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Feature Retention and Phonological Knowledge across Children with Suspected Developmental Apraxia of Speech, Phonological Impairment, and Typically Developing Speech.

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by
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ABSTRACT

Feature Retention and Phonological Knowledge Across Children with Suspected Developmental Apraxia of Speech, Phonological Impairment, and Typically Developing Speech

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The purpose of this research effort was to examine whether the feature retention patterns and phonological knowledge of children with suspected apraxia of speech (AOSc) in comparison to those of children with phonological impairment (PI). A second purpose was to determine if a relationship exists between phonological knowledge and feature retention.

The study consisted of three groups of children: PI, AOSc, and typically developing (TD), ages four to seven. A 245-item speech sample was collected from each group. Feature retention percentages and phonological knowledge, represented by percent correct underlying representations (PCUR) were calculated for each child.

All groups retained place the least, followed by manner, with voicing being retained most. The null hypothesis was confirmed, with PI and AOSc groups exhibiting no significant differences across feature retention percentages or phonological knowledge. The positive correlation of voicing retention and PCUR of the AOSc group was the only significant relationship found.

DEDICATION

This thesis is dedicated to my family, who has given me an unbelievable amount of love and support throughout this project and my educational career. Your faith, encouragement, and sacrifices have touched me beyond words. I love you and thank you with all my heart.

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CHAPTER 1

REVIEW OF THE LITERATURE

Introduction

Speech production is an integration of both speech motor control processes and phonological representations. Developmental changes in anatomy and neurophysiology co-occur along with phonological development. Due to this strong integration, one of the challenges in understanding speech disorders is distinguishing impairments of phonology from impairments of motor control (Kent, 2000). This challenge has led many researchers to question the nature of developmental speech disorders, particularly regarding the controversial diagnosis of apraxia of speech in children (AOSc) versus phonological impairment (PI). To address this issue, theories of speech motor control and phonological acquisition will be reviewed, along with information on the typical course and disorders of motor speech and phonological development, and finally the current controversy that involves these areas.

Phonological Acquisition

Theories of Phonological Acquisition

In order to grasp the development and disorders of phonology, several predominant theories serving as their groundwork will first be discussed. Earlier theories regarded acquisition as being an innate and universal process, with the more recent theories accepting the notion that a child plays an active role in the acquisition of his or her phonological system.

Universalist Theories. The Universalist theory proposed by Jakobson (1941; cited by Locke, 1983; Macken & Ferguson, 1981; Oller, 1997; Stoel-Gammon & Dunn, 1985) suggested there is a relationship between phonological acquisition in children and phonological universals of human languages. This theory further claimed there is a universal order of sound development that tends to occur in children, with two distinct periods of vocal productions: babbling and meaningful speech. Babbling consists of a wide diversity of sound productions that do not follow a regular sequence of sound acquisition. During the onset of meaningful speech, the sound repertoire is greatly reduced and speech sounds are reacquired as part of the phonemic system of the child's language, in a universal and innate order of sound acquisition order regulated by a set of structural rules. Acquisition proceeds from simple and undifferentiated sounds to complex and differentiated sounds with varying rates between children, but in the same order. Acquisition involves the learning of feature contrasts rather than sounds, including consonantal-vocalic, nasal-oral, and labial-alveolar. This theory was based on speculation rather than empirical evidence and research has refuted some aspects of this theory. Further investigations have shown that babbling and meaningful speech are not two separate periods, but instead are related by sharing common phonetic repertoires and syllable shapes. The concept of universal sound development has also been proven untrue by individual variation among children.

Stampe's (1969, 1973) theory of Natural Phonology (cited by Edwards, 1992; Stoel-Gammon & Dunn, 1985) suggests that acquisition of a phonological system is the suppression of processes not occurring in a child's language. The child plays a passive role that is governed by innate, universal phonological processes, which Stampe defined as being mental operations. These processes serve as a one-to-one correspondence with the adult target to simplify the target and are grouped into three categories: 1) processes that modify the syllabic structure of the target (e.g., unstressed syllable deletion, final consonant deletion, cluster reduction); 2) processes that substitute one sound for another (e.g., gliding, stopping, fronting); and 3) processes that assimilate one sound to another (e.g., consonant harmony, reduplication). According to Stampe, children limit these processes by suppressing, limiting, or reordering them. Although this theory has become popular as the basis for assessing speech disorders in children, it is limited in that: a) no strong evidence supports the claim that phonological processes are mental operations; b) knowledge regarding children's perceptual systems is too limited to make claims concerning their status; and c) this view is in noncompliance with studies showing that the child is an active participant in phonological acquisition.

<u>Individualist Theories.</u> Locke (1983) proposed the Biological Theory. This theory has three premises: 1) the prelinguistic productions of infants from all linguistic environments are similar; 2) because babbling patterns are universal, the phonetic repertoire and phonological patterns of late babbling and early meaningful speech closely resemble each other; and 3) when substitutions occur, frequently occurring sounds often serve as substitutions for infrequent babbling sounds. According to this theory, there are three stages of phonological acquisition: 1) the prelinguistic stage when the infant realizes that his or her vocalizations can carry information; 2) when the child attempts to produce conventional, meaningful words; and 3) marked change occurs in the child's phonological system. As the system develops, phonological acquisition is no longer dominated by biologic (phonetic) tendencies and becomes an interaction of cognitive and phonetic factors that allows individual differences in the course of development.

Macken and Ferguson (1981) proposed the Cognitive Theory. This theory is based on the premise that children play an active role in phonological acquisition by formulating and testing hypotheses of the sound system. During the early stages of production, children selectively attend to the language spoken to them and choose which phonological characteristics to include and exclude from their lexicon. They are creative in their production of segments and forms that are not found in the adult language. The overgeneralization, regression, and experimentation of sounds in children's speech provide evidence supporting the premise of hypothesis formation.

As evidenced by the many premises put forth by the above theories, variations exist among the notions of when and how children acquire phonological sound systems. Earlier models suggest that children learn through a universal and innate process, others suggest that biological tendencies or environmental input primarily drives acquisition, and finally some put forth the notion that children are creative and active in acquiring their sound system. Despite these variations; however, all are in agreement that phonological acquisition is a complex process of phonetics, phonological rules, and environmental input that children proceed through in learning the sound system of the ambient speech community.

Typical Phonological Development

Phonological acquisition involves learning both phonetic and phonemic features of a language; the child must learn to articulate sounds and sound sequences correctly, as well as how to use those sounds in accordance with the adult phonological patterns. Stoel-Gammon and Dunn (1985) explained the stages of this process.

The first, the prelinguistic stage, occurs during the first year when the infant produces both speech and non-speech-like babbling that lack a sound-meaning correspondence. Productions during the first month are characterized by reflexive vocalization such as crying or coughing. Cooing is then produced during the second and third months. The fourth through sixth month is a period of vocal play such as producing growls and raspberries. The seventh through ninth month is characterized by reduplicated babbling, followed by productions of variegated babbling at 10 to 12 months. By nine months of age, the child demonstrates comprehension of words and develops a receptive vocabulary of approximately 50 words by 13 months of age.

The next stage, known as “first words,” develops when the child is around one year of age. At this stage, the child experiences the onset of meaningful speech and a growing productive vocabulary of 50 words, which are learned as whole units rather than as sequences of sounds. As productions are limited to stops, nasals, and glides, children show a preference for words with specific phonological characteristics consistent with their developing phonological system and avoid words outside of their system.

The phonemic development stage then occurs around 18 months to four years of age. The child no longer uses the whole-word approach and rapidly learns rule-governed, stable forms of adult productions. The number of sound types and complex syllable structure increases. In terms of manner, productions of nasals, stops, and glides are learned earlier than liquids, fricatives, and affricates. With regard to place, front consonants are commonly acquired before back ones. In terms of syllable shape, CV is commonly learned first and is the most commonly used in early stages of acquisition. The child’s incorrect productions are related to the adult form in systematic ways commonly referred to as phonological processes, which may modify syllabic structure, substitute another sound for the target, or assimilate one sound to another.

The final stage consists of stabilization of the phonological system, which occurs between four and eight years of age. Children stabilize their productions and acquire the last sounds to complete the phonetic inventory. The introduction of reading and writing skills during school age helps provide an understanding of the phonemic nature of the sound system.

To summarize, phonological maturation is a process that continues to eight years of age. Acquisition involves both phonetic and phonemic aspects of a sound system throughout this period.

Phonological Impairment

When a child continues to produce phonological processes (mentioned in the previous section) beyond a typical age, this persistence results in a phonological impairment. In order to pronounce most sounds and sound sequences of English, a child must be able to recognize and store new lexical items, plan and execute articulatory movements necessary for production of these new items, compare the adult input with his or her own output, then modify his or her production if the two do not match (Stoel-Gammon & Dunn, 1985). A phonological impairment, then, can be reflected in difficulty articulating sounds or a deficit in how sound information is stored and retrieved in the mental lexicon (Gierut, 1998).

Grunwell (1997) defined phonology as "concerned both with the signaling of meanings and with the physical phonetic substance whereby meanings are transmitted" (p. 64). She then described phonological impairments as failing to adequately signal meaning differences, consequently preventing children with these impairments from being understood. Phonological systems are stable, ensuring the predictability of systemic and structural patterns, or in other words, there is "order in the disorder."

A 1970 study by Compton also demonstrated the notion of order within the disorder. The results of an investigation using two boys, ages four and six, found that the children's misarticulation patterns stemmed from a small number of underlying phonological principles.

These findings supported the premise that defective sounds of a phonological impairment are part of a coherent and productive system organized by phonological principles.

Characteristics

Grunwell (1997) mentioned several characteristics of phonological impairment with regard to system, structure, and stability. There are correlations between the adult system and the child system, which is smaller and less complex than the adult system. The child's realizations of the adult targets tend to simplify the complex adult structures. There is a tendency for some inconsistency in the child's realization of the adult target in that they may use different phonemes for the same target. The variability in the child's system is indicative of change and development of the system.

Hodson and Paden (1981) investigated the phonological processes of children with severe speech disorders and those with normal speech development by using a phonological process analysis. Results revealed that five processes were demonstrated by all nonintelligible subjects: cluster reduction, stridency deletion, stopping, liquid deviation, and assimilation. Stridency and continuancy were well established in typically developing children but absent in unintelligible children's productions. Cluster reduction was rare in the typically developing children, but was exhibited by all unintelligible children. The five processes of the unintelligible children seem to be a key indicator of a phonologically deviant system. Additional deviations of the unintelligible children, such as backing, final consonant deletion, and glottal replacement, were absent in the productions of the intelligible children. Hodson and Paden concluded that there are specific patterns that can be predictive of unintelligible speech and differ from the speech of typically developing children.

In 1994, Shriberg and Kwiatowski attempted to provide a clinical profile of children with PI by studying 178 children with developmental phonological disorders. An assessment battery of the following was administered: audiologic evaluation, acoustic immitance screening, orofacial screening examination, isolated and sequenced volitional oral movements tasks, diadochokinesis tasks, conversational speech sample, articulation testing, syllable sequencing tasks, vocabulary testing, comprehensive and expressive language tests, and an oral language sample. Results indicated that the speech patterns of children with speech involvement are basically similar to the patterns of younger children with normal speech acquisition. This implies that the term speech delay would be a more appropriate term than disorder because it reflects the temporal onset and rate of sound development. The profiles provided mixed support of a system-wide delay in phoneme acquisition, which is characterized by substitutions and omissions across all consonants, including those normally mastered earliest. The error patterns of children with phonological disorders significantly deviated from those of children with normal speech acquisition.

