DEVELOPMENT AND VALIDATION OF KANNADA APRAXIA OF SPEECH AND NONVERBAL ORAL APRAXIA SCREENING TOOL (K-ASNAST)

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Register Number: P01II24S123035

A Dissertation Submitted in Part Fulfillment for the Degree of Master of Science (Speech - Language Pathology)

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JUNE - 2026

CERTIFICATE

This is to certify that this dissertation entitled **"Development and Validation of the Kannada Apraxia of Speech and Nonverbal Oral Apraxia Screening Tool (K-ASNAST)"** is a bonafide work submitted as part of fulfilment of the degree of Master of Science Speech Language Pathology of the student with Registration Number P01II24S123035. This has been carried out under the guidance of a faculty of this institute and has not been submitted earlier to any other university for the award of any other Diploma or Degree.

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CERTIFICATE

This is to certify that this dissertation entitled **"Development and Validation of the Kannada Apraxia of Speech and Nonverbal Oral Apraxia Screening Tool (K-ASNAST)"** has been prepared under my supervision and guidance. It is also being certified that this dissertation has not been submitted earlier to any other university for the award of any other Diploma or Degree.

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DECLARATION

This is to certify that this dissertation entitled **"Development and Validation of the Kannada Apraxia of Speech and Nonverbal Oral Apraxia Screening Tool (K-ASNAST)"** is the result of my own study under the guidance of Dr. Mahesh B V M., Assistant Professor in Speech Pathology, All India Institute of Speech and Hearing, Mysuru and has not been submitted earlier to any other university for the award of any other Diploma or Degree.

Mysuru
June, 2026

Registration no. P01II24S123035

Acknowledgement

Appa and Amma, you are my biggest support; I love you so much. You have enlightened me with all you good learnings and support and always asked me to choose the right path, I am so great full for the person I am today, it is all because your prayers, love, and support. My heart feels so blessed to be you daughter, I Thank God for your love every day.

Bharath and Bhoomika, my little ones, I love you guys!

I would like to express my gratitude for my guide, **Dr. Mahesh sir,** under whose guidance and mentorship I have learnt a lot and working under you felt very comfortable sir.

Nithya, my girl, my best friend, my all-time person to relay upon. My life is too close with very little people and you are one of the biggest parts of it, you have always been there for me, our outings and endless yapping has been like therapy to me, so lucky to have a good soul like you. I love you!!

Kavya, we will be completing 10years of friendship this year and you are the sweetest friend and have always been a greatest support in this journey. I feel like home whenever I am with you.

Amal, you have been one of the biggest parts of my master's journey, thank you for everything!

Rashmi, the person who trusts me more than myself, you have always been full of positiveness and encouraged me in this journey, thank you so much for everything.

Ganesh, thank you for helping me throughout masters!

Yashika, Gupta ji! My cheerleader… Girl us being so far from each other, yet nothing has changed between us, our friendship has grown stronger over time, thank you for your kind words and encouragement.

Preethi, thank you for being there and helping me with my dissertation!

My friends **Namrata, Tristan, Ajith, Pranjal, Eshvar, and Himanshu,** thank you for being there and motivating me throughout!

Prakruthi mam, thank you for your support and helping me complete my dissertation work!

Neeraja, my dissertation partner, you have always kept this journey happy and supportive, thank you da!

Kavana, thank you for helping me with case files for my dissertation!

Finally, I would like to **thank myself** for completing this, my heart is full of gratitude while writing this, Thank you!!

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LIST OF FREQUENTLY USED ABBREVIATIONS

AMR- Alternating Motion Rate (AMR)

AOS- Apraxia of Speech

CV- Consonant Vowel syllable

DYS- Dysarthria

HF- High frequency

K-ASNAST- Kannada Apraxia of Speech and Nonverbal Oral Apraxia Screening Tool

LF- Low frequency

LMBF- Log Mean Biphone Frequency

NVOA- Non-verbal Oral Apraxia

NW- Neuromuscular weakness

ODDK- Oral Diadochokinesis

PND- Phonological Neighbourhood Density

SGC- Stoel-gammon Complexity

SMR- Sequential Motion Rate (SMR)

TA- Typical adults

Chapter 1

Introduction

Motor Speech Disorders (MSDs) are speech disorders that are caused due to neurological impairments affecting the planning, programming, control, or execution of speech, including both the dysarthria and apraxia of speech (Duffy, 2013). Apraxia of Speech can be understood as impairment in the capacity to execute voluntary, acquired motor movements as a result of brain damage, in the absence of any underlying motor deficits (Knollman-Porter, 2008). Prevalence study conducted in Mayo clinic reported 6.9% of apraxia of speech (AOS) cases of all motor speech disorders (Duffy, 2013) and 4.7% of all MSD cases in adults, (Duffy, 2020). This recent study also reports that the prevalence of AOS maybe slightly higher when it is associated with dysarthria and aphasia. A follow-up analysis of 202 individuals primarily diagnosed with apraxia shed light on the etiological distribution underlying the condition. Degenerative causes accounted for the majority at 61%, followed by vascular lesions at 25%. The remaining cases were attributed to tumors (5%), trauma (4%), and other miscellaneous causes (5%).

A handful of recent studies have reported the incidence and prevalence of AOS. Ziegler et al. (2022) reported AOS in individuals with chronic aphasia following stroke in 156 patients using auditory perceptual analysis. A prevalence rate of 0.44% was seen, but this distribution dropped to 0.35% only when moderate and severe cases were considered. Oral apraxia and dysarthria incidence were reported to be 30% and 61%, respectively, among 100 patients who received the diagnosis of acute stroke in Tehran (Ghoreyshi et al., 2022). A recent study by Moghimi et al. (2024) reported the distribution of oral apraxia and verbal apraxia to be 35.7% 5 and 2.3%, respectively. Both oral and verbal apraxia were co-present for a rate of 4.7% as per the study. Clinically, stroke (25%) is the common cause for AOS; however, neurodegenerative etiologies such as primary progressive apraxia of speech (PPAOS), progressive supranuclear palsy, corticobasal degeneration, and other conditions account for 61% of all AOS in adults (Duffy, 2013).

The diagnosis of AOS relies on the identification of specific clinical features; however, there remains ongoing debate within the field regarding precisely which symptoms should be considered definitive. Among the traditionally recognized and well-established features are articulatory groping and searching behaviours, difficulty initiating speech, and a dissociation between voluntary and involuntary actions. Individuals with AOS demonstrate characteristics such as relatively preserved performance on automatic and involuntary speech tasks, while experiencing notable difficulty when attempting to produce the same actions on a voluntary or purposeful basis. A frequently cited illustration of this is the individual who is unable to perform tasks on command such as licking their lips, yet performs the similar movement effortlessly and automatically during eating or drinking. Additional hallmark features of the disorder include errors at the phonemic level, specifically omissions, substitutions, distortions, and additions of speech sounds, as well as difficulties in correctly sequencing those sounds in the intended order (Code, 2021). In a study by McNeil et al. (2009) reported that the two core symptoms are lengthened segment durations and lengthened intersegment durations, while suggesting that groping and searching are not differential symptoms.

Diagnosing AOS accurately has been a clinical challenge since long, and the stakes are high. The process of assessment, description, and diagnosis of AOS are complicated because of several overlapping factors, evolving understanding of its core features, and its co-occurrence with the other disorders, perceived challenges in subjectivity of perceptual judgements, and lack od standardized, formal metrics to describe it. Hurst (as cited in DePietro, 2024) stated that individuals with apraxia of speech (AOS) are frequently misdiagnosed in hospital settings as having aphasia, and this incorrect label tends to often persist them throughout their care, affecting the treatment they receive and the progress they make. Therefore, there is a need for a reliable and valid tool. While perceptual judgements remain the gold standard for diagnosis, there is a demand for a quantifiable measure that can distinguish AOS from aphasia and dysarthria, given the overlapping features among the disorders (Duffy, 2023).

In a study conducted by Haley (2012), made three pivotal recommendations for improving the diagnostic practices. First, she called for more transparency, including the explicit documentation of diagnostic protocols, clinical training procedures, and inter-observer reliability estimates. Second, she argued for the value of including operationally defined quantitative measures of speech characteristics in clinical and research reports to permit independent evaluation of diagnostic validity. Third, she suggested that we move toward empirical, data-driven ways to group individuals based on direct speech measures rather than relying on impressionistic diagnostic categories, as this approach could lead to a more systematic and nuanced understanding of motor speech profiles.

To advance the clinical diagnosis of AOS, more rigorous and systematically designed research framework is required. Specifically, there is a need for studies that evaluate the diagnostic accuracy of multiple potential markers simultaneously, rather than examining single features in isolation. Additionally, future research should make greater use of speech-disordered control groups to improve the specificity of diagnostic findings (Allison, 2020).

1.1 Need of the study

Need for the Study The only commercially available to tool to assess AOS in adults is Apraxia battery for adults- Second edition (ABA-2) given by Dabul (2000). ABA-2 is a diagnostic test and it takes anywhere between 30-45 minutes to completely assess an individual suspected with AOS. The intra-judge, inter-judge and test-retest reliability is not clearly reported for ABA-2. ABA-2 is developed for English speaking population and requires extensive adaptation across various subtests, if it needs to be useful for other languages, given it was normed two decades back. The Apraxia of Speech Rating Scale (ASRS) by Strand et al., (2014) that uses a checklist with a 5-point scale across phonetic, prosodic, and other aspects of speech motor control (e.g., DDK and fluency related errors) seems promising, however this also needs adaptation to other languages for it to become clinically useful.

In the Indian context, a protocol was developed by Maria (2001), to identify Apraxia of speech in Individuals with Broca's aphasics. The developed protocol was administered on limited samples (n =5), who were suspected to have AOS. Apart from documenting the praxis errors across five individuals with suspected AOS secondary only to Broca's Aphasia, no other psychometric measures (e.g., content validity ratio, inter-intra judge reliability, discriminant validity) were reported. Currently, at AIISH, AOS and non-verbal oral apraxia (NVOA) in adults are tested using informal measures coupled with perceptual judgement of the salient clinical features largely dependent on the clinicians' knowledge. Therefore, developing a screening tool to flag the presence of AOS along with NVOA, as there is moderate positive correlation between the two (Whiteside et al., 2015), will help clinicians to accurately identify the disorder. This will also enhance the inter and intra rater judgement and helps in consistent identification of oral praxis and verbal praxis errors in adults with NVOA and AOS.

1.2 Aim and Objectives of the study

The primary aim of the study is to develop and validate a screening tool for Apraxia of Speech and Nonverbal oral Apraxia in Kannada speaking adults.

The specific objectives are:

1. To develop a screening tool to assess Apraxia of Speech and Non-verbal Oral Apraxia in Kannada speaking adults with suspected AOS and NVOA.

2. To establish content validity for the developed screening tool on individuals with suspected AOS and NVOA.
3. To determine the inter and intra rater reliability of the screening tool across individuals with suspected AOS and NVOA, individuals with dysarthria and typical adults.
4. To determine the discriminant validity of the screening tool by comparing performance across individuals with suspected AOS and NVOA, individuals with dysarthria, and typical adults.

Chapter 2

Review of Literature

Definitions and Conceptual Foundations of Adult Apraxia of Speech

Adult Apraxia of Speech is consistently defined across the literature as a motor speech disorder affecting the planning and programming of speech movements. Gorno-Tempini et al. (2004) defined AOS as a disorder of speech motor control that compromises the planning of sensorimotor sequences essential for voluntary speech, characterized by apraxic errors including initiation difficulty, sound substitutions, omissions, transpositions, slow rate, and inappropriate stops/starts. Motor programming nature of the disorder is being emphasized by this definition, differentiating it from linguistic deficits associated with aphasia and dysarthria which is characterized by neuromuscular weakness

Itoh (1990) provided a more anatomically based definition, describing AOS as a disorder distinctively characterized by impairments in both speech production and prosody, arising from damage to Broca's area or the adjacent regions of the left cerebral hemisphere. The localization of AOS to specific brain regions highlighted by the neuroanatomical perspective, particularly the left precentral gyrus of the insula, lateral premotor cortex, supplementary motor area, and their white matter substrates has been associated with apraxia of speech in neuroimaging studies (Croot et al., 2025; Gorno-Tempini, 2004). AOS is a sensorimotor speech disorder that occurs due to a sensorimotor impairment that is evident in segmental production errors and irregular prosodic patterns (Croot et al., 2025).

AOS is a complex disorder involving a broad spectrum of disturbances affecting the segmental and prosodic features of speech production not due to muscle weakness but due to CNS programming inhibition (Kent & Rosenbek, 1983). This definition distinguishes AOS from dysarthria and emphasizes the impairment in programming of central nervous system rather than peripheral motor execution.

Recent perspectives on apraxia of speech (AOS) highlight a marked shift in understanding. Botha et al. (2019) characterize primary progressive apraxia of speech (PPAOS) as a distinct neurodegenerative disorder that selectively impairs the planning and programming of speech movements. Unlike acquired forms, PPAOS emerges gradually, with an insidious onset that evolves into steadily worsening speech deterioration. In these instances, AOS presents as the central and defining feature of the clinical presentation. This perspective is important as it recognizes AOS not only as a consequence of cerebrovascular events such as stroke, but also as a disorder that can itself serve as the primary indication of an underlying neurodegenerative process.

From the phonological perspective AOS can be viewed as disorders due to motor programming, in which the non-speech-specific deficit is seen in the preprograming stage of motor programming, sequencing and movement initiation appear to remain intact (Maas, 2011). This finding is important as it suggests that nonspeech oral motor tasks may provide valuable diagnostic information.

To summarize the understanding of these definitions, AOS is a motor speech disorder and not a linguistic or neuromuscular disorder that affects both planning and programming of speech movements and results from central nervous system damage, especially to left hemisphere structures. It presents both segmental (articulatory) and suprasegmental (prosodic) abnormalities and can occur in isolation or with aphasia and dysarthria (Duffy, 2006; Knollman-Porter, 2008; Peach, 2004). Although the errors re variable, they are consistent with a word location, thus helping in targeted intervention (Scholl et al., 2018).

Clinical Characteristics and Diagnostic Features

AOS can be distinguished from aphasia and other motor speech disorder as this disorder presents with a distinct cluster of perceptual characteristics. A thorough understanding of these defining features is fundamental to the development of reliable and effective tools for both screening and clinical diagnosis.

Segmental Features

The hallmarks features of AOS are significantly reduced speaking rate, disrupted prosodic patterns, and a range of articulatory errors including distorted sound substitutions, additions, repetitions, and prolongations with visible groping behaviours and trial-and-error attempts at articulation, reflecting the underlying impairment in speech motor planning and programming (Josephs, 2006), however, these features are particularly evident in motorically complex utterances and multisyllabic words (Gorno-Tempini, 2004). The phonetic errors, specifically distortions, are characteristic of AOS (Bislick et al., 2017), however, diagnosing AOS based solely on distortions is not recommended.

Acoustically, AOS presents with a slowed speech rate, limited variation in vocal intensity, imprecise or sluggish articulatory movements, difficulties with voicing timing and initiating speech, and errors in selecting and sequencing segments (Kent & Rosenbek, 1983). These acoustic features provide objective correlates that can be quantified and correlated with perceptual features during assessment.

Prosodic Features

Prosodic disruptions are fundamental to acquired apraxia of speech (AOS), typically seen as slowed rate of speech, separating syllables in speech, and atypical placement of stress. Haley et al. (2023) described apraxia of speech (AOS) as a complex syndrome involving both articulatory deficits and disruptions in the rhythmic organization of speech. They identified three principal markers: the rate of phonemic errors, the rate of distortion errors, and the duration of syllables within words. Of these, syllable timing serves as a particularly important indicator of prosodic disturbance. In AOS, prosodic disturbances are characterized as difficulties with the coordination of the timing and sequencing of articulatory movements. In this case, the disturbance leads to a speech pattern that is slow and laborious, as well as characterized by the presence of pauses and stress placement errors (Josephs et al., 2006; Ogar et al., 2005).

Variability and Consistency

A controversial aspect of AOS is the consistency of speech errors. Bislick et al. (2017) found that AOS is not differentiated by relatively consistent errors. Their study revealed that individuals with AOS and Aphasia showed greater variability in error type during blocked presentation, but error consistency was not influenced by error rate, severity, or stimulus presentation. Shuster et al. (2008) found variable consistency depending on how errors were elicited. This complexity in defining and measuring error variability challenges the assessment and differential diagnosis of AOS from dysarthria.

Word Length Effect

Error rates increase with utterance length and complexity, and AOS is marked by inconsistent attempts to self-correct inaccurate utterances. This founded the word length effect as a characteristic diagnostic feature of AOS (Darley, et al., 1975). One of the earliest controlled demonstrations of the length effect in AOS with minimal Aphasic involvement, was the higher difficulty in producing three-syllable words compared to monosyllabic words.

The increasing word length effect is a well-documented in AOS, with poor performance as syllable complexity increases. Nor et al. (2022) found that false starts, lexical stress errors and incorrect syllables increased with increase in word length in AOS.

This finding supports the use of multisyllabic word production tasks in AOS assessment.

Word Complexity Effect

Ziegler (2005) suggests that errors are not only because of the length of the word but also with the demands placed on the phonetic structure of that word i.e., complexity.Words with a greater number of structurally complex units that requires independent programming are more likely to elicit errors, regardless of their overall length, indicating that four-syllables-word arranged in a predictable syllabic pattern may actually be produced with comparatively fewer errors, as its metrical structure supports consistent speech motor planning. On the other hand, a short word with peculiar stress patterns or difficult consonant clusters within the initial part of the syllables may actually prove difficult to pronounce because of the excessive phonetic encoding required, irrespective of the length of the word.

Groping and Initiation Difficulties

Another major feature of AOS is visible or audible groping and difficulty initiating speech. Jonkers et al. (2017) identified groping and initiation problems as two of the eight distinctive signs for diagnosing AOS. These difficulties reflect an awareness of the motor programming difficulty and their attempts to achieve correct articulatory configurations. Towne and Crary (1988) measured the reaction time and correlated with muscle activity using electromyographic (EMG). It was reported that is the initiation difficulty was specifically localized to the motor planning phase rather than the execution phase, thus suggesting a direct link to the observable difficulties in speech initiation to pre-articulatory programming impairment. One of the probable reasons for this might be that these individuals have longer premotor preparatory time as against typical speakers.

Differential Diagnostic Features

Certain features are of importance when differentiating AOS from Aphasia and

Dysarthria, such as the motor planning and programming nature of AOS versus the linguistic deficits in aphasia and neuromuscular weakness in dysarthria (Peach, 2004). However, the frequent co-occurrence of these disorders complicates differential diagnosis, particularly in stroke populations (Basilakos, 2018). In addition to speech measures, objectives findings on neuroimaging to determine the site of lesion are some of the other aspects to improve differential diagnosis (Allison et al., 2020).

Perceptual studies also provide an understanding for differentially diagnosing AOS. AOS is commonly associated with consonant distortions and distorted substitutions, distinguishing it from the categorical phoneme substitutions typical of phonemic paraphasia in aphasia (Odell et al., 1990, 1991). Previous studies suggest that individuals with AOS demonstrate more frequent errors on fricatives compared with stops, clusters compared with singletons, trisyllabic compared with monosyllabic words, and word onsets compared with other locations within a word. These findings help establish error type and error locus as key differential diagnostic markers.

According to Duffy (2013, 2020), AOS can be differentially diagnosed from dysarthria based on the following: speech task, where automatic speech like counting is distinctly more normal than regular speech; speech subsystem, where speech difficulties are restricted to articulation and prosody with no evidence of abnormal phonation or hypernasality; word structure (complexity), where the person has considerable difficulties repeating complex and meaningless syllable sequences like "puh-tuh-kuh"; oral mechanism exam, which shows no evidence of muscle weakness; type of error, where distortion types are diverse and variable rather than uniform and consistent; and repeated trials, where sound errors are often corrected, sometimes with repeated attempts.

Existing Speech Assessment Tools

Screening Instruments

The aim of any screening tool is to provide rapid identification of the disorder, typically using a subset of tasks that capture the most diagnostic features. However, the literature reveals a relative scarcity of validated screening instruments specifically designed for AOS.

Dey et al. (2025) developed Screening Checklist for Adults with Apraxia of Speech. The checklist consists of 12 items across 3 domains (articulation, rate and prosody). Scored as one if the behaviour is present and zero if it is absent. The findings indicate that the AOS group exhibited increased errors with word length and spontaneous speech than volitional speech, followed by articulatory groping and false starts. While this represents an important contribution, lack of detailed comparative analysis with other motor speech disorders was a significant limitation of the study.

The Quick Assessment of Apraxia of Speech (QAAS) (Tanner & Culbertson,1999) is a screening tool developed for adolescents and adults. It compares non-speech oral tasks with voluntary speech tasks that increase in difficulty on a five-point Likert scale. Tavares (2015) validated QAAS for European Portuguese and found that the QAAS demonstrated good reliability (Cronbach's alpha = 0.99) and showed moderate positive correlation (r=0.469) between QAAS and EQ-5D (EuroQol) scores, indicating praxic difficulties negatively influence quality of life.

Jonkers et al. (2017) developed the Diagnostic Instrument for Apraxia of Speech (DIAS) in the Netherlands, which assesses eight specific signs of AOS including primary and secondary signs such as inconsistency of errors, more errors in consonants than vowels, greater difficulty with alternating DDK, visible or audible groping, initiation problems, syllable segmentation, cluster segmentation, and articulatory complexity effect. The study found that a differential diagnosis of AOS could be made in 88% of cases using a minimum of three out of these eight specific signs. It was concluded that the presence of at least 3 of the 8 signs is sufficient to differentially diagnose AOS from aphasia and dysarthria in most cases.

Costa et al. (2024) developed an assessment protocol for acquired apraxia of speech (AOS) in Brazilian Portuguese speakers, addressing the lack of linguistically controlled tools for this population. The final protocol consists of five components — a Repetition Task (88 words), a Reading Aloud Task (88 words), spontaneous speech via open-ended questions, a picture description task, and diadochokinetic rates (/pa/, /ta/, /ka/, /pataka/).

Comprehensive Diagnostic Tools

The Apraxia of Speech Rating Scale (ASRS) by Starnd et al., (2014) is a widely used standardized assessment for AOS. The ASRS is a 16-item tool with a five-point Likert scale (0 = absent or never observed, 4 = always evident and severe). It measures presence, frequency, and severity of specific characteristics associated with AOS and differentiate it from Dysarthria and Aphasia. A total score of eight indicates AOS.

The ARSS-3.5 (Duffy et al., 2023) is a 13-item tool that measures specific phonetic and prosodic features. It uses a five-point Likert scale (0 = not observed in any task and 4 = predominant or pervasive), higher the total score more severe the motor speech characteristics. Further validity studies have validated the ASRS's psychometric properties and established its excellent diagnostic sensitivity and specificity in AOS, where total scores under 7 and above 10 showed good sensitivity and specificity, respectively.

The apraxia battery for adults (ABA-2) proved sensitive and specific, effectively discriminating between normal subjects and apraxic patients. Maas (2006) utilized the ABA-2 as a classification tool in conjunction with aphasia batteries such as the Boston Diagnostic Aphasia Examination (BDAE) and Western Aphasia Battery (WAB). The fact that AOS co-occurs with Aphasia, requiring a thorough evaluation of both domains, is reflected in this multi-instrument approach.

Task-Based Assessment Approaches

Apart from these standarised tools, task-based approaches are also used for AOS assessment. These tasks can be conversational or narrative speech and writing samples, sentence repetition, and focused speech examination, including speech alternating motion rates, repetition of graded-in-complexity words, and nonverbal oral praxis assessment (Botha et al., 2019).

The most commonly used task to assess is the word of increasing length (WIL), a subtest in ABA. This task uses a three-point rating to score word accuracy. However, this task has limitations, such as penalising patients for multiple error types at once, thereby reducing specificity (Md Nor et al., 2022). Some authors prefer combining perceptual, acoustic, and physiological assessments to identify speech deviations, gain an understanding of the underlying causes and abnormalities (Ballard et al., 2002). The use of this multi-faceted analysis technique offers additional data on the characterization of AOS. Haley et al. (2023) suggested to use multiple syllables in succession which is hard even for a person with mild AOS.

Haley et al. (2021) investigated whether error consistency can reliably distinguish apraxia of speech (AOS) from phonemic paraphasia in aphasia. 171 speakers with aphasia were asked to repeat four multisyllabic words five times each. Their findings revealed that error frequency was a strong predictor, and consistency errors in AOS were either similar to or lower than those in the aphasia-only group, suggesting that apraxics and aphasics often produce inconsistent errors during a repetition task.

Existing Nonspeech Assessment Task

The role of nonspeech tasks in AOS assessment has been widely investigated for its implications in understanding the nature of the disorder and for differential diagnosis. Research has shown that AOS exhibits motor programming deficits in both speech and non-speech movements. Studies have included visuomotor tracking and oral-motor assessment to evaluate fine isometric force and static position control, and have reported impairment, thus supporting the notion (Maas, 2006). Some authors have included them in comprehensive assessments to examine the ability to perform volitional oral movements on command, such as tongue protrusion, lip rounding, and sequential oral movements (Botha et al., 2019). DDK is another method for assessing nonspeech movements and is used as core test in many comprehensive assessment tools (Jonkers, 2017) as it requires rapid repetition of syllables (e.g., /pa/, /ta/, /ka/) and syllable sequences (e.g., /pataka/), assessing the speed and accuracy of articulatory movements. These tasks are sensitive to motor programming deficits and can help differentiate AOS from other speech disorders.

The specificity of using these non-speech tasks remains debated. They are not a predictor of the disorder, although they reveal the disorder's motor programming defect and must be interpreted in conjunction with speech-based assessments (Peach, 2004).

Pitfalls and Limitations of Current Assessment Tools

Reliability and Validity

Even with advances in AOS assessment, issues with its reliability and validity persist. Haley et al. (2012) highlight the need for efficient training and calibration processes as scaling methodologies alone cannot be expected to provide adequate dependability. They emphasize that to obtain adequate reliability, even well-designed perceptual rating scales require extensive rater training.

Numerous studies have evaluated the reliability and validity of the assessment tools. Wambaugh et al. (2019) investigated ASRS 3.0 and reported that the total ASRS 3.0 score is considered a reliable indicator of the prevalence of apraxia of speech features.

Most features exhibited good to acceptable ratings; however, the authors suggest further refinement of procedures for defining and rating individual features to improve inter-rater reliability.

Jonkers et al. (2017) found that while most signs in the DIAS showed strong inter- and intra-rater reliability, articulatory complexity had poor test-retest reliability. This variability in reliability across different features underscores the challenge of achieving consistent measurement across all aspects of AOS.

Differential Diagnosis Challenges

AOS, Childhood Apraxia of Speech (CAS), Aphasia, and Dysarthria share overlapping characteristics that make them challenging to differentiate. Most often, AOS co-occurs with Aphasia and Dysarthria, particularly in the post-stroke recovery period and differentiating them perceptually is challenging (Basilakos, 2018). Pernon (2024) also reports that a differential diagnosis by perceptual evaluation for mild severities is not suitable and notes a lack of international consensus on the main diagnostic criteria for Apraxia of Speech (AOS).

A scoping review by Allison et al. (2020) suggests that clinicians use a set of criteria to differentiate AOS from CAS; to select appropriate speech tasks, such as multisyllabic stimuli and contrastive stress patterns, as these stimuli result in greater diagnostic accuracy; and to use quantitative measures, such as pause marker, pairwise variability indices, and neuroimaging as a means to support diagnosis. Haley et al. (2023) emphasize that AOS and Aphasia with phonemic paraphasia (APP) pose a challenge to differentiate, as phonemic errors are common in both these disorders. They can be differentiated by evaluating motor-specific dimensions, such as lengthened phonemes, syllable segmentation, and disrupted stress contrast.

Cultural and Linguistic Limitations

Another limitation to these assessment tools is their lack of cross-linguistic validation and cultural adaptation. A scoping review by Wong et al. (2023) highlights this gap and the lack of a reliable and valid test or method for diagnosing Apraxia of Speech (AOS) in Chinese speakers. As a result, clinicians must rely on subjective judgment, creating a significant diagnostic barrier for non-English populations.

Allie et al. (2024) argue that adapting a test to a given language is inadequate, as each language has unique linguistic features that need to be assessed and altering the scoring renders the tool invalid and unreliable. Consequently, they developed an assessment tool in the isiXhosa language (South African language) in which complexity is added by the first consonant rather than by the initial phoneme.

Kripanan et al. (2022) adapted and validated the ASRS in Thai. The results show 100% sensitivity and 86.7% specificity at a cut-off score of 16 for identifying AOS. The German adaptation of the S-PRAX (Screening tool for Apraxia of Speech) screening tool (Spath, 2024) showed comparable sensitivity and specificity to the HWL-Kompakt ("Hierarchische Wortlisten – Kompakt" Hierarchical Word Lists – Compact Version). The authors note that the screening requires further optimization for predictive power and reasonability, and validation on a larger sample.

