral was a speech-language pathologist's concern not only with slow progress, but also with a specific observation that raised the question of possible or suspected DAS. Thus, slow progress alone did not invariably lead to suspected DAS, at least for the experienced speech-language pathologists in the local community.

Referrals From Parents

Referrals directly from parents typically occurred because they had another child who received speech services in the Phonology Clinic or had heard about the clinic from another parent or professional in the community who was pleased with the service. For some children, there was concern about the child's rate of progress or lack of generalization, with questions regarding suspected DAS.

Results

The data in Table 1 indicate large differences in the sources, and therefore ages, of referrals for the 14 children with suspected DAS. Of the 97 preschool children referred for intervention by the two experienced members of the early childhood screening team, there were no children (0%) whose speech delays were suspected to be associated with DAS. In contrast, 22%–40% of the 45 children referred by speech-language pathologists, working alone or on multidisciplinary teams, were suspected to have DAS. Most of these children were considerably older than the preschool children referred by the early childhood team, and all had been enrolled in intervention services in schools.

Conclusions

The findings in Table 1 support the strong functional value of *suspected DAS* as a diagnostic label. These data

suggest that, among experienced speech-language pathologists, the construct of DAS is associated with an otherwise inexplicable lack of progress. Considering the widespread dissemination of information on normal and disordered phonology during the past 2 decades, including advances in treatment efficacy, children whose speech delays have not normalized with contemporary intervention procedures appear to be the prime candidates for the tentative classificatory term suspected DAS. It should also be noted that referral rates are influenced by the reputation of the diagnostic center. Colleagues with known expertise in DAS report that their referral rates from speech-language pathologists working with older children with suspected DAS are even higher than the approximately 1 out of every 10 children referred to our Phonology Clinic.

The literature review and the local ascertainment study suggest two conclusions concerning the state of knowledge about characteristics of DAS and alternative theoretical perspectives. First, the primary research problem affecting both description and explanation is that findings to date are based on children with *suspected* DAS. Without a diagnostic marker for the disorder, there is a circularity in the inferences that can be made about deficits that define the disorder and the psycholinguistic processes that underlie the deficits. DAS appears to persist as a clinically functional explanation for children with speech delays that, in some way, differ from error patterns in typical speech delay and that take longer to normalize even with usually sufficient intervention.

A second conclusion, notwithstanding the lack of a diagnostic marker, is that DAS is classified in textbooks as a motor-speech disorder involving deficits in the prearticulatory sequencing of segmental targets. That is, despite cautions about confusing description with explanation and in the absence of the neurological support documented in the adult AOS literature, DAS is viewed as a developmental form of an acquired motor-speech disorder. Thus, any claim that DAS reflects a deficit in "linguistic" stages—including representational, transformational, and, in some systems, selection and retrieval processes—threatens the nosological validity of the term *apraxia* of *speech* as documented in the literature on praxis disorders.

The primary goal of the three studies reported in two following papers is to address the first problem—to determine whether a diagnostic marker for DAS can be identified using several clinical samples of children with suspected DAS and detailed speech and prosody-voice analysis methods. Secondary goals are to address the level of support for several hypotheses about the nature and origin of DAS, and to consider implications for research and clinical practice.

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Contact author: Lawrence D. Shriberg, PhD, Phonology Project, Waisman Center on Mental Retardation and Human Development, University of Wisconsin-Madison, 1500 Highland Avenue, Madison, WI 53705. Email: shriberg@waisman.wisc.edu

Developmental Apraxia of Speech: I. Descriptive and Theoretical Perspectives

Lawrence D. Shriberg, Dorothy M. Aram, and Joan Kwiatkowski
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