Weiner (1981) conducted a study involving 14 children, ages 3;5 to 5;10, who were referred by a parent for unintelligible speech. An articulation proficiency test was administered to each child and each child's responses were analyzed to determine whether phonological patterns could be predicted on the basis of sound preference. Results demonstrated a sound preference process. The specific preferences varied from child to child. Some similarities were observed, including: a) the same manner of production was replaced by one sound or a few similar sounds; b) replacement was specific to word-initial position; c) if sound preference did not affect all members of a particular manner of production, then it affected the voiceless or non-labial sounds; and d) sound preference affected fricatives more than any other manner of production. Weiner noted that sound preference is not the same as phonological processes; it is a collapsing process where a group of sounds sharing common features are represented by one sound or a few similar sounds.

In summary, characteristics of phonological impairment reflect "order in the disorder" in which disordered sound systems are rule governed, systemic, and predictable.

Language Abilities

Research has suggested that many children with PI also have language impairments in addition to phonological deficits. Shriberg and Kwiatowski (1994) found that 50-75% of children with delayed speech have deficits in language production, and 10-40% also having a language comprehension delay. Fey, Cleave, Ravida, Long, Dejmal, and Easton (1994) found a higher incidence of co-occurrence of language impairment and phonological impairment. Their investigation indicated that 90% of children identified as having a language impairment also had impairments of phonology. These co-occurring deficits in language abilities appear to reflect the relationship of phonology within the broader context of language. Such relationships are revealed in the integration of effects between phonology and other dimensions of language. For example, several studies (Panagos, 1974; Panagos & Prelock, 1982; Panagos, Quine, & Klich, 1979; Paul & Shriberg, 1982; Schwartz, Leonard, Folger, & Wilcox, 1980) have revealed that changes in syntactic complexity result in changes in speech production accuracy. Specifically, increased syntactic complexity is often associated with an increase in the number of phoneme errors. Hodson (1998) stated that children with PI tend to demonstrate phonological awareness disabilities, which include greater reading difficulties and poorer performance on phonological awareness tasks. These difficulties place children with phonological impairment at academic risk when entering school.

Assessment

In order to identify a child as exhibiting the previously described characteristics, an assessment, which thoroughly describes his or her sound system, should be completed on the child. There are several different protocols that can be followed to identify the existence of the impairment and as well as to describe the phonological rules that are operating in the child's system.

Williams (2001) mentioned two frameworks of phonological analyses: relational and independent. Relational analyses, which compare the child’s speech to that of adults, include phonological process analysis (a description of error patterns) or a PVM analysis (a description of errors in terms of place, voice, and manner of articulation). Conversely, independent analyses examine the child’s productions independently of adult productions, describing the child’s speech as a self-contained, unique sound system, with no comparisons made between the child and adult speech. According to Williams, a combination of an independent and relational analysis provides a more thorough description of the child’s speech production and is useful for children with limited speech intelligibility.

According to Grunwell (1997), a phonological analysis primarily deals with identifying, describing, and classifying sound differences that signal meaning differences in a child’s speech. There are three components to the analysis: 1) system, the set or inventory of different sound productions; 2) structure, the rules and organization of the sound system; and 3) stability, the predictability of the speaker’s organization, structural, and systemic patterns of his or her sound system. Five categories of developmental classification can be identified based on this phonological analysis. One is persisting normal processes, which are normal patterns remaining in the child's system long after they would normally disappear. Another, chronological mismatch, involves the co-occurrence of both earlier patterns and later-developing patterns. The third pattern involves the occurrence of unusual or idiosyncratic patterns that are rarely found in normal development. Systematic sound preference, a fourth category, is indicated by the substitution of one sound for multiple consonants. Finally, variable use of processes is indicated by the use of more than one sound for the same target.

In summary, children with phonological impairments exhibit difficulties communicating meaningful differences with their limited, yet orderly, sound systems. Many of these children share common phonological rules; however, wide individual variations are evident across children. Complete assessment is necessary to identify an individual child's organizational patterns to effectively understand his or her unique phonological system.

Speech Motor Control

Theories of Motor Control

To better understand motor speech disorders, theories upon which motor speech control is based will be reviewed. Speech motor control refers to the strategies and systems that control speech production (Kent, 2000). There are many theories proposed in the literature addressing different parameters of motor speech control.

The role of sensory information in speech production is addressed in the theoretical framework of closed loop models (Hall, Jordan, & Robin, 1992). Closed loop models are comprised of three components: the effector units (the speech musculature), the feedback loop carrying sensory information to the effector units, and the comparator which compares speech output with the intended target of production. Here, speech control relies on sensory feedback and sensory information that is sent back to the comparator. The comparator then decides if the output signal is the same as or different from the intended target and an error signal is sent to correct the speech output. From this process, closed loop models imply that an error-correcting device regulates the timing between the sensory and motor systems. A drawback of this model is the lack of explanation of speech as a dynamic and integrated process.

Hall et al. (1992) also cited Folkins' (1985) approach to motor speech control that considers the issues of flexibility and variability. Unlike closed loop models, this approach addresses perceptual speech goals rather than individual sound segments. The speaker's intent to produce perceptually adequate speech output drives the motor system to develop strategies to achieve a perceptual goal. According to this theory, variations across different physiological parameters can occur during speech production without changing the perceived output, indicating flexibility of the motor system.

Another class of speech motor theories acknowledging variability of speech production, known as gesture theories, is defined by Perkell, Matthies, Svirsky, and Jordan (1995) and Weismer, Tjaden, and Kent (1995). These theories propose that the infrastructure of speech is found in simple gestures defined in terms of place and degree of vocal tract constrictions. These gestures combine various activation strengths and timings to produce phonetic diversity. Advantages of such theories include the recognition of articulatory timing abnormalities and allowment for the formulation of hypotheses regarding variable speech production.

Recently, computational models of motor speech control have developed that also address motor system flexibility. Guenther (1995) developed a model to account for coarticulation, the ability of different motor actions to produce the same sound, known as the DIVA (directions into velocities of articulators) model. According to this model, the control of speech production is comprised of four reference frames: acoustic, phonetic, orosensory, and articulatory (motor). Signals in the acoustic frame (created by the speech mechanism) form the medium through which speech is communicated. The transduction and processing of these acoustic signals result in the phonetic frame that consists of speech and proprioceptive receptors. The orosensory frame then determines the sounds being produced by providing information about the vocal tract shape. Subsequently, the articulatory frame describes the commands to the articulators and muscles to produce speech movements. There are two learned mappings between these reference frames: a phonetic-to-orosensory mapping which specifies a vocal tract target for each speech sound and an orosensory-to-articulatory mapping that transforms orosensory targets into appropriate articulator movements.

In summary, speech motor theories often account for the role of sensory information and variability in speech productions. However, many variations are evident across theories of speech motor control in terms of their focus and elements. Levelt (cited by Guenther, 1995) addressed this diversity in stating, “There is no lack of theories, but a great need of convergence” (p. 617). Despite this lack of convergence, these theories provide a backbone for understanding typical speech development and, subsequently, disorders of speech motor control.

Typical Motor Speech Development

The course of typical motor speech development must first be acknowledged before addressing disorders of speech motor control in children. Much of the literature regarding this development was limited to the child’s first attempts to produce speech through babbling. No information was available on motor speech development from first words to stabilization of sound system; therefore, this section will be focused on that particular stage of children's speech development.

To determine if speech emerges from more primitive nonspeech oral movements, Moore and Ruark (1996) studied the coordinative organization of mandibular muscle activation during speech and nonspeech movements in seven 15-month-old children. Electromyographic (EMG) waveforms were collected from sucking, chewing, and reduplicated and variegated babbling. Results suggested that speech does not emerge from earlier acquired nonspeech movements, but that separate neural controls are established at infancy. This study supports a developmental continuum for mandibular coordination through nonspeech and speech tasks.

Babbling is an infant's first venture into speech motor control (Kent, 2000). According to Guenther (1995), babbling is not a nonrandom production but is constrained by neuromotor development and the child's environment, which makes sound learning easier by providing training sequences that resemble adult-like productions. He then described the stages of babbling through an infant's first year. In the first two months, infants pass through a stage where speech-like sounds are rare. Then at approximately two to three months of age, infants enter a goo stage that is characterized by velar and vowel-like combinations. At four to six months of age, infants enter an expansion stage during which they exhibit vocal play and marginal babbling. The canonical stage of babbling (also known as reduplicated babbling) occurs around seven months of age, where adult-like characteristics are seen for the first time. The final stage, variegated babbling, typically begins around 10 months of age.

Establishing speech motor control is a continuing lifelong process necessary for verbal communication. With advancing age, speech changes in its fluency, vocal quality, precision, and communicative effectiveness. The maintenance and arrangement of well-established motor speech control processes continue over much of adulthood (Kent, 2000).

Apraxia of Speech in Children

An impairment in the volitional planning, programming, and coordination of speech movements in the absence of neuromuscular deficit is termed apraxia of speech (Code, 1998; Kent, 2000). Apraxia of speech in children (AOSc), also known as developmental apraxia of speech (DAS), developmental verbal apraxia (DVA), developmental verbal dyspraxia (DVD), developmental dyspraxia, articulatory apraxia, and childhood apraxia of speech (CAS), is defined from differing viewpoints. According to Horwitz (1984), AOSc is defined as "disorders of learned skilled movements not caused by weakness, akinesia, deafferentation, abnormality of tone or posture, abnormal movements such as tremors and chorea, intellectual deterioration, poor comprehension, or uncooperativeness" (p. 111). AOSc may affect the phonologic or motoric processes by which spoken language is learned (Kent, 2000). Crary (1984) defined AOSc as "a phonological disorder resulting from a breakdown in the ability to control the appropriate spatial-temporal properties of speech articulators…DVD is a motor-linguistic disorder of the developing phonological system with the underlying etiology being deficits in spatial-temporal control of the speech mechanism" (p. 80). This developmental speech disorder is weighted with controversy concerning etiology, clinical manifestations, and the identification of the disorder as a distinct clinical entity.

Etiologies

Another contentious issue surrounding AOSc is etiology. To date, no neurological lesions have been documented to explain the speech production difficulties of children with AOSc; therefore, many researchers have found it difficult to accept it as a neuromotor disorder (Pena-Brooks & Hedge, 2000).

Horwitz (1984) conducted a study to determine whether brain lesions could be identified in 10 children diagnosed with AOSc using computed tomography (CT) scanning and to identify any specific neurological signs or electroencephalogram (EEG) patterns. Each child's history, cranial nerves, motor system, deep tendon reflexes, and sensation were examined. Laboratory testing included EEG, CT, and urine amino chromatography. Results of the study were as follows: a) CT scans failed to show any anatomical basis for AOSc; b) neurological and congenital abnormalities varied across all children from the examinations; and c) most EEGs and all amino acid profiles were normal. This study failed to demonstrate any consistent neurological findings or a specific localizing anatomical basis for the clinical manifestations of AOSc. The researchers concluded that determining the presence or absence of apraxia is mainly qualitative, dependent upon the examiners' own judgment. There are diverse neurological findings in children with AOSc and "the underlying nervous system abnormalities remained undefined" (p. 117).

Motor Versus Language Impairment

One of several controversial issues regarding AOSc centers on whether the disorder is best described as a language-based deficit or a motor-based deficit. From a motor-based perspective, the variability of speech errors implies that the deficit is in motor-speech processing

(Shriberg, Aram, & Kwiatowski, 1997a). Children with AOSc are often inconsistent in speech productions and perform speech tasks with difficulty and inaccuracy (Hall, 1992). From a language-based view, according to Hall (2000b), the child has difficulty learning the rules governing speech sound usage and sequencing. The child has difficulty with all aspects of language learning and usage. The results of a 1983 study by Ekelman and Aram (cited by Ekelman & Aram, 1984) lend support to this view by suggesting that some errors of children with AOSc cannot be attributed to motor-speech limitations, but a syntactic component instead. As noted by these two perspectives, overlap and confusion are common in the use of the term AOSc with PI. Characteristics noted by these researchers supporting a lay-based perspective are similar to the characteristics reported for PI.