Tavares's validation of the QAAS for European Portuguese found good reliability (Cronbach's alpha = 0.99). The study revealed a moderate positive correlation (r=0.469) between QAAS and EQ-5D scores, indicating praxic difficulties negatively influence quality of life. However, a limitation noted is the absence of test-retest reliability due to practical constraints (Tavares, 2015).

Standardization and Clinical Utility

A survey of French-speaking clinicians revealed a lack of standardization in adult speech disorder assessment, with clinicians often using non-standardized methods and many not utilizing existing assessment batteries fully (Pommée et al., 2022). This lack of standardization reflects broader issues with the clinical utility and accessibility of existing tools. The authors note that available tools are considered only moderately satisfactory due to issues like exhaustiveness, practicality, and consideration of specific speech parameters. There is a need for new, reliable, and standardized tools, including acoustic measures, to optimize assessment".

Recent Studies on Newly Developed Assessment Tools

The Apraxia of Speech Rating Scale (ASRS)

ASRS is the latest achievement in the area of AOS tests. Several versions of the test have already been created, where ASRS 3.5 exhibits better psychometric characteristics. Mailend et al. (2025) have improved ASRS in regard to operational definitions, inter-rater reliability, and scoring instructions.

Computer-Mediated Approaches and Telehealth Assessment

Quantitative approaches to AOS assessment have been employed recently moving beyond purely perceptual evaluation.

There have been studies into whether AOS can be assessed using telehealth. The feasibility of assessing acquired apraxia of speech through telehealth is well established by Cherney et al. (2012). The findings of his study show that telerehabilitation assessments of acquired apraxia of speech are not only feasible but also reliable, as there were no statistical differences in the scores for each subtest of the Apraxia Battery for Adults-2 (ABA-2). In addition, the respondents expressed high satisfaction with being assessed through the telerehabilitation method. Nevertheless, there was some difficulty encountered during the process by SLPs in assessing severe cases of apraxia of speech using this method.

In addition, testing of AOS may use computer-based methods through telehealth mode. Haley et al. (2011) designed computerized tests for single-word intelligibility having reliable re-test and inter-listener reliability and validity with the use of motor speech and phonetic transcriptions. With the help of pre-recorded models, the test can be conducted in a standard manner.Studies have shown that Support Vector Machines (SVM) models can correctly differentiate between normal speech, dysarthria, and AOS. The SVM is more efficient than perceptual assessment carried out by certified speech pathologists, which makes it possible to use these models clinically (Kodrasi et al., 2021).

Cross-Linguistic Adaptations

Adapting and validating AOS assessment tools for non-English languages has been focused on recently. A validation of the ASRS-Thai represents a significant contribution, demonstrating 100% sensitivity and 86.7% specificity at a cut-off score of 16 (Kripanan et al., 2022). The ASRS-Thai showed moderate-to-strong negative correlations with the Apraxia Test for Thai Adults (ATTA), showing concurrent validity and excellent reliability, with intra-rater ICCs (Intraclass Correlation Coefficient) ranging from 0.96 to 0.976 and an inter-rater ICC of 0.927 for the total score.

Bangladeshi adaptation study of the Apraxia Battery for Adults-2 (ABA-2) for adults with apraxia of speech was done. It aimed to make the tool culturally and linguistically appropriate for Bangladesh and tested its reliability and validity in adult speakers aged 37–80 years. The study reported that the modified ABA-2 was culturally appropriate for Bangladeshi patients with apraxia. The authors found good to excellent internal consistency for several subtests (Ahmed et al., 2020).

Utilization of Existing Aphasia Battery

Nealon et al. (2024) explored whether WAB-R oral subtests stimuli would be useful in establishing features that differentiate between AOS and individuals who only have aphasia. The findings revealed differences in the production of total phonetic and prosodic errors between the two groups, as well as correlation between phonetic complexity and error production. According, to this study, WAB-R's oral language measures may serve as an appropriate part of AOS evaluation because of the frequent occurrence of AOS along with aphasia.

The use of existing and popular tests could make the process of AOS testing more convenient. There have been many developments in the creation of the screening and diagnostic test for adult AOS during the last two decades, with the creation of standard tests, especially the Apraxia of Speech Rating Scale, being the most important step. Such developments have improved the clarity, reliability, and usefulness of diagnosing adult apraxia of speech, but there is still there is a high need to develop tools to assess AOS. These prospective tests will help to refine the diagnostic criteria, linguistic cross-validation, differential diagnosis from other related conditions, and quantitative diagnosis of AOS.

Chapter 3

Method

This study aimed to develop and validate, Apraxia of Speech and Nonverbal Oral Apraxia Screening Tool in Kannada for adults.

3.1 Ethical Consideration

The research was conducted in accordance with the ethical guidelines for Bio-behavioural Sciences concerning human subjects established by the AIISH ethical committee (Basavaraj & Venkatesh, 2009). The ethical clearance certificate was approved on 11.03.2026. Participants were chosen, and their engagement adhered to all ethical standards. Participants were briefed about the study and its aims before the field testing, and their consent was obtained by having them sign a written consent form.

3.2 Screening Tool development, and Validation

The study was conducted in two phases.

PHASE 1: Development of the screening tool to assess Apraxia of Speech and Non-verbal Oral Apraxia.

There is no standardized screening tool available in Kannada to screen Apraxia of Speech and Nonverbal Oral Apraxia in adults. A protocol called "Protocol to Identify Apraxia of Speech in Broca's Aphasics" was developed by Maria (2001). The developed protocol was administered on limited samples (n =5), with the diagnosis of Broca's aphasia. Apart from documenting the praxis errors in five individuals with suspected AOS secondary only to Broca's Aphasia, no other psychometric measures (e.g., content validity ratio, inter-intra judge reliability, discriminant validity) were reported and no attempt was made to establish a quantitative cut-off score which aids in diagnostic conclusion because of the number of subjects considered.

The purpose of this study was to develop, validate, and administer these sub-sections of the test on individuals with Suspected AOS and NVOA.

The Sub-sections included in this study are as follows:

3.2.1 Oro-Motor Assessment

To assess oral structures at rest, four structures were included: the jaw, lips, tongue, and soft palate. Each structures were rated using a 3-point scale ranging from 0 to 2, where 0 indicated normal presentation and 2 indicated marked abnormality. In addition to the overall rating, each structure was further described across four dimensions: *position, muscle tone, structural signs, and any other observable features.*

a) Jaw

The jaw at rest was evaluated for symmetry, closure, deviation, and instability. The articulator jaw was evaluated on a 3-point scoring as given below

0 = Symmetrical alignment with adequate closure at rest

1 = Mild deviation and/or instability and,

2 = Marked abnormality, such as a fixed or hanging jaw.

Additional descriptors across other dimensions were added for qualitative analysis of the Jaw. This included (1) *Position* — any deviations from the midline alignment such as right or left deviation; (2) *Tone* — to be recorded as normal, reduced, or increased; (3) *Structural signs* — to be recorded if there is a presence of jaw tremor, or any involuntary movements; and (4) *Any Other* — this included additional clinical signs such as sensory tricks (clenching the teeth, holding a pipe in the mouth, touching a hand to the side of the jaw or neck). These descriptors have to be additionally rated, as applicable, by an SLP along with the 3-point scoring.

b) Lips

The lips at rest were evaluated for symmetry, closure, lip seal and drooping. The articulator lip was evaluated on a 3-point scoring as given below:

0 = Symmetrical appearance and adequate closure at rest;

1 = Mild asymmetry or drooping and/or partial closure, and

2 = Marked asymmetry or drooping and/or reduced lip seal.

Additional descriptors across other dimensions were added for qualitative analysis for the lips. This included: (1) *Position* — to be recorded in terms of drooping such as right droop, or left droop, and no drooping as applicable; (2) *Tone* — to be recorded as normal, reduced, or increased tone; (3) *Closure* — to be classified as adequate, partial, or poor lip seal; and (4) *Any Other* —this included additional signs such as flattening of the nasolabial folds, involuntary movements (such as lip smacking, pursing, or retraction), or tremors. Apart from rating the lips on a 3-point Likert scale, the SLP has to additionally rate these descriptors too.

c) Tongue

The tongue at rest was evaluated for symmetry, bulk, and the presence of abnormal movements. The articulator tongue was evaluated on a 3-point scoring as given below:

0 = Midline symmetry and typical bulk with no abnormal movements;

1 = Mild asymmetry or reduced bulk with slight abnormal movement and/or mild deviation and,

2 = Marked deviation and/or notable structural signs.

Additional descriptors were documented across four dimensions: *(1) Position*—Defined as midline, right deviation, or left deviation, as appropriate; *(2) Tone*—to be recorded as normal, diminished, or increased; (*3) Structural signs*—encompassing atrophy, fasciculations, instability (inability to maintain position on the floor of the mouth), or none; and (*4) Any Other*—additional noticed aspects were recorded.

d) Soft Palate

The soft palate at rest was evaluated for symmetry and drooping of the palatal arches. A score of 0 indicated symmetrical palatal arches; 1 indicated mild asymmetry and/or drooping; and 2 indicated marked asymmetry of the palatal arches and/or drooping. Additional descriptors were recorded across three areas: (1) *Position* — midline, right, or left drooping, as applicable; (2) *Structural signs* — encompassing palatal atrophy, palatal tremor, or none; and (3) *Other* — any additional features were documented if present. The maximum summed subsection score documented for this subsection is 8. The additional features or descriptors provided along with the 3-point Likert scale used in this section will hint at a plausible presence of dysarthria with or without AOS.

3.2.2 Non-Verbal Oral Praxis Assessment

Non-verbal oral apraxia (NVOA) refers to the impaired ability to volitionally plan, organise, and carry out oral motor movements, despite the absence of any underlying muscular weakness (Garcia-Guaqueta et al., 2024). However, in certain cases where dysarthria coexists with AOS, the deficits in the nonverbal oral movements of a dysarthric could mimic those of AOS. Therefore, to address this issue, a separate score for nonverbal oral movements affected by neuromuscular weakness (NW) was included in the rating. A set of 10 tasks involving the oral structures was formulated for this purpose.

Tasks were first administered on command; wherein clear verbal instructions were provided to the subject. If the subject was unable to perform a given movement on command, the examiner demonstrated the movement and the subject was asked to imitate it. Responses were scored using a 5-point scale ranging from 0 to 4 for Praxis errors. For each task, the clinician needs to rate both praxis errors as well as the errors due to neuromuscular weakness. In this way, it could be ascertained whether the performance on NVOA is due to praxis or neuromuscular issues. In cases where praxis impairment and neuromuscular weakness coexist, raters should attempt to judge whether movement failure primarily reflects impaired motor planning or impaired motor execution due to neuromuscular weakness. The maximum summed score documented for this subsection for praxis errors is 40 and for errors due to neuromuscular weakness is 40. It is important to note that only in this section do higher scores for either praxis errors or NW ratings signify normalcy; in all other sections, elevated ratings indicate abnormality in speech motor control.

Table 3.1

Description of Ratings for Praxis Errors in Nonverbal Oral Apraxia (NVOA)

Score	Description for Praxis Error
4	Correct response on command, immediate and accurate
3	Correct response on command after a delay (> 2 seconds) and/or with groping
2	Correct response on imitation, immediate and accurate
1	Correct response on imitation after a delay (> 2 seconds) and/or with groping
0	Incorrect response on both command and imitation

Table 3.2

Description of Ratings for Neuromuscular Weakness in Nonverbal Oral Apraxia (NVOA)

Score	Description for error due to Neuromuscular weakness (NW)
4	No weakness with typical range and speed of articulatory movement
3	Mild weakness with mildly restricted range/slightly reduced speed
2	Moderate weakness with moderately restricted range/noticeably slow speed
1	Severe weakness with severely restricted range/markedly slow speed
0	No response due to very severe weakness/no functional movement

Table 3.3 provides the test stimuli for the Non-Verbal Oral Praxis Assessment subsection.

Table 3.3

Test Stimuli for the Nonverbal Oral Apraxia (NVOA) Subsection

Sl. No.	Test Stimuli
1.	ನಿಮ್ಮ ಬಾಯಿಯನ್ನು ತೆಗೆಯಿರಿ
2.	ಕೆಮ್ಮಿ
3.	ನಿಮ್ಮ ಕೆನ್ನೆಗಳನ್ನು ಉಬ್ಬಿಸಿಕೊಳ್ಳಿ
4.	ನಿಮ್ಮ ತುಟಿಗಳಿಂದ 'ಊ' ಆಕರ ಮಾಡಿ
5.	ನಿಮ್ಮ ತುಟಿಗಳಿಂದ 'ಈ' ಆಕರ ಮಾಡಿ
6.	ನಿಮ್ಮ ನಾಲಿಗೆಯನ್ನು ಹೊರಗೆ ಚಾಚಿ
7.	ನಿಮ್ಮ ನಾಲಿಗೆಯನ್ನು ಮೇಲಕ್ಕೆತ್ತಿ
8.	ನಾಲಿಗೆಯನ್ನು ಬಾಯಿಯ ಎಡ ಮತ್ತು ಬಲ ಬದಿಗೆ ಮುಟ್ಟಿಸಿ
9.	ನಿಮ್ಮ ತುಟಿಗಳಿಂದ 'ಈ' ಆಕರ ಮಾಡಿ ನಂತರ ನಾಲಿಗೆಯನ್ನು ಮೇಲಕ್ಕೆತ್ತಿ
10.	ನಿಮ್ಮ ತುಟಿಗಳಿಂದ 'ಊ' ಆಕರ ಮಾಡಿ ನಂತರ ನಿಮ್ಮ ಬಾಯಿಯನ್ನು ತೆಗೆಯಿರಿ

3.2.3 Oral Diadochokinetic Rate (DDK)

Oral Diadochokinetic (ODDK) rate is considered one of the sensitive measures to detect AOS and is included in most AOS assessment protocols. A key clinical finding is the differential pattern of Alternating Motion Rate (AMR) and Sequential Motion Rate (SMR) performance between AOS and dysarthria. Traditionally, an overall poorer performance is noted for SMR compared to AMRs in AOS whereas characteristic AMR patterns exist in dysarthria depending on the type of neuropathology (Spasticity: slow but regular; Ataxia: slow but irregular; Hypokinetic: Fast and Regular etc). Additionally, poorer performance on SMR relative to AMR is also noted in AOS in comparison to ataxic dysarthria (Duffy, 2020).

This subsection comprised two parts, each targeting a distinct aspect of oral diadochokinesis.

Part A- Alternating Motion Rate (AMR)

The AMR task required participants to repeat the syllables /pə/, /tə/, and /kə/ as rapidly and accurately as possible. Response accuracy was rated on parameters of a) initiation, b) regularity, c) distortion, d) articulatory groping, e) substitution, and f) omission. The maximum summed score documented for AMR task for each item is 11.

Part B-Sequential Motion Rate (SMR)

The SMR task required participants to repeat the syllable sequence /pətəkə/ or /pətə:ki/ as rapidly and accurately as possible. Response accuracy was scored in terms of a) initiation, b) c) distortion, d) distorted substitution or addition, e) articulatory groping, f) syllable sequencing, g) syllable segmentation, h) substitution, and i) omission. For SMRs, either the stimuli /pətəkə/ or /pətə:ki/ is recommended, but not both. If the participant does not understand to repeat the nonsense sequence /pətəkə/ even after repeated instructions, the real word /pətə:ki/ could be instructed to repeat. In comparison to AMRs, SMRs were rated for distorted substitution or addition, articulatory groping, syllable sequencing, and syllable segmentation, as these errors have been reported, particularly for individuals with AOS, when they attempt to produce a non-repeating sequence of syllables. The maximum summed score documented for SMR task is 15 (for either /pətəkə/ or /pətə:ki/).

For both subsections, the clinician first demonstrated the target sequence for approximately two to three seconds. Participants were then instructed to produce each target twice, with each trial lasting five seconds and a short pause between trials, timed using a stopwatch. The total number of syllables produced in each trial was counted, and the highest oral DDK rate (syllables per second) across both trials for each stimulus target was recorded. In addition to scoring the errors for accuracy and documenting the speed of production of SMRs, consistency for each item across trials was also recorded.

3.2.4 Automatic Versus Propositional Speech

In adults with AOS, automatic speech-which refers to overlearned, highly practised speech (e.g., counting numbers, days of the week, months of a year, etc) is typically better preserved than propositional speech (Duffy, 2020). This dissociation between automatic and propositional speech serves as a clinically significant marker in the assessment of AOS. To examine this differential performance, this subsection was divided into part A (propositional speech) and part B (automatic speech).

To avoid any facilitatory effect of the automatic speech task on the propositional speech task, the propositional speech task was administered first, followed by the automatic speech task. For the propositional speech task, participants were asked to count backwards from 10 to 1, and for the automatic speech task, subjects were asked to count forwards from 1 to 10.

Performance on both tasks were rated on a 3-point scale (0–2) across eight parameters which include a) Initiation, b) Distortion, c) Distorted Substitution or Addition, d) Articulatory Groping, e) Syllable Sequencing, f) Syllable Segmentation, g) Substitution, and h) Omission. A score of 0 indicated typical performance, 1 indicated mild deficits, and 2 indicated marked deficits. The maximum summed score documented for this subsection for each automatic speech task and propositional speech task is 15.

3.2.5 Isolated Oral Movements for Speech

This subsection included a total of nine stimuli across two parts, with the first part consisting of vowels and the second part having consonants and a diphthong. The stimuli were selected based on the predominant involvement of the jaw, lips, and tongue in their production, ensuring representation of the primary oral articulators. The stimuli included in part A (Vowels) were /a/, /iː/, and /uː/ whereas in part B [Diphthongs and CV (Consonant-Vowel) Syllables] were /d̪a/, /ka/, /ʈa/, /pa/, /ma/, and /ai̯/.

Participants were instructed to imitate each sound immediately after the investigator model. Two trials were administered for each stimulus, and the trial reflecting the greater number of errors was retained for scoring. For part A, the performance accuracy was evaluated using a 3-point rating scale (0–2) on four parameters such as *initiation, articulatory groping, distortion, and substitution*. Part B included syllabic stimuli set, which was rated using the aforementioned anchors, along with the addition of *omission*.

A score of 0 indicated typical performance, 1 indicated a mild deficit, and 2 indicated a marked deficit. The maximum summed score documented for vowels is 21 and for Diphthongs and CV (Consonant-Vowel) Syllables is 54.

3.2.6 Syllable and Word Repetition Task

a) Syllable Repetition Task

The stimuli for this section were selected from a Kannada lexical database containing psycholinguistic data called KannadaLex (Aithal et al., 2024). This lexical database has published psycholinguistic data for the Kannada language that includes orthographic, phonologic, syllabic information, phonological neighborhood, bigram syllable frequency, and inflectional family information using magazines, newspapers and related reading materials of Kannada language and the psycholinguistic data was published for nearly 170 thousand words.

The syllable frequency data from this database was uploaded and sorted using Microsoft excel. The syllable that had highest and lowest frequency without any clusters were chosen. The stimuli selected were ಕೊ (/ko/) and ಟೇ (/ʈe/), where ಕೊ showed a syllable frequency of 34616 (hence high frequent) and ಟೇ had 528 (hence low frequent) respectively. Practice item for syllable repetition task was ಮ. The performance of the participants was assessed using 3-point rating ranging from 0 to 2 across six speech production accuracy parameters [*Initiation, Distortion, Distorted substitution/addition, Articulatory groping, Substitution, and Omission*]. The participants were given with two trials and the trial with more error was considered for scoring. The maximum summed score documented for the syllable repetition task is 22.

b) Word Repetition Task

For the word repetition task, the bisyllabic and trisyllabic words were chosen from the KannadaLex lexical database. The bisyllabic and trisyllabic words were part of a 1 lakh-word corpus that included words ranging from monosyllabic to 12-syllable words in the Kannada language. The parameters which were considered while selecting the words for this task were Phonological neighbourhood density (PND) and Biphone frequency. PND is defined in terms of number of words differing from a target word by one phoneme addition, deletion, or substitution. Based on this definition, a word can have denser neighbourhood or sparse neighbourhood. In case of a dense neighbourhood, the lexical competition could be high and vice versa for the sparse neighbourhood target.

Biphone frequency is the frequency with which a pair of adjacent phonemes (a biphone) occurs in a specific language. This is commonly derived using a lexical corpus. Words with high biphone frequency tend to occur more frequently in a language and consequently have stronger motoric practise and representations. In contrast, words with low biphone frequency challenges the speech motor planning or programming as these sound sequences will be less frequent in a given language.

In PND, *PND count* and in Biphone frequency, *Log Mean Biphone frequency* were specifically considered in the word selection.

Table 3.4 shows the descriptive statistical data used for selecting bisyllabic and trisyllabic words.

Table 3.4

Descriptive Statistics [Median and Interquartile Range] for Bisyllabic and Trisyllabic Words Across PND and Log Mean Biphone Frequency

Syllable length of Words	PND count (for Phonological Neighbourhood Density)			Log mean Biphone frequency		
	Median	Q1	Q3	Median	Q1	Q3
Bisyllabic	6	3	12	12.53	11.80	13.16
Trisyllabic	2	0	3	13.09	12.65	13.46

To control the word lists across bi and tri syllable lengths, PND counts and log mean biphone Frequency parameters were considered. Word lists across bi and tri syllable lengths that were ≥ Q3 and ≤ Q1 of PND count and log mean biphone frequency were sorted. Wordlists that were ≥ Q3 indicating *high probability* to have more phonological neighbours and words that had *high biphone frequency* (indicating frequent occurrence of two sounds in an adjacent manner) were listed. Similarly, words that were less than or equal to the first quartile i.e., ≤ Q1 that indicated the absence of high number of phonological neighbours and low adjacent occurrence of two phones in Kannada were also listed. Based on this data words were identified as given below in Table 3.5. Practice item for syllable repetition task was ಗಾಯ High PND and High Log mean Biphone frequency.

Table 3.5

Stimulus Words Used in the Word Repetition Task and Their Phonotactic Neighbourhood Density and Log Mean Biphone Frequency Characteristics

Sl. No.	Words	PND	Log Mean Biphone Frequency (LMBF)
Bisyllables			
1.	ನಟ	High PND	High LMBF
2.	ಪಾಚಿ	High PND	Low LMBF
3.	ಶರ್ಟು	Low PND	High LMBF
4.	ಬೀಜ	Low PND	Low LMBF
Trisyllables			
1.	ತಬಲ	High PND	High LMBF
2.	ಹುಡುಗಿ	High PND	Low LMBF
3.	ಕೇಸರಿ	Low PND	High LMBF
4.	ಚಪಾತಿ	Low PND	Low LMBF

The performance of the subjects was assessed using 3-point rating ranging from 0 to 2 across eight parameters such as *Initiation, Distortion, Distorted substitution/addition, articulatory groping, syllable sequencing, syllable segmentation, substitution, and omission*. The subjects were given with two trials and the trial with more error shall be considered for scoring. The maximum summed score documented for the word repetition task is 120.

3.2.7 Length and Complexity task

a) Length task

The stimulus for the Part A of this subsection was selected from a lexical database with psycholinguistic data in Kannada (Aithal et al., 2024). The words for this subsection were selected from 3 syllable word list based on its frequency of occurrence. The Q1 and Q3 value for the frequency of this data was obtained using the IBM SPSS Statistics, Version 26 software.

The Q1 value obtained was 13 and Q3 value obtained was 92, and words below Q1 was considered as low frequency words and above Q3 was considered as high frequency word. High and low frequency words were selected and the length was varied from the base word by increasing the number of syllables. Base word was of 3 syllable length and the subsequent length of the word was varied by adding +1 and +2 syllables to increase the length of the word. The length was varied in 2 ways, first by adding the syllables without any geminate to the base word the length was increased to obtain 4 and 5 syllable words, and then by adding a syllable to the base word without any geminate to obtain a 4 syllable word, and then a syllable with geminate was added to the previously developed 4 syllable word to obtain a 5syllable word. Practice item was added for the familiarization of the items and for the practice before the actual stimulus was provided. For the actual test items a total of 12 words were given.

Table 3.6

Psycholinguistic data on Word frequency for Length task

Words	Psycholinguistic data on Word Frequency
ಹಿರಿಯ	10600 (HF)
ಹೋರಾಡು	11 (LF)
ಹೆಸರು	6251 (HF)
ಎದಿರು	8 (LF)

The performance of the subjects was assessed using 3-point rating ranging from 0 to 2 across nine parameters such as *Initiation, Distortion, Distorted substitution/addition, articulatory groping, syllable sequencing, syllable segmentation, increased error with increased length, substitution, and omission*. The subjects were given with two trials and the trial with more error shall be considered for scoring. The maximum summed score documented for the length task is 204.

Table 3.7

Stimuli table for Length task

Sl. No.	Word frequency	3 (base)	4 (+1 syllable) (No geminate)	5 (+2 syllable) (With or without geminate)
1.	High frequency	ಹಿರಿಯ	ಹಿರಿಯರು	ಹಿರಿಯರಿಂದ
2.	Low frequency	ಹೋರಾಡು	ಹೋರಾಡುವ	ಹೋರಾಡುವುದು
3.	High frequency	ಹೆಸರು	ಹೆಸರಿನ	ಹೆಸರಿನಲ್ಲಿ
4.	Low frequency	ಎದಿರು	ಎದಿರಿಸು	ಎದಿರುಗೊಳ್ಳು

b) Complexity task

The stimulus for the Part B of this subsection was selected from the same lexical database used for word repetition and syllable length task (Aithal et al., 2024). A set of words were selected based on their frequency of occurrence within the 4- and 5-syllable word lengths. The high and low frequency words were selected based on the Q1 and Q3 values obtained for the 4- and 5- syllable words using the IBM SPSS Statistics, Version 26 software. *The Q1 value obtained for 4- syllable word list was 13 and Q3 value obtained was 68, and the Q1 value obtained for 5- syllable word list was 12 and Q3 value obtained was 52, and words below Q1 was considered as low frequency words and above Q3 was considered as high frequency word.*

To maintain consistency across varying syllable lengths and word frequencies, we controlled word complexity using a combination of metrics from Stoel-Gammon (2011) and Namasivayam et al. (2021). We refer to this as the Stoel Gammon Complexity (SGC) metric to describe the variations in complexity across the selected words, as most parameters influencing complexity are derived from Stoel-Gammon's metric. For the selected words, the SGC was held constant at levels 4, 6, and 8. This approach allowed for systematically graded stimuli along a continuum from lower to higher complexity. Table 3.8 shows the complexity metric used in the current study.

Table 3.8

Parameters used for scoring word complexity: Modified Stoel-gammon word complexity measure (Stoel-Gammon, 2010; Namasivayam et al. 2021).

Item description	Feature / Parameter	Score
Word pattern	Productions with more than two syllables	1 point
Syllable structure	Productions with a consonant cluster (two or more consecutive consonants within a syllable)	1 point per cluster
Syllable structure	Productions with Arka Hotthu (೯) — represents complex consonant articulation unique to Kannada	1 point per ೯
Sound class	Productions with a velar consonant	1 point per velar
Sound class	Productions with a liquid, syllabic liquid, or rhotic vowel	1 point per liquid/rhotic
Sound class	Productions with a fricative or affricate	1 point per fricative/affricate
Sound class	Productions with a voiced fricative or affricate (in addition to point for #6)	1 additional point each
Movement trajectory	Productions with labial rounding vowels (ಉ, ಊ, ಒ, ಓ, ಔ) and/or labial retraction vowels (ಇ, ಈ, ಎ, ಏ, ಐ), diphthongs, and syllables ending with these vowels/diphthongs	1 point per occurrence

Table 3.9 shows the selected words for the complexity subsection based on word frequency and syllable length. Table 3.10 displays the individual words and their complexity ratings based on a combination of metrics from Stoel-Gammon (2011) and Namasivayam et al. (2021).

Table 3.9

Syllable Length and Word Frequency Characteristics of Kannada Words Selected for the Word Complexity Measure

Word	Number of syllables	Word Frequency
ಕರ್ನಾಟಕ	4	14954 (HF)
ಪ್ರದರ್ಶನ	4	4683 (HF)
ಪ್ರತಿಷ್ಠಿತ	4	924 (HF)
ಆಧ್ಯಾತ್ಮಕ	4	8 (LF)
ನಿತ್ಯೋತ್ಸವ	4	8 (LF)
ಕಾರ್ಯಧ್ಯಕ್ಷ	4	10 (LF)
ಮಂಗಳವಾರ	5	9126 (HF)
ಮಾರ್ಗದರ್ಶನ	5	1250 (HF)
ಚಿತ್ರೀಕರಣ	5	1228 (HF)
ಆವೃತವಾಗಿ	5	8 (LF)
ಸತ್ಯದರ್ಶನ	5	8 (LF)
ಚಿತ್ರನಗರಿ	5	8 (LF)

The performance of the subjects was assessed using 3-point rating ranging from 0 to 2 across nine parameters such as Initiation, Distortion, Distorted substitution/addition, articulatory groping, syllable sequencing, syllable segmentation, increased error with increased complexity, substitution, and omission. The subjects were given with two trials and the trial with more error shall be considered for scoring. The maximum summed score documented for the complexity task is 204.