Characteristics

In 1974, Yoss and Darley completed one of the first studies attempting to define AOSc. The purpose of this study was to detect a possible developmental apraxia of speech by identifying differences between normally speaking children and those with defective articulation (DAC) and to identify characteristics that would differentiate a subgroup of children from the DAC group. The DAC group consisted of 30 children aged 5-10 years, with problematic articulatory production. The control group was matched by gender and age to the DAC group. A test battery was administered to investigate auditory perception and discrimination, execution of volitional oral movements, phoneme production in spontaneous contextual speech, phoneme production in 13 real and nonsense words, and oral diadchokinetic rate. Results indicated that the DAC group demonstrated poorer auditory discrimination and auditory sequencing abilities and difficulty with volitional oral movement and sequence abilities.

The DAC group was then divided into two groups based on isolated volitional oral movement (IVOM) performance, with Group 1 demonstrating higher performance on the IVOM than Group 2. The articulatory patterns of Group 2 were characterized by significantly greater extents of distortions, prolongations, repetitions, and additions, as well as difficulty maintaining syllable integrity on three-syllable words. Group 2 displayed a higher incidence of neurological findings based on a neurological rating scale. Yoss and Darley (1974) concluded that the symptom cluster demonstrated by DAC Group 2 lends support to the term "developmental apraxia of speech." The five differentiating speech characteristics included: slow rates of oral diadochokinesis, greater difficulty with multisyllabic words, error feature patterns in repeated speech, error feature patterns in spontaneous speech, and altered prosodic features. Nonspeech characteristics included difficulty in performing oral movements of articulators, high incidence of "soft" neurological signs, the need for further demonstration to perform volitional oral movements, and poor auditory perception and auditory sequencing.

Davis, Jakielski, and Marquardt (1998) completed a study to identify distinctive characteristics of AOSc. From another ongoing longitudinal study following 22 children diagnosed with AOSc, five children, ages 3;2-5;7, were chosen to be discussed in-depth for this particular study. Each child was administered a diagnostic protocol comprised of a spontaneous speech sample, a single-word articulation test, an oral mechanism examination, and informal oral and limb praxis tasks. The samples were analyzed to evaluate each child's phonetic inventory, suprasegmentals, diadochokinetic performance, oral mechanism structure and function, oral praxis, and general receptive and expressive language development. The results indicated that one subject (S1) was diagnosed with a severe speech disorder characterized as AOSc. The other four were diagnosed with a severe speech disorder without AOSc. Characteristics that led to the diagnosis of AOSc included variability of productions, variable consonant and vowel errors, suprasegmental variability, and decreased intelligibility due to variable output. The subject appeared to have a speech system that was not following a normal developmental course, and his speech production was constrained by motor planning and sequencing deficits. Davis et al. found that the characteristics used in the differential diagnosis of S1 included limited consonant and vowel phonemic repertoire, inconsistent productions of complex word shapes, many variations of consonant and vowel errors in conversational speech and single words, and many suprasegmental differences. Because only one child out of the initial 22 children was diagnosed with AOSc, the researchers concluded that this disorder is often misdiagnosed by professional speech-language pathologists.

Shriberg, Aram, and Kwiatowski (1997b) investigated the prosodic characteristics of children with suspected AOSc through two studies. In Study I, speech samples and articulation response tests were collected on 14 children with suspected AOSc. The goal of this study was to use the samples to identify at least one characteristic of children with AOSc that differentiated them from children with speech delay. Inappropriate stress was the only characteristic found to have construct validity and divergent criterion validity. Study II was a retrospective study of 20 children with suspected AOSc. The goal was to assess the level of support for inappropriate stress as a diagnostic marker for AOSc and to serve as a follow up study to Study I. Results indicated that inappropriate phrasing or prosody-voice variables (loudness, pitch, laryngeal quality, and resonance quality) do not qualify as useful diagnostic markers for AOSc. Differences in rate performance were found between Study I and Study II. Inappropriate stress was again found in children with suspected AOSc. The findings for Study I and Study II provided evidence that inappropriate stress may be a diagnostic marker for apraxia of speech in children.

Thoonen, Maassen, Gabreels, and Schreuder (1994) investigated the feature retention patterns of children with developmental verbal dyspraxia compared to those of typically developing children. Subject selection criteria for the DVD group included a diagnosis by a school speech-language pathologist based upon the diagnostic criteria listed by Hall (1992). All children were administered a set of nine speech tasks, including multisyllabic and nonsense words, with each task representing one or more aspects of speech production (i.e., respiration, voicing, articulation). Results revealed that the DVD group produced nearly three to five times as many feature errors as the control group, characterized by high rates of consonant substitutions and omissions. Feature retention patterns were similar for both groups in that higher retention of voice was achieved than for place or manner. However, the DVD group achieved the lowest percentages for the feature place of articulation, followed by manner and voicing. A correlational analysis revealed that low feature retention patterns were associated with high severity as rated by the speech-language pathologist. These results suggested that place retention may be a determining factor in the severity of DVD and a diagnostic marker of the disorder.

Groenen, Maassen, Crul, and Thoonen (1996) investigated place of articulation errors in the perception and production of 17 children with AOSc as compared to a control group of 16 typically developing children. Two experiments were conducted: 1) identification and discrimination tasks of words differing in place of articulation and 2) an imitation task of single and nonsense words. Experiment 1 showed that children with AOSc had equally consistent phonetic processing as the control group. The AOSc children showed poorer discrimination and than the control group, indicating poorer auditory processing and less access to information in auditory memory. Experiment 2 indicated that the degree of disturbance of place discrimination was correlated to the number of place substitutions in speech production. No relation was found between place discrimination and manner or voicing substitutions in production.

To summarize, there are a range of characteristics described across studies, but characteristics primarily involve prosody and inconsistent productions. The fact that four out five children are misdiagnosed with AOSc when using these characteristics (Davis, Jakielski, & Marquardt, 1998) indicates that they are not reliable diagnostic markers of AOSc. Lack of consensus on the characteristics further confounds the incorporation of AOSc as a separate clinical entity.

Language Abilities

Hall (2000c) gave a general description of the language development problems observed in children with AOSc. These children are often late in developing language skills, such as first words. Children with AOSc usually have receptive language skills superior to those of expressive language; however, limitations in expressive language may be due to the speech disorder.

Few research attempts have been made to describe the language abilities of children with AOSc. Ekelman and Aram (1984) cited an earlier study (Ekelman & Aram, 1983) to summarize spoken syntax abilities in children with AOSc. The data collected from the study indicated that some syntactic deficits include: a) low developmental sentence scores; b) notable difficulties in grammatical categories of indefinite pronoun, personal pronoun, and main verb; c) a high incidence of grammatical marker errors of third person singular, regular and irregular past tense, auxiliaries, copula, modal, and past participle; d) reliance on simple sentence construction; pronoun selection errors; and e) omission or failure to invert auxiliary, copula, and do-support in question transformations. These deficits lent support to the notion that some errors produced by children with AOSc cannot be attributed to a motor or phonological component, but rather to a primary syntactic component.

In summary, just as children with PI, children with suspected AOSc have been described to have co-occurring language impairments. This again clouds the distinction of AOSc as a separate clinical entity or as a purely motoric problem.

Assessment

As with phonological impairment, a thorough assessment of a child's speech must be completed in order to identify the existence of the above characteristics and, subsequently, the motor speech disorder. Pena-Brooks and Hedge (2000) mentioned several assessment objectives for identifying AOSc. Like phonological assessment, this assessment should provide an estimate of severity and describe the nature of child's speech production. The assessment should also include an evaluation of the child's auditory comprehension skills, verbal expression skills, reading and writing skills, resonance, prosody, and fluency, and oral motor skills during speech and nonspeech tasks.

Current Controversy

One of the debates regarding AOSc is the questionable nature of the research upon which this disorder is based. Williams, Ingham, and Rosenthal (1981) replicated Yoss and Darley's 1974 study and found variance with almost every conclusion posited by the original study. None of the previous data could be interpreted as identifying apraxia of speech in children. The children displayed a wide range of articulatory problems consistent with those found by Yoss and

Darley, but there was no significant evidence of soft neurological signs. Yoss and Darley detected differences between typically developing children and children with AOSc across parameters of articulation, auditory perception and sequencing, and volitional oral movements; however, the replicated study found no differences except in auditory sequencing. Yoss and Darley found a definite relationship between neurological findings and performance on the test battery in children with articulation deficits, but the replicated study found no evidence of that. Yoss and Darley discerned five speech variables in repeated speech tasks and four in spontaneous speech tasks that differentiated a subgroup of children with articulation deficits, yet Williams et al. failed to identify a subgroup. Williams et al. explain the implications of their study by stating:

> Yoss and Darley's findings have been used to uphold the notion that there exists a subgroup of defective articulation children called 'dyspraxic.' At the very least, the present study's failure to support Yoss and Darley's findings should raise questions about the premises on which this clinical literature has grown—and is growing. (p. 503)

Much of the literature on AOSc is based on subject selection criteria involving referral from speech-language pathologists. It is important to note; however, Davis et al. (1998) stated that, "DAS is often misdiagnosed by professional speech language pathologists…findings of previous studies based on referral with the disorder (e.g. Thoonen et al., 1994) must be reviewed with caution" (p. 42).

A Comparison of AOS and AOSc

AOSc demonstrates similar symptoms to those of the adult acquired form, apraxia of speech (AOS). The most noted similarity is the lack of volitional control over the speech mechanism. However, Pena-Brooks and Hedge (2000) stated:

> Simply because a group of children presents with similar speech characteristics to those found in adults with a known neurological disorder does not imply that the cause of the disorder is also neurogenic based…the label DAS should be used with caution. (p. 336)

Past research has also indicated significant differences that may question the correlation between AOS and AOSc. Yoss and Darley (1974) noted several AOSc characteristics that were unlike those of AOS. Accompanying oral apraxia, audible groping, and trial-and-error searching was not usually apparent in children. Multiple features of phoneme production were in error, with the distortions being characteristic of speech production patterns. Further, children did not appear to be aware of their problem, unlike adults with AOS.

Odell and Shriberg (2001) compared the prosody-voice characteristics of 14 adults with AOS to those of 14 children with suspected AOSc. The AOS subjects were given the diagnosis of AOS by a certified speech-language pathologist and exhibited no history of dementia, dysarthria, or aphasia. The identification of the AOSc group was based on the judgment of the clinician making the diagnosis, inappropriate stress in at least 20% of 24 conversational speech utterances, and no evidence of hearing loss or dysarthria. Conversational samples were collected from all subjects, transcribed, and prosody-voice coded by three transcribers using narrow transcription. From each sample, 24 utterances were coded to reveal percentages on seven suprasegmental parameters: phrasing, rate, stress, loudness, pitch, laryngeal quality, and resonance. Results indicated that phrasing and rate were within normal limits in for AOSc speakers' utterances, whereas half of the utterances of AOS speakers were inappropriate. Stress for AOS speakers' utterances were within normal range, whereas half of AOSc speakers' utterances met criteria for inappropriate stress. The finding of infrequent inappropriate stress in AOS differs from the view emphasizing inappropriate stress as a diagnostic marker. Normal rate and phrasing found in children with suspected AOSc was not consistent with earlier AOSc literature, particularly Rosenbek and Wertz (1972) and Yoss and Darley (1974). Importantly, the finding that adults with AOS did not show evidence of stress deficits weakens support for the notion that the two disorders have similar explanatory origins. Finally, the fact that the children with AOSc did not demonstrate the slow speech of the adults with AOS weakens the motor speech explanation for this disorder.