Table 3.10

Phonological Characteristics and Word Complexity Scores of Kannada Words Selected for the Word Complexity Measure

Word	IPA	>2 syllables	Cluster	Velar	Fricative, affricate	Voiced Fricatives, affricates	Liquid and/or rhotic vowel	Movement trajectory Labial rounding or retraction	Presence of ɛ	Total
ಕರ್ನಾಟಕ	/kərnaːʈəkə/	1	0	2	0	0	0	0	1	4
ಪ್ರದರ್ಶನ	/prəd̪ərɕənə/	1	1	0	1	1	1	0	1	6
ಪ್ರತಿಷ್ಠಿತ	/prət̪iʂʈʰit̪ə/	1	2	0	1	1	1	2	0	8
ಆಧ್ಯಾತ್ಮಕ	/aːd̪ʱjaːt̪məkə/	1	2	1	0	0	0	0	0	4
ನಿತ್ಯೋತ್ಸವ	/n̪it̪joːt̪sʌʋʌ/	1	2	0	1	0	0	2	0	6
ಕಾರ್ಯಾಧ್ಯಕ್ಷ	/kaːrjəd̪jəkʂə/	1	2	2	1	1	0	0	1	8
ಮಂಗಳವಾರ	/məŋgəɭaʋaːra/	1	0	1	0	0	2	0	0	4
ಮಾರ್ಗದರ್ಶನ	/maːrgəd̪ərʃana/	1	0	1	1	1	0	0	2	6
ಚಿತ್ರೀಕರಣ	/t͡ʃit̪riːkəraɳa/	1	1	1	1	0	2	2	0	8
ಆವೃತವಾಗಿ	/aːʋr̩at̪aʋaːgi/	1	0	1	0	0	1	1	0	4
ಸತ್ಯದರ್ಶನ	/sət̪jəd̪ərʃana/	1	1	0	2	1	0	0	1	6
ಚಿತ್ರನಗರಿ	/t͡ʃit̪ranəgari/	1	1	1	1	0	2	2	0	8

3.2.8 Sentence repetition task

High and low frequency words were selected from a Kannada lexical database across 2-, 3-, 4-, and 5-syllable lengths. Using these high and low frequency words, phrases and sentences were constructed by a native Kannada speaker. The resulting stimuli were evaluated by a group of 58 native Kannada speakers for familiarity and word usage on a 5-point rating scale, as 1-highly familiar phrase/sentence and concrete word usage, 2-Familiar phrase/sentence and concrete word usage, 3-Familiar phrase/sentence and moderately abstract word usage, 4-less familiar phrase/sentence and moderately abstract word usage, and 5-Unfamiliar phrase/sentence and highly abstract word usage.

Those phrases which were rated as ‘1’ was considered for high frequency phrase/sentence and those stimuli rated as 4 or 5 was considered for considered as low frequency phrase/sentence. Later, the investigators matched the syllable lengths and Stoel-Gammon complexity for each pair of high and low frequency sentences across 2-, 3-, 4-, and 5-syllables. A total of eight pairs of high and low frequency sentences were selected, by matching the Modified Stoel-Gammon complexity. Table 3.11 shows the stimuli for the sentence repetition task.

Table 3.11

High and Low Frequency Sentences and Their Complexity Scores

Word frequency	Sentences	Complexity
High Frequency	ಮಳೆ ನೀರು	5
Low Frequency	ಪಂಜಿನ ಹಬೆ	5
High Frequency	ಅರಣ್ಯ ಇಲಾಖೆ	8
Low Frequency	ಟಪಾಲು ರಶೀತಿ	9
High Frequency	ನಿರ್ದೇಶಕ ಸಿನಿಮಾ ನಿರ್ಮಿಸಿದನು	18
Low Frequency	ದಿಗಂತವ್ಯಾಪಿ ಮೌನವು ಚಿತ್ತವನ್ನು ಆವರಿಸಿತು	18
High Frequency	ಜನರಿಗೆ ವೈದ್ಯಕೀಯ ಸೌಲಭ್ಯ ಅಗತ್ಯವಾಗಿದೆ	23
Low Frequency	ಅವಿಚ್ಛಿನ್ನ ಧ್ಯಾನಸ್ಥಿತಿಗೆ ಮನಸ್ಸು ನಿಶ್ಚಲವಾಯಿತು	23

The performance of the subjects was assessed using 3-point rating ranging from 0 to 2 across eleven parameters such as *Initiation, Distortion, Distorted substitution/addition, articulatory groping, syllable sequencing, syllable segmentation, excess/equalized stress, false starts/re-starts, sound/syllable repetition, substitution, and omission*. The subjects were given with two trials and the trial with more error shall be considered for scoring. The maximum summed score documented for the complexity task is 168.

3.2.9 Spontaneous Speech Task

Open-ended questions were developed and were given for rating to a group of 15 native Kannada speakers. The raters evaluated each question across four parameters — *Naturalness, Clarity, Familiarity of Vocabulary, and Speech Elicitation Potential* - using a 4-point rating scale (0–3). Naturalness was rated as: 0-Not at all natural, 1-Slightly unnatural, 2-Mostly natural, and 3 -Completely natural. Clarity was rated as: 0 - Not at all clear, 1 -Somewhat unclear, 2 -Clear, and 3 -Very clear. Familiarity of Vocabulary was rated as: 0 - Rare or unknown word usage, 1 - Slightly familiar word usage, 2 -Mostly familiar word usage, and 3 - Completely familiar word usage. Speech Elicitation Potential was rated as: 0 - Minimal (yes/no response), 1-Short (one to two words or phrases), 2 - Moderate (sentence level), and 3 -Rich and extended (paragraph or extended discourse).

Questions that received the highest ratings across all four parameters were selected for inclusion. A final set of three questions was retained for this subsection.

The responses elicited by these questions were analysed for prosodic and fluency errors. Prosodic errors included: (1) *Normal stress pattern* — normal emphasis placed on a particular syllable or word; and (2) *Excess/equalized stress* — excess and/or equal stress placed on a particular syllable or word, resulting in a perceived abnormality in prosodic stress. Fluency errors included: (1) *False starts/restarts* — the speaker restarts or changes the utterance midway through production; (2) *Transient cessation* — a temporary stop or brief involuntary pause in speech output; and (3) *Sound/syllable repetition* — a sound, syllable, or word, whether single-syllabic or multisyllabic, repeated multiple times during production. The presence or absence of each error type was indicated on a binary yes/no basis. This subsection does not contribute to the overall score.

Table 3.12

Questions Used to Elicit Spontaneous Speech Samples

	Questions
1.	ಇವತ್ತು ನಿಮ್ಮ ಆರೋಗ್ಯ ಹೇಗಿದೆ?
2.	ನೀವು ಇಲ್ಲಿಗೆ ಬಂದ ಕಾರಣ ತಿಳಿಸಿ ಮತ್ತೆ ನಿಮಗೆ ಏನು ತೊಂದರೆ ಆಗಿದೆ ಅಂತ ವಿವರಿಸಿ.
3.	ನಿಮ್ಮ ಕುಟುಂಬದ ಬಗ್ಗೆ ಹೇಳಿ.

PHASE 2: Validation of Newly Developed Screening Tool

Step 1- Content validation

For content validation, 11 SLPs ehaving experience in assessing and treating motor speech disorders were asked to evaluate the developed tool. They were asked to rate the developed tool of K-ASNAST on a three-point Likert scale (0-No Fit, 1-Neutral Fit, and 2-Excellent Fit) on Clarity, Simplicity, Relevance, Framing, and Applicability of the item. Table 3.13 shows the parameters, operational definitions, and 3-point ratings considered for the content validation.

Table 3.13

The Parameters, Operational Definitions, and 3-point Ratings Considered for the Content Validation.

Parameters	Rating scale		
	0 – No Fit	1 – Neutral Fit	2 – Excellent Fit
Clarity	Unclear	Somewhat clear	Very clear
Simplicity	Complex	Somewhat simple	Very simple
Relevance	Not relevant	Somewhat relevant	Highly relevant
Framing	Poorly framed	Somewhat well framed	Framed well
Applicability	Not applicable	Somewhat applicable	Highly applicable

Items were modified only if six judges rated it as '0-No Fit' or '1-Neutral Fit'. Necessary changes were made accordingly, and then the final translated version was administered to three groups, AOS, Dysarthric group, and Typical adults. The final version of K-ASNAST is attached as Appendix I.

Step 2- Administration and Psychometric Evaluation of the Screening Protocol Tool

The final screening tool was administered on the target population of individuals with suspected apraxia of speech and individuals diagnosed as having Dysarthria, and typical adults.

Participants:

The current study included 11 adults with suspected AOS and NVOA, 9 adults with dysarthria, and 10 typical adults, who had their native language as Kannada.

Table 3.14

Participants Characteristics of individuals Suspected with AOS and NVOA

Participants	Age (in years)	Sex	Etiology	Diagnosis	Aphasia quotient
P1	45	Male	Stroke	BA	20.5
P2	37	Male	Stroke	BA	4.2
P3	28	Male	Stroke	BA	3.3
P4	46	Female	Left frontal glioma	BA	16
P5	35	Male	Road traffic accident	BA	60.5
P6	49	Male	Road traffic accident	BA	57.3
P7	45	Female	Stroke	BA	17.2
P8	46	Male	Stroke	BA	32.5
P9	37	Male	Stroke	BA	40
P10	34	Male	Stroke	BA	18.1
P11	41	Male	Stroke	BA	10.4

BA = Broca's Aphasia

Table 3.15

Participant Characteristics of the Dysarthria Group

Participants	Age (in years)	Sex	Etiology	Diagnosis	Articulators/Subsystem Involved
P12	79	Male	Parkinson-like symptoms	Dysarthria	Tongue
P13	78	Male	Suspected Mild ataxia and PD	Dysarthria	Tongue and larynx
P14	65	Male	Brain stem stroke	Dysarthria	Larynx
P15	56	Male	Clival Chondroma	Dysarthria	Tongue
P16	62	Female	Bell's palsy	Dysarthria	Lips
P17	80	Male	Mild Left fronto-parieto-occipital and right fronto-temporal region lesion	Dysarthria	Lips, Larynx, tongue
P18	64	Male	MND- ALS	Dysarthria	-
P19	45	Male	CVA	Dysarthria	Lips, Larynx, tongue
P20	28	Male	Childhood dysarthria	Dysarthria	Tongue

Table 3.16

Participant Characteristics of the Typical Adult Group participants details

Participants	Age (in years)	Sex
P21	39	Female
P22	24	Male
P23	38	Female
P24	24	Female
P25	37	Male
P26	42	Male
P27	30	Female
P28	24	Female
P29	26	Female
P30	25	Female

Procedure

For data collection, the investigator of this study administered the screening tool on both the clinical groups (AOS and Individuals with dysarthria) and typical adults in a well-lit quiet room set up. The recording time ranged from 15-20 minutes depending on the severity of the disorder and the subject's cognitive status. The responses of the participants were audio-video recorded using phone camera for further analysis.

Recording and Instrumentation

Prior to testing, participants were informed about the study procedures and provided written informed consent. Audio-video recordings of their responses were obtained using a smartphone camera mounted on a tripod while the examiner administered the test protocol and provided task-specific instructions, demonstrations, cues, and feedback as needed. The recorded samples were transferred to a computer for detailed analysis, including video-based observation of articulatory movements. Each sample was independently analyzed, transcribed using broad IPA transcription, and scored using task-specific 3-point rating scales according to the established scoring guidelines.

3.3 Data Analysis

1. Content validity: This was calculated using the content validity ratio (CVR)

The formula for CVR;

CVR = (ne-N/2) / N/2

Where;

ne is the number of experts who rated the item as "essential"

N is the total number of experts on the panel.

According to Lawshe's table, for a panel of 11 experts, the minimum acceptable Content Validity Ratio (CVR) is 0.59. This value indicates the level of agreement among experts needed to consider an item as having acceptable content validity. Later Content Validity Index (CVI) was derived for each subsection by calculating the average score of CVR of all the item in that particular subsection.

2. Intra and Inter-rater reliability:

Intra-judge reliability: It refers to the consistency of judgments made by the same judge (an SLP) across multiple occasions. A 25% of the samples from AOS, Dysrathric, and Typical adults was reanalysed for their total scores by the same judge.

Inter-judge reliability: It refers to the degree of agreement between 2 qualified SLPs on the overall scores obtained for the screening tool to assess AOS and NVOA. Data analysis was calculated using the Cronbach's coefficient alpha (α).

3. Discriminant Validity

The cumulative error rates across all the speech production accuracy for each relevant subsection scores obtained for the screening protocol on AOS and NVOA was compared between three groups i.e., suspected Apraxia of Speech (AOS), Dysarthria (DYS) and Typical Adults (TA) using Independent-Samples Kruskal-Wallis Test. Any significance observed was followed up with and pairwise comparison of groups adjusted using adjusted Bonferroni's 'p' correction.

Chapter 4

Results and Discussion

The primary aim of the study was to develop and validate a screening tool for Apraxia of Speech and Nonverbal oral Apraxia in Kannada speaking adults. The specific objectives were:

1. To establish content validity for the developed screening tool on individuals with suspected AOS and NVOA.

3. To examine the inter and intra rater reliability of the screening tool on individuals with suspected apraxia of speech.

4. To evaluate the discriminant validity of the screening tool through comparison of performance scores among individuals with suspected apraxia of speech (AOS) and/or nonverbal oral apraxia (NVOA), individuals with dysarthria, and neurologically typical adults.

The screening tool was administered on 30 adults across three groups. Group I included individuals with suspected AOS and NVOA with or without any other neurological conditions (n=11), Group II included individuals with Dysarthria (n=9), and Group III included typical adults (TA). Individuals with suspected AOS were included in the study based on the Apraxic features observed as reported by McNeil et al., (2009) and suspected to have AOS and/or NVOA by a qualified Speech Language Pathologist.

The subsections included in the screening tool were: (1) Oro-motor assessment at rest, (2) non-verbal oral praxis assessment, (3) Diadochokinetic rate (DDK), (4) Automatic vs Propositional speech, (5) Isolated Oral Movements for Speech, (6) Syllable and Word repetition task, (7) Length and Complexity task, (8) Sentence repetition task, (9) Spontaneous speech task. In the Spontaneous speech task prosodic and fluency errors were noted as present or absent and this subsection was noted included for rating. To rule out severe dysarthria, severe comprehension deficits secondary to aphasia, and cognitive deficits, appropriate tests such as FDA-2 (Enderby & Palmer, 2008), Montreal Cognitive Assessment (MoCA) (Nasreddine et al., 2005) were administered.

Recording and Instrumentation

The subjects were informed about the procedure of the test and the informed written consent was taken prior to the recording. For data collection, the examiner of this study administered the screening tool on all the three groups in a well-lit quiet room set up. The recording time ranged from 15-20 minutes depending on the severity of the disorder and the subject's cognitive status. The responses of the participants were audio-video recorded using phone camera of Realme Narzo 20 Pro, Model RMX2161, realme UI version V3.0 placed on a tripod stand in front of the subject within a metre distance.

The participants were suitably instructed before recording the response and task specific instructions were given. Video recording was started whilst administration of the test battery where positive feedback and appropriate cues were given in order to elicit the response. Whenever required the particular task was demonstrated. The trials were given according to the fixed protocol.

The audio and video recorded samples were transferred to a Personal computer for further analysis. Each sample was transcribed using broad IPA transcription and analysed separately and the scores were recorded in the scoring sheet of the screening tool. Scoring of test items was carried out using a 3-point Likert rating scale that on parameters that were operationally defined and relevant for each subsection of the screening tool.

The results are presented and discussed separately under the following subsections:

(1) Oro-motor assessment at rest (OMA),

(2) Non-verbal oral praxis assessment (NVOA),

(3) Oral Diadochokinetic rate (ODDK),

(4) Automatic vs Propositional speech,

(5) Isolated Oral Movements for Speech,

(6) Syllable and Word repetition task,

(7) Length and Complexity task,

(8) Sentence repetition task,

(9) Spontaneous speech task.

4.1 Content Validation

Content validity was measured using Content Validity Ratio (CVR). According to Lawshe's table, for a panel of 11 experts, the minimum acceptable Content Validity Ratio (CVR) is 0.59. This value indicates the level of agreement among experts needed to consider an item as having acceptable content validity. Each item in the tool was evaluated on a 3-point Likert scale on five parameters such as clarity, simplicity, relevance, applicability, and framing by 11 qualified speech language pathologists. All items had a ratio above 0.59 for relevance and applicability. Average Content validity ratio was calculated by taking the mean of CVR for all the item for each subsection. Based on the scores and suggestions provided by the expert's modifications were made to the final screening tool before the tool was administered.

Table 4.1

Mean Content Validity Ratio (CVR) for each Subsection of the screening tool for Apraxia of Speech and Nonverbal oral Apraxia

	Content Validity Ratio				
Subsections	Clarity	Simplicity	Relevance	Framing	Applicability
SS1	0.90	0.95	1	0.81	0.85
SS2	0.85	0.94	1	0.81	0.98
SS3: A	1	0.81	1	0.81	1
SS3: B	1	0.81	0.90	0.81	1
SS4	0.90	0.90	0.90	0.81	1
SS5	1	1	1	0.87	1
SS6: A	1	1	1	0.81	1
SS6: B	1	1	1	0.81	1
SS7: A	0.93	0.93	0.93	0.78	0.95
SS7: B	0.96	0.95	0.98	0.78	0.98
SS8	0.83	0.79	0.90	0.78	0.90
SS9	1	1	1	0.81	0.93

SS: Subsection

Based on the scores and suggestions provided by the expert's modifications were made to the final screening tool before the tool was administered.

4.2 Reliability Analysis: Intra-rater and Inter-rater Reliability

4.2.1 Intra-rater Reliability

Intra-rater reliability was examined to determine the consistency of a single rater's scoring of the screening tool across two separate scoring occasions. Reliability was assessed using Cronbach's coefficient alpha (α), computed via the SPSS Reliability procedure (IBM SPSS Statistics, Version 26), for each of the 39 parameters comprising the eight subsections of the tool. Six cases were included in the analysis for all subsections (AOS = 2, Dys = 2, TA = 2). For each parameter, the rater's scores from occasion 1 and occasion 2 constituted the two items which was further subjected for reliability analysis.

Cronbach's alpha coefficients of ≥ .90 are conventionally interpreted as indicative of excellent reliability (Cicchetti, 1994; George & Mallery, 2003). Cronbach's alpha values of 1.000 were obtained across all 39 parameters spanning all eight subsections of the screening tool, indicating perfect intra-rater reliability. This demonstrated that the rater produced completely consistent scores across two separate administrations of the screening tool for all parameters assessed, regardless of the nature of the task subsections.

Collectively, these findings indicate that the screening tool demonstrated excellent intra-rater reliability across all subsections and parameters, providing strong evidence for the stability and consistency of the scoring protocol when applied by the same rater on repeated occasions.

4.2.2 Inter-rater Reliability

Inter-rater reliability was examined to determine the consistency of a two different rater's scoring of the screening tool across two separate scoring occasions. Six cases were included in the analysis for all subsections (AOS = 2, Dys = 2, TA = 2). Inter-rater reliability was done by the examiner of the study and a qualified SLP. Cronbach's alpha values ranged from 0.66to 1, indicating varying degrees of agreement between the two raters. The screening tool demonstrated good to excellent inter-rater reliability across most subsections. The Oral Mechanism Assessment (Section 1) showed moderate agreement ($\alpha = 0.667$), whereas Non-verbal Oral Apraxia Praxis and Non-verbal Oral Apraxia Dysarthria sections demonstrated excellent agreement ($\alpha = 0.99$). Similarly, Oral Diadochokinetic Alternating Motion Rates for /pa/ and /ta/ showed perfect agreement ($\alpha = 1.000$), while Sequential Motion Rate exhibited excellent reliability ($\alpha = 0.961$). Propositional and Automatic Speech tasks demonstrated high reliability with alpha values of 0.946 and 0.828, respectively. The repetition-based tasks demonstrated exceptionally high agreement between raters. Inter-rater reliability for Isolated oral movements, syllable and word repetition, length and complexity task, and sentence repetition tasks was consistently excellent, with Cronbach's alpha values ranging from 0.990 to 1.

Overall, the findings indicate that the developed screening tool possesses strong inter-rater reliability, suggesting that different raters can administer and score the tool consistently. The predominance of alpha coefficients above 0.90 supports the reliability and objectivity of the screening tool for assessing apraxia of speech and non-verbal oral apraxia in adults.

4.3 Discriminant Validity

Discriminant Validity was established between 3 groups, AOS (11), Individuals with Dysarthria (09), and Typical adults (10). Median, First Quartile (Q1), and Third Quartile (Q3) was considered for speech production accuracy in each subsection. Independent-Samples Kruskal-Wallis Test was used to compare the overall performance between the 3 groups across subsections. This was followed by pairwise comparisons between groups using Bonferroni-adjusted p-value corrections.

4.3.1 Oro-motor Assessment at Rest (OMA)

In this subsection, there were four tasks which assessed the integrity of Jaw, Lip, Tongue, and soft palate. This was assessed on a 3-point rating scale ranging from 0 to 2, where 0 indicated normal presentation and 2 indicated marked abnormality. In addition to the overall rating, each structure was further described across four dimensions: *position, muscle tone, structural signs, and any other* observable features. Median was calculated across groups for Jaw, Lip, Tongue, and soft palate. For consistency across tables and figures in this section, we have used short forms to address the participant groups: AOS for individuals with apraxia, DYS for individuals with dysarthria, and TA for typical adults.

Table 4.2

Descriptive Statistics (Median and Interquartile Range [Q1–Q3]) for Oro-motor Assessment at rest (OMA) Across the AOS, Dysarthria, and Typical Adult Groups

	AOS			DYS			TA		
	Median	Q1	Q3	Median	Q1	Q3	Median	Q1	Q3
Jaw	0	0	0	0	0	0	0	0	0
Lip	0	0	1	0	0	1	0	0	0
Tongue	0	0	1	1	0.50	1.5	0	0	0
Soft Palate	0	0	0	0	0	0	0	0	0

In the AOS group for the jaw at rest, the jaw was in a midline position, and the tone was normal at rest in all 11 individuals, and no other structural signs were noted. For the lip at rest, 8 individuals had their lips in a midline position; among them, 2 exhibited right droop, and 1 person had left drooping lips. All individuals had normal tone and lip closure, with no other structural signs. For the tongue, all individuals had a midline position and normal tone; however, tongue instability was observed in 3 individuals. In the soft palate, a midline position with no structural signs was noted in all the individuals.

In the dysarthria group for the jaw at rest, the jaw was in a midline position, and the tone was normal at rest in all 9 individuals, and no other structural signs were noted. For lips at rest, the lip was in a midline position in 7 individuals; 1 of them had a right droop, and 1 person presented with left drooping lips. The tone was normal, with adequate lip closure observed in 7 individuals, partial lip closure in 2 individuals, and no other structural signs noted in any of the participants. For the tongue at rest, the tongue was in a midline position in 7 individuals; 1 of them had right deviation, and 1 person presented with a left-deviated tongue. Reduced tongue tone was noted in 1 individual. In structural signs, tongue instability was noted in 5 individuals, and fasciculation and atrophy were noted in 1 individual. In the soft palate, a midline position with no structural signs was noted in all the individuals. Typical adults presented with a midline position of all the articulators, with normal tone, closure, and without any structural signs.

The final subsection scores across the articulators (jaw, lips, tongue, and soft palate) were combined to derive the global median score. This global median score for the subsection of oral motor assessment at rest was compared between the groups using Kruskal-Walli's test. Kruskal-Wallis test revealed a statistically significant difference between groups, χ^2 (2) = 14.42, $p < 0.01$. Figure 4.1 shows the subsection scores cutting across the articulators for each group.

Figure 4.1

Box plot of Oral Motor Assessment at Rest Subsection Scores Across the Participant Groups

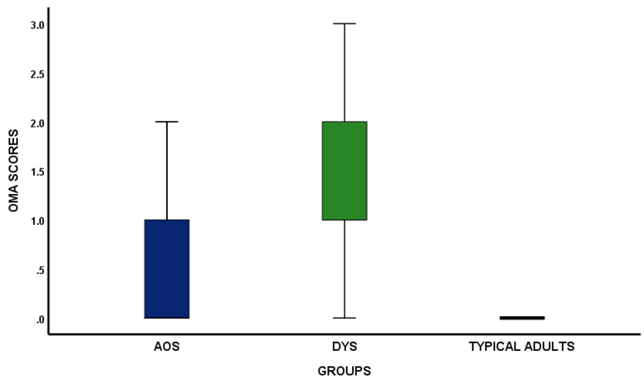


Table 4.3

Pairwise Comparisons of Subsection Scores for the Oral Motor Assessment at Rest Across Participant Groups

Pairwise Comparison	Standardized Test Statistic (Z)	Adjusted p Value (Bonferroni)
TA vs. AOS	1.58	0.33
TA vs. DYS	3.78	< 0.01**
AOS vs. DYS	-2.32	0.06#

*** = significant at 0.01 level of significance; # = marginally significant at 0.06 level of significance*

Pairwise comparisons of groups in this subsection following Bonferroni's adjusted p values showed a high statistical significance between the TA and Dysarthric group. This indicated that this subsection identified and differentiated individuals with dysarthria from typical adult group. As recorded in descriptors, many participants with dysarthria had weakness in tongue and lips that increased their overall ratings which differentiated them from AOS group. The current findings are in line with some of the previous investigations. Solomon et al. (2017) demonstrated that individuals with dysarthria exhibit considerably reduced orofacial muscle strength compared to neurologically healthy adults. Hartelius et al. (2009) evaluated 59 healthy controls, 30 individuals with Parkinson Disease (PD), and 30 with Multiple sclerosis (MS) using a 54-item dysarthria protocol spanning six subtests. The oral motor subtest proved particularly effective in distinguishing various neurological groups, including those with PD, MS, and even perceptually normal-sounding MS speakers, from healthy individuals. However, TA and AOS did not differ from each other. We posit that this lack of significance could be due to the absence of oral motor deficits in the AOS participants of our study. Typically, AOS without dysarthria does not lead to oral motor deficits, so in this study, participants with AOS were similar to typical adults. There was a marginal significance ($p = 0.06$) between the AOS and DYS groups, which was on the anticipated lines, as oral motor deficits were clearly high in DYS compared to the AOS group.***4.3.2 Non-Verbal Oral Praxis Assessment***

In this subsection there were 10 tasks and these tasks aimed to assess the non-verbal praxis errors across the groups. The tasks in this section targeted specific articulators such as jaw, lip, tongue and laryngeal/respiratory coordination along with two commands on sequential movements of the jaw, lip, and tongue. As the non-verbal movements could be impaired in both dysarthria and AOS for various physiological reasons, responses for praxis errors and errors due to neuromuscular weakness (NW) were scored separately using a 5-point scale ranging from 0 to 4. Table 4.4 shows the Median, and interquartile ranges for the praxis error and error due to neuromuscular weakness.

Table 4.4

Descriptive Statistics (Median and Interquartile Range [Q1–Q3]) for Non-Verbal Oral Praxis Assessment Across the AOS, Dysarthria, and Typical Adult Groups

	AOS			DYS			TA		
	Median	Q1	Q3	Median	Q1	Q3	Median	Q1	Q3
Praxis Errors	27	23	32	39	31.5	40	40	40	40
NW	39	36	40	30	23.5	33	40	40	40

Figure 4.2 displays the subsection scores, which combine the errors from all items related to non-verbal oral praxis assessment across the articulators for each group, presented as a box plot below. Similarly, Figure 4.3 displays the subsection scores as a box-plot combining all the items related to errors due to neuromuscular weakness across the articulators for each group. Please note that, unlike the rating scales in previous sections, higher scores in this section indicate normal functioning.

Figure 4.2

Distribution of Nonverbal Oral Praxis Assessment Subsection Scores for Praxis Errors Across Participant Groups

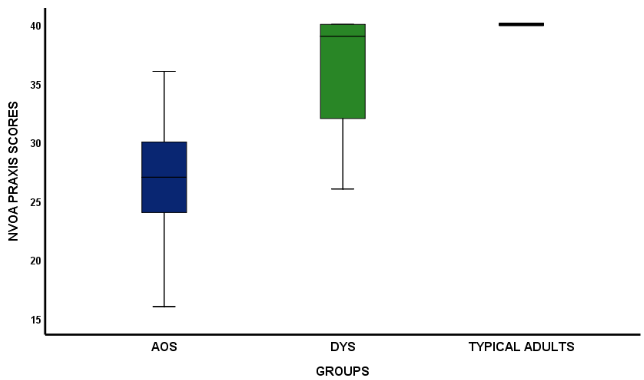
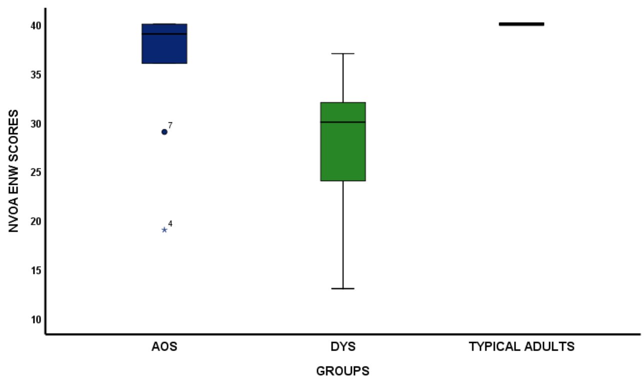


Figure 4.3

Distribution of Nonverbal Oral Praxis Assessment Subsection Scores due to Neuromuscular weakness Across Participant Groups



For both praxis errors and errors due to neuromuscular weakness Kruskal-Walli's test revealed a statistically significant difference between groups [χ^2 (2) = 21.17, $p < 0.01$; χ^2 (2) = 18.68, $p < 0.01$].

Table 4.5

Pairwise Comparisons of Subsection Scores for the Praxis error Across Participant Groups

Pairwise Comparison	Standardized Test Statistic (Z)	Adjusted p Value (Bonferroni)
TA vs. AOS	-4.58	< 0.01**
TA vs. DYS	-1.97	0.14
AOS vs. DYS	-2.43	0.04*

** = significant at 0.05 level of significance; ** = significant at 0.01 level of significance*

Pairwise comparisons of praxis errors revealed that participants with AOS showed lower scores compared to typical adult group indicating the presence of movement control deficits may be due to speech motor planning/programming errors in this population.

Additionally, the differences were also evident between TA and Dysarthric groups (possibly due to more dispersion in the interquartile ranges) indicating that this subsection could be used to differentiate the non-verbal movement deficits observed in participants with dysarthria from typical adult group.

Table 4.6

Pairwise Comparisons of Subsection Scores for Error due to Neuromuscular Weakness Across Participant Groups

Pairwise Comparison	Standardized Test Statistic (Z)	Adjusted p Value (Bonferroni)
TA vs. AOS	-1.97	0.14
TA vs. DYS	-4.31	< 0.01**
AOS vs. DYS	2.49	0.03*

** = significant at 0.05 level of significance; ** = significant at 0.01 level of significance*

Additionally, pairwise comparisons revealed differences between TA and AOS and TA and DYS for neuromuscular weakness. Here, participants with AOS and TA performed at ceiling limits of the rating scale with comparable median data but the group with dysarthria showed lower median values indicating poor performance due to neuromuscular weakness. We also posit that the median scores obtained across the praxis error and errors due to neuromuscular weakness could be considered to differentiate the performance between AOS and dysarthric population. Together these findings indicate that this subtest is facilitating the differentiation between AOS from TA and DYS groups in nonverbal praxis domain and DYS from TA and AOS using neuromuscular weakness scoring.

The above findings are supported by a study done by Botha et al. (2014) who investigated the frequency of occurrence of nonverbal oral apraxia (NVOA), in individuals diagnosed with primary progressive aphasia (PPA) or progressive apraxia of speech (PAOS). They reported that NVOA was most frequently observed among those with PAOS, affecting

59% of that group, though it was also detected across the remaining diagnoses, occurring in 78% of PPA cases, 41% of LPA cases, and 40% of those with semantic dementia. Notably, the fact that certain patients demonstrated NVOA in the absence of apraxia of speech, and others showed the reverse pattern, indicates that these conditions are not entirely overlapping and can occur independently of one another. However, this study supports that individuals with AOS may have an associated NVOA component.

Whiteside et al. (2015) investigated the relationship between acquired apraxia of speech (AOS) and oral apraxia (OA) in 50 post-stroke individuals who had been diagnosed with AOS. They evaluated this group with a comprehensive assessment battery addressing speech, non-speech and language functionsand reported a statistically positive relationship between the degree of AOS impairment and the severity of OA, pointing to a tendency for the two conditions to present together in some individuals. Considering the above studies along with the findings obtained in our analysis of AOS, it is important to rule out for any impairment in the voluntary control of nonspeech oral movements in this population.

4.3.3 Oral Diadochokinetic rate (ODDK)

Alternating motion rate (AMR) and Sequential motion rate task (SMR) tasks were included in this subsection. The performance for the task was analysed for*: (a) speech production accuracy, (b) consistency.*

Part A: Alternating motion rate (AMR)

The AMR task required subjects to repeat the monosyllables /pə/, /tə/, and /kə/ as rapidly and accurately as possible. The accuracy was measured across errors such as *initiation, regularity, distortion, articulatory groping, substitution, and omission*. Consistency was recorded as consistent or inconsistent across two trials for each monosyllable. Table 4.7 shows the Median, 25th percentile (first quartile), and 75th percentile (third quartile) for the accuracy measures of the error across the syllables /pə/, /tə/, and /kə/. From Table 4.7, it could be observed that in the group of AOS, errors were more across the factors of *initiation, articulatory groping and substitution* whereas errors were recorded only for *regularity and distortion* in the dysarthria group.

Table 4.7

Descriptive Statistics on Factors Affecting Speech Production Accuracy for Alternating motion rate (AMRs) across the AOS, Dysarthria, and Typical Adult Groups

Speech Production Accuracy	AOS			DYS			TA		
	Median	Q1	Q3	Median	Q1	Q3	Median	Q1	Q3
Initiation	1	0	3	0	0	0	0	0	0
Regularity	0	0	1	1	0	2.5	0	0	0
Distortion	0	0	1	0	0	2	0	0	0
Articulatory groping	2	0	3	0	0	0	0	0	0
Substitution	1	0	3	0	0	0	0	0	0
Omission	0	0	0	0	0	0	0	0	0

The overall cumulative error rates on factors affecting speech production accuracy for ODDK productions for syllables /pə/, /tə/, and /kə/ separately were subjected to further analysis to check for between-group differences, if any. . For AMR of syllable /pə/, Kruskal-Wallis test revealed a statistically significant difference between groups, χ^2 (2) = 10.61, $p < 0.01$. Figure 4.4 presents the cumulative error rates associated with speech production accuracy for the ODDK production of the syllable /pə/. Though the median is same between individuals with dysarthria and AOS, the overall interquartile range is higher for AOS than for dysarthria indicating more variability even in simple repetition of bilabial stimuli. Pairwise comparisons shown in Table 4.8 reveals that the overall error rate differentiated the typical adult group from participant groups of AOS and dysarthria while producing syllable /pə/.

Figure 4.4

Box Plot of Cumulative Error Rates for Factors Affecting Speech Production Accuracy During ODDK Production of /pə/ Across Participant Groups

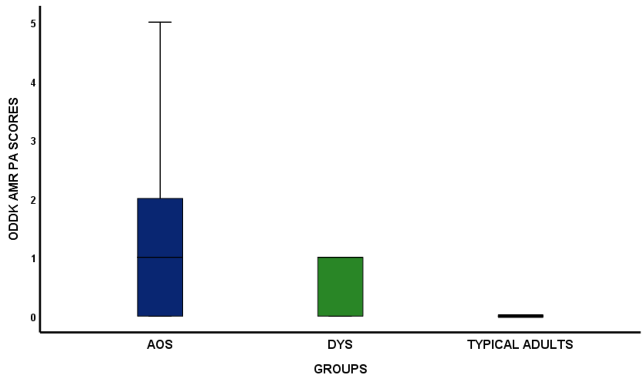


Table 4.8

Pairwise Comparisons of Cumulative ODDK Error Rates for the speech production accuracy of the Syllable /pə/ Across Participant Groups.

Pairwise Comparison	Standardized Test Statistic (Z)	Adjusted p Value (Bonferroni)
TA vs. AOS	3.04	< 0.01**
TA vs. DYS	2.51	0.03*
AOS vs. DYS	0.39	1.00

** = significant at 0.05 level of significance; ** = significant at 0.01 level of significance*

For AMR of syllable /tə/, Kruskal-Wallis test revealed a statistically significant difference between groups [χ^2 (2) = 16.31, $p < 0.01$]. Figure 4.5 displays the cumulative error rates in speech production accuracy for ODDK production for syllable /tə/. Median of AMR /tə/ was observed to be higher for AOS group compared to others. A follow up pairwise comparisons between groups shown in Table 4.9 revealed that the overall error rate differentiated the typical adult group from participant groups of AOS and dysarthria. But the differences were not significant between AOS and dysarthria due to the accumulation of cumulative error rates for the AMR task. As mentioned earlier in this section, analyzing the types of errors in speech production accuracy may provide valuable insights into the nature of speech motor breakdown between the AOS and DYS groups.

Figure 4.5

Box Plot of Cumulative Error Rates for Factors Affecting Speech Production Accuracy During ODDK Production of /tə/ Across Participant Groups

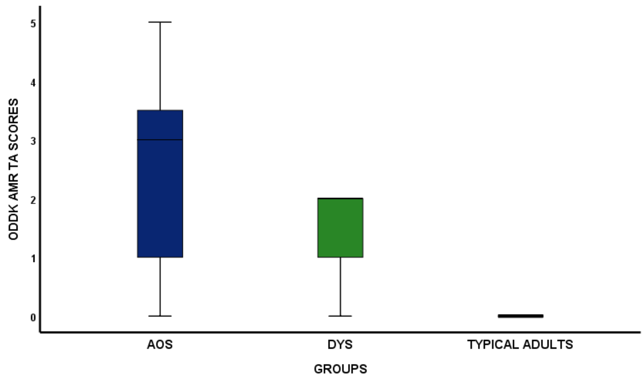


Table 4.9

Pairwise Comparisons of Cumulative ODDK Error Rates for the speech production accuracy of the Syllable /tə/ Across Participant Groups.

Pairwise Comparison	Standardized Test Statistic (Z)	Adjusted p Value (Bonferroni)
TA vs. AOS	3.92	< 0.01**
TA vs. DYS	2.79	0.01*
AOS vs. DYS	0.95	1.00

** = significant at 0.05 level of significance; ** = significant at 0.0 level of significance*

For AMR /kə/, Kruskal-Wallis test revealed a statistically significant difference between groups, χ^2 (2) = 12.02, $p < 0.01$. Follow up analysis using bonferroni's adjusted pairwise comparison revealed (see Table 4.10) differences between typical adults and AOS but not from the DYS group. The overall cumulative error rates were higher in AOS group, followed by the participant group of DYS whereas near zero errors were noted in TA group (see Figure 4.6).

Figure 4.6

Box Plot of Cumulative Error Rates for Factors Affecting Speech Production Accuracy During ODDK Production of /kə/ Across Participant Groups

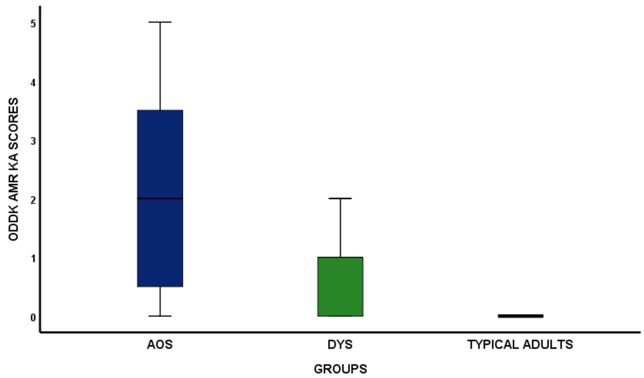


Table 4.10

Pairwise Comparisons of Cumulative ODDK Error Rates for the Speech Production Accuracy of the syllable /tə/ by Participant Group

Pairwise Comparison	Standardized Test Statistic (Z)	Adjusted p Value (Bonferroni)
TA vs. AOS	3.46	< 0.01**
TA vs. DYS	1.92	0.16
AOS vs. DYS	1.40	0.48

*** = significant at 0.01 level of significance*

The findings are in congruence with one of the earlier reports by Nishio & Niimi (2006), who reported that the AMR task was clinically more sensitive than speaking rate/articulation rate in differentiating dysarthric speakers with diverse etiologies, including stroke, ALS, Parkinson's disease, and ataxia, from neurologically healthy controls by bypassing the compensatory coarticulatory strategies commonly used by the clinical population during connected speech tasks. The increased median scores in individuals with dysarthria may be attributed to the weak force physiology (strength, speed, range, effort, steadiness) that is also in consonance with few of the earlier reports (Ackermann et al., 1995; Dworkin & Aronson, 1986). This subsection has shown that AMRs of syllables /pa/,/ta/ and /ka/ could differentiate the speech motor errors of AOS from typical adults when the overall cumulative error rate is considered and not only the rate of delivery. This finding contrasts with a few of the earlier studies that reported preserved performance rapid syllable repetition in individuals with AOS (Ziegler, 2002). We have not provided the rate of production of AMRs in this section, as the sample sizes were minimal, and we recommend using the language-specific norms available in Kannada to judge the rate differences between the groups.

Part B: Sequential motion rates (SMRs)

The SMR task required subjects to repeat either /pətəkə/ or /pətə:ki/ as rapidly and accurately as possible. The speech production accuracy was measured across errors such *as initiation, distortion, distorted substitution/addition, articulatory groping, syllable sequencing, syllable segmentation, substitution, and omission* for the participant groups. Consistency was recorded as consistent or inconsistent across two trials for each item.

From the speech production accuracy table (Table 4.11), it can be inferred that the overall speech production errors in AOS resulted from multiple cumulative factors, including *initiation difficulties, distorted substitutions or additions, articulatory groping, syllable sequencing, syllable segmentation, substitutions, and omissions*. In contrast, dysarthria-related errors are limited to distortions, syllable segmentation, and substitutions. These qualitative differences can enhance our understanding and further facilitate judging the nature of speech motor deficits in AOS compared to those with dysarthria.

Table 4.11

Descriptive Statistics on Factors Affecting Speech Production Accuracy for Sequential Motion Rate (SMRs) across the AOS, Dysarthria, and Typical Adult Groups

Speech Production Accuracy	AOS			DYS			TA		
	Med.	Q1	Q3	Med.	Q1	Q3	Med.	Q1	Q3
Initiation	1	1	1	0	0	0	0	0	0
Distortion	0	0	0	0	0	1	0	0	0
Distorted substitution/addition	0	0	1.25	0	0	0	0	0	0
Articulatory groping	1	0	2	0	0	0	0	0	0
Syllable sequencing	0	0	1	0	0	0	0	0	0
Syllable segmentation	0	0	1.25	0	0	1	0	0	0
Substitution	0	0	0.25	0	0	0.50	0	0	0
Omission	0	0	1.25	0	0	0	0	0	0

Med. = Median

Figure 4.7 shows a box-plot of cumulative error rates of speech production accuracy for SMRs across the groups. It reveals that the median score and its interquartile range is larger in the AOS group compared to dysarthric and typical adult population. This cumulative error rates combined across the factors affecting speech production accuracy was further compared using Kruskal-Wallis test which revealed a statistically significant difference between groups [χ^2 (2) = 18.11, $p < 0.01$]. Follow-up analysis using Bonferroni's adjusted pairwise comparison revealed differences between typical adults and individuals with DYS and AOS. This indicated that SMR facilitates differentiating the speech motor deficits of individuals with AOS and DYS from the TA group using the cumulative error rates of speech production accuracy. Previous studies have supported the usage of SMRs among one of the tasks to be used while assessing AOS, as it acts 'speech-like' task and may well correlate with sentence production measures (Lancheros et al., 2023)

Figure 4.7

Box Plot of Cumulative Error Rates for Factors Affecting Speech Production Accuracy During ODDK Production of SMRs Across Participant Groups

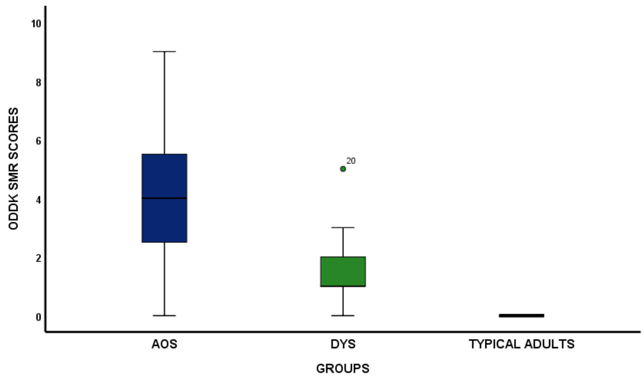


Table 4.12

Pairwise Comparisons of Cumulative Error Rates for the Speech Production Accuracy of the of SMRs (/pətəkə/ or /pətə:ki/) by Participant Group

Pairwise Comparison	Standardized Test Statistic (Z)	Adjusted p Value (Bonferroni)
TA vs. AOS	4.24	< 0.01**
TA vs. DYS	2.40	0.04*
AOS vs. DYS	1.67	0.28

* = significant at 0.05 level of significance; ** = significant at 0.01 level of significance

4.3.4 Automatic and Propositional Speech

The propositional speech task required the subjects to count backwards from 10 to 1, and for the automatic speech task to count forwards from 1 to 10. To avoid any facilitatory effect of the automatic speech task on the propositional speech task, the propositional speech task was administered first, followed by the automatic speech task. The speech production accuracy was measured across factors such *as initiation, distortion, distorted substitution/addition, articulatory groping, syllable sequencing, syllable segmentation, substitution, and omission* for the participant groups.

Part A: Propositional speech task

Table 4.13 shows the speech production accuracy measures for the propositional speech task. From this table it can be inferred that the overall speech production errors of apraxia of speech (AOS) results from mainly initiation difficulties and articulatory groping. In contrast, dysarthria-related errors were seen due to distortions.

Table 4.13

Descriptive Statistics on Speech Production Accuracy Factors for Propositional speech task across the AOS, Dysarthria, and Typical Adult Groups

Speech Production Accuracy	AOS			DYS			TA		
	Med.	Q1	Q3	Med.	Q1	Q3	Med.	Q1	Q3
Initiation	2	1	2	0	0	0	0	0	0
Distortion	0	0	0	1	0	1	0	0	0
Distorted substitution/addition	0	0	0	0	0	0	0	0	0
Articulatory groping	2	2	2	0	0	0	0	0	0
Syllable sequencing	0	0	0	0	0	0	0	0	0
Syllable segmentation	0	0	-	0	0	0	0	0	0
Substitution	0	0	0	0	0	0	0	0	0
Omission	0	0	0	0	0	0	0	0	0

Med. = Median

Figure 4.8 shows a box-plot of cumulative error rates of speech production accuracy for propositional speech task across the groups. It reveals that the median and its interquartile range is larger in the AOS group compared to DYS and typical adult population. Many in the AOS group (n = 8) could not finish this section due to initiation issues, and some had only articulatory groping. Furthermore, when a person with AOS shows severe initiation difficulty, other measures of speech production accuracy was rated as not applicable (NA), as there needs to be speech output to rate these factors. This rule does not apply to articulatory groping, as it could be rated for trial-and-error difficulties in producing speech when no actual speech is being rated.

The final subsection scores cutting across the errors for speech production accuracy for propositional speech was calculated to arrive at the global median score and its interquartile range. This cumulative error rates was further compared using Kruskal-Wallis test which revealed a statistically significant difference between groups [χ^2 (2) = 24.29, $p < 0.01$]. Follow-up analysis using Bonferroni's adjusted pairwise comparison revealed differences between TA and individuals with AOS, and individuals with dysarthria and AOS (see Table 4.14). There was no statistically significant difference observed between DYS and TA as the errors were minimal in these groups (see Figure 4.8). Additionally, DYS group is known to show consistent errors in their performance in propositional or non-propositional speech. Overall, this indicated that propositional speech task facilitates differentiating the speech motor deficits of individuals with AOS from TA and between AOS and DYS groups.

Figure 4.8

Box Plot of Cumulative Error Rates for Factors Affecting Speech Production Accuracy During Propositional Speech Task Across Participant Groups

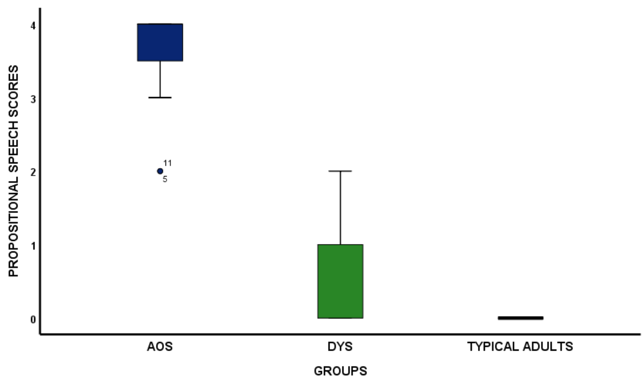


Table 4.14

Pairwise Comparisons of Cumulative Error Rates Affecting Speech Production Accuracy for Propositional speech task by Participant Group

Pairwise Comparison	Standardized Test Statistic (Z)	Adjusted p Value (Bonferroni)
TA vs. AOS	4.80	< 0.01**
TA vs. DYS	1.45	0.44
AOS vs. DYS	3.18	< 0.01**

*** = significant at 0.01 level of significance*

Part B: Automatic speech task

Table 4.15 shows the speech production accuracy scores for the automatic speech task. From this table it can be inferred that the overall speech production errors of apraxia of speech (AOS) results from mainly *initiation difficulties, articulatory groping, and distortions*. In contrast, dysarthria-related errors were seen only due to distortions.

Table 4.15

Descriptive Statistics on Speech Production Accuracy Factors for Automatic speech task across the AOS, Dysarthria, and Typical Adult Groups

Speech Production Accuracy	AOS			DYS			TA		
	Med.	Q1	Q3	Med.	Q1	Q3	Med.	Q1	Q3
Initiation	2	0	2	0	0	0	0	0	0
Distortion	0	0	0.50	1	0	1	0	0	0
Distorted substitution/addition	0	0	0	0	0	0	0	0	0
Articulatory groping	2	0	2	0	0	0	0	0	0
Syllable sequencing	0	0	0	0	0	0	0	0	0
Syllable segmentation	0	0	0	0	0	0	0	0	0
Substitution	0	0	0	0	0	0	0	0	0
Omission	0	0	0	0	0	0	0	0	0

Med. = Median

Figure 4.9 shows a box-plot of cumulative error rates of speech production accuracy for automatic speech task across the groups. It reveals that the median score and its interquartile range is larger in the AOS group compared to dysarthric and typical adult population. The final subsection scores cutting across the errors for automatic speech was calculated to arrive at the global median score. This cumulative error rates combined across the production accuracy was further compared using Kruskal-Wallis test. This revealed a statistically significant difference between groups [χ^2 (2) = 12.70, p < 0.01]. Follow-up analysis using Bonferroni's adjusted pairwise comparison revealed differences between TA and individuals with AOS (Table 4.16). Compared to the propositional speech, the overall production accuracy in automatic speech of AOS was considerably better which could be observed from their median scores across the tasks.

Figure 4.9

Box Plot of Cumulative Error Rates for Factors Affecting Speech Production Accuracy During Automatic Speech Task Across Participant Groups

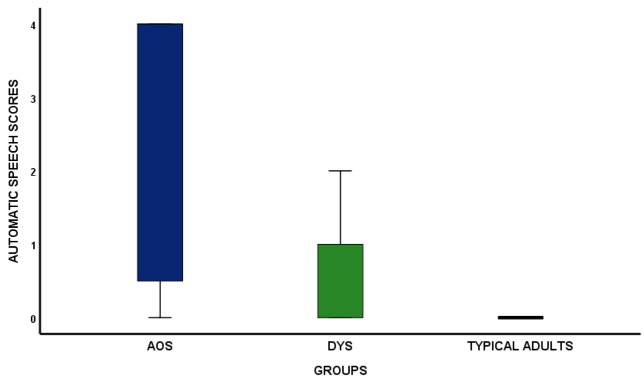


Table 4.16

Pairwise Comparisons of Cumulative Error Rates Affecting Speech Production Accuracy in Automatic Speech Task by Participant Group

Pairwise Comparison	Standardized Test Statistic (Z)	Adjusted p Value (Bonferroni)
TA vs. AOS	3.56	< 0.01**
TA vs. DYS	1.81	0.20
AOS vs. DYS	1.60	0.32

*** = significant at 0.01 level of significance*

4.3.5 Isolated Oral movements for speech

This subsection included a total of nine stimuli comprising vowels and diphthongs and CV syllables. The stimuli were selected based on the predominant involvement of the jaw, lips, and tongue in their production, ensuring representation of the primary oral articulators. The stimuli included were: [ಅ, ಈ, ಊ, ದ, ಕ, ಟ, ಪ, ಮ, and, ಐ].

Part A: Vowels

The Vowel repetition task required the subjects to repeat the vowels ಅ, ಈ, and ಊ after the examiner of the study. The speech production accuracy was measured across errors such *as initiation, articulatory groping, distortion, and substitution* for the participant groups. Consistency was recorded as consistent or inconsistent across two trials for each item. AOS group showed inconsistent responses based on the severity.

From the speech production accuracy table (see Table 4.17), it can be inferred that the overall speech production errors in apraxia of speech (AOS) resulted majorly due to *articulatory groping and substitution errors* in this task. In contrast, DYS and TA groups did not show near zero errors based on the median scores. These qualitative differences in the speech production accuracy factors can enhance our understanding of the speech motor deficits present in individuals with AOS compared to those with dysarthria and typical adults.

Table 4.17

Descriptive Statistics on Factors Affecting Speech Production Accuracy in Vowel Repetition Task Across the AOS, Dysarthria, and Typical Adult Groups

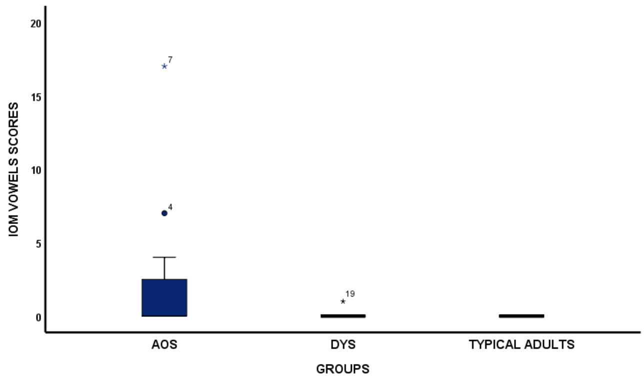
	AOS			DYS			TA		
	Med.	Q1	Q3	Med.	Q1	Q3	Med.	Q1	Q3
Initiation	0	0	0	0	0	0	0	0	0
Articulatory groping	0	0	2	0	0	0	0	0	0
Distortion	0	0	0	0	0	0	0	0	0
Substitution	2	0	0	0	0	0	0	0	0

Med. = Median

Figure 4.10 shows a box-plot of cumulative error rates of speech production accuracy for vowel repetition task across the groups. It reveals that the median score and its interquartile range is larger in the AOS group compared to dysarthric and typical adult population. The final subsection scores by combining the errors noted across the factors of speech production accuracy errors (ಅ, ಈ, ಊ) was calculated to arrive at the global median score. This was further compared between the groups using Kruskal-Wallis test which revealed statistical insignificance between the groups significance [χ^2 (2) = 5.40, p = 0.06].

Figure 4.10

Box Plot of Cumulative Error Rates for Speech Production Accuracy Factors During Vowel Repetition Task Across Participant Groups



The current finding aligns with a previous investigation by Jacks, Mathes, and Marquardt (2010) who examined vowel production in individuals with acquired AOS typical participants, using acoustic measures of vowel formants. Participants were seven adults with co-occurring AOS and aphasia, each of whom produced 15 repetitions of six American English vowels embedded in /hVC/ words. The study computed formant values, the overall size of the vowel space, inter-vowel distances, and variability across repeated productions of the same token. Across all of these measures, the AOS group showed performance that was comparable to typical speakers. The findings suggest that vowel production remains largely intact at the single-word level in AOS. The authors proposed that the sensorimotor planning/programming disruptions minimally affects vowels in AOS, though this conclusion may not extend to more demanding, connected speech contexts.

Part B: Diphthong and CV

The Diphthong and CV repetition task required the subjects to repeat the diphthong and CV ದ, ಕ, ಟ, ಪ, ಮ, and, ಐ after the examiner of the study. The speech production accuracy was measured across errors such *as initiation, articulatory groping, distortion, substitution, and omission* for the participant groups. Consistency was recorded as consistent or inconsistent across two trials for each item. Few of the individuals in AOS group showed inconsistent responses in this task.

From the error rates recorded on speech production accuracy (see Table 4.18), it can be inferred that the overall speech production errors in apraxia of speech (AOS) result from multiple cumulative factors, including *initiation difficulties, articulatory groping, distortions, substitutions, and omissions*. In contrast, errors were limited to distortions, and substitutions in the DYS group.