PI or AOSc?

As was previously mentioned, one of the challenges facing speech-language pathologists is distinguishing motor speech impairments from phonological impairments in children. Based on the review of the literature, phonological impairment and apraxia of speech in children appear to share many similar characteristics. Only a couple of studies have addressed this issue by comparing children with PI to children with AOSc.

McCabe, Rosenthal, and McLeod (1998) conducted a retrospective study to determine if diagnostic features of AOSc were found in 50 children with functional phonological impairment. A checklist of 30 features was developed to determine the presence or absence of an AOSc feature and the severity of the feature for each subject. Percent consonants correct (PCC) were also determined on all subjects to serve as an index of severity. Results indicated that the number of features present in individuals ranged from four to 23. The most common features were effect of increasing complexity on speech, expressive language impairment, and delayed development of speech skills. The number of features present correlated with the measure of severity of speech impairment. These results showed that common features included in the descriptions or definitions of AOSc frequently occur among the general speech-impaired population and are not sufficient to delineate the disorder. Two interpretations were derived from these results: 1) AOSc is a syndrome that includes many features that occur in the general speech-impaired population, but for it to be diagnosed, additional, yet unknown, features must be found; 2) AOSc is no different from general functional speech impairments and there are no distinctive features.

Forrest and Morrisette (1999) viewed the study by Thoonen et al. (1994) as shortsighted in that it only compared AOSc children to typically developing children. They followed the same procedures as Thoonen et al. to compare the articulation feature retention patterns of two groups of ten children with phonological disorders with the children diagnosed with AOSc in the Thoonen et al. study. The results of Thoonen et al. were replicated in the children with phonological impairment. The children with PI retained the place feature the least, followed by manner and voicing. Further, place retention was found to be inversely related to phonological knowledge. Based upon these results, patterns of feature retention cannot be used to uniquely define children with AOSc.

Lambert (2001) examined the feature retention patterns of 10 children with phonological impairment (PI) and ten children with typically developing speech (TD) in order to compare the two groups and to compare the PI subjects with those described by Forrest and Morrisette (1999). The study also examined whether a relationship existed between phonological knowledge and feature retention. Results indicated that for the both groups place was the least retained feature, followed by manner, then voice was retained the most. The patterns found in the PI group of this study followed the same pattern as that described in the Forrest and Morrisette study; however, Lambert found no relationship between phonological knowledge and feature retention. These feature retention patterns also paralleled those of the AOSc children described by Thoonen et al. (1994), further weakening the notion that feature retention patterns can be used as a diagnostic marker.

To summarize, the previously mentioned research indicates that PI and AOSc share many characteristics, including those that were previously viewed as being exclusive to AOSc. This again demonstrates how the lines between disorders of phonology and motor speech control are not definitively drawn.

Conclusions

As evidenced by this review of the literature, there is an interaction between phonology and motor speech control in the production of speech sounds. In order to produce a word or utterance, a child must know the phonological patterns of his or her language and the motor sequences involved to articulate the sound sequence correctly. Because of this integration, a disorder that is completely separate from the phonological aspects of speech production seems questionable and therefore should be explored in comparison to phonological impairment and typical speech development.

Apraxia of speech in children is laden with controversy due to the lack of consensus regarding its diagnosis, etiology, or characteristics. There are no set diagnostic criteria, there are significant differences between it and the adult form of AOS, and much of its research bases lack sound empirical evidence to distinguish it from other childhood speech disorders. The AOSc literature to date is limited by low subject numbers, heterogeneous subject groups, and symptoms that do not appear to be truly unique of AOSc. Additionally, much of the present literature (McCabe, Rosenthal, & McLeod, 1998; Thoonen et al., 1994) has used only two-way comparisons, such as AOSc versus PI or AOSc versus TD. Forrest and Morrisette (1999) did attempt to compare feature retention patterns and phonological knowledge of phonologically impaired children to the TD and AOSc groups examined by Thoonen et al. However, this study was limited in that its comparisons were made between English speaking children and Dutch speaking children and it employed measures of phonological knowledge differing from those of Thoonen et al. Lambert (2001) compared TD and PI groups, then compared those to the AOSc group described by Thoonen et al., but like Forrest and Morrisette, this study did not follow the same procedures as those used by Thoonen et al. A comprehensive three-way study investigating feature retention patterns and phonological knowledge across children with AOSc, children with PI, and children with typically developing speech, which uses the same procedures across all three groups, is necessary to denote whether distinguishing characteristics between the two disordered groups actually exist.

In conclusion, the purpose of this research effort was to extend the research findings of the recent study by Lambert (2001) to present a comparison of typically developing children, children with phonological impairment, and children with suspected apraxia of speech. This study will examine: 1) the description of feature retention patterns, with regard to place, voice, and manner, for children with suspected AOSc; 2) a comparison of these patterns to those of children with typically developing speech and phonological impairments described by Lambert (2001); and 3) determine the correlation between feature retention patterns and phonological knowledge for children with suspected AOSc and compare them to the TD and PI groups described by Lambert. By using this three-way comparison, a more accurate description of suspected AOSc can be presented, possibly supporting the notion that this controversial disorder cannot be truly distinct from other childhood speech disorders such as phonological impairment.

CHAPTER 2

METHODS

The purpose of this research effort was to extend the research findings of the recent study by Lambert (2001) in order to answer the question: Are the feature retention patterns and phonological knowledge of children with suspected AOSc the same as those of children with PI? This study hypothesized that between two of the groups, PI and AOSc, there will be no significant difference in the feature retention patterns and phonological knowledge, whereas the alternative hypothesis was there will be a difference in the feature retention patterns and phonological knowledge between these two groups. The dependent variables of this study include the percentages of feature retention for place, manner, and voice in addition to phonological knowledge. Independent variables include the three groups of children investigated in this study: typically developing (TD) children, children diagnosed with phonological impairment (PI), and children diagnosed with suspected developmental apraxia of speech (AOSc). The TD children were described by Lambert, with ages ranging from 4;2 to 6;5, with a mean age of 4;7. The children with PI, also described by Lambert (2001), were part of a larger study by Williams (1997). These children ranged in age from 4;0 to 6;0, with a mean age of 4;10. The children with suspected AOSc ranged in age from 4;0 to 7;0, with a mean age of 5;4. The procedures of Lambert were followed in order to investigate and compare across these three groups of children.

Participant Selection

TD Group

The selection of TD participants described by Lambert (2001) were based on the following criteria: 1) normal hearing as determined by an audiometric screening (e.g., 500, 1000, 2000, 4000 Hz at 25 dB); 2) no oral structural or functional anomalies; 3) no known history of speech disorders; 4) normal receptive language abilities as determined by the Peabody-Picture Vocabulary Test-III (Dunn & Dunn, 1997); and 5) normal articulation skills as determined by the Sounds-In-Words subtest of the Goldman-Fristoe Test of Articulation-2 (Goldman & Fristoe, 1999). These criteria were determined during a screening session of children who, according to their classroom teacher, demonstrated age-appropriate speech and intelligence (see Table 1).

PI Group

The children with PI described by Williams (1997) were chosen based on the following criteria: 1) normal hearing as determined by audiometric screening (e.g., 500, 1000, 2000, 4000 Hz at 25 dB); 2) no known history of organic or motor disorders based upon an oral mechanism exam and case history; 3) normal non-verbal cognitive skills as determined by the Test of Nonverbal Intelligence (Brown, Sherbenou, & Honsen, 1982); 4) exclusion of six or more sounds across three manner categories of sound production as determined by the Goldman-Fristoe Test of Articulation (Goldman & Fristoe, 1986); 5) between 42 and 78 months of age; 6) reside in a mono-lingual English speaking family; and 7) not presently enrolled in a speech therapy program or received speech therapy services within the previous six months (see Table 1).

Table 1

Subject Profiles of PI Group (Williams, 1997) and TD Group (Lambert, 2001)

Child	Age	Gender	PPVT-III	GFTA	Hearing Screening	Oral Mech Exam
			PI Group			
				(%ile)		
1	4;10	male	102	<1%	+	+
2	5;01	female	103	<1%	+	+
3	4;03	male	123	<1%	+	+
4	4;10	male	99	NR	+	+
5	4;10	male	108	18%	+	+
6	6;00	female	90	<1%	+	+
7	4;02	female	110	4%	+	+
8	4;07	male	114	NR	+	+
9	4;00	male	101	<1%	+	+
10	5;10	male	111	NR	+	+
M	4;10		106.1			
SD	0.07		9.1			
			TD Group			
				(%ile*)		
11	6;05	male	113	63%	+	+
12	4;06	female	108	70%	+	+
13	4;06	male	99	63%	+	+
14	4;03	female	110	70%	+	+
15	4;08	male	114	96%	+	+
16	5;03	female	109	>83%	+	+
17	4;07	male	100	83%	+	+
18	4;03	female	103	93%	+	+
19	4;02	male	123	96%	+	+
20	4;03	female	124	88%	+	+
M	4;07		110.3			
SD	0.07		8.6			

Key. + (unremarkable)
NR (not reported)
* (TD scores were taken from the GFTA-II)

AOSc Group

There are very little subject selection criteria based on the existing AOSc literature, with the common criterion being the referral by a speech-language pathologist (Crary, 1984; Davis et al., 1998; Odell & Shriberg, 2001; Thoonen et al., 1994; Yoss & Darley, 1974). Following the procedures of the previous studies, children with suspected AOSc in this study were chosen based on the following criteria: 1) normal hearing as determined by an audiometric screening (e.g., 500, 1000, 2000, 4000 Hz at 25 dB); 2) no evidence of oral structural abnormalities or dysarthria as determined by an oral mechanism examination; 3) normal intelligence as determined by case history and a standard score of at least 85 on the Peabody-Picture Vocabulary Test-III (Dunn & Dunn, 1997); 4) referral by a certified speech-language pathologist; and 5) a score of three or lower, as judged by two graduate clinicians, on the Screening for Developmental Apraxia of Speech (SDAS; Morehouse & Linderman, 2000). Table 2 provides information regarding the subject profiles of this group.

Table 2

Subject Profiles of AOSc Group

Child	Age	Gender	PPVT-III	DAS Screening	Hearing Screening	Oral Mech Exam
21	4;11	male	88	0	+	+
22	5;06	male	90	3	+	+
23	6;02	male	86	3	+	+
24	7;00	male	93	3	+	+
25	4;00	female	92	2	+	+
26	6;05	male	98	3	+	+
27	4;09	male	85	1	+	+
28	4;02	female	95	1	+	+
29	5;05	male	86	0	+	+
30	5;00	female	99	2	+	+
M	5:04		91.20	1.80		
SD	0.04		5.05	1.23		

Key. + (unremarkable)

Procedures

AOSc Screening

The SDAS (Morehouse & Linderman, 2000) was employed as an inclusionary criterion for the AOSc group because research has shown that AOSc is often misdiagnosed by clinicians (Williams et al., 1981). This screening tool included six subtests that examined different parameters of each child's speech: oral motor movements, phoneme stimulability, intelligibility, a checklist of the 10 most common DAS characteristics, increasing word length across trials, and multisyllabic words across trials. Each subtest was scored as "pass" or "fail" based upon scoring criteria stated on the test form. According to the SDAS, three or fewer passing scores indicates suspected AOSc. The test was administered to each child and scored independently by two graduate clinicians for reliability purposes.