Table 4.18

Descriptive Statistics on Factors affecting Speech Production Accuracy for Diphthongs and CV Across the AOS, Dysarthria, and Typical Adult Groups

	AOS			DYS			TA		
	Med.	Q1	Q3	Med.	Q1	Q3	Med.	Q1	Q3
Initiation	2	0	5	0	0	0	0	0	0
Articulatory groping	4	0	7	0	0	0	0	0	0
Distortion	0.5	0	1.25	0	0	2	0	0	0
Substitution	2	2	4	0	0	1	0	0	0
Omission	0.5	0	1	0	0	0	0	0	0

Med. = Median

Figure 4.11 shows a box-plot of cumulative error rates of speech production accuracy for diphthong and CV repetition task across the groups. Here again, the overall trends revealed similar to the vowel repetition task. The median score and its interquartile range is larger in the AOS group compared to dysarthric and typical adult population. The final subsection scores cutting across the errors (ದ, ಕ, ಟ, ಪ, ಮ, and, ಐ) of speech production accuracy was calculated to arrive at the global median score for each group separately. The Kruskal-Wallis test revealed a statistically significant difference between groups on these cumulative error rates [χ^2 (2) = 18.70, $p < 0.01$]. Follow-up analysis revealed differences between typical adults and the AOS group and between AOS and the dysarthria group. This indicated that Diphthong and CV repetition task facilitates differentiating the speech motor deficits of individuals with AOS from the typical adult group and dysarthric group using the cumulative error rates of speech production accuracy.

Figure 4.11

Box Plot of Cumulative Error Rates for Speech Production Accuracy for Diphthongs and CV Repetition Task Across Participant Groups

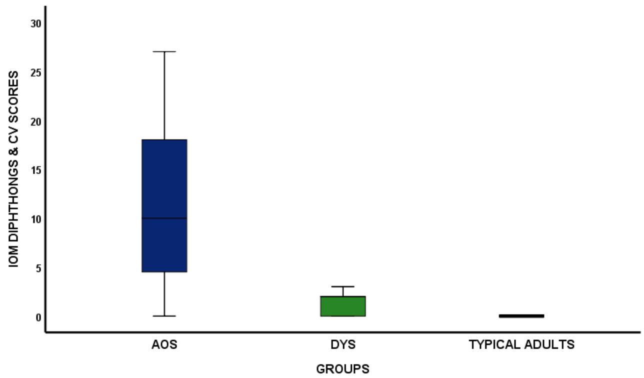


Table 4.19

Pairwise Comparisons of Cumulative Error Rates for Speech Production Accuracy for Diphthong and CV repetition task by Participant Group

Pairwise Comparison	Standardized Test Statistic (Z)	Adjusted p Value (Bonferroni)
TA vs. AOS	4.28	< 0.01**
TA vs. DYS	1.65	0.29
AOS vs. DYS	2.48	0.03*

** = significant at 0.05 level of significance; ** = significant at 0.01 level of significance*

4.3.6 Syllabic and Word repetition task

This subsection included a total of 10 stimuli comprising a) Two syllables and and b) 8 words. The word stimuli were selected based on the Phonological Neighbourhood Density (PND) and biphone frequency.

Part A: Syllable repetition task

The Syllable repetition task required the subjects to repeat the syllables ಕೊ and ಟೇ after the model provided by the investigator of the study. The speech production accuracy was measured across errors such *as initiation, distortion, distorted substitution/addition, articulatory groping, substitution, and omission* for the participant groups. Consistency was recorded as consistent or inconsistent across two trials for each item. Comapred to other groups, AOS group showed minimal inconsistent responses.

From the speech production accuracy table (Table 4.20), it can be inferred that the overall speech production errors in apraxia of speech (AOS) result from multiple cumulative factors, including *initiation difficulties, distorted substitutions or additions, articulatory groping, substitutions, and omissions*. In contrast, dysarthria-related errors were limited to *distortion and substitution* errors.

These qualitative differences in the type of errors shown by these two groups could be used while differentiating their sensorimotor planning and execution difficulties.

The overall errors observed in this subsection across the groups were generally less as this involved only two stimulus which were monosyllables in nature. As the overall number of errors were limited, analysis was not computed to check the effect of syllable frequeny on speech production accuracy across the groups.

Table 4.20

Descriptive Statistics on Speech Production Accuracy Factors for Syllable repetition task across the AOS, Dysarthria, and Typical Adult Groups

	AOS			DYS			TA		
	Med.	Q1	Q3	Med.	Q1	Q3	Med.	Q1	Q3
Initiation	1	0	2	0	0	0	0	0	0
Distortion	0	0	0	0	0	1.5	0	0	0
Distorted substitution/addition	0	0	2	0	0	0	0	0	0
Articulatory groping	1	0	2	0	0	0	0	0	0
Substitution	1	0	1	0	0	1	0	0	0
Omission	0	0	2	0	0	0	0	0	0

Med. = Median

Figure 4.12 shows a box-plot of cumulative error rates of speech production accuracy for syllable repetition task across the groups. It reveals that the median score and its interquartile range is larger in the AOS group compared to dysarthric and typical adult population. The final subsection scores cutting across the errors (ಕೊ and ಟೆ) was calculated to arrive at the global median score. This global median score that reflected the cumulative error rates combined across the speech production accuracy was compared using Kruskal-Wallis test. This revealed a statistically significant difference between groups [χ^2 (2) = 15.53, $p < 0.01$]. A follow-up pairwise analysis using Bonferroni's adjusted comparison values revealed differences only between typical adults and individuals with AOS (Table 4.21). This indicated that Syllable repetition task facilitates differentiating the speech motor deficits of individuals with AOS from the typical adult group.

Figure 4.12

Box Plot of Cumulative Error Rates for Factors Affecting Speech Production Accuracy During Syllable Repetition Task Across Participant Groups

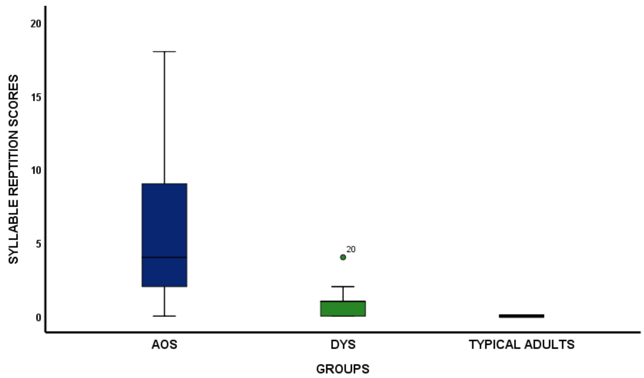


Table 4.21

Pairwise Comparisons of Cumulative Error Rates Across Speech Production Accuracy for Syllable repetition task by Participant Groups

Pairwise Comparison	Standardized Test Statistic (Z)	Adjusted p Value (Bonferroni)
TA vs. AOS	3.93	< 0.01**
TA vs. DYS	1.70	0.26
AOS vs. DYS	2.08	0.11

** = significant at 0.01 level of significance

Part B: Word repetition task

The Word repetition task required the participants to repeat the words after the examiner of the study. The speech production accuracy was measured across errors such *as initiation, distortion, distorted substitution/addition, articulatory groping, syllable sequencing, syllable segmentation, substitution, and omission* for the participant groups. Consistency was recorded as consistent or inconsistent across two trials for each item. AOS group showed minimally inconsistent responses in comparison to other two participant groups.

From the speech production accuracy table (Table 4.22), it can be inferred that the overall speech production errors in apraxia of speech (AOS) result from multiple cumulative factors, including *initiation difficulties, distortions, distorted substitutions or additions, articulatory groping, syllable sequencing, syllable segmentation, substitutions, and omissions*. In contrast, dysarthria-related errors were mostly limited to distortions with negligible errors across distorted substitutions or additions, syllable segmentation, and substitutions.

Table 4.22

Descriptive Statistics on Factors Affecting Speech Production Accuracy for Word Repetition Task Across the AOS, Dysarthria, and Typical Adult Groups

	AOS			DYS			TA		
	Med.	Q1	Q3	Med.	Q1	Q3	Med.	Q1	Q3
Initiation	9	5	11	0	0	0	0	0	0
Distortion	0.5	0	2	3	0	8	0	0	0
Distorted substitution/addition	2	0	4.75	0	0	0.5	0	0	0
Articulatory groping	9	5	12	0	0	0	0	0	0
Syllable sequencing	0	0	4.75	0	0	0	0	0	0
Syllable segmentation	0	0	3	0	0	0.5	0	0	0
Substitution	3	1.75	4.25	0	0	1.5	0	0	0
Omission	1	0	2.25	0	0	0	0	0	0

Med. = Median

Figure 4.13 shows a box-plot of cumulative error rates of speech production accuracy for Word repetition task across the groups. It reveals that the median score and its interquartile range is larger in the AOS group compared to dysarthric and typical adult population. The final subsection scores combining all the accuracy errors word repetition were calculated to arrive at the global median score. This was compared between the groups using Kruskal-Wallis test. The test revealed a statistically significant difference between groups [χ^2 (2) = 24.42, $p < 0.01$]. Follow-up analysis demonstrateddifferences between TA and AOS and AOS and DYS groups (see Table 4.23). This indicated that word repetition task facilitated differentiating the speech motor deficits of individuals with AOS from the typical adult group and AOS from dysarthric group.

Figure 4.13

Box Plot of Cumulative Error Rates for Speech Production Accuracy Factors During Word Repetition Task Across Participant Groups

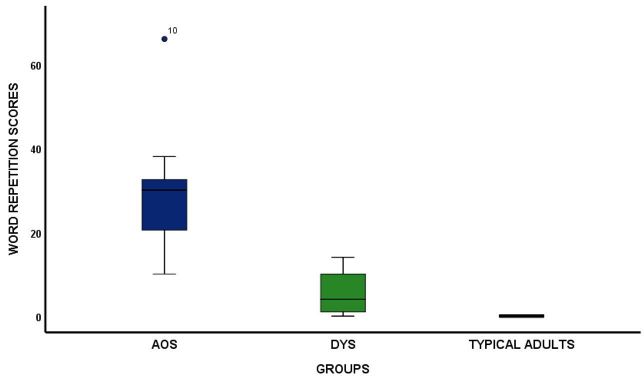


Table 4.23

Pairwise Comparisons of Cumulative Error Rates Across Speech Production Accuracy Factors for Word repetition task by Participant Groups

Pairwise Comparison	Standardized Test Statistic (Z)	Adjusted p Value (Bonferroni)
TA vs. AOS	4.91	< 0.01**
TA vs. DYS	1.95	0.15
AOS vs. DYS	2.77	0.01*

* = significant at 0.05 level of significance; ** = significant at 0.01 level of significance

The current findings of increased initiation, articulatory groping and substitution errors in AOS was contradicted by Odell et al. (1990). They studied single-word repetitions by 4 brain-damaged adults with apraxia of speech (AOS) but without concomitant aphasia and were transcribed using a standard narrow phonetic transcription system. Among the results was the atypical finding that consonant distortions exceeded all other error types including sound substitutions. In addition, errors predominated in the medial position of words, and monosyllabic words had approximately the same error rate per number of consonants as did multisyllabic words. The finding of increased distortions in DYS group and higher substitution errors of AOS is supported by the findings of Johns and Darley (1970). Due to time constraints and requirement of complex statistical analysis, the effect of PND and biphone frequency could not be separately analyzed in the word repetition subtest.

4.3.7 Length and Complexity task

This subsection included both length and complexity task.

Part A: Length task

This subsection included a total of 12 stimuli comprising of base word (3, 4 and 5 syllable length) with increase in length and required the subjects to repeat the stimulus after the examiner. The base words also varied in terms of its frequency of occurrence and were further divided into high frequent (HF) and low frequent (LF) words. The speech production accuracy was measured across errors such *as initiation, distortion, distorted substitution/addition, articulatory groping, syllable sequencing, syllable segmentation, increase in error with increase in length, substitution, and omission* for the participant groups. Consistency was recorded as consistent or inconsistent across two trials for each item. AOS were relatively inconsistent compared to other two groups.

Table 4.24 shows the overall combined error rates across HF and LF words for the length task. It could be inferred from the below table that the overall speech production errors in apraxia of speech (AOS) result from multiple cumulative factors, including *initiation difficulties, distortions, distorted substitutions or additions, articulatory groping, syllable segmentation, increase in error with increase in length, substitutions, and omissions*. In contrast, major dysarthria-related errors were due to *distortion and a few syllable segmentations, increase in error with increase in length, and substitutions*. These qualitative differences can enhance our understanding of the speech motor deficits present in individuals with AOS compared to those with dysarthria and typical adults.

Table 4.24

Descriptive Statistics on Speech Production Accuracy Factors for Length task across the AOS, Dysarthria, and Typical Adult Groups

	AOS			DYS			TA		
	Med.	Q1	Q3	Med.	Q1	Q3	Med.	Q1	Q3
Initiation	20	15	24	0	0	0	0	0	0
Distortion	1.5	0	3	7	2.50	17	0	0	0
Distorted substitution/addition	1.5	0	3.75	0	0	0	0	0	0
Articulatory groping	10.50	2	21.25	0	0	0	0	0	0
Syllable sequencing	0	0	0	0	0	0	0	0	0
Syllable segmentation	0	0	3.25	0	0	3.5	0	0	0
Increase in error with increase in length	10	4.75	14.25	0	0	2	0	0	0
Substitution	0	0	1.5	0	0	2	0	0	0
Omission	4.50	2.25	6	0	0	0	0	0	0

Med. = Median

Figure 4.14 shows a box-plot of cumulative error rates of speech production accuracy for high frequency 3 syllable words across the groups. It reveals that the median score and its interquartile range is larger in the AOS group compared to dysarthric and typical adult population. The final subsection scores combining all the errors for high frequency 3 syllable words were calculated to arrive at the global median score.

This combined error rates for the 3 syllable lengths across the production accuracy was further compared using Kruskal-Wallis test. There was a statistically significant difference between groups [χ^2 (2) = 22.65, $p < 0.01$]. Follow-up analysis using Bonferroni's adjusted pairwise comparison (Table 4.25) revealed statistically significant differences between typical adults and AOS group and AOS and Dysarthria group but no differences seen between TA and

DYS due to comparable median scores. This indicated that high frequency 3 syllable word task facilitates differentiating the speech motor deficits from AOS and DYS with TA groups.

Figure 4.14

Box Plot of Cumulative Error Rates for Factors Affecting Speech Production Accuracy During Production of High frequency 3 syllable words Across Participant Groups

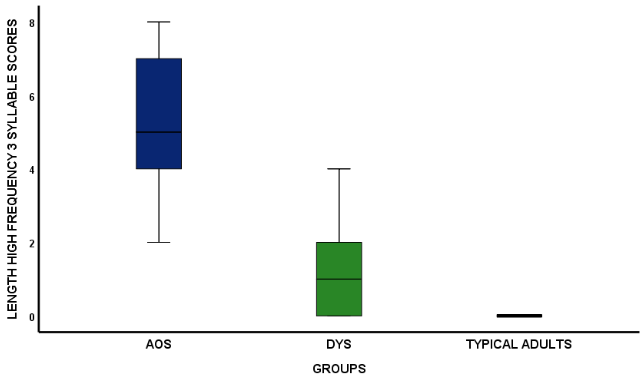
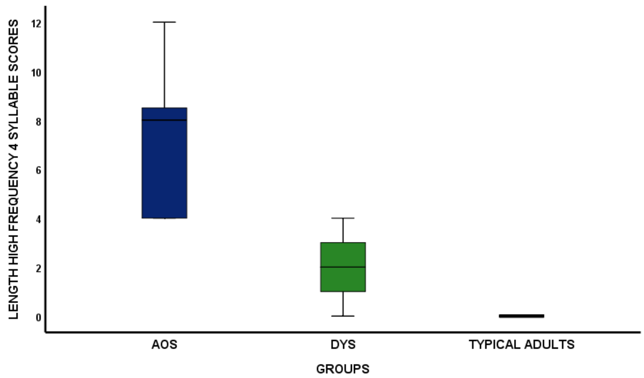


Figure 4.15 shows a box-plot of cumulative error rates of speech production accuracy for high frequency 4 syllable words across the groups. It reveals that the median score and its interquartile range is larger in the AOS group compared to dysarthric and typical adult population. Kruskal-Wallis test revealed a statistically significant difference between groups [χ^2 (2) = 25.01, $p < 0.01$] for the cumulative error rates for the 4 syllable length condition. Pairwise comparison (Table 4.25) revealed trends similar to the 3 syllable lengths wherein differences were significant between TA vs. AOS and AOS vs. DYS groups with no significant difference seen for TA vs. DYS groups.

Figure 4.15

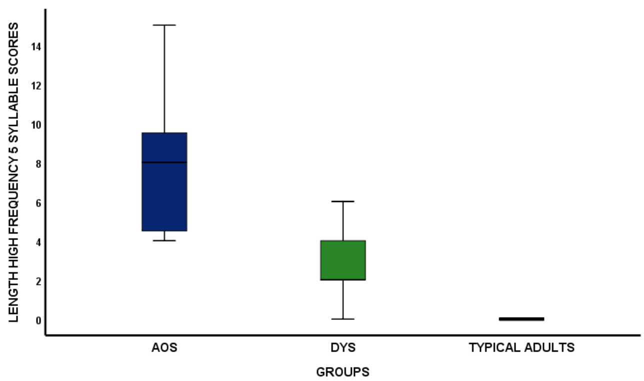
Box Plot of Cumulative Error Rates for Factors Affecting Speech Production Accuracy During Production of High frequency 4 syllable words Across Participant Groups



However, when the error rates were compared for 5 syllable HF words, statistically highly significant differences were seen between TA vs. AOS groups whereas marginally significant differences were observed between TA vs. DYS and AOS vs. DYS groups. This indicated that at increased lengths the both AOS and DYS showed more errors compared to TA groups. This further indicated that increasing the syllable length reveals the speech motor deficits across speech motor disorders of AOS and dysarthria.

Figure 4.16

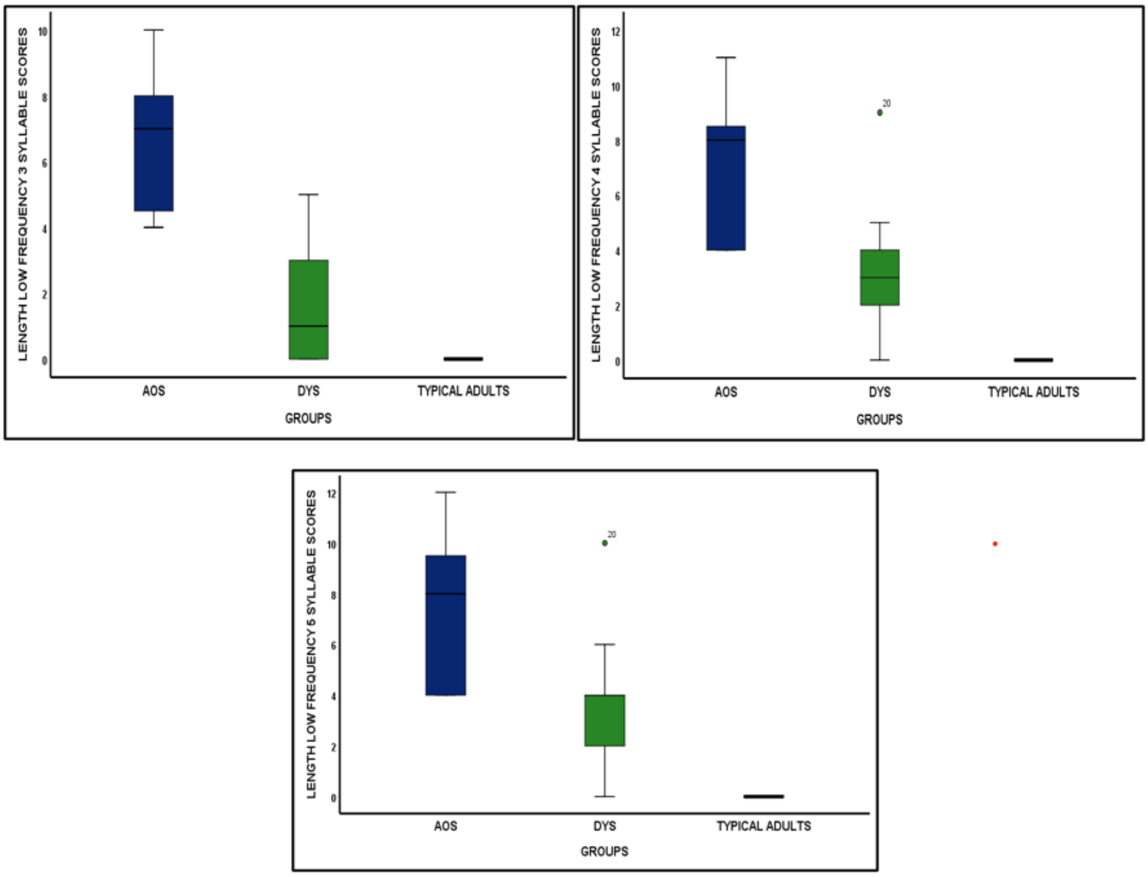
Box Plot of Cumulative Error Rates for Factors Affecting Speech Production Accuracy During Production of High frequency 5 syllable words Across Participant Groups



Comparison of cumulative error rates for speech production accuracy across low-frequency words with syllable lengths varying from 3 syllables, 4 syllables, and 5 syllables showed significant differences in the Kruskal-Wallis analysis. Pairwise comparisons revealed interesting results. At 3 syllable lengths, statistically significant differences were observed between TA vs. AOS and AOS vs. DYS groups. No significant differences were seen between TA and DYS. For 4 syllable lengths, statistically significant differences were observed between TA vs. AOS and TA vs. DYS, but no differences were seen between AOS vs. DYS. The trends for 5-syllable lengths mimicked those for the 4-syllable length condition.

Figure 4.17

Box Plot of Cumulative Error Rates for Low-Frequency 3-, 4-, and 5-Syllable Length Words Across Participant Groups



This indicated that at longer syllable LF words (4 and 5 syllables), there will be comparable error rates between AOS and DYS groups, whereas differences will emerge between these groups only at shorter syllable length conditions. The overall increase in the error rates at the longer syllable lengths could be attributed to the lack of difference between these two speech motor disorders. The pairwise comparison is shown in Table 4.3.37.2, and cumulative error rates for this subsection pertaining to low-frequency word lengths are shown as Figure 4.17.

Table 4.25

Pairwise Comparisons of Cumulative Error Rates Across Speech Production Accuracy Factors for Length task by Participant Group

Words	Pairwise Comparison	Standardized Test Statistic (Z)	Adjusted p Value (Bonferroni)
High Frequency words			
3 syllables	TA vs. AOS	4.67	< 0.01**
	TA vs. DYS	1.53	0.37
	AOS vs. DYS	2.96	< 0.01**
4 syllables	TA vs. AOS	4.99	< 0.01**
	TA vs. DYS	2.26	0.07
	AOS vs. DYS	2.53	0.03*
5 syllables	TA vs. AOS	4.91	< 0.01**
	TA vs. DYS	2.34	0.05#
	AOS vs. DYS	2.37	0.05#
Low Frequency Words			
3 syllables	TA vs. AOS	4.75	< 0.01**
	TA vs. DYS	1.79	0.21
	AOS vs. DYS	2.7	0.01*
4 syllables	TA vs. AOS	4.68	< 0.01**
	TA vs. DYS	2.61	0.02*
	AOS vs. DYS	1.88	0.18
5 syllables	TA vs. AOS	4.64	< 0.01**
	TA vs. DYS	2.69	0.02*
	AOS vs. DYS	1.75	0.23

** = significant at 0.05 level of significance; ** = significant at 0.01 level of significance; # = marginally significant at 0.06 level of significance*

One of the key findings of this study is that the high-frequency words were marginally superior in differentiating the speech motor performance of individuals with AOS and DYS compared to low-frequency words, as it was clear that except at shorter lengths (3 syllables only), longer low-frequency words led to comparable performance between the AOS and DYS groups. This subsection is crucial, as the results revealed that the word lists across frequencies and length conditions could differentiate the speech motor performance of AOS from typical adults. A few earlier studies have demonstrated an increase in overall production errors in AOS (increase in false starts, consonant omissions, and lexical stress errors) along with movement deficits in the tongue during a kinematic investigation with increased word length conditions (Bartle et al., 2007; Md Nor et al., 2022).

Part B: Complexity task

This subsection included a total of 12 stimuli comprising of word with increase in complexity and required the subjects to repeat the stimulus after the examiner. The speech production accuracy was measured across errors such *as initiation, distortion, distorted substitution/addition, articulatory groping, syllable sequencing, syllable segmentation, increase in error with increase in complexity, substitution, and omission* for the participant groups. The complexity of the words was increased using Stoel-Gammon's Complexity (SGC) metric, which includes three levels of word complexity: 4, 6, and 8 SGC. Consistency was recorded as consistent or inconsistent across two trials for each item. AOS group showed inconsistent response based on the severity.

From the speech production accuracy table (see Table 4.26), it can be inferred that the overall speech production errors in apraxia of speech (AOS) result from multiple cumulative factors, including initiation difficulties, distortions, distorted substitutions or additions, articulatory groping, syllable sequencing, syllable segmentation, increase in error with increase in complexity, substitutions, and omissions. In contrast, major dysarthria-related errors were due to distortion and a few distorted substitutions or additions, syllable segmentations, and substitutions. These qualitative differences can enhance our understanding of the speech motor deficits present in individuals with AOS compared to those with dysarthria and typical adults.

Table 4.26

Descriptive Statistics on Speech Production Accuracy Factors for Complexity task across the AOS, Dysarthria, and Typical Adult Groups

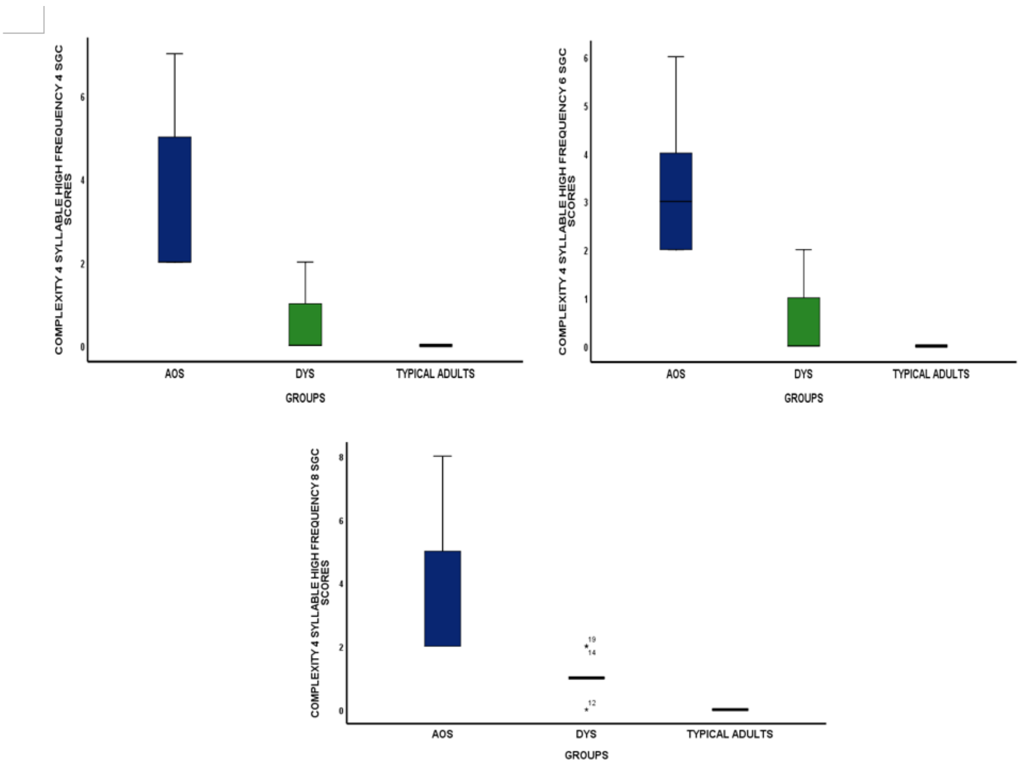
	AOS			DYS			TA		
	Median	Q1	Q3	Median	Q1	Q3	Median	Q1	Q3
Initiation	22.50	20.50	24	0	0	0	0	0	0
Distortion	0.50	0	4.50	4	4	13.50	0	0	0
Distorted substitution/addition	1	0	2.25	0	0	0.50	0	0	0
Articulatory groping	23	12	24	0	0	0	0	0	0
Syllable sequencing	0	0	0.25	0	0	0	0	0	0
Syllable segmentation	0	0	0.50	0	0	1.5	0	0	0
Increase in error with increase in complexity	3	1.75	8	0	0	0	0	0	0
Substitution	0	0	2.25	0	0	1	0	0	0
Omission	2	1.75	4	0	0	0	0	0	0

A. Four syllable high frequency words across speech complexity.

Kruskal Wallis analysis revealed statistically significant differences between the groups across various SGC conditions [4 SGC: [χ^2 (2) = 23.63, p < 0.01]; 6SGC: [χ^2 (2) = 23.68, p < 0.01] 8SGC: χ^2 (2) = 24.93, p < 0.01] for ***4 syllable high frequency words.*** Pairwise comparison with respect to 4 syllable high-frequency words, statistically highly significant differences were observed across all speech complexity conditions between TA and AOS groups. This was true across all speech complexity conditions (4, 6, and 8 SGC; all $p < .01$). This indicated that all speech complexity conditions derived using Stoel-Gammon's speech complexity metric was equally effective in bringing the differences between TA and AOS groups. Similar trend was observed for comparisons made between AOS and DYS. However, the differences were insignificant between TA and DYS groups. A slight increase in error rates for the DYS group was seen at the highest complexity level (8 SGC), and the comparison between TA and DYS approached significance (p = .05), suggesting a slight increase in error rates for the DYS group under more demanding speech production conditions. Overall, a clear performance hierarchy was observed where AOS group showed the highest error followed by DYS and TA groups. Figure 4.18 shows the box-plot for 4 syllable high frequency words across speech complexity levels across the participant groups.

Figure 4.18

Box Plot of Cumulative Error Rates for Speech Production Accuracy in 4-Syllable High-Frequency Words Across Complexity Levels and Participant Groups

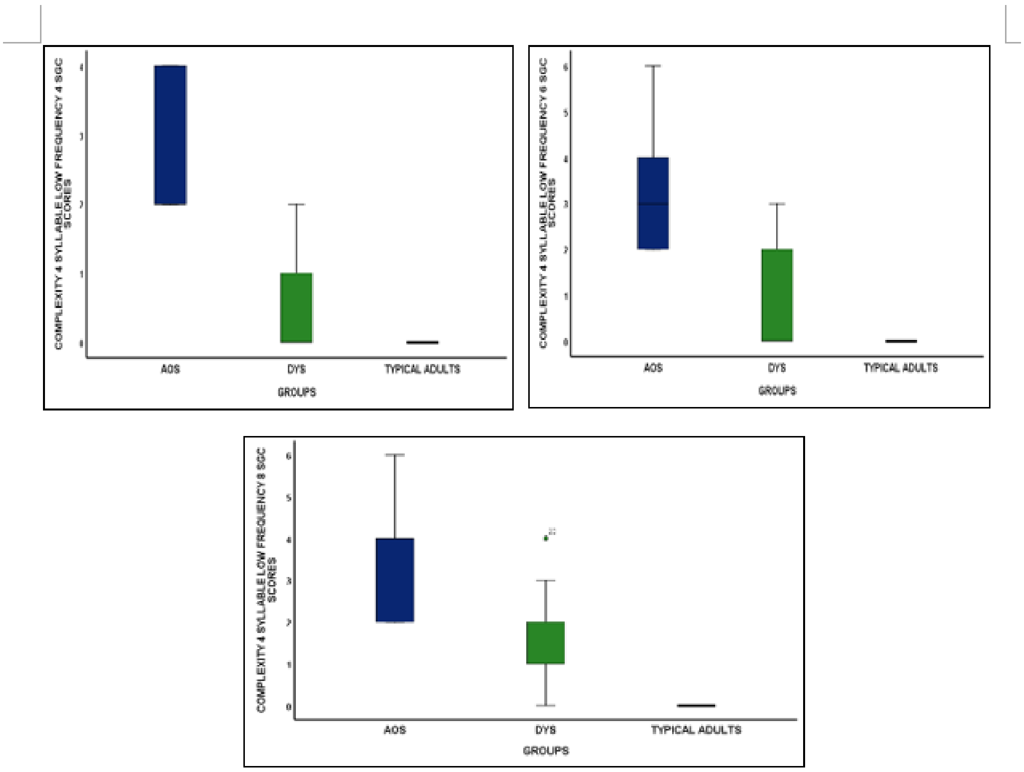


B. Four syllable Low Frequency Words Across Speech Complexity.

Kruskal Wallis analysis revealed statistically significant differences between the groups across various SGC conditions [4 SGC: χ^2 (2) = 22.80, p < 0.01]; 6SGC: χ^2 (2) = 21.08, p < 0.01] 8SGC: χ^2 (2) = 21.17, p < 0.01] for ***4 syllable low frequency words***. The trends were same here with 4 syllable low-frequency words to that of high frequency words where significant differences were observed between the TA and AOS groups across all speech complexity levels. At 4, 6 levels of complexity differences were seen between the AOS and DYS groups too but no such differences were seen at 8 level of syllabic complexity. also differed significantly at the lower and intermediate complexity levels (4 and 6 SGC; $p < .01$ and $p = .01$, respectively). Additionally, TA and DYS was significant only at 8-SGC level.

Figure 4.19

Box Plot of Cumulative Error Rates for Speech Production Accuracy in 4-Syllable Low-Frequency Words Across Complexity Levels and Participant Groups



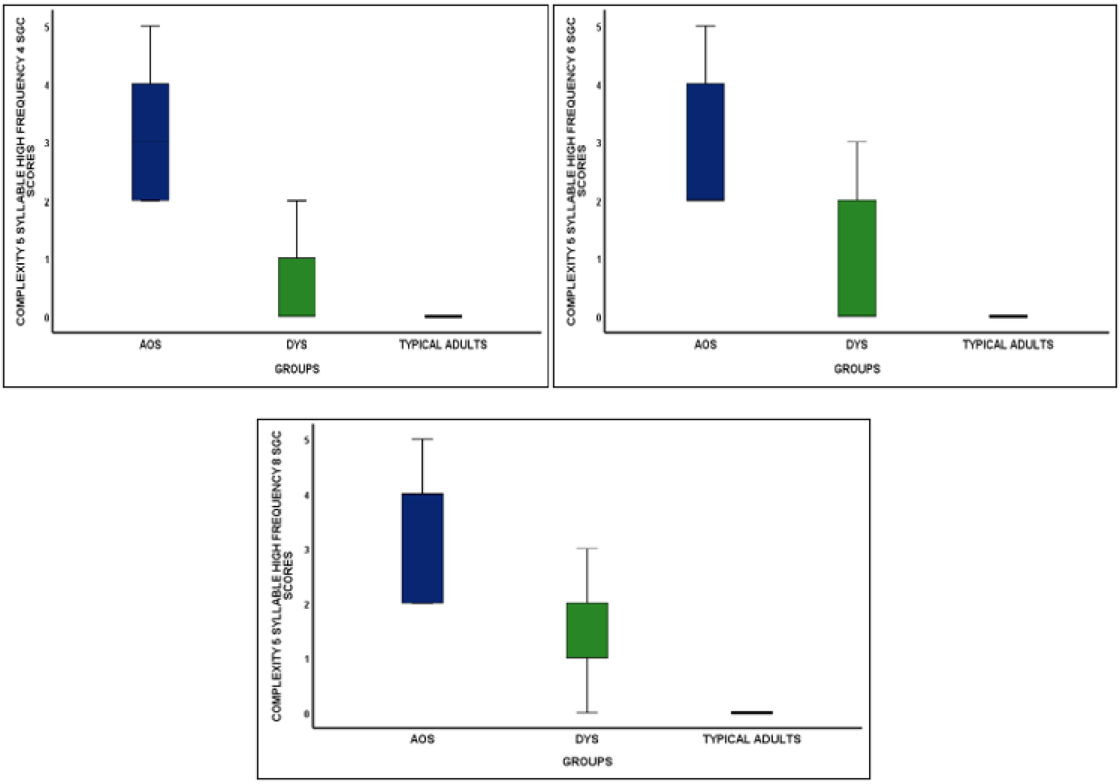
These findings suggest that when speech complexity level increases in low-frequency words, the difference between the AOS and DYS groups reduces while simultaneously increasing the distinction between the DYS and TA groups. Hence, at the high complexity low-frequency condition, comparable cumulative errors were observed between individuals with apraxia of speech and dysarthria. Figure 4.19 displays the cumulative error rates across groups for 4 syllable low frequency condition across speech complexity levels.

C. Five Syllable High Frequency Words Across Speech Complexity.

Kruskal-Wallis analysis revealed statistically significant differences between the groups across various SGC conditions [4SGC: χ^2 (2) = 23.69, $p < 0.01$; 6SGC: χ^2 (2) = 20.57, $p < 0.01$; 8SGC: χ^2 (2) = 22.84, $p < 0.01$] for 5-syllable high-frequency words across speech complexity levels. Pairwise comparison revealed significant differences between the TA and AOS groups across all speech complexity levels. Similar trends were also observed between AOS and DYS groups across all complexity levels. On the contrary, no significant differences were observed between the TA and DYS groups. These findings indicate that AOS showed the highest cumulative errors in speech production accuracy irrespective of the change in the speech complexity. While individuals with dysarthria performed similarly to typical adults, it may possibly be attributed to the facilitatory effects of high-frequency words on their speech motor performance. Additionally, as AOS and DYS showed significant differences across complexity levels, this subsection could differentiate these two groups based on cumulative error rates for speech motor performance. Figure 4.20 displays the cumulative error rates across groups for 5 syllable high frequency condition across speech complexity levels.

Figure 4.20

Box Plot of Cumulative Error Rates for Speech Production Accuracy in 5-Syllable High-Frequency Words Across Complexity Levels and Participant Groups

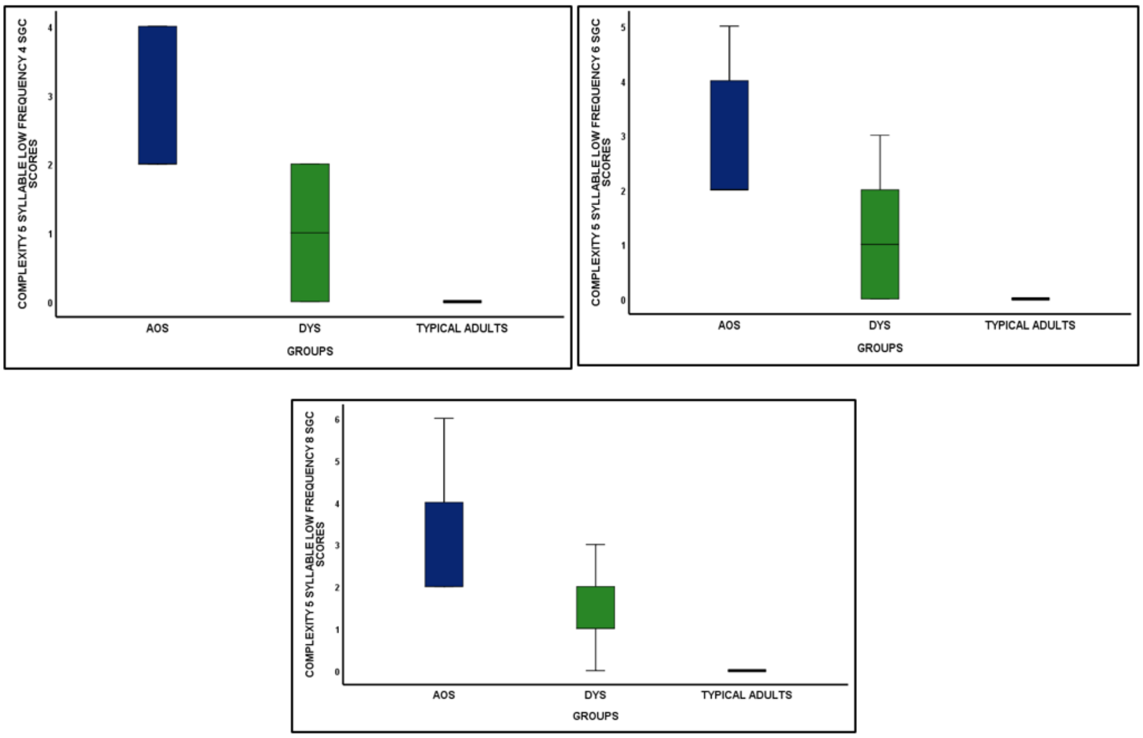


D. Five Syllable Low Frequency Words Across Speech Complexity.

Kruskal-Wallis analysis revealed statistically significant differences between the groups across various SGC conditions [4SGC: χ^2 (2) = 21.19, $p < 0.01$; 6SGC: χ^2 (2) = 21.06, $p < 0.01$; 8SGC: χ^2 (2) = 22.44, $p < 0.01$] for 5-syllable low-frequency words across speech complexity levels. For 5-syllable low-frequency words, statistically significant differences were observed between the TA and AOS groups across all speech complexity levels. Significant differences between the AOS and DYS groups were evident only at the lowest complexity level, whereas at the higher complexity levels, such as 6- and 8-SGC conditions, the groups' differences were no longer statistically significant. Similar to the 5-syllable high-frequency words, no differences were observed between TA and DYS groups. Figure 4.21 displays the cumulative error rates across groups for 5 syllable low frequency condition across speech complexity levels.

Figure 4.21

Box Plot of Cumulative Error Rates for Speech Production Accuracy in 5-Syllable Low-Frequency Words Across Complexity Levels and Participant Groups



Together these findings indicate that as speech complexity increased, the overall distinctions between AOS and DYS progressively reduced, suggesting comparable error rates between these two groups. At the same time, the AOS group showed higher overall cumulative error rates for speech production accuracy, and the TA group continued to demonstrate near-zero error rates.

Table 4.27

Pairwise Comparisons of Cumulative Error Rates Across Speech Production Accuracy Factors for Complexity task by Participant Group

Frequency	Syllable length	SGC	Pairwise Comparison	Standardized Test Statistic (Z)	Adjusted p Value (Bonferroni)
High Frequency (HF)	Four	4	TA vs. AOS	4.68	< 0.01**
			TA vs. DYS	1.21	0.67
			AOS vs. DYS	3.31	< 0.01**
		6	TA vs. AOS	4.68	< 0.01**
			TA vs. DYS	1.19	0.69
			AOS vs. DYS	3.33	< 0.01**
		8	TA vs. AOS	4.99	< 0.01*
			TA vs. DYS	2.34	0.05#
			AOS vs. DYS	2.45	0.04*
Low Frequency (LF)	Four	4	TA vs. AOS	4.63	< 0.01**
			TA vs. DYS	1.30	0.57
			AOS vs. DYS	3.16	< 0.01**
		6	TA vs. AOS	4.49	< 0.01**
			TA vs. DYS	1.43	0.45
			AOS vs. DYS	2.90	0.01*
		8	TA vs. AOS	4.60	< 0.01**
			TA vs. DYS	2.39	0.05#
			AOS vs. DYS	2.02	0.12
High Frequency (HF)	Five	4	TA vs. AOS	4.68	< 0.01**
			TA vs. DYS	1.19	0.69
			AOS vs. DYS	3.33	< 0.01**
		6	TA vs. AOS	4.45	< 0.01**
			TA vs. DYS	1.50	0.40
			AOS vs. DYS	2.80	0.01*
		8	TA vs. AOS	4.77	< 0.01**
			TA vs. DYS	2.19	0.08
			AOS vs. DYS	2.39	0.04*
Low Frequency (LF)	Five	4	TA vs. AOS	4.65	< 0.01**
			TA vs. DYS	1.66	0.28
			AOS vs. DYS	2.82	0.01*
		6	TA vs. AOS	4.58	< 0.01**
			TA vs. DYS	2.09	0.10
			AOS vs. DYS	2.31	0.06
		8	TA vs. AOS	4.73	< 0.01**
			TA vs. DYS	2.25	0.07
			AOS vs. DYS	2.29	0.06

** = significant at 0.05 level of significance; ** = significant at 0.01 level of significance; # = marginally significant at 0.06 level of significance*

4.3.8 Sentence repetition task

This subsection included a total of 8 phrase/sentences with increase in syllable count and complexity and required the subjects to repeat the stimulus after the examiner. The sentences were constructed based on a) word frequency (high or low frequent) and b) Word complexity using the Stoel Gammon's Complexity (SGC) metric [across 5, 8, 18, 23 SGC]. The speech production accuracy was measured across errors such *as initiation, distortion, distorted substitution/addition, articulatory groping, syllable sequencing, syllable segmentation, excess/equal stress, false starts/restarts, sound/syllable/word repetition, substitution, and omission* for the participant groups. Consistency was recorded as consistent or inconsistent across two trials for each item. AOS group showed inconsistent response based on the severity.

From the speech production accuracy table (Table 4.3.8.1), it can be inferred that the overall speech production errors in apraxia of speech (AOS) result from multiple cumulative factors, including initiation difficulties, distortions, distorted substitutions or additions, articulatory groping, syllable sequencing, false starts/restarts, sound/syllable/word repetition, substitutions, and omissions. When carefully observed most individuals in the AOS group got higher median scores only in initiation and articulatory groping errors indicating that these two were the major contributors for the overall cumulative increase in their error rates. In contrast, major dysarthria-related errors were due to distortion, substitution, distorted substitution or addition, and omission. In very few individuals syllable sequencing, syllable segmentations, excess/equal stress, false starts/restarts, and sound/syllable/word repetition were observed (Please note the median across these factors is zero)

Table 4.28

Descriptive Statistics on Factors Affecting Speech Production Accuracy for Sentence repetition task across the AOS, Dysarthria, and Typical Adult Groups

Speech Production Accruacy	AOS			DYS			TA		
	Med.	Q1	Q3	Med.	Q1	Q3	Med.	Q1	Q3
Initiation	15	13	16	0	0	0	0	0	0
Distortion	0	0	1	3	1.5	10	0	0	0
Distorted substitution/addition	0	0	3	1	0	2.5	0	0	0
Articulatory groping	14	3	16	0	0	0	0	0	0
Syllable sequencing	0	0	2	0	0	0.5	0	0	0
Syllable segmentation	0	0	0	0	0	1	0	0	0
Excess/ Equalized stress	0	0	0	0	0	3	0	0	0
False starts/ Restarts	0	0	1	0	0	1	0	0	0.25
Sound/ Syllable/Word repetition	0	0	1	0	0	1	0	0	0
Substitution	0	0	1	1	0	1.5	0	0	1
Omission	0	0	2	3	0	4	0	0	0.25

Med. = Median

In typical adults there were some errors observed less frequently during the production of low frequency sentences with high complexity and the errors observed were false starts/restarts, substitutions, and omissions. Table 4.28 displays the overall cumulative error rates for phrases/sentences constructed across word frequency and complexity measures.

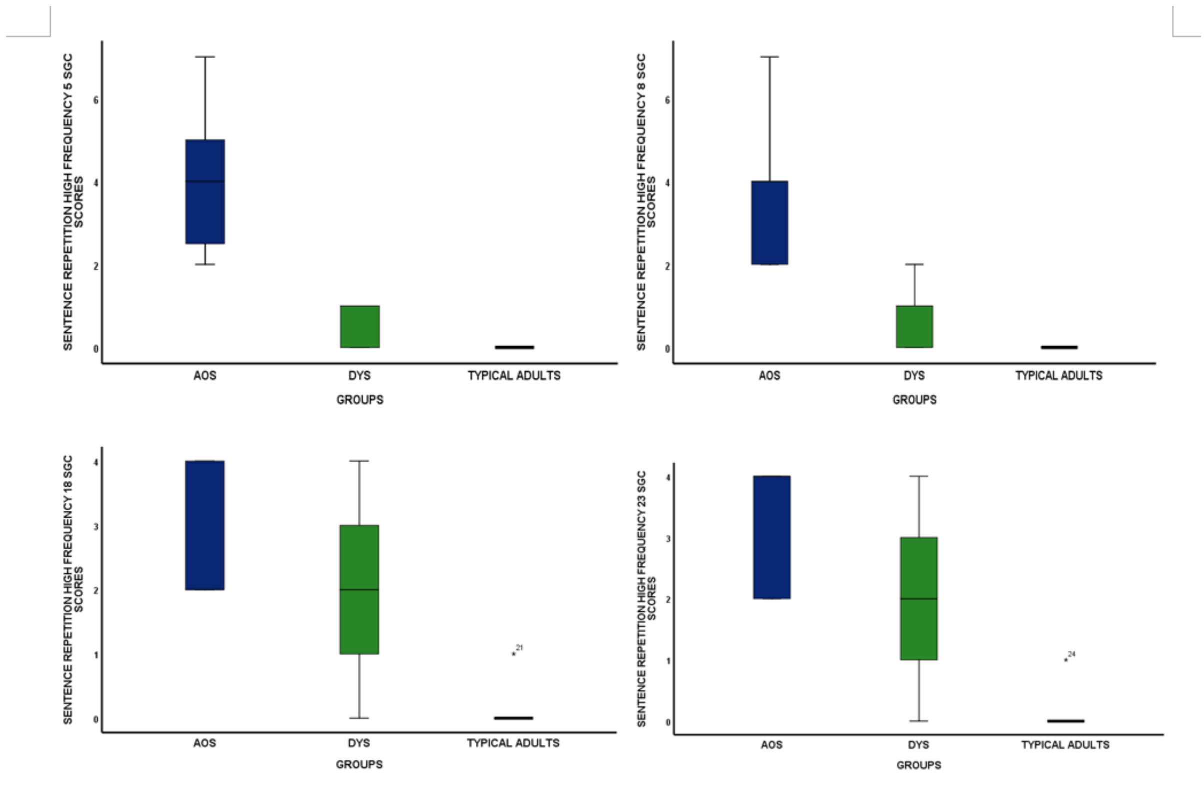
A. High Frequency Sentences Across Speech Complexity Conditions

The Kruskal-Wallis test for the cumulative errors across speech production accuracy for high frequency sentences across different SGC levels showed statistically highly significant differences between the groups [5SGC: χ^2 (2) = 24.61, $p < 0.01$; 8SGC: χ^2 (2) = 24.38, $p < 0.01$; 18 SGC: χ^2 (2) = 19.08, $p < 0.01$; and 23SGC: χ^2 (2) = 20.45, $p < 0.01$]. The cumulative errors across various SGC levels is shown as a box-plot in Figure 4.3.8.1.

Pairwise comparisons of cumulative error rates across sentence complexity levels revealed significant group differences for high frequency sentence conditions. The TA and AOS groups were statistically significantly different across all sentence complexity levels. No differences were observed between TA and DYS at lower SGC levels (5 or 8 SGC) but both the groups differed at higher complexity levels of 18 SGC and 23 SGC. Between group differences for AOS and DYS were significant at the lower SGC levels (5 and 8 SGC) but were non-significant at 18 and 23 SGC.

Figure 4.22

Box Plot of Cumulative Error Rates for Speech Production Accuracy in High-Frequency Sentences Across Complexity Levels and Participant Groups

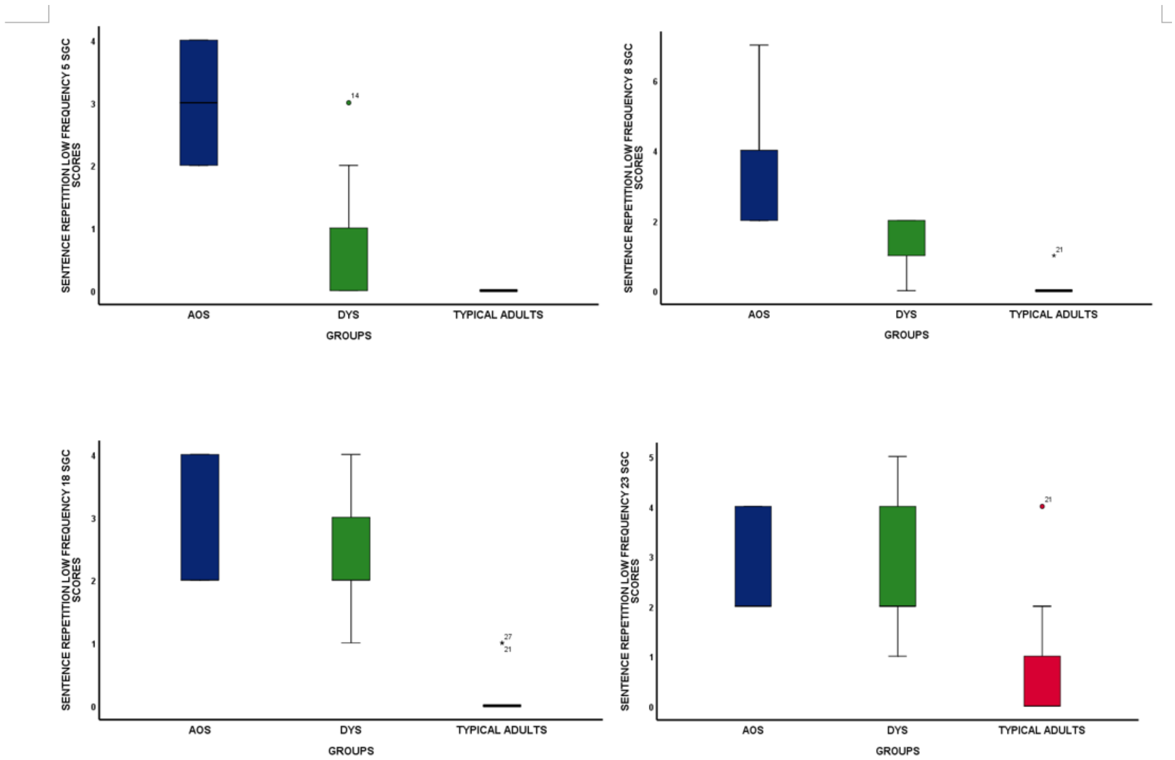


B. Low Frequency Sentences Across Speech Complexity Conditions.

As the Kruskal-Wallis test for the overall speech production errors for low frequency sentences across various SGC levels showed statistically highly significant differences between the groups [5SGC: χ^2 (2) = 22.82, $p < 0.01$; 8SGC: χ^2 (2) = 23.58, $p < 0.01$; 18 SGC: χ^2 (2) = 21.05, $p < 0.01$; and 23SGC: χ^2 (2) = 12.65, $p < 0.01$], pairwise comparisons were further carried out to analyze the results. The cumulative errors across various SGC levels for low farequency sentences is shown as a box-plot in Figure 4.23.

Figure 4.23

Box Plot of Cumulative Error Rates for Speech Production Accuracy in Low-Frequency Sentences Across Complexity Levels and Participant Groups



Pairwise comparisons of of low-frequency sentences were similar in trend to that of high frequency sentences. Significant differences between TA and AOS were present across all sentence complexity levels (all $p < .01$). The TA and DYS comparison was non-significant at 5 and 9 SGC but became significant at 18 SGC ($p < .01$) and 23 SGC ($p = .01$). In contrast, significant differences between AOS and DYS were observed only at the lower complexity levels of 5 SGC ($p = .02$) and 9 SGC ($p = .04$), whereas no significant differences were found at 18 and 23 SGC.

The overall findings suggest that sentence complexity influences the speech production accuracy across participant groups. The consistent differences between the TA and AOS groups across all SGC levels indicate that individuals with AOS may experience sensorimotor planning/programming difficulties irrespective of sentence frequency or complexity. On contrary, differences between the AOS and DYS groups were apparent only at lower complexity levels but not observed as sentence complexity increased. This trend indicates that any increase in sentence complexity correspondingly increases its error rate on both clinical groups, resulting in comparable error rates at higher complexity levels.

Besides, the observed statistical differences between the TA and DYS groups only at higher SGC levels indicates that individuals with dysarthria are more sensitive in their speech motor performance when linguistic and motor demands increase. Taken together, these findings suggest that increasing sentence complexity reduces the distinction between the two speech motor disorder groups while simultaneously heightening performance differences between clinical and non-clinical participants. The current findings are in agreement with Strand & McNeil (1996) who showed both within and between-subject variability in AOS while producing sentences compared to words.

Table 4.29

Pairwise Comparisons of groups for high and low frequency phrase/sentence

Word Frequency	Sentence complexity	Pairwise Comparison	Standardized Test Statistic (Z)	Adjusted p Value (Bonferroni)
High Frequency	5 SGC	TA vs. AOS	4.82	< 0.01**
		TA vs. DYS	1.38	0.50
		AOS vs. DYS	3.27	< 0.01**
	8 SGC	TA vs. AOS	4.86	< 0.01**
		TA vs. DYS	1.70	0.26
		AOS vs. DYS	2.99	< 0.01**
	18 SGC	TA vs. AOS	4.22	< 0.01**
		TA vs. DYS	3.07	< 0.01**
		AOS vs. DYS	0.95	1.00
	23 SGC	TA vs. AOS	4.49	< 0.01**
		TA vs. DYS	2.70	0.02*
		AOS vs. DYS	1.60	0.32
Low Frequency	5 SGC	TA vs. AOS	4.74	< 0.01**
		TA vs. DYS	1.84	0.19
		AOS vs. DYS	2.72	0.02*
	9 SCG	TA vs. AOS	4.85	< 0.01**
		TA vs. DYS	2.25	0.07
		AOS vs. DYS	2.41	0.04*
	18 SGC	TA vs. AOS	4.32	< 0.01**
		TA vs. DYS	3.48	< 0.01**
		AOS vs. DYS	0.64	1.00
	23 SGC	TA vs. AOS	3.26	< 0.01**
		TA vs. DYS	2.85	0.01*
		AOS vs. DYS	0.25	1.00

* = significant at 0.05 level of significance; ** = significant at 0.01 level of significance;

4.3.9 Spontaneous speech task

The responses elicited by three questions were analysed for prosodic and fluency errors. Prosodic errors included: (1) *Normal stress pattern* — normal emphasis placed on a particular syllable or word; and (2) *Excess/equalized stress* — excess and/or equal stress placed on a particular syllable or word, resulting in a perceived abnormality in prosodic stress. Fluency errors included: (1) *False starts/restarts* — the speaker restarts or changes the utterance midway through production; (2) *Transient cessation* — a temporary stop or brief involuntary pause in speech output; and (3) *Sound/syllable/word repetition* — a sound, syllable, or word, whether single-syllabic or multisyllabic, repeated multiple times during production. The presence or absence of each error type was indicated on a binary yes/no basis. This subsection does not contribute to the overall score.