Speech Sample

Once participants were chosen for the study, a comprehensive speech sample was collected from each child independently using a probe comprised of 245 single words (Williams, 1993). The samples examined each child's production of all English phonemes in each word position a minimum of five times. The probe was administered over two 45-minute sessions. Responses were elicited from the children through the presentation of a picture stimulus and the use of a cueing hierarchy to avoid direct imitation. The hierarchy consisted of the following sequence: 1) if the child did not spontaneously name the picture correctly, a cue was given; 2) if the child did not respond correctly to the cue, delayed imitation was then employed, during which a choice between two items is given to the child with the target item presented first; 3) if the child still did not respond appropriately, direct imitation was used. Two graduate clinicians independently transcribed each speech sample using the International Phonetic Alphabet for reliability purposes.

Feature Analyses

The responses of the children with suspected AOSc were analyzed according to the same procedures followed by Lambert (2001) that replicated the procedures described by Forrest and Morrisette (1999) and Thoonen et al. (1994). The only sounds included in the analyses were those omitted from each child's phonetic inventory. To determine feature retention patterns for phonemes substituted for the targeted sounds, a confusion matrix was constructed for each subject in the AOSc group. Each substituted phoneme was compared to the targeted phoneme in terms of place, voice, and manner. No features were determined to be retained on target sounds characterized as omissions. A percentage of retention was calculated for each feature by dividing the number of substituted phonemes with correct feature retention by the total number of omissions and substitutions. Table 3 provides an example of calculation of feature retention.

In a second analysis, percent correct underlying representations (PCUR; cited by Forrest & Morrisette, 1999) were calculated to determine each child's productive phonological knowledge. Following procedures described by Forrest and Morrisette, each child was given one point for each consonant produced that was characterized as having a correct underlying representation in each allowable word position. The maximum score attainable for English consonants is 65; therefore, PCUR was calculated by dividing each child's score by 65.

Table 3

<u>Example of Calculation of Feature Retention for /f/, Subject 24, AOSc Group</u>

Target	Substitute	Bilabial	Labio-dental	Lingua-dental	Alveolar	Palatal	Velar	Glottal	Ø	#Retained	Total	% Place Retention
f	k						7					
	g						5					
	z				1							
	ʔ							1				
	Ø								6			
Total		0	0	0	1	0	12	1	6	0	20	0

Target	Substitute	Stop	Fricative	Affricate	Nasal	Liquid	Glide	Ø	#Retained	Total	% Manner Retention
f	k	7									
	g	5									
	z		1								
	ʔ	1									
	Ø							6			
Total		13	1	0	0	0	0	6	1	20	5

Target	Substitute	Voiced	Voiceless	Ø	#Retained	Total	% Voice Retention
f	k		7				
	g	5					
	z	1					
	ʔ		1				
	Ø			6			
Total		6	8	6	8	20	40

<u>Note.</u> The shaded column represents the correct feature production of the target sound /f/.

Interjudge Agreement

Transcription Agreement

AOSc Group. All responses of each participant were transcribed by two graduate clinicians using broad phonetic transcription. From a consonant-by-consonant comparison of each transcription from the two clinicians, the reliability was calculated. The number of consonants in agreement was divided by the total number of consonants transcribed. Interjudge agreement ranged from 68.7% to 95.7% with a mean of 86.9%. This lower interjudge agreement is attributed to the severity level of one child, which made transcription judgment difficult.

PI Group. Interjudge agreement of the PI group was calculated using the procedures described above. Reliability ranged from 88.7% to 99.0% with a mean of 96.7% (Lambert, 2001).

TD Group. Interjudge agreement was calculated using the same procedures as the AOSc and PI groups. Reliability ranged from 91.2% to 99.0% with a mean of 97.0% (Lambert, 2001).

SDAS Agreement

All responses to the SDAS (Morehouse & Linderman, 2000) were recorded by two graduate clinicians. From a comparison of tests for each child, interjudge agreement was calculated. Although there was slight variation between responses on individual items within subtests, interjudge agreement was 100% on all test scores.

Reliability of Feature Analysis

AOSc Group. Two randomly selected speech samples (20% of the samples) were reanalyzed by a second judge trained in completing the feature analysis to assess the interjudge reliability of the analysis. To determine agreement between the two analyses, results from the first analysis (A1) were compared with results from the second analysis (A2). Reliability of the analyses ranged from 97.86 to 98.0% with a mean of 97.9%.

PI and TD Groups. Lambert (2001) reported four randomly selected speech samples (20% of the total) were chosen from the PI and TD groups to assess interjudge reliability of the feature analysis. Reliability of the analyses ranged from 96.7% to 98.6% with a mean of 97.4%.

Data Analysis

The procedures of data analysis followed those of Lambert (2001). Measurements from each study participant were stored in a computer file which distinguished participants by study numbers. The data values (i.e., % place retention, % manner retention, % voice retention, and PCUR) of the AOSc group were summarized by means and standard deviations. In order to answer the questions posed by this study, analysis of variance (three groups) and the least significant difference procedure within each group of speakers was used to compare the mean responses for % place, % manner, % voice, and PCUR. Lastly, the linear correlation coefficient was used to correlate the values of % place retention, % manner retention, and % voice retention with PCUR.

Data values were stored in Microsoft Excel and analyzed for correlations and group effects in Minitab software. A probability level of 0.05 or smaller was used to indicate statistical significance.

CHAPTER 3

RESULTS

The purpose of this study was to: 1) describe the feature retention patterns for three groups of speakers (children with suspected apraxia of speech, children with phonological impairment, and children with typically developing speech); and 2) determine if a relationship exists between feature retention and phonological knowledge. The results will be reported in terms of: 1) feature retention patterns across the three groups of subjects; 2) a comparison of phonological knowledge across the three groups of subjects; and 3) phonological knowledge in relation to feature retention for the three groups of speakers.

Feature Retention Patterns Across Subject Groups

Feature retention patterns were determined from responses given on the 245-word probe. The percentages of feature retention and PCUR for each child in all three groups are summarized in Table 4. As indicated by this table, the feature place was retained least across all three groups (range = 0 to 100), followed by feature manner retention (range = 0 to 100), with the feature voice retained the most (range = 0 to 100). With regard to the three groups, the AOSc group retained place the least (3.62%) compared to 10.96% for the PI group and 60% for the TD group. For manner retention, the PI group retained 15.78%, the AOSc group retained 19.5%, and the TD group retained 98.22%. Finally the PI group retained the voice feature 35.5% compared to 51.74% for the AOSc group and 100% for the TD group.

Within the PI group, two subjects (4 and 7) deviated from the feature retention pattern described above. These children retained manner the least, followed by place, with the feature voice retained the most. Within the AOSc group, two subjects (28 and 29) also deviated from the feature retention pattern across groups. Subject 28 retained place the least, followed by voicing, with manner retained the most. Subject 29 retained manner least, followed by voice, with place retained the most. Of these four children, only Subject 29 had a remarkable case history in that there was suspected substance abuse by the child's mother during pregnancy.

Data analysis indicated that the mean responses across all three features (place, manner, and voice) for the PI and AOSc groups differed significantly from those of the TD group (2-way ANOVA, $P<0.05$). However, no significant differences were found between the PI and AOSc group mean responses across place, voice, or manner retention. The individual and mean percentages of feature retention for each subject group are also illustrated in Figure 1 (place retention), Figure 2 (manner retention), and Figure 3 (voice retention).

Table 4

Summary of Feature Retention Patterns and PCUR for Each Subject

Subject Number	Place (%)	Manner (%)	Voice (%)	PCUR
		PI Group		
1	1.64	6.56	52.87	28
2	14.90	20.70	30.20	13
3	7.89	11.83	52.90	19
4	13.33	0.00	56.97	31
5	5.75	6.32	69.54	34
6	6.09	21.74	48.70	34
7	19.35	15.05	91.40	71
8	7.08	7.96	27.43	58
9	11.41	39.26	59.73	24
10	22.20	28.40	53.10	43
M*	10.96	15.78	54.28	35.5
SD	6.50	11.88	18.21	17.7
		TD Group		
11	100.00	100.00	100.00	100
12	100.00	100.00	100.00	100
13	0.00	100.00	100.00	95
14	0.00	100.00	100.00	95
15	100.00	100.00	100.00	100
16	100.00	100.00	100.00	100
17	0.00	88.89	100.00	92
18	100.00	100.00	100.00	100
19	100.00	100.00	100.00	100
20	0.00	93.33	100.00	95
M*	60.00	98.22	100.00	97.70
SD	51.60	3.89	0.00	3.09

Table 4 (continued)

Subject Number	Place (%)	Manner (%)	Voice (%)	PCUR
		AOSc Group		
21	0.00	5.89	49.02	40
22	0.00	55.88	97.06	74
23	2.78	2.78	2.78	34
24	0.00	0.75	35.82	34
25	6.42	19.27	40.83	28
26	5.56	0.00	100.00	63
27	2.17	30.43	82.61	60
28	2.67	20.61	12.98	25
29	16.61	9.90	15.34	9
30	0.00	49.49	80.43	40
M*	3.62	19.50	51.74	40.70
SD	5.13	20.09	36.20	19.67

Note. * Group mean and standard deviation.

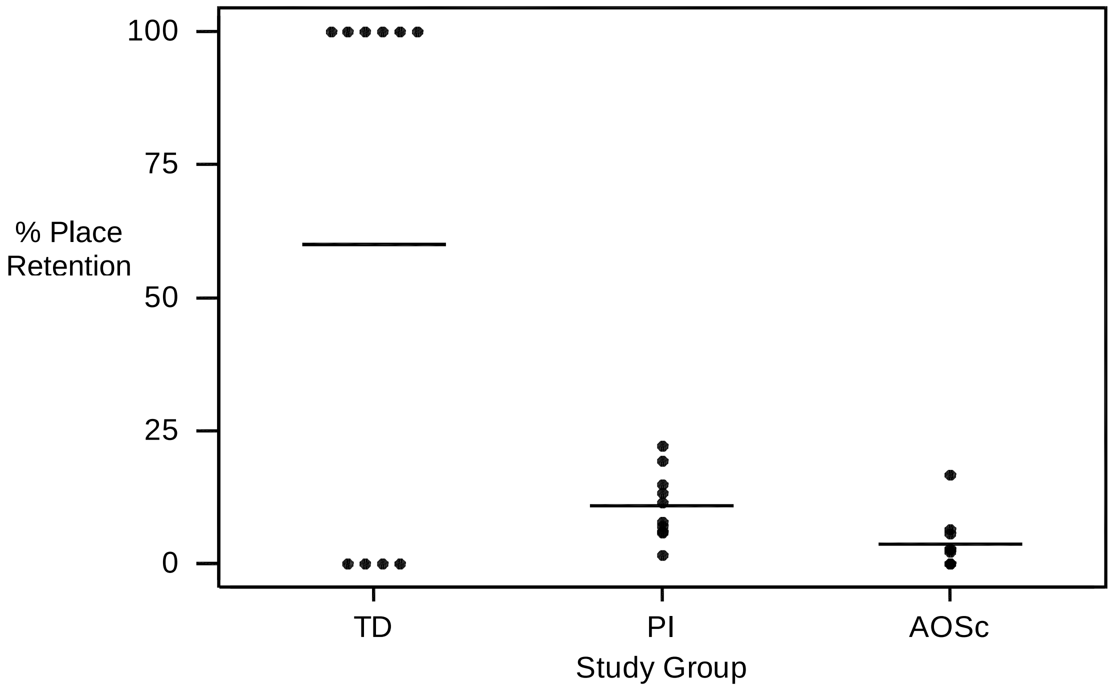

Figure 1. Illustration of Individual and Mean Percentages of Place Feature Retention Values Across All Subject Groups.