AOS group: 8 out of 11 individuals in this group were not able to produce connected speech due to severe AOS and hence spontaneous speech could not be assessed. Normal stress pattern was seen in 1 individual. Two of the individuals produced speech with excess and/or equal stress. False starts/ Restarts and transient cessation was observed in one and sound/syllable/word repetition was seen in 2 individuals with AOS. The observed findings are in agreement with a study by Costa and Ortiz (2026) who showed that AOS could be differentiated from typical group using spontaneous speech tasks and AOS demonstrated less fluent and slower speech with a higher frequency of speech production errors compared to controls.

Dysarthria group: Normal stress pattern was observed in 5 individuals. Excess and/or equal stress noted in 4 individuals. False starts/ Restarts and transient cessation was observed in one whereas sound/syllable/word repetition was seen in 1 participant with dysarthria. Among the tasks of reading aloud, spontaneous speech, and DDK syllable repetition ("ba" for 5 seconds), Lowit et al. (2018) concluded that Spontaneous speech is a viable and potentially superior medium to measure the speech errors in AOS. TA: The normal group showed normal prosodic and fluency pattern during the spontaneous speech task.

Chapter 5

Summary and Conclusion

Apraxia of Speech (AOS) is a motor speech disorder caused by neurological impairment in the planning and programming of speech movements, which is different from aphasia and dysarthria. It is responsible for approximately 4.7–6.9% of all adult motor speech disorders and is mainly caused by stroke and neurodegenerative diseases. The clinical diagnosis of AOS is difficult because it often occurs together with aphasia and dysarthria, because the consensus on its defining features is evolving, and because there are no standardized, quantifiable assessment tools for the condition in diverse languages.

After a thorough review of the literature, major gaps were identified: no standardized screening tool was available in Kannada to assess AOS and Nonverbal Oral Apraxia (NVOA) in adults. The existing tools were either developed only for English speakers, were not psychometrically validated, or did not consider the unique phonological and prosodic features of Kannada. The only protocol developed earlier for Kannada (Maria, 2001) was administered on a very small sample (n = 5) and no formal psychometric measures were reported. Therefore, this study was conducted to develop, and validate a comprehensive screening tool: Kannada Apraxia of Speech and Nonverbal Oral Apraxia Screening Tool (K-ASNAST)

5.1 Objectives

The study aimed to: (1) develop a culturally and linguistically appropriate screening tool for AOS and NVOA in Kannada-speaking adults; (2) establish content validity through expert review; (3) examine intra- and inter-rater reliability; and (4) establish discriminant validity by comparing performance across individuals with suspected AOS, dysarthria, and typical adults.

5.2 Method

The study was carried out in two stages. Before the development of the test material a google form, survey was done where experts opinion was collected on the subsections to be included in the study. Phase 1 involved the development of the K-ASNAST, which consisted of nine subsections. Stimuli for the word-level tasks were chosen from the KannadaLex psycholinguistic database (Aithal et al., 2024), controlling for phonological neighbourhood density, biphone frequency, word frequency, syllable length, and word complexity, as measured by the Modified Stoel-Gammon complexity (SGC) measure adapted for Kannada.

Phase 2 included content validation by 11 expert Speech-Language Pathologists (SLPs) applying a Content Validity Ratio (CVR) framework based on Lawshe's criteria (minimum acceptable CVR = 0.59 for 11 experts). The final tool was administered to 30 Kannada speaking adults: 11 with suspected AOS and/or NVOA (with or without co-occurring aphasia or dysarthria), 9 with dysarthria and 10 typical adults. Data analysis used Content Validity Index (CVI), Cronbach's alpha for intra- and inter-rater reliability and Independent-Samples Kruskal-Wallis Test with Bonferroni corrected pairwise comparisons for discriminant validity.

Findings

5.3.1 Content Validity

Across the nine subsections all the items exceeded the minimum acceptable CVR of 0.59 for relevance and applicability. The Mean Content Validity ratio across subsections ranged from 0.78 to 1.00 for framing, and approached till 1.00 for clarity, simplicity, relevance, and applicability in most subsections, confirming strong content validity of the tool.

5.3.2 Reliability

All 39 speech production accuracy measurements across eight subsections had perfect intra-rater reliability with Cronbach's alpha value of 1showing perfect consistency of scoring by a single rater on two separate occasions. Inter-rater reliability was mostly excellent with Cronbach's alpha ranging from 0.66 to 1. Moderate agreement was observed for the Oral Mechanism Assessment ($\alpha = 0.667$), and all repetition-based tasks (isolated oral movements, syllable and word repetition, length and complexity, and sentence repetition), which demonstrated near perfect inter-rater agreement ($\alpha = 0.99$–1). The automatic speech task showed good reliability ($\alpha = 0.82$) and the propositional speech task showed high reliability ($\alpha = 0.94$).

5.3.3 Discriminant Validity

The Kruskal-Walli's test revealed statistically significant group differences across all major subsections ($p < 0.01$). Pairwise comparisons with Bonferroni correction yielded the following key findings:

1. Oro-Motor Assessment: Typical adults had normal structures at rest. The AOS group was generally similar with minor lip drooping and instability of the tongue in a few individuals. The dysarthria group was more prominent with findings including deviation of the tongue, decreased tone, instability, and partial lip closure. The Kruskal-Wallis test indicated a statistically significant difference between groups ($\chi2 = 14.42$, $p < 0.01$). The pairwise comparison showed that the dysarthria group was significantly different from typical adults, possibly related to orofacial muscle weakness. *The AOS and typical adult groups did not differ significantly, in line with the understanding that AOS without co-occurring dysarthria does not typically produce oral motor deficits at rest.*

2. Nonverbal Oral Praxis: Kruskal–Wallis tests showed significant group differences for praxis errors ($\chi 2 = 21.17$, $p < 0.01$) and neuromuscular weakness ($\chi 2 = 18.68$, $p < 0.01$). The AOS group had significantly lower scores for praxis errors, suggesting motor planning/programming deficits. The dysarthria group was differentiated from AOS on the basis of neuromuscular weakness scores, with the dysarthric participants performing poorly due to underlying neuromuscular impairment. *Overall, the pattern of scores across both measures supports the utility of the subtest to differentiate AOS from dysarthria and from typical adults in the nonverbal praxis domain.*

3. Oral Diadochokinesis: (AMRs and SMRs): For AMRs, cumulative error rates significantly differentiated typical adults from both AOS and dysarthria groups for /pə/ and /tə/, while /kə/ only distinguished typical adults from the AOS group, with AOS errors characterized by initiation problems, articulatory groping and substitutions, whereas dysarthria errors showed regularity and distortion problems related to neuromuscular weakness. The AOS group had the highest cumulative error rates across multiple accuracy factors for SMRs, and Kruskal-Wallis analysis confirmed significant group differences, with pairwise comparisons differentiating both clinical groups from typical adults. *Overall, the ODDK subsection, specifically AMRs of /pə/ and /tə/ and the SMR task, showed clinical utility in differentiating speech motor deficits in AOS and dysarthria from typical performance when examining cumulative error rates rather than rate alone.*

4. a)Propositional Speech: The propositional speech task was found to be significantly different ($\chi 2=24.29$, $p<0.01$) and pairwise comparisons showed that TA differed significantly from both AOS and dysarthria, *suggesting its utility in distinguishing AOS from both typical adults and dysarthric speakers.*

4. b) Automatic Speech: The automatic speech task *differentiated TA from AOS significantly, indicating that it is more sensitive to AOS detection than typical performance, but less sensitive to differential diagnosis between the two clinical groups*.

5. Isolated oral movements for speech: In the vowel repetition task, errors in AOS were primarily articulatory groping and substitutions, but no statistically significant group differences were found with the Kruskal-Wallis test, corroborating previous literature that the *production of vowels is relatively spared in AOS at the isolation/single word level*. Significant group differences were observed on the diphthong and CV repetition task ($\chi2=18.70$, $p<0.01$) with a wider range of errors noted in AOS, including initiation, articulatory groping, distortions, substitutions and omissions, whereas errors in dysarthria consisted of distortions and substitutions only. *Pairwise comparisons showed that this task successfully discriminated AOS from typical adults and the dysarthria group, indicating its greater diagnostic utility than the vowel task alone.*

6. Syllable and word repetition task: For the syllable repetition task, pairwise comparisons showed significant differences only between TA and AOS, *suggesting its utility in detecting AOS relative to typical performance but not in the differential diagnosis of AOS vs. dysarthria.*

   The word repetition task demonstrated greater discriminative power with significant pairwise differences between TA vs. AOS and AOS vs. dysarthria. Errors in the AOS group were across the full spectrum of factors of accuracy including initiation, articulatory groping, syllable sequencing and segmentation, substitutions, and omissions, while those in the dysarthria group were mostly limited to distortions and limited substitutions. *The word repetition task overall was more informative for the purpose of diagnosis and successfully discriminated AOS from both typical adults and dysarthric speakers.*

7. Length and Complexity Tasks: For both length and complexity tasks, significant group differences emerged in terms of cumulative speech production errors. For both tasks, the AOS was the only group that consistently exhibited the highest error rates, which involved initiation and articulatory groping, whereas the dysarthria group errors were primarily distortion-based. For the length task, the TA and AOS groups were significantly different for all syllable lengths and word frequencies, while differences between AOS and DYS groups diminished with increasing syllable lengths, especially for low frequency words (4 and 5 syllables), suggesting converging error rates with increased length and word frequency demands. Also, the TA and AOS differences in the complexity task were robust across all SGC levels and conditions, while the AOS and DYS differences gradually decreased with increasing complexity, especially for low frequency words. *These results suggest that increasing syllable length or word complexity decreases the discriminability between AOS and dysarthria, but consistently increases the difference between clinical and typical groups.*

8. Sentence Repetition Task: In the sentence repetition task, group differences in the cumulative speech production errors were significant for high- and low-frequency sentences at all levels of complexity (SGC 5, 8, 18, 23) with Kruskal-Wallis tests reaching significance (all $p < 0.01$). The AOS group was characterized primarily by initiation problems and articulatory groping, whereas the dysarthria group exhibited errors primarily in distortion, substitution, and omission. Both TA and AOS groups were significantly different across all complexity levels, TA and DYS group differences emerged only at higher complexity levels (18 and 23 SGC). Importantly, the only significant difference between the AOS and DYS groups was at the lower complexity levels, as error rates were more comparable at the higher complexity levels. *This suggests that discrimination between the groups diminishes as the linguistic and motor demands increase, whereas the difference between the clinical and non-clinical groups becomes more apparent.*

9. Spontaneous Speech: Eight of eleven AOS participants could not produce connected speech due to the severity of their condition, limiting formal scoring. Observations confirmed characteristic prosodic abnormalities and dysfluencies in those who could produce some speech, consistent with the literature on AOS in connected speech.

5.4 Conclusion

This study developed and validated the Kannada Apraxia of Speech and Nonverbal Oral Apraxia Screening Tool (K-ASNAST), addressing a critical gap in motor speech assessment resources for Kannada-speaking adults. The tool is the first standardized, psychometrically validated instrument in Kannada designed to assess both AOS and NVOA, and represents an important step toward linguistically appropriate motor speech assessment..

The K-ASNAST demonstrated strong content validity, with all items rated as relevant and applicable by expert SLPs. The tool exhibited perfect intra-rater reliability and excellent inter-rater reliability, indicating that it can be scored with high consistency by trained SLPs. Discriminant validity analyses confirmed that the screening tool can reliably differentiate between typical adults and AOS across all subsections. Additionally, propositional speech task, the sentence repetition task, and the length task, was found capable in differentiating AOS from dysarthria.

5.5 Clinical Implications

- The screening tool can be used to determine the presence or absence of apraxia of speech (AOS) and/or nonverbal oral apraxia (NVOA) in adults suspected of having apraxia of speech including those presenting with co-occurring conditions such as aphasia and dysarthria.

- The tool facilitates differential diagnosis between AOS and NVOA. Additionally, several subsections could potentially differentiate the speech motor deficits of AOS from individuals with dysarthria.
- Beyond screening, the tool can be used as a baseline assessment measure to identify an individual's speech motor strengths and weaknesses and guide clinical management.As the stimuli developed using Kannada psycholinguistic data, the tool may be useful for assessing speech motor impairments in clinical populations beyond those examined in the present study (e.g., amyotrophic lateral sclerosis and Parkinson's disease).

5.6 Limitations of the study

- Sample size was limited across the participant groups and this could be increased in the future studies.
- Although phonological neighborhood density (PND) and biphone frequency were controlled in the word repetition subtest, the effects of these variables were not examined due to the complexity of the required statistical analyses. No statistical analysis was performed to arrive at a cut off score to differentiate AOS from individuals with dysarthria and typical adults.

5.7 Future directions

- The screening tool may be adapted for use in other languages, provided that adequate psycholinguistic data and larger sample sizes are available.
- If psychometric data is available for children, similar tool can be developed for this population.

- Spontaneous speech samples obtained through picture-description tasks may offer a controlled method for assessing speech production in AOS.

References

Ackermann, H., Hertrich, I., & Hehr, T. (1995). Oral diadochokinesis in neurological dysarthrias. *Folia phoniatrica et logopaedica : official organ of the International Association of Logopedics and Phoniatrics (IALP)*, *47*(1), 15–23. https://doi.org/10.1159/000266338

Ahmed, M. S., Naznin, N., & Alam, M. J. (2020). *Adaptation of Apraxia Battery for Assessing the Patient with Apraxia*. *Journal of Medical Research and Health Sciences, 3*(10), 1114–1123. https://doi.org/10.15520/jmrhs.v3i10.263

Aithal, S. R., Muralikrishna, S. N., Ganiga, R., Rao, B. A., & Hegde, K. G. (2024). KannadaLex: A lexical database with psycholinguistic information. *ACM Transactions on Asian and Low-Resource Language Information Processing, 23*(7), Article 104. https://doi.org/10.1145/3670688

Allie, N. (2024). Towards the development and validation of an isiXhosa tool for the assessment of apraxia speech in adults: A descriptive study.

Allison, K. M., Cordella, C., Iuzzini-Seigel, J., & Green, J. R. (2020). Differential Diagnosis of Apraxia of Speech in Children and Adults: A Scoping Review. *Journal of speech, language, and hearing research*, *63*(9), 2952–2994. https://doi.org/10.1044/2020_JSLHR-20-00061

Balkaya, I. Y., Sepkowitz, E. M., Qin, A. C. R., Morgenstern, K., & Altschuler, E. L. (2021). A Case of Crossed Apraxia for Propositional Speech. *Annals of Indian Academy of Neurology*, *24*(5), 817–819. https://doi.org/10.4103/aian.AIAN_1150_20

Ballard, K. J., & Robin, D. A. (2002). Assessment of AOS for treatment planning. In *Seminars in speech and language* (Vol. 23, No. 04, pp. 281-292). Copyright© 2002 by Thieme Medical Publishers, Inc., 333 Seventh Avenue, New York, NY 10001, USA. Tel.:+ 1 (212) 584-4662.

Bartle, C. J., Goozée, J. V., & Murdoch, B. E. (2007). An EMA analysis of the effect of increasing word length on consonant production in apraxia of speech: a case study. *Clinical linguistics & phonetics*, *21*(3), 189–210. https://doi.org/10.1080/02699200601007865

Basavaraj, V. (2009). Ethical guidelines for bio-behavioral research involving human subjects (2nd ed.). ISBN: 978-81-909355-6-2.

Basilakos A. (2018). Contemporary Approaches to the Management of Post-stroke Apraxia of Speech. *Seminars in speech and language*, *39*(1), 25–36. https://doi.org/10.1055/s-0037-1608853

Bislick, L., McNeil, M., Spencer, K. A., Yorkston, K., & Kendall, D. L. (2017). The Nature of Error Consistency in Individuals With Acquired Apraxia of Speech and Aphasia. *American journal of speech-language pathology*, *26*(2S), 611–630. https://doi.org/10.1044/2017_AJSLP-16-0080

Botha, H., & Josephs, K. A. (2019). Primary Progressive Aphasias and Apraxia of Speech. *Continuum (Minneapolis, Minn.)*, *25*(1), 101–127. https://doi.org/10.1212/CON.0000000000000699

Botha, H., Duffy, J. R., Strand, E. A., Machulda, M. M., Whitwell, J. L., & Josephs, K. A. (2014). Nonverbal oral apraxia in primary progressive aphasia and apraxia of speech. *Neurology*, *82*(19), 1729–1735. https://doi.org/10.1212/WNL.0000000000000412

Cherney, L. R., & van Vuuren, S. (2012). Telerehabilitation, virtual therapists, and acquired neurologic speech and language disorders. *Seminars in speech and language*, *33*(3), 243–257. https://doi.org/10.1055/s-0032-1320044

Cicchetti, D. V. (1994). Guidelines, criteria, and rules of thumb for evaluating normed and standardized assessment instruments in psychology. *Psychological assessment*, *6*(4), 284.

Code, C. (2021). Contemporary issues in apraxia of speech. *Aphasiology*, *35*(4), 391–396. https://doi.org/10.1080/02687038.2021.1896108

Costa, B. M., & Ortiz, K. Z. (2026). Assessment of acquired apraxia of speech: pilot study with the CBO protocol. *Arquivos de neuro-psiquiatria*, *84*(2), 1–9. https://doi.org/10.1055/s-0046-1816038

Costa, B. M., Brescancini, C. R., & Ortiz, K. Z. (2023). Assessment protocol for acquired apraxia of speech. Protocolo de avaliação para apraxia de fala adquirida. *CoDAS*, *36*(1), e20220251. https://doi.org/10.1590/2317-1782/20232022251pt

Croot, K., Wauters, L., & Staiger, A. (2025). Apraxia of speech in primary progressive aphasia and primary progressive apraxia of speech. In L. Cummings (Ed.), *The Oxford handbook of communication disorders in neurodegenerative diseases* (Oxford Library of Psychology). Oxford University Press. https://doi.org/10.1093/oxfordhb/9780198888482.013.0007

DePietro, M. (2024). *Apraxia of speech in adults: Signs, causes & treatment* (J. Hurst, Medical Reviewer). Brooks Rehabilitation. https://brooksrehab.org/resources/apraxia-of-speech-in-adults/

Dey, S., & Kumar, S. (2025). Screening checklist for adults with apraxia of speech. *Journal of Indian Speech, Language & Hearing Association*, *39*(2), 109–118. https://doi.org/10.4103/jisha.jisha_16_25

Duffy, J. R. (2013). Motor speech disorders: Substrates, differential diagnosis, and management (3. ed). Mosby.

Duffy, J. R. (2020). *Motor speech disorders: Substrates, differential diagnosis, and management* (4th ed.). Elsevier.

Duffy, J. R., Martin, P. R., Clark, H. M., Utianski, R. L., Strand, E. A., Whitwell, J. L., & Josephs, K. A. (2023). The Apraxia of Speech Rating Scale: Reliability, Validity, and Utility. *American journal of speech-language pathology*, *32*(2), 469–491. https://doi.org/10.1044/2022_AJSLP-22-00148

Dworkin, J. P., & Aronson, A. E. (1986). Tongue strength and alternate motion rates in normal and dysarthric subjects. *Journal of communication disorders*, *19*(2), 115–132. https://doi.org/10.1016/0021-9924(86)90015-8

Enderby, P., & Palmer, R. (2008). *Frenchay Dysarthria Assessment – Second Edition (FDA-2)*. PRO-ED.

Garcia-Guaqueta, D. P., Botha, H., Utianski, R. L., Duffy, J. R., Clark, H., Meade, G., ... & Josephs, K. A. (2024). Clinicopathologic and Neuroimaging Correlations of Nonverbal Oral Apraxia in Patients With Neurodegenerative Disease. *Neurology*, *103*(4), e209717.

George, D., & Mallery, P. (2003). *SPSS for Windows step by step: A simple guide and reference. 11.0 update* (4th ed.). Allyn & Bacon.

Gorno-Tempini, M. L., Dronkers, N. F., Rankin, K. P., Ogar, J. M., Phengrasamy, L., Rosen, H. J., Johnson, J. K., Weiner, M. W., & Miller, B. L. (2004). Cognition and anatomy in three variants of primary progressive aphasia. *Annals of neurology*, *55*(3), 335–346. https://doi.org/10.1002/ana.10825

Haley, K. L., & Jacks, A. (2023). Three-Dimensional Speech Profiles in Stroke Aphasia and Apraxia of Speech. *American journal of speech-language pathology*, *32*(4S), 1825–1834. https://doi.org/10.1044/2022_AJSLP-22-00170

Haley, K. L., Cunningham, K. T., Jacks, A., Richardson, J. D., Harmon, T., & Turkeltaub, P. E. (2021). Repeated word production is inconsistent in both aphasia and apraxia of speech. *Aphasiology*, *35*(4), 518-538.

Haley, K. L., Jacks, A., de Riesthal, M., Abou-Khalil, R., & Roth, H. L. (2012). Toward a quantitative basis for assessment and diagnosis of apraxia of speech. *Journal of Speech, Language, and Hearing Research, 55*(5), S1502–S1517. https://doi.org/10.1044/1092-4388(2012/11-0318)

Haley, K. L., Jacks, A., Richardson, J. D., Harmon, T. G., Lacey, E. H., & Turkeltaub, P. (2023). Do People With Apraxia of Speech and Aphasia Improve or Worsen Across Repeated Sequential Word Trials?. *Journal of speech, language, and hearing research : JSLHR*, *66*(4), 1240–1251. https://doi.org/10.1044/2022_JSLHR-22-00438

Haley, K. L., Roth, H., Grindstaff, E., & Jacks, A. (2011). Computer-Mediated Assessment of Intelligibility in Aphasia and Apraxia of Speech. *Aphasiology*, *25*(12), 1600–1620. https://doi.org/10.1080/02687038.2011.628379

Hartelius, L., Svensson, P., & Bubach, A. (1993). Clinical assessment of dysarthria: Performance on a dysarthria test by normal adult subjects, and by individuals with Parkinson's disease or with multiple sclerosis. *Scandinavian Journal of Logopedics and Phoniatrics*, *18*(4), 131-141.

J. R. Duffy, "Apraxia of speech in degenerative neurologic disease," Aphasiology, vol. 20, no. 6, pp. 511-527, 2006. https://doi.org/10.1080/02687030600597358

Jacks, A., Mathes, K. A., & Marquardt, T. P. (2010). Vowel acoustics in adults with apraxia of speech. *Journal of speech, language, and hearing research : JSLHR*, *53*(1), 61–74. https://doi.org/10.1044/1092-4388(2009/08-0017)

Johns, D. F., & Darley, F. L. (1970). Phonemic variability in apraxia of speech. *Journal of speech and hearing research*, *13*(3), 556–583. https://doi.org/10.1044/jshr.1303.556

Jonkers, R., Feiken, J., & Stuive, I. (2017). Diagnosing apraxia of speech on the basis of eight distinctive signs. *Canadian Journal of Speech-Language Pathology and Audiology*, *41*(3), 303-319.

Josephs, K. A., Duffy, J. R., Strand, E. A., Whitwell, J. L., Layton, K. F., Parisi, J. E., Hauser, M. F., Witte, R. J., Boeve, B. F., Knopman, D. S., Dickson, D. W., Jack, C. R., Jr, & Petersen, R. C. (2006). Clinicopathological and imaging correlates of progressive aphasia and apraxia of speech. *Brain : a journal of neurology*, *129*(Pt 6), 1385–1398. https://doi.org/10.1093/brain/awl078

Kent, R. D., & Rosenbek, J. C. (1983). Acoustic patterns of apraxia of speech. *Journal of Speech and Hearing Research, 26*(2), 231–249. https://doi.org/10.1044/jshr.2602.231

Knollman-Porter K. (2008). Acquired apraxia of speech: a review. *Topics in stroke rehabilitation*, *15*(5), 484–493. https://doi.org/10.1310/tsr1505-484

Kodrasi, I., Pernon, M., Laganaro, M., & Bourlard, H. (2021, June). Automatic and perceptual discrimination between dysarthria, apraxia of speech, and neurotypical speech. In *ICASSP 2021-2021 IEEE International Conference on Acoustics, Speech and Signal Processing (ICASSP)* (pp. 7308-7312). IEEE.

Kripanan, N., Rattakorn, P., & Chinchai, S. (2022). Psychometric properties of the Apraxia of Speech Rating Scale Thai version. *Journal of Associated Medical Sciences*, *55*(1), 60-72.

Lancheros, M., Pernon, M., & Laganaro, M. (2023). Is there a continuum between speech and other oromotor tasks? Evidence from motor speech disorders. *Aphasiology*, *37*(5), 715-734.

Lowit, A., Marchetti, A., Corson, S., & Kuschmann, A. (2018). Rhythmic performance in hypokinetic dysarthria: Relationship between reading, spontaneous speech and diadochokinetic tasks. *Journal of communication disorders*, *72*, 26–39. https://doi.org/10.1016/j.jcomdis.2018.02.005

M. Itoh, "Apraxia of speech," The Japan Journal of Logopedics and Phoniatrics, vol. 31, no. 4, pp. 242-254, 1990. https://doi.org/10.5112/JJLP.31.242

Maas, E. (2006). *The nature and time course of motor programming in apraxia of speech* (Doctoral dissertation, University of Califonia, San Diego & San Diego State University).

Maas, E. (2011). *The nature and time course of motor programming in apraxia of speech* [Doctoral dissertation, University of California San Diego]. eScholarship, University of California. https://escholarship.org/uc/item/3vb0z9bx

Mailend, M. L., Jacks, A., & Haley, K. L. (2025). *Refined Operational Definitions for the Apraxia of Speech Rating Scale* (Vol. 34, No. 4S, pp. 2519-2532). American Speech-Language-Hearing Association.

Maria, B. (2001). Protocol to identify apraxia of speech in Broca's aphasics (Unpublished master's dissertation). All India Institute of Speech and Hearing, University of Mysore, Mysore, India.

Mauszycki, S. C., Wambaugh, J. L., & Cameron, R. M. (2010). Variability in apraxia of speech: Perceptual analysis of monosyllabic word productions across repeated sampling times. *Aphasiology*, *24*(6-8), 838-855.

McNeil, M. R., Robin, D. A., & Schmidt, R. A. (2009). Apraxia of speech: Definition and differential diagnosis. Clinical management of sensorimotor speech disorders, 2, 249 267.

Md Nor, A., Masso, S., & Ballard, K. J. (2022). Identifying segmental and prosodic errors associated with the increasing word length effect in acquired apraxia of speech. *International Journal of Speech-Language Pathology*, *24*(3), 294-306.

Namasivayam, A. K., Huynh, A., Bali, R., Granata, F., Law, V., Rampersaud, D., Hard, J., Ward, R., Helms-Park, R., van Lieshout, P., & Hayden, D. (2021). Development and Validation of a Probe Word List to Assess Speech Motor Skills in Children. *American journal of speech-language pathology*, *30*(2), 622–648. https://doi.org/10.1044/2020_AJSLP-20-00139

Nasreddine, Z. S., Phillips, N. A., Bédirian, V., Charbonneau, S., Whitehead, V., Collin, I., Cummings, J. L., & Chertkow, H. (2005). The Montreal Cognitive Assessment, MoCA: A brief screening tool for mild cognitive impairment. *Journal of the American Geriatrics Society*, *53*(4), 695–699. https://doi.org/10.1111/j.1532-5415.2005.53221.x

Nealon, K., & Edmonds, L. (2024). Utilization of Western Aphasia Battery–Revised Spoken Language Subtest Stimuli to Characterize Differentially Diagnostic Characteristics of Acquired Apraxia of Speech. *Perspectives of the ASHA Special Interest Groups*, *9*(5), 1265-1279.