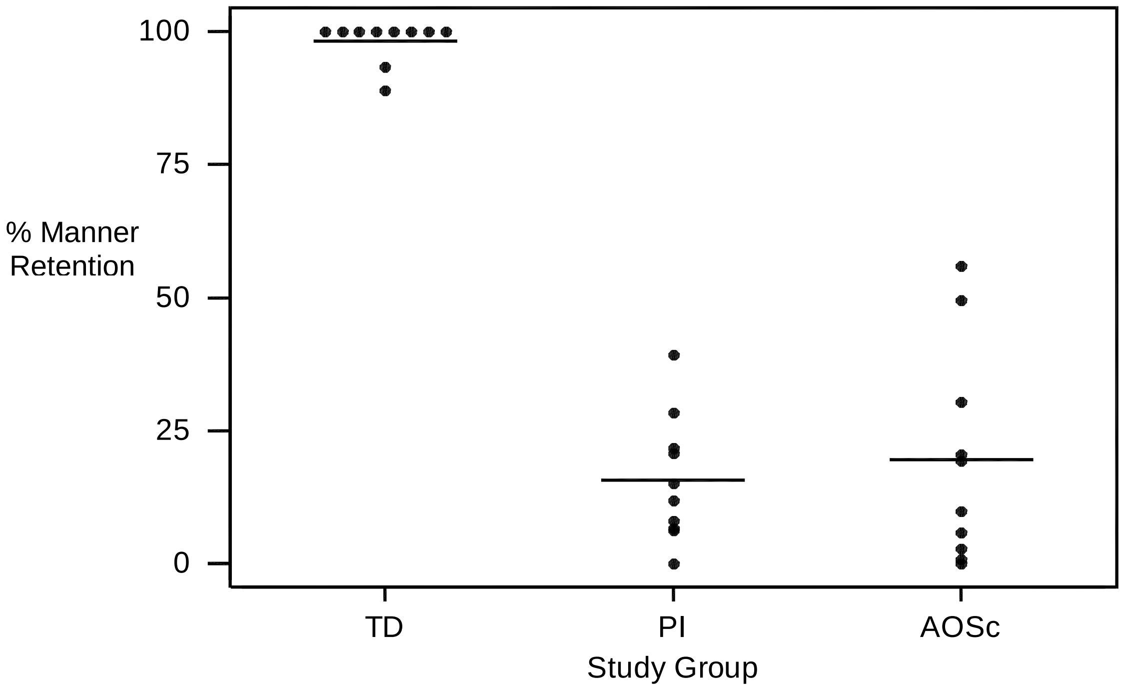

Figure 2. Illustration of Individual and Mean Percentages of Manner Feature Retention Values Across All Subject Groups.

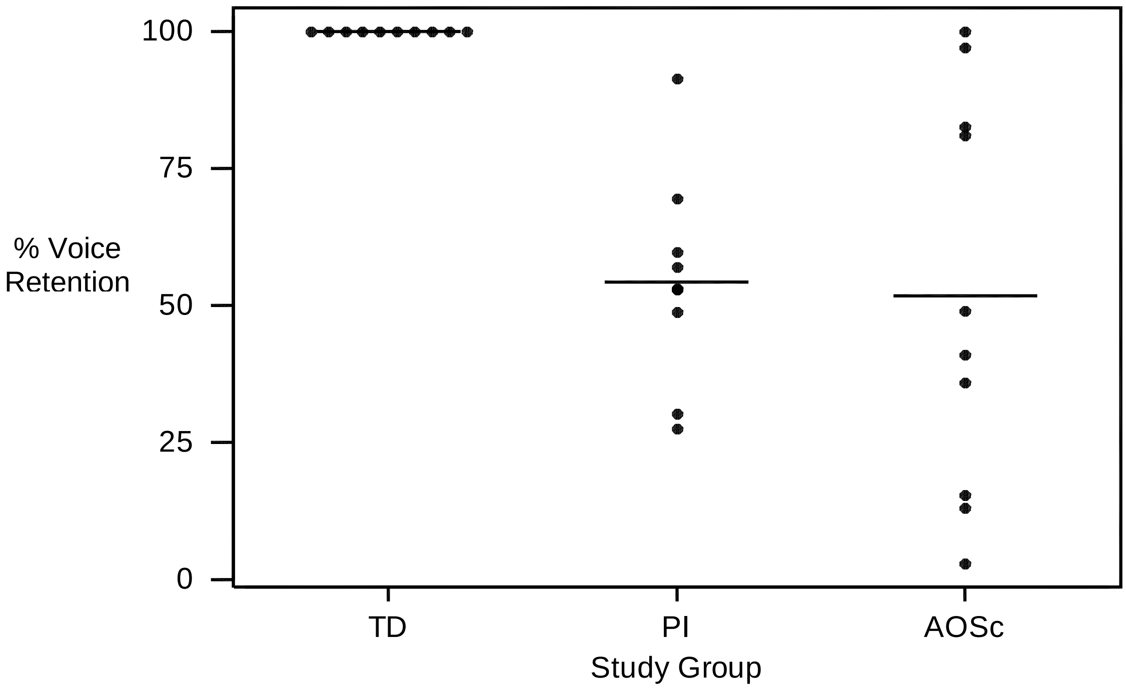

Figure 3. Illustration of Individual and Mean Percentages of Voice Feature Retention Values Across All Subject Groups.

Comparison of Phonological Knowledge Across Subject Groups

Phonological knowledge, which is presented in the form of PCUR values, was compared across the three subject groups. Individual and mean PCUR values for each group are listed on Table 4. Data analysis indicated that the mean PCUR values for the PI and AOSc groups differed significantly from those of the TD group (2-way ANOVA, $P<0.05$). Again, no significant differences were found between the PI and AOSc group mean PCUR values. Figure 4 illustrates the individual and mean PCUR values for each subject group.

Relationship Between Phonological Knowledge and Feature Retention Across Subject Groups

Phonological knowledge, represented by PCUR values, was compared and related to the feature retention scores within the subject groups. Results from the data analysis of the AOSc group indicated that PCUR does not significantly correlate with percentages of place or manner retention. However, voice retention was found to positively correlate with PCUR (t-test, $P<0.05$). Figure 5 illustrates this correlation: as the percentage of voice retention increases, the PCUR value also increases. Within the PI and TD groups, no correlation was found between PCUR and feature retention percentages for place, manner, and voice.

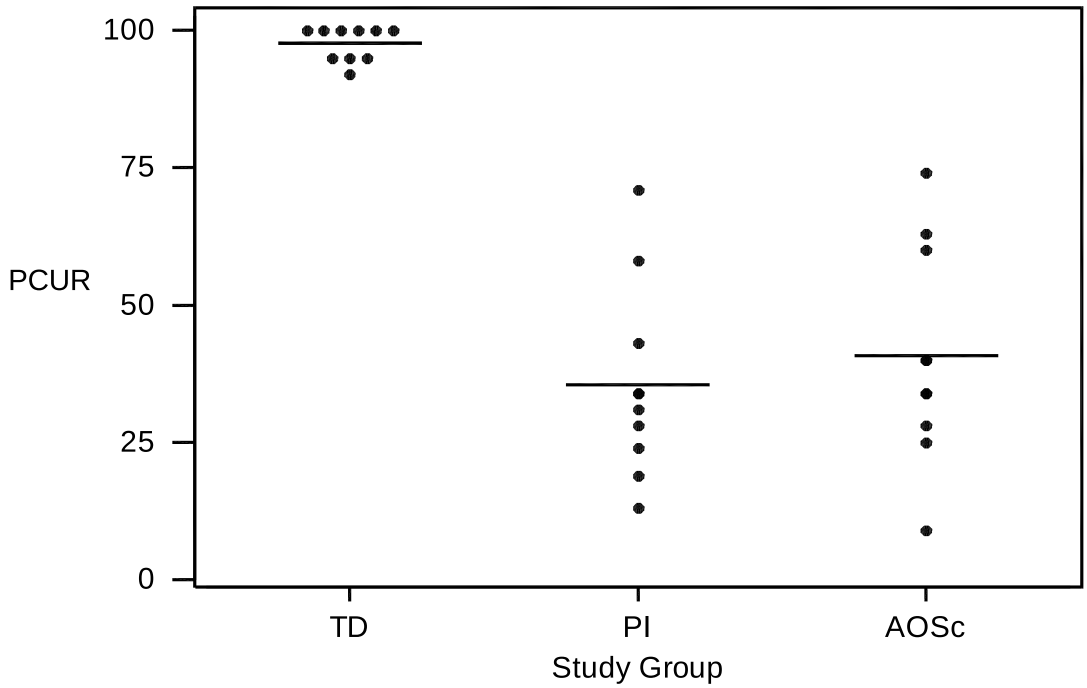

Figure 4. Illustration of Individual and Mean PCUR Values Across All Subject Groups.

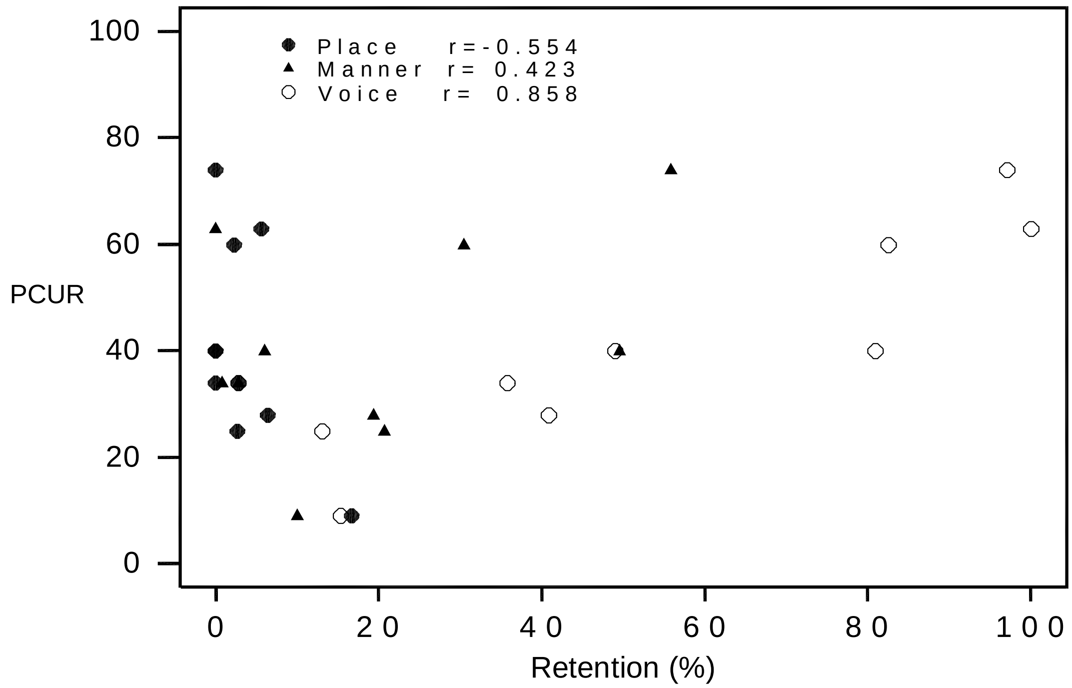

Figure 5. Scatter Plot of PCUR Values and Feature Retention Percentages for AOSc group.

Summary

1. Describe the feature retention patterns (in terms of place, manner, and voice) for three groups of speakers (children with suspected apraxia of speech, children with phonological impairment, and children with typically developing speech).

- Mean percentages of feature retention in all groups revealed that voice was the highest retained feature, followed by manner, with place the least retained.