Nishio, M., & Niimi, S. (2006). Comparison of speaking rate, articulation rate and alternating motion rate in dysarthric speakers. *Folia Phoniatrica et Logopaedica, 58*(2), 114–131. https://doi.org/10.1159/000089612

Odell, K., McNeil, M. R., Rosenbek, J. C., & Hunter, L. (1990). Perceptual characteristics of consonant production by apraxic speakers. *The Journal of speech and hearing disorders*, *55*(2), 345–359. https://doi.org/10.1044/jshd.5502.345

Odell, K., McNeil, M. R., Rosenbek, J. C., & Hunter, L. (1991). Perceptual characteristics of vowel and prosody production in apraxic, aphasic, and dysarthric speakers. *Journal of speech and hearing research*, *34*(1), 67–80. https://doi.org/10.1044/jshr.3401.67

Ogar, J., Slama, H., Dronkers, N., Amici, S., & Luisa Gorno-Tempini, M. (2005). Apraxia of speech: an overview. *Neurocase*, *11*(6), 427-432.

Pernon, M. (2024). Évaluation des dysarthries et des apraxies de la parole: quelles approches?. *Glossa*, (142), 29-48.

Pommée, T., Balaguer, M., Mauclair, J., Pinquier, J., & Woisard, V. (2022). Assessment of adult speech disorders: current situation and needs in French-speaking clinical practice. *Logopedics Phoniatrics Vocology*, *47*(2), 92-108.

R. K. Peach, "Acquired apraxia of speech: Features, accounts, and treatment," Topics in Stroke Rehabilitation, 2004. https://doi.org/10.1310/ATNK-DBE8-EHUQ-AA64

Scholl, D. I., McCabe, P. J., Heard, R., & Ballard, K. J. (2018). Segmental and prosodic variability on repeated polysyllabic word production in acquired apraxia of speech plus aphasia. *Aphasiology*, *32*(5), 578-597.

Shuster, L. I., & Wambaugh, J. L. (2008). Token-to-token variability in adult apraxia of speech: A perceptual analysis. *Aphasiology*, *22*(6), 655-669.

Solomon, N. P., Makashay, M. J., Helou, L. B., & Clark, H. M. (2017). Neurogenic Orofacial Weakness and Speech in Adults with Dysarthria. *American journal of speech-language pathology*, *26*(3), 951–960. https://doi.org/10.1044/2017_AJSLP-16-0144

Spath, E., Kelke, J., Hußmann, K., & Fimm, B. (2024). *Diagnostik der Sprechapraxie: Erweiterung und Erprobung des SPRAX-Screenings* (No. RWTH-2024-05740). Lehr- und Forschungsgebiet Epileptologie.

Speech of Nonfluent/Agrammatic Primary Progressive Aphasia. *Journal of Alzheimer's disease reports*, *7*(1), 589–604. https://doi.org/10.3233/ADR-220089

Stoel-Gammon C. (2010). The Word Complexity Measure: description and application to developmental phonology and disorders. *Clinical linguistics & phonetics*, *24*(4-5), 271–282. https://doi.org/10.3109/02699200903581059

Strand, E. A., & McNeil, M. R. (1996). Effects of length and linguistic complexity on temporal acoustic measures in apraxia of speech. *Journal of speech and hearing research*, *39*(5), 1018–1033. https://doi.org/10.1044/jshr.3905.1018

Strand, E. A., Duffy, J. R., Clark, H. M., & Josephs, K. (2014). The Apraxia of Speech Rating Scale: a tool for diagnosis and description of apraxia of speech. *Journal of communication disorders*, *51*, 43–50. https://doi.org/10.1016/j.jcomdis.2014.06.008

Tanner, D. & Culbertson, W. (1999). *Quick Assessment for Apraxia of Speech.* Oceanside: Academic Communication Associates, Inc.

Tavares, A. M. A. (2015). Contributo para a Validação do Quick Assessment of Apraxia of Speech (QAAS) para o Português-Europeu.

Towne, R. L., & Crary, M. A. (1988). Verbal reaction time patterns in aphasic adults: consideration for apraxia of speech. *Brain and language*, *35*(1), 138–153. https://doi.org/10.1016/0093-934x(88)90105-8

Wambaugh, J. L., Bailey, D. J., Mauszycki, S. C., & Bunker, L. D. (2019). Interrater Reliability and Concurrent Validity for the Apraxia of Speech Rating Scale 3.0: Application With Persons With Acquired Apraxia of Speech and Aphasia. *American* *journal of speech-language pathology*, *28*(2S), 895–904. https://doi.org/10.1044/2018_AJSLP-MSC18-18-0099

Whiteside, S. P., Dyson, L., Cowell, P. E., & Varley, R. A. (2015). The Relationship Between Apraxia of Speech and Oral Apraxia: Association or Dissociation?. *Archives of clinical neuropsychology: the official journal of the National Academy of Neuropsychologists*, *30*(7), 670–682. https://doi.org/10.1093/arclin/acv051

Wong, E. C. H., Wong, M. N., & Velleman, S. L. (2023). Assessment and Diagnostic Standards of Apraxia of Speech in Chinese-Speaking Adults and Children: A Scoping Review. *American journal of speech-language pathology*, *32*(1), 316–340. https://doi.org/10.1044/2022_AJSLP-21-00355

Ziegler W. (2002). Task-related factors in oral motor control: speech and oral diadochokinesis in dysarthria and apraxia of speech. *Brain and language*, *80*(3), 556–575. https://doi.org/10.1006/brln.2001.2614

Ziegler W. (2005). A nonlinear model of word length effects in apraxia of speech. *Cognitive neuropsychology*, *22*(5), 603–623. https://doi.org/10.1080/02643290442000211

Ziegler, W., Aichert, I., Staiger, A., Willmes, K., Baumgaertner, A., Grewe, T., Flöel, A., 24 Huber, W., Rocker, R., Korsukewitz, C., & Breitenstein, C. (2022). The prevalence of apraxia of speech in chronic aphasia after stroke: A bayesian hierarchical analysis. Cortex, 151, 15–29. https://doi.org/10.1016/j.cortex.2022.02.01

APPENDIX I

Kannada Apraxia of Speech and Nonverbal Oral Apraxia Screening Tool (K-ASNAST)

Important Instructions to be followed by the Examiner

1. Only the parameters relevant to each subsection shall be rated. The subsection score shall be derived by summing the scores obtained across all applicable parameters within that subsection.

2. Except for Sections 1 (Oro-motor assessment), 4 (Automatic versus propositional speech), and 9 (Spontaneous speech task), all stimuli are administered across two trials. Scoring shall be based on the production with more errors by the participant. In cases where responses differ across trials, the corresponding stimulus shall be identified as inconsistent by marking the designated consistency checkbox within the relevant subsection.

3. Most subsection begins with an Initiation rating. If the participant demonstrates no articulatory attempt or produces no verbal response due to initiation difficulty, the Initiation parameter shall be scored as “2” (Marked impairment). In such cases, all remaining parameters for that particular stimulus shall be marked as “NA” (Not Applicable) except for ‘articulatory groping’ wherein the patient will show visible or audible trial-and-error articulatory movements despite unsuccessful verbal output. This procedure shall be followed for each stimulus across all relevant subsections.

4. Only when the Initiation parameter is rated as “0” (Normal) or “1” (Mild impairment) shall the remaining relevant parameters within that subsection be scored.

5. Use the Master Scoring Descriptor provided at the end of the test to rate the participant’s responses across all subsections, except for section 1 (Oro-motor assessment), 2 (non-verbal oral praxis assessment), and 9 (Spontaneous speech task) where the scoring is provided within the same section. Only the parameters specified as relevant for a given subsection shall be rated.

Subsection 1: Oro-motor Assessment

Oral structures at rest

Instructions: Ask the subject to sit upright in a relaxed, natural posture. Observe the oral structures at rest without movement. For assessing the tongue and soft palate at rest, instruct the subject to gently open their mouth and keep it relaxed while you observe the structures.

No.		Documented score
1.	Jaw	
2.	Lip	
3.	Tongue	
4.	Soft Palate	

Scoring description:

Parameters/ Scoring	0	1	2	Descriptors (Tick all that apply)
Jaw	Symmetrical alignment and adequate closure at rest	Mild Deviation and/or Instability	Marked abnormality (fixed or hanging jaw)	**Position:** ☐ Midline ☐ Right Deviation ☐ Left Deviation **Tone:** ☐ Normal ☐ Reduced ☐ Increased **Structural Signs:** ☐ Tremor ☐ Involuntary movements ☐ None ☐ **Any Other:** sensory tricks (clenching the teeth, holding a pipe in the mouth, touching a hand to the side of the jaw or neck)
Lip	Symmetrical appearance and adequate closure at rest	Mild Asymmetry or drooping and/or partial closure at rest	Marked asymmetry or drooping and/or reduced lip seal	**Position:** ☐ No Drooping ☐ Right droop ☐ Left droop **Tone:** ☐ Normal ☐ Reduced ☐ Increased **Closure:** ☐ Adequate ☐ Partial ☐ Poor seal ☐ Any Other: Flattening of nasolabial folds/ Involuntary movements (smacking of lips or pursing or retraction of lips)/Tremors
Tongue	Midline symmetry and typical bulk with no abnormal movement	Mild asymmetry and bulk with slight abnormal movement and/or mild deviation	Marked Deviation and/or notable structural signs	**Position:** ☐ midline ☐ right deviation ☐ left deviation **Tone:** ☐ normal ☐ reduced ☐ increased **Structural signs:** ☐ None ☐ atrophy ☐ fasciculations ☐ instability (unable to rest on the floor of mouth) ☐ Any other: __________
Soft Palate	Symmetrical palatal arches	Mild asymmetry of the palatal arches and/or drooping	Marked asymmetry of the palatal arches and/or drooping	**Position:** ☐ Midline ☐ Right Drooping ☐ Left Drooping **Structural Signs:** ☐ None ☐ Atrophy ☐ Palatal tremor ☐ Any Other: __________

Maximum Subsection Score: 8

Subsection 2: Non-verbal Oral Praxis Assessment

Instructions:

Inform the subject: *"I am going to ask you to carry out some movements with your tongue and lips."*
Begin by giving clear verbal commands for each task. Observe the response.
If the subject is unable to perform the movement on command, say: *"I will show you the movements. Please watch and do the same"*. Then demonstrate each movement and ask the subject to imitate.

Instruction to the clinician: For each task score for both Praxis errors and errors due to Neuromuscular weakness (NW).

Sl No.	Item	4		3		2		1		0	
		Praxis	NW	Praxis	NW	AOS	NW	AOS	NW	AOS	NW
1.	ನಿಮ್ಮ ಬಾಯಿಯನ್ನು ತೆಗೆಯಿರಿ										
2.	ಕೆಮ್ಮಿ										
3.	ನಿಮ್ಮ ಕೆನ್ನೆಗಳನ್ನು ಉಬ್ಬಿಸಿಕೊಳ್ಳಿ										
4.	ನಿಮ್ಮ ತುಟಿಗಳಿಂದ 'ಊ' ಆಕರ ಮಾಡಿ										
5.	ನಿಮ್ಮ ತುಟಿಗಳಿಂದ 'ಈ'ಆಕರ ಮಾಡಿ										
6.	ನಿಮ್ಮ ನಾಲಿಗೆಯನ್ನು ಹೊರಗೆ ಚಾಚಿ										
7.	ನಿಮ್ಮ ನಾಲಿಗೆಯನ್ನು ಮೇಲಕ್ಕೆತ್ತಿ										

8.	ನಾಲಿಗೆಯನ್ನು ಬಾಯಿಯ ಎಡ ಮತ್ತು ಬಲ ಬದಿಗೆ ಮುಟ್ಟಿಸಿ										
9.	ನಿಮ್ಮ ತುಟಿಗಳಿಂದ ‘ಈ’ಆಕರ ಮಾಡಿ ನಂತರ ನಾಲಿಗೆಯನ್ನು ಮೇಲಕ್ಕೆತ್ತಿ										
10.	ನಿಮ್ಮ ತುಟಿಗಳಿಂದ ‘ಊ’ ಆಕರ ಮಾಡಿ ನಂತರ ನಿಮ್ಮ ಬಾಯಿಯನ್ನು ತೆಗೆಯಿರಿ										

Scoring description:

Score	Description for error due to error in Praxis
4	Correct response on command, immediate and accurate
3	Correct response on command after a delay (> 2 seconds) and/or with groping
2	Correct response on imitation, immediate and accurate
1	Correct response on imitation after a delay (> 2 seconds) and/or with groping
0	Incorrect response on both command and imitation

Score	Description for error due to Neuromuscular weakness (NW)
4	No weakness with typical range and speed of articulatory movement
3	Mild weakness with mildly restricted range/slightly reduced speed
2	Moderate weakness with moderately restricted range/noticeably slow speed
1	Severe weakness with severely restricted range/markedly slow speed
0	No response due to very severe weakness/no functional movement

Maximum Subsection Score: Praxis = 40

Neuromuscular Weakness: 40

Subsection 3: Oral Diadochokinetic rate (ODDK)

Part A: Alternating Motion Rate (AMR)

Instructions: *The subject is asked to repeat the syllables /pə/, /tə/, and /kə/ as rapidly and accurately as possible.*

Inform the subject: "I want you to produce some sounds as quickly and clearly as you can. Say /pə/." The clinician should demonstrate each target syllable for approximately 2–3 seconds.

Ask the subject to produce each target 2 times for 5 seconds each with a short gap between the trials. Use a stop-watch for 5 seconds and count the number of syllables uttered for each trial. Document the highest ODDK rate (syllables/second) for each stimulus target from both the trials. Please tick for consistency for each item.

	Trial 1	Trial 2	Consistent	Inconsistent
/pə/				
/tə/				
/kə/				

Scoring:

A. *Speed:* ___________ syllables/second

B. *Accuracy* (Scoring must be done using both the trials)

Speech Production Accuracy	*Documented Score*		
	/pə/	/tə/	/kə/
Initiation			
Regularity			
Distortion			
Articulatory Groping			
Substitution			
Omission			

Maximum Subsection Score: AMR of /pə/ = 11

AMR of /tə/ =11

AMR of /kə/ =11

Part B: Sequential Motion Rate (SMR)

Instructions: The subject is asked to repeat the syllable sequence /pətəkə/ **OR** /pətə:ki/ as rapidly and accurately as possible. Only one of these two sequences needs to be administered and used for scoring purposes.

Inform the subject: "I would like you to produce some sound sequences as quickly and clearly as you can. Say /pətəkə/." The clinician should demonstrate the target sequence for approximately 2–3 seconds.

Ask the subject to produce each target 2 times for 5 seconds each with a short gap between the trials. Use a stop-watch for 5 seconds and count the number of syllables uttered for each trial. Document the highest ODDK rate (syllables/second) for each stimulus target from both the trials. Please tick for consistency for each item.

	Trial 1	Trial 2	Consistent	Inconsistent
/pətəkə/				
OR				
/pətə:ki/				

Scoring:

A. *Speed:* __________ syllables/second

B. *Accuracy* (Scoring must be done using both the trials)

Speech Production Accuracy	*Documented Score*	
	/pətəkə/	/pətə:ki/
Initiation		
Distortion		
Distorted substitution/ Addition		
Articulatory groping		
Syllable sequencing		
Syllable segmentation		
Substitution		
Omission		

Maximum subsection score: /pətəkə/ or /pətə:ki/= 15

Subsection 4: Automatic versus Propositional speech

Part A: Propositional speech

Instructions: *The subject is asked to count backwards from 10 to 1.*

Inform the subject: "I would like you to count from 10 to 1." The clinician may demonstrate the task if needed by taking any other series of numbers.

Part B: Automatic Speech

Instructions: *The subject is asked to count forward from 1 to 10.*

Inform the subject: "I would like you to count from 1 to 10." The clinician may demonstrate the task if needed by taking any other series of numbers.

	Transcribed Response
Automatic speech	
Propositional speech	

Accuracy Scoring

Speech Production Accuracy	*Documented Score*	
	Automatic speech	Propositional speech
Initiation		
Distortion		
Distorted substitution/ Addition		
Articulatory groping		
Syllable sequencing		
Syllable segmentation		
Substitution		
Omission		

Maximum subsection score: Automatic Speech: 15

Propositional Speech: 15

Subsection 5: Isolated Oral movements for speech

Instructions: *The subject is informed that they will be asked to produce some sounds, each of which will be demonstrated by the clinician beforehand. A model must be provided for every sound prior to eliciting the subject's response. The subject is given with two trials. Production with more error must be considered for scoring. Please tick for consistency for each item.*

Part A: Vowels

Sl No.	Stimuli	Trial 1	Trial 2	Consistent	Inconsistent
1.	ಅ				
2.	ಈ				
3.	ಊ				

Part B: Diphthongs and CV (Consonant-Vowel) Syllables

Sl No.	Stimuli	Trial 1	Trial 2	Consistent	Inconsistent
1.	ದ				
2.	ಕ				
3.	ಟ				
4.	ಪ				
5.	ಮ				
6.	ಐ				

Part A: Vowels

Speech Production Accuracy	*Documented score*		
	ಅ	ಈ	ಊ
Initiation			
Articulatory Groping			
Distortion			
Substitution			

Part B: Diphthongs and CV (Consonant-Vowel) Syllables

Speech Production Accuracy	*Documented score*					
	ದ	ಕ	ಟ	ಪ	ಮ	ಐ
Initiation						
Articulatory Groping						
Distortion						
Substitution						
Omission						

Maximum subsection score: Vowels: 21

Diphthongs and CV (Consonant-Vowel) Syllables: 54

Subsection 6: Syllabic and Word Repetition task

Instructions: *The target words are presented to the subject verbally, and they are required to imitate the syllables and words produced by the clinician.*

Inform the subject: "I am going to say some syllables and words, and I would like you to repeat them after me." Begin by presenting practice items so the subject becomes familiar with the task, followed by the actual test items. Production with more error must be considered for scoring. Please tick for consistency for each item.

Practice items:

1. ಮ
2. ಗಾಯ

Test items:

A. Syllable repetition:

Sl No.	Transcribe the response			Consistent	Inconsistent
	Stimuli	Trial 1	Trial 2		
1.	ಕೊ				
2.	ಟೇ				

Speech Production Accuracy	*Documented Score*	
	ಕೊ	ಟೇ
Initiation		
Distortion		
Distorted substitution/ Addition		
Articulatory groping		
Substitution		
Omission		

Maximum subsection score (syllable repetition): 44

B. Word repetition:

Sl No.		Transcribe the response		Consistent	Inconsistent
	Stimuli	Trial 1	Trial 2		
1.	ನಟ				
2.	ಪಾಚಿ				
3.	ಶರ್ಟು				
4.	ಬೀಜ				
5.	ತಬಲ				
6.	ಹುಡುಗಿ				
7.	ಕೇಸರಿ				
8.	ಚಪಾತಿ				

Speech Production Accuracy	***Documented Score***							
	ನಟ	ಪಾಚಿ	ಶರ್ಟು	ಬೀಜ	ತಬಲ	ಹುಡುಗಿ	ಕೇಸರಿ	ಚಪಾತಿ
Initiation								
Distortion								
Distorted substitution/ Addition								
Articulatory groping								
Syllable sequencing								
Syllable segmentation								
Substitution								
Omission								

Maximum subsection score (word repetition): 120

Subsection 7: Length and Complexity task

Part A: Length task

Instructions: *The target words are presented to the subject verbally, and they are required to imitate words of progressively increasing length.*

Inform the subject: "I am going to say some words that get longer, and I would like you to repeat them after me." Begin by presenting a practice item to familiarize the subject with the task, followed by the actual test items. Each word should be produced slowly, and the subject is given two attempts to imitate the correct production. Production with more error must be considered for scoring. Please tick for consistency for each item.

Practice item:

1. ಮನೆ ಮನೆಯ ಮನೆಯಲ್ಲಿ

Stimulus/ Trials	A	B	C
L1	ಹಿರಿಯ	ಹಿರಿಯರು	ಹಿರಿಯರಿಂದ
Transcribe Trial 1			
Transcribe Trial 2			
Consistent			
Inconsistent			
L2	ಹೋರಾಡು	ಹೋರಾಡುವ	ಹೋರಾಡುವುದು
Transcribe Trial 1			
Transcribe Trial 2			
Consistent			
Inconsistent			
L3	ಹೆಸರು	ಹೆಸರಿನ	ಹೆಸರಿನಲ್ಲಿ
Transcribe Trial 1			
Transcribe Trial 2			
Consistent			
Inconsistent			
L4	ಎದಿರು	ಎದಿರಿಸು	ಎದಿರುಗೊಳ್ಳು
Transcribe Trial 1			
Transcribe Trial 2			
Consistent			
Inconsistent			

L= Length

Accuracy Scoring for length task section

Speech Production Accuracy	***Documented Score for length task***											
	L1A	*L1B*	*L1C*	*L2A*	*L2B*	*L2C*	*L3A*	*L3B*	*L3C*	*L4A*	*L4B*	*L4C*
Initiation												
Distortion												

Distorted substitution/ Addition												
Articulatory groping												
Syllable sequencing												
Syllable segmentation												
Increased errors with increased length/ complexity												
Substitution												
Omission												

Maximum Subsection Score: 204

Part B: Complexity task

Instructions: *The target words are presented to the participant verbally, and they are required to imitate words of progressively increasing complexity.*

Instruct the Subject: "I am going to say some words that get more complex, and I would like you to repeat them after me." Begin by presenting a practice item to familiarize the subject with the task, followed by the actual test items. Each word should be produced slowly, and the participant is given two attempts to imitate the correct production. Production with more error must be considered for scoring.

Practice items:

1. ಸದಸ್ಯ

2. ನಿಯಂತ್ರಣ

Stimulus/ Trials	A	B	C
C1	ಕರ್ನಾಟಕ	ಪ್ರದರ್ಶನ	ಪ್ರತಿಷ್ಠಿತ
Transcribe Trial 1			
Transcribe Trial 2			
Consistent			
Inconsistent			
C2	ಆಧ್ಯಾತ್ಮಕ	ನಿತ್ಯೋತ್ಸವ	ಕಾರ್ಯಧ್ಯಕ್ಷ
Transcribe Trial 1			
Transcribe Trial 2			
Consistent			
Inconsistent			
C3	ಮಂಗಳವಾರ	ಮಾರ್ಗದರ್ಶನ	ಚಿತ್ರೀಕರಣ

Transcribe Trial 1			
Transcribe Trial 2			
Consistent			
Inconsistent			
C4	ಆವೃತವಾಗಿ	ಸತ್ಯದರ್ಶನ	ಚಿತ್ರನಗರಿ
Transcribe Trial 1			
Transcribe Trial 2			
Consistent			
Inconsistent			

C= Complexity

Accuracy Scoring for complexity

Speech Production Accuracy	***Documented Score for Complexity task***											
	C1 A	*C1 B*	*C1 C*	*C2 A*	*C2 B*	*C2 C*	*C3 A*	*C3 B*	*C3 C*	*C4 A*	*C4 B*	*C4 C*
Initiation												
Distortion												
Distorted substitution/ Addition												
Articulatory groping												
Syllable sequencing												
Syllable segmentation												
Increased errors with increased length/ complexity												
Substitution												
Omission												

Maximum Subsection Score: 204

Subsection 8: Sentence repetition task

Instructions: *The target sentences are presented to the subject verbally, and they are required to imitate each sentence produced by the clinician.*

Instruct the subject: "I am going to say some sentences, and I would like you to repeat them after me." Each sentence should be presented slowly, and the subject is given two attempts to imitate the correct production. Production with more error must be considered for scoring. Please tick for consistency for each item.

Practice item:

1. ಹೊಸ ಮನೆ

2. ಜನರು ಸಹಕಾರ ನೀಡಿದರು

Stimuli No.	Sentence Stimuli	Transcribe the response		Consistent	Inconsistent
		Trial 1	Trial 2		
S1	ಮಳೆ ನೀರು				
S2	ಪಂಜಿನ ಹಬೆ				
S3	ಅರಣ್ಯ ಇಲಾಖೆ				
S4	ಟಪಾಲು ರಶೀತಿ				
S5	ನಿರ್ದೇಶಕ ಸಿನಿಮಾ ನಿರ್ಮಿಸಿದನು				
S6	ದಿಗಂತವ್ಯಾಪಿ ಮೌನವು ಚಿತ್ತವನ್ನು ಆವರಿಸಿತು				
S7	ಜನರಿಗೆ ವೈದ್ಯಕೀಯ ಸೌಲಭ್ಯ ಅಗತ್ಯವಾಗಿದೆ				
S8	ಅವಿಚ್ಛಿನ್ನ ಧ್ಯಾನಸ್ಥಿತಿಗೆ ಮನಸ್ಸು ನಿಶ್ಚಲವಾಯಿತು				

‘S’ = Sentence

Speech Production Accuracy	*Documented Score*							
	S1	S2	S3	S4	S5	S6	S7	S8
Initiation								
Distortion								
Distorted substitution/ Addition								
Articulatory groping								
Syllable sequencing								

Syllable segmentation								
Excess/ Equalized stress								
False starts/ Restarts								
Sound/ Syllable/Word repetition								
Substitution								
Omission								

Maximum Subsection Score: 168

Subsection 9: Spontaneous speech task

Instructions: *The questions are presented to the subject verbally, and they are asked to respond to each one.*

Test questions:

1) ಇವತ್ತು ನಿಮ್ಮ ಆರೋಗ್ಯ ಹೇಗಿದೆ?
2) ನೀವು ಇಲ್ಲಿಗೆ ಬಂದ ಕಾರಣ ತಿಳಿಸಿ ಮತ್ತೆ ನಿಮಗೆ ಏನು ತೊಂದರೆ ಆಗಿದೆ ಅಂತ ವಿವರಿಸಿ.
3) ನಿಮ್ಮ ಕುಟುಂಬದ ಬಗ್ಗೆ ಹೇಳಿ

Scoring: Indicate the observed characteristics as 'yes' or 'no' based on the responses observed for all the three questions.

Scoring Descriptors	1		2		3	
	Yes	No	Yes	No	Yes	No
Normal Stress pattern						
Excess/ Equalized stress						
False starts/ Restarts						
Transient Cessation						
Sound/ Syllable/Word repetition						

Yes= Present; No= Absent

Scoring description:

Normal Stress pattern	Perceived appropriate emphasis placed on words during speech production.
Excess/ Equalized stress	Excess and/or equal stress placement on a particular syllable/word.
False starts/ Restarts	A speech interruption in which the speaker starts a sound, syllable, word, or utterance but stops and restarts.
Transient Cessation	Temporary stopping or brief pause in speech output
Sound/ Syllable/Word repetition	Sound, syllable, or single-syllable or a multisyllabic word repetition.

Master scoring descriptor to rate the parameters across subsections

Sl. No.	Parameter/ Scoring	0 (Normal)	1 (Mild)	2 (Marked)
1.	**Initiation**	Initiates verbal response promptly without any hesitation	* Occasional inconsistent initiations/delays prior to speech initiation	#Frequent delays in initiating speech OR no response despite adequate comprehension and attention
2.	**Regularity**	Regular and equal timing between syllables	Occasional breakdown in syllable chains and minimal rate fluctuations	Frequent breakdown of syllable chains with marked rate fluctuations
3.	**Distortion**	Clear and accurate sound production	Occasional imprecise sounds; target difficult to identify	Frequent imprecise sounds; target difficult to identify
4.	**Distorted Substitution / Addition**	No substitutions or additions for the intended sound productions	Occasional substitutions/additions with distortion; mostly recognizable sound sequences	Frequent substitutions/additions with distortion; often inconsistent or hard to understand sound sequences
5.	**Articulatory Groping**	No visible or audible groping	Occasional effort or hesitation during production	Frequent trial-and-error movements or visible struggle
6.	**Syllable Sequencing**	Syllables should be arranged in the correct order.	Occasional errors in syllable order	Frequent errors in order or inconsistent syllable sequences
7.	**Syllable Segmentation**	Smooth and continuous production of syllables	Occasional pauses between syllables	Frequent pauses; syllables clearly separated
8.	**Excess/ Equalized stress**	Typical emphasis placed on a particular syllable/word	Occasional atypical stress placement on a particular syllable/word	Frequent excess and/or equal stress placement on a particular syllable/word
9.	**False starts/ Restarts**	Typical production of intended syllables/words/utterances.	Occasional interruption and restarting of syllables/words/utterances	Frequent interruption and restarting of syllables/words/utterances
10.	**Sound/ Syllable/Word repetition**	Normal fluent production of words	Occasional sound/ syllable/word repetitions	Frequent sound/ syllable/word repetitions
11.	**Increased errors with increased**	Clear and accurate target production	Occasional increase in errors as the	Frequent increase in errors as the length/ complexity increases

	length/ complexity		length/ complexity increases	
12.	**Substitution**	No substitutions; target sound/syllable produced correctly	Occasional substitutions of target sound/syllable with another recognizable sound/syllable	Frequent substitutions of the intended target sounds/syllables.
13.	**Omission**	No omissions; all target sounds/syllables produced correctly	There are occasional omissions of sounds or syllables, but the overall syllable shape of the word is mostly preserved.	Frequent omission of syllables; the syllable shape of the word is significantly altered.

Occasional: ≤ 25% of sounds/syllables; #Frequent: > 25 % of sounds/syllables