2. Compare the feature retention percentages (in terms of place, manner, and voice) of children with suspected apraxia of speech, phonological impairments, and typically developing speech.

- The mean percentages of feature retention for children with suspected apraxia of speech and children with phonological impairments differed significantly from those of children with typically developing speech.
- No statistically significant difference was found between the mean feature retention percentages of children with suspected apraxia of speech and those of children with phonological impairments.

3. Compare phonological knowledge (represented by PCUR values) of children with suspected apraxia of speech, phonological impairments, and typically developing speech.

- The mean PCUR for children with suspected apraxia of speech and children with phonological impairments differed significantly from those of children with typically developing speech.

- No statistically significant difference was found between the mean PCUR values of children with suspected apraxia of speech and those of children with phonological impairments.

4. Determine if a relationship exists between phonological knowledge and feature retention in children with suspected apraxia of speech, phonological impairments, and typically developing speech.

- Within the AOSc group, a positive correlation was revealed between the percentage of voice feature retention and phonological knowledge, such that as the percentage of voice retention increases, PCUR also increases.
- Within the PI and TD groups, no relationship was found between phonological knowledge and feature retention.

CHAPTER 4

DISCUSSION

The purpose of this study was to compare the feature retention patterns of children with typically developing speech, children with phonological impairments, and children with suspected apraxia of speech. This study found that mean scores for all three groups followed the same feature retention pattern in which place was retained the least, followed by manner, with voicing being retained the most. A positive correlation was found between phonological knowledge and voice retention within the AOSc group. These results will be discussed in relation to current literature and in terms of theoretical and clinical implications.

Comparison of Present Study to Current Literature

Phonological Characteristics

Differentiating characteristics must exist in order to define a disorder as a separate clinical entity. There have been several research attempts to differentiate AOSc from other childhood speech disorders, particularly phonological impairment (Groenen et al., 1996; Shriberg et al., 1997b; Thoonen et al., 1994; Yoss & Darley, 1974). Davis et al. (1998) listed several differentiating characteristics of AOSc: 1) variable consonant and vowel errors; 2) limited consonant and vowel phonemic repertoire; 3) suprasegmental differences; and 4) variability of productions. Each of these characteristics will be discussed in terms of both PI and AOSc findings from the present study.

One differentiating characteristic of AOSc stated in the literature (Davis et al., 1998; Hall, 2000a) is variable consonant and vowel errors in single words, meaning the child may substitute several sounds for one target. However, variable substitutions are prevalent in the speech of children with phonological impairment as well (Forrest, Elbert, & Dinnsen, 2000; Grunwell, 1997). Variable consonant and vowel error productions were again found in both the AOSc and PI groups of the present study, further weakening this characteristic as a distinctive feature of AOSc. In the present study, subjects in both groups produced errors with variable substitutions, with some children substituting as many as six phonemes for one target sound. Specifically, most consonant substiutions included fronting or backing errors, stopping, and voicing errors. Most vowel substitutions were lax for tense vowels.

Another phonological characteristic of AOSc reported in the research (Crary, 1984; Davis et al., 1998; Shriberg et al., 1997a) is a limited sound inventory. Again, other literature (Forrest & Morrisette, 1999; Grunwell, 1997; Williams, 2000) found this characteristic to be present in children with PI as well. In the present study, limited sound inventories were found across subjects in both the AOSc and the PI groups as indicated by low percentages of correct underlying representation (PCUR). The mean PCUR for the PI group in the present study was 35.5 and 40.7 for the AOSc group. The lack of significant difference between the PCUR findings of the PI and AOSc groups support the notion that limited sound inventory cannot be used to differentiate AOSc as a clinical entity.

Suprasegmental speech errors are also described as being a distinguishing characteristic of AOSc (Davis et al., 1998; Odell & Shriberg, 2001; Shriberg et al., 1997b; Yoss & Darley, 1974). Although prosodic characteristics were not formally assessed in the present study, based upon observation during collection of the speech sample, only one child in the AOSc group was noted to have altered prosodic features. One subject of the PI group described by Williams

(1997) also exhibited altered prosodic features, again weakening this characteristic as a distinguishing characteristic of AOSc.

Variability of complex word productions across trials is another characteristic acknowledged in the literature as a distinguishing characteristic of AOSc (Davis et al., 1998; Yoss & Darley, 1974). Based upon findings from the SDAS, most subjects in the AOSc group exhibited this characteristic. However, because the SDAS was not administered to the PI participants, it cannot be determined whether this finding would also be evident in the PI group.

In addition to the characteristics listed by Davis et al. (1998), another characteristic used to describe AOSc is the presence of a persistent, irregular, and severely impaired sound system (Shriberg et al., 1997a). According to Hodson and Padden (1981), however, this is also typical of children with phonological impairment. In the present study, 80% of the PI subjects and 70% of the AOSc subjects were considered profoundly to severely impaired based on PCUR (Williams, 1993). Many of the children also exhibited deviant systems in that some later-developing sounds were included in their sound system, whereas earlier sounds were absent. All phonological systems were unique to each child, indicating that irregular systems are present in both AOSc and PI groups, again weakening support for AOSc as a distinct disorder.

Feature Retention Patterns

Thoonen et al. (1994) put forth the notion that feature retention patterns can serve as a diagnostic marker of AOSc, in that these subjects retain place the least, followed by manner, with voicing being retained most. This notion was weakened by the results of Forrest and Morrisette (1999), which found the same pattern in PI subjects. Because this pattern was again present in all three groups of the present study, the use of feature retention patterns as a diagnostic marker is further weakened.

The present study found similar results as Thoonen et al. (1994) regarding feature retention of TD subjects. In both studies, the majority of subjects retained 100% of features. However, the percentages of feature retention in word production differed greatly between the AOSc group of the Thoonen et al. study and that of the present study as indicated by Figure 6 below. It should be noted that two methodological differences may contribute to this discrepancy. First, Thoonen et al. used 36 words to determine these percentages, whereas the present study employed a sample of 245 words. Secondly, Thoonen et al. examined phonemes by three classes of place and four classes of manner, whereas the present study examined phonemes by seven classes of place and six classes of manner.

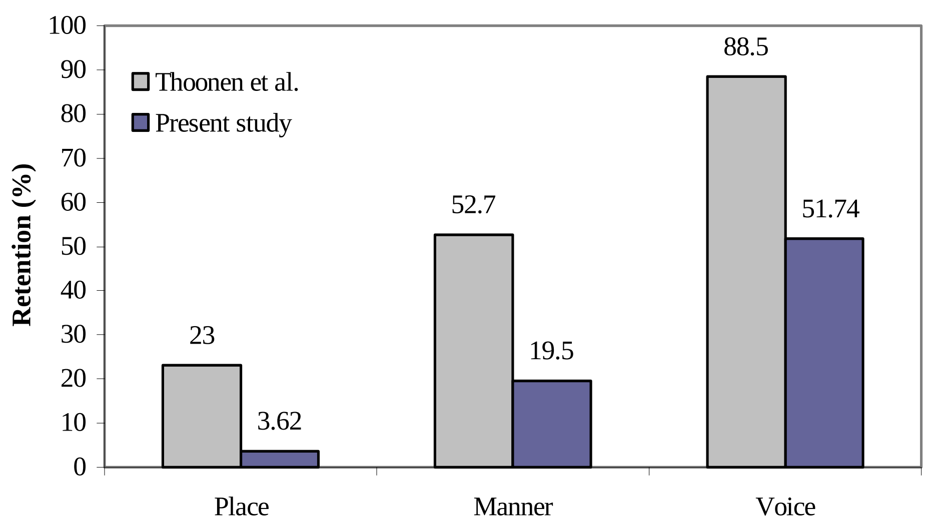

Figure 6. Comparison of AOSc Mean Feature Retention Percentages in Word Production Between the Present Study and the Study Conducted by Thoonen et al. (1994).

PCUR

Forrest and Morrisette (1999) examined the relationship between phonological knowledge and feature retention for PI subjects and found the strongest correlation to occur with PCUR and voicing (r = .714), in addition to a negative correlation between PCUR and place (r = -.54), and finally a significant relationship between PCUR and manner (r = .46). Likewise, the present study examined this relationship and found similar results for the AOSc group, but not in the PI or TD groups. Voicing and PCUR were found to have a significant positive relationship (r = .858). Similar to the PI subjects of Forrest and Morrisette, less signifiicant correlations were found between PCUR and place (r = -.554) and PCUR and manner (r = .423). The similarities between these two groups again may prove as evidence for the lack of differentiation of AOSc as a clinical entity. However, as discussed by Lambert (2001), no significant correlations were found between PCUR and feature retention patterns of the PI and TD groups described in the present study. The difference in correlations between the PI groups of the two studies was attributed to differences in the severity of the subjects: Forrest and Morrisette had more subjects in the moderate category whereas more PI subjects in the present study fell into the severe and profound categories. The correlations found by this investigation and Forrest and Morrisette may indicate that feature retention impacts the severity of a child's speech disorder. Specifically, children exhibiting more place errors may also exhibit a more severely disordered sound system. Likewise, a child exhibiting less voicing errors may exhibit a milder speech disorder.

Theoretical Implications

A model of speech disorders must incorporate what Chomsky and Halle (1968) called "descriptive adequacy" as well as "explanatory adequacy." Such a model would specify the characteristics and provide an explanation of errors made by individuals with speech disorders. In the area of apraxia of speech in children, such a model does not exist, neither in description nor explanation. Most proponents of AOSc (Hall, 2000b; Robin, 1992) ascribe to motor-based models such as closed loop models and Folkins' approach to motor speech control (cited by Hall et al., 1992). At best, these models appear limited to serving as a descriptive tool; however, many of the descriptions of AOSc overlap with the phonological descriptions of phonological impairment.

The results from this study contribute to the existing literature that the descriptive power of such models to identify AOSc as a separate clinical entity are inadequate to account for the overlap in phonological characteristics between PI and AOSc. This is an essential point. Theory and models are used to understand why children produce the errors that they do. Consequently, independent categories of AOSc versus PI are crucial in understanding the differences between these two speech disorders, if they do indeed exist.

Given the current lack of distinguishing phonological characteristics, it is impossible to claim that AOSc represents a separate clinical entity. Further, these theories lack any empirical evidence to provide an explanation for a separate clinical diagnosis of AOSc.

Clinical Implications

Across several parameters, this study reinforced the evidence that there are numerous similarities between children with PI and children with AOSc, further diminishing the speculation that AOSc is a separate clinical entity. No significant difference was found between the two groups in terms of feature retention patterns, percentages of feature retention, or phonological knowledge. Other similarities were also present, including inconsistent consonant errors, a profound or severe sound system characterized by a limited sound inventory, and deviant development of speech production.

The Screening for Developmental Apraxia of Speech (Morehouse & Linderman, 2000) was employed as an inclusionary criterion. Despite the use of this criterion, the children in the AOSc group appeared to have few differences from those in the PI group. This finding supports one of two possibilities put forth by McCabe et al. (1998): 1) this particular screening tool for AOSc is not sensitive enough to distinguish children with AOSc from those with PI; or 2) there is no difference between AOSc and PI. Furthermore, if other assessment tools are examining the same parameters of speech as the SDAS, it is probable that they too are not adequate in identifying children with AOSc. One explanation for this inadequacy is the present lack of differentiating characteristics proven to identify this disorder. With no distinguishing characteristics, a sufficient assessment tool cannot be developed at this time. A disconcerting presumption that can be drawn from the above speculations is that children currently identified as developmentally apraxic based on these assessment tools may be misdiagnosed and; therefore, may be receiving inappropriate intervention.

Another possible interpretation of these results, given that no study has definitively identified a diagnostic marker for AOSc, may be that AOSc is not a separate clinical entity; rather AOSc may be a severe expression of a phonological disorder. This possibility was also put forth by Epperly, Gaffney, O'Malley, and Williams (2000) following an extensive review of literature regarding clinical assessment of AOSc, speech characteristics, the presence of concomitant language characteristics, treatment outcomes, and research methodology used to study AOSc. The authors suggested that AOSc is at an extreme end of a continuum of speech impairments and does not represent a separate diagnosis from PI.

Given that much of the present literature, including this study, is supporting the lack of differentiation between PI and AOSc; implications for treatment of AOSc should be acknowledged. If in fact the two disorders are not distinct clinical diagnoses, treatment should not differ for these groups. Currently, treatment of phonological disorders follows a linguistically based approach (cf., Geirut, 1997) whereas treatment of apraxia is motorically based (Hall, 2000d; Pena-Brooks & Hedge, 2000; Strand, 1995). According to Hall (2000d), children with AOSc progress slowly in treatment and, as of yet, there is no literature proving efficacious treatment for this disorder. However, present literature supports the effectiveness of phonological treatment for children with PI (Gierut, 1998). Because AOSc exhibits essentially identical speech characteristics as those of PI and because motoric intervention approaches are not proven to be efficacious, phonological intervention may prove to be a beneficial approach for children diagnosed with AOSc.

Future Research

Future research is needed in order to definitively determine whether AOSc is a distinct clinical entity. Although this study is unique in being the first three-way comparison of PI, TD, and AOSc children, this uniqueness also represents the study's greatest limitation. Using data from previous investigations provided a basis for comparison of PI and AOSc groups. Consequently, the SDAS (Morehouse & Linderman, 2000) was administered only to the AOSc group; therefore, it cannot be fully determined at this time whether the screening would yield the same results with the PI and TD groups. It is unlikely that identification of a PI group separate and independent from the AOSc group, based on the SDAS, would have been possible. Indeed, three of the 10 children identified as apraxic by local speech-language pathologists and the SDAS were diagnosed as PI and enrolled in a phonological intervention study.

A more reliable comparison of AOSc, PI, and TD groups should include two components: 1) completion of the SDAS on all subjects; and 2) a concurrent comparison of all three groups. However, it should be noted that a true 3-way comparison would be challenging due to the ambiguous nature of AOSc at this time. Criteria distinguishing PI from AOSc speakers would be difficult to establish because, as of yet, there are no distinguishing characteristics to differentiate the two disorders. In the present study, the groups were "artificially" separated in that the PI group was established prior to the selection of the AOSc group.

The present study was also limited to an examination of only the segmental elements of speech. Few attempts have researched the suprasegmental characteristics of children with suspected AOSc. Odell and Shriberg (2001) compared the prosodic elements of speech in children with suspected AOSc and adults with acquired AOS and found that the children demonstrated more inappropriate stress patterns than the adults. Shriberg et al. (1997b) compared prosodic findings of speech samples of an AOSc group to PI and also found inappropriate stress patterns to be the only distinguishing feature. Like the present study, this investigation was limited in that the comparison was made between the AOSc group and a pre-existing PI group from previous studies. Therefore, a concurring 3-way comparison of TD, PI, and AOSc groups examining prosodic and suprasegmental characteristics of speech may identify potential differences. Future research investigating these dimensions of speech may yield further information on whether these parameters may distinguish AOSc from other disorders of speech.

At this time, no neurological basis of AOSc has been identified, although advocates of this disorder claim that it is neurologically based (Hall, 2000b; Yoss & Darley, 1974). Finally, future research relating relevant medical histories to current speech abilities of children across TD, PI, and AOSc groups may also yield important distinctions across these groups.

As previously mentioned, there are two separate intervention approaches to treat AOSc and PI: motorically-based and linguistically-based approaches. At this time; however, treatment efficacy data exists only for linguistically-based approaches used to treat children with PI (c.f., Gierut, 1998). A treatment study of four groups of children (two PI and two AOSc), using each intervention approach to treat a PI group and an AOSc group, may bring forth important efficacy data. In addition, this study may yield distinctions across these two groups.

In closing, many questions remain to be answered regarding the nature of apraxia of speech in children. This study added one more piece to the very complex puzzle of AOSc, but many more must be filled in to determine whether this is a truly distinct from other childhood speech disorders and, subsequently, appropriate assessment and treatment for children carrying this label.

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APPENDICES

APPENDIX A

Informed Consent

APPENDIX A

Informed Consent

PRINCIPAL INVESTIGATOR: Tracy A. Ford, B.S.Ed.

TITLE OF PROJECT: The Description and Comparison of Feature Retention Patterns for Children with Phonological Impairment, Development Apraxia of Speech, and Typically Developing Children

This is a research project. This Informed Consent will explain about being a research participant in an experiment. It is important that you read this material carefully and then decide if you wish to be a volunteer.

PURPOSE

The purposes of this research study are as follows:

(1) to describe speech patterns for children with suspected developmental apraxia of speech
(2) to compare these patterns to children with typically developing speech and phonological impairments as described by previous research

DURATION

Children will participate in a maximum of three 60-minute individual sessions.

PROCEDURES

In this study, your child's speech will be evaluated using a list of 245 words. Your child will be shown pictures and will be asked to name them.

POSSIBLE RISKS/DISCOMFORTS

The possible risks and/or discomforts of your child's involvement include fatigue or boredom during the picture-naming task. This is a standard clinical practice.

BENEFITS and COMPENSATION

The possible benefits of your child's participation include:
(1) An extensive evaluation of your child's speech.

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(2) Society may gain information concerning speech patterns of children with suspected developmental apraxia of speech and how they compare to those of children with typically developing speech and phonological impairments.

CONTACT FOR QUESTIONS

If you have any questions or problems at any time, you may call Tracy Ford at (423) 975-6715 or Dr. Lynn Williams at (423) 439-7188. You may call the Chairperson of the Institutional Review Board at (423) 439-6134 for any questions you may have about your rights as a research participant.

CONFIDENTIALITY

Every attempt will be made to see that my study results are kept confidential. A copy of the records from this study will be stored in Dr. Lynn Williams' office in a locked file cabinet, for at least 10 years after the end of this research. The results of this study may be published and/or presented at meetings without naming your child as a subject. Although your rights and privacy will be maintained, the Secretary of the Department of Health and Human Services, the East Tennessee State University Institutional Review Board, and the ETSU Department of Communicative Disorders have access to the study records. Your child's records will be kept completely confidential according to current legal requirements. They will not be revealed unless required by law, or as noted above.

COMPENSATION FOR MEDICAL TREATMENT

East Tennessee State University (ETSU) will pay the cost of emergency first aid for any injury which may happen as a result of your child being in this study. They will not pay for any other medical treatment. Claims against ETSU or any of its agents or employees may be submitted to the Tennessee Claims Commission. These claims will be settled to the extent allowable as provided under TCA Section 9-8-307. For more information about claims call the Chairperson of the Institutional Review Board of ETSU at 423/439-6134.

VOLUNTARY PARTICIPATION

The nature, demands, risks, and benefits of the project have been explained to me as well as are known and available. I understand what my participation involves. Furthermore, I understand that I am free to ask questions and withdraw from the project at any time, without penalty. I have

PRINCIPAL INVESTIGATOR: Tracy A. Ford, B.S.Ed.

TITLE OF PROJECT: The Description and Comparison of Feature Retention Patterns for Children with Phonological Impairment, Development Apraxia of Speech, and Typically Developing Children

read, or have had read to me, and fully understand the consent form. I sign it freely and voluntarily. A signed copy has been given to me.

Your child's study record will be maintained in strictest confidence according to current legal requirements and will not be revealed unless required by law or as noted above.

____

SIGNATURE OF PARENTS OR GUARDIAN (if applicable) DATE

____

SIGNATURE OF INVESTIGATOR DATE

____

SIGNATURE OF WITNESS (if applicable) DATE

Note. The title stated on the Informed Consent, The Description and Comparison of Feature Retention Patterns for Children with Phonological Impairment, Development Apraxia of Speech, and Typically Developing Children, was revised to the current title, Feature Retention and Phonological Knowledge Across Children with Suspected Developmental Apraxia of Speech, Phonological Impairment, and Typically Developing Speech, following the submission of this form to the International Review Board.

APPENDIX B

Word List from 245-word Probe

APPENDIX B

Word List from 245-word Probe

1. Jimmy
2. gauge
3. fudge
4. wash
5. path
6. ship
7. tongue
8. chicken
9. keyhole
10. father
11. visit
12. magic
13. beehive
14. zoom
15. elephant
16. gun
17. them
18. jug
19. go
20. shave
21. Kathy
22. zero
23. dinosaur
24. teeth
25. buy
26. pig
27. zip
28. behind
29. ladder
30. charge
31. witch
32. gush
33. doll
34. giraffe
35. scissors
36. eat
37. pitch
38. shadow
39. nose
40. view
41. rope
42. chop
43. come
44. gum
45. gain
46. cheep
47. page
48. catch
49. rub
50. jelly
51. hop
52. mom
53. donkey
54. fan
55. fun
56. robe
57. chase
58. rob
59. cookie
60. cut
61. fill
62. boss
63. show
64. big
65. hug
66. sob
67. sing
68. mail
69. thumb
70. zombie
71. cook
72. push
73. wish
74. coyote
75. yawn
76. leaf
77. thirteen
78. watch
79. fog
80. laugh
81. they
82. reach
83. yo-yo
84. hide
85. do
86. dive
87. zipper
88. lawyer
89. think
90. seven
91. cough
92. python
93. duck
94. nail
95. van
96. yahoo
97. Matthew
98. pay
99. walk
100. shower
101. rain
102. yes
103. feather
104. ride
105. tall
106. nothing
107. vote
108. you
109. wait
110. read
111. long
112. those
113. use
114. monkey
115. valley
116. kayak
117. tack
118. knee
119. bed
120. that

121. join
122. thing
123. doughnut
124. kiss
125. bathe
126. this
127. booth
128. live
129. south
130. heavy
131. happy
132. toothache
133. rethink
134. review
135. rewash
136. rebuy
137. recharge
138. refill
139. reread
140. rezip
141. rejoin
142. repay
143. renail
144. resing
145. remail
146. rehide
147. retack
148. recut
149. reship
150. relive
151. regain
152. redo
153. gauges
154. bridges
155. noses
156. pages
157. matches
158. taller
159. smoother
160. eating
161. rubbing
162. going
163. showing
164. charging
165. pushing
166. wishing
167. fanning
168. singing
169. diving
170. quacking
171. riding
172. blooming
173. pitching
174. reading
175. growing
176. shipping
177. closing
178. coughing
179. walking
180. robbing
181. chopping
182. coming
183. watching
184. chasing
185. throwing
186. crashing
187. grabbing
188. shaving
189. breathing
190. mailing
191. dragging
192. washing
193. driving
194. hiding
195. sneezing
196. bathing
197. kissing
198. hopping
199. sniffing
200. sobbing
201. dressing
202. waiting
203. catching
204. voting
205. hugging
206. zooming
207. reaching
208. cutting
209. stirring
210. laughing
211. gushing
212. using
213. bossy
214. mommy
215. piggy
216. foggy
217. funny
218. scary
219. rainy
220. froggy
221. ducky
222. dolly
223. drive
224. frog
225. sniff
226. breathe
227. close
228. scare
229. playhouse
230. strawberry
231. dress
232. bloom
233. stir
234. sneeze
235. glove
236. quack
237. tweed
238. crash
239. grab
240. cloth
241. sweater
242. drag
243. bridge
244. sleeve
245. smooth

VITA

TRACY A. FORD

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