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Clinical Focus

"The Caterpillar": A Novel Reading Passage for Assessment of Motor Speech Disorders

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Purpose: A review of the salient characteristics of motor speech disorders and common assessment protocols revealed the need for a novel reading passage tailored specifically to differentiate between and among the dysarthrias (DYSs) and apraxia of speech (AOS).
Method: "The Caterpillar" passage was designed to provide a contemporary, easily read, contextual speech sample with specific tasks (e.g., prosodic contrasts, words of increasing length and complexity) targeted to inform the assessment of motor speech disorders. Twenty-two adults, 15 with DYS or AOS and 7 healthy controls (HC), were recorded reading "The Caterpillar" passage to demonstrate its utility in examining motor speech performance.
Conclusion: Analysis of performance across a subset of segmental and prosodic variables illustrated that "The Caterpillar" passage showed promise for extracting individual profiles of impairment that could augment current assessment protocols and inform treatment planning in motor speech disorders.

Key Words: motor speech evaluation, reading passage, contextual speech

The motor speech evaluation is critical to identifying the presence of, differentiating between, and rating the severity of impairment. Observations based on this assessment provide guidance for which aspects of speech production may be most amenable to treatment and effective for enhancing communication. Speech production is examined at various levels of complexity, from nonsense syllables to words to sentences to connected speech, using a reading from a standard passage and elicited through picture description or conversation. Specific tasks used to examine speech motor programming and execution include maximum phonation time, diadochokinetic rates (alternating/sequential motion rates), isolated sound and syllable production, words in simple and complex syllable structures, words of increasing length, automatic/frequent words or phrases (e.g., days of the week, counting), and contextual speech (Duffy, 2005; Freed, 2012).

Of the speech evaluation tasks, contextual speech is the most useful for observing the integrated function of all components of speech (see, e.g., Bunton, Kent, Duffy, Rosenbek, & Kent, 2007; Duffy, 2005). The reading passage provides a sample that can be compared to tokens gathered through syllable and word repetition tasks. Ideally, the passage should afford a controlled and repeatable speaking task to tax the speech production system and aid in differential diagnosis. For the researcher, knowing the context within which speech sounds are produced and the nature of the errors made, as well as examining the suprasegmental structure of utterances, may provide insight into deficits at varying levels of speech production.

A variety of reading passages have been reported in the literature, yet "My Grandfather" (Van Riper, 1963) is anecdotally the most well known and used. This passage, however, is not particularly well suited for examining speech motor skills that differentiate among motor speech disorders. In fact, Van Riper described the passage as "useful for a quick survey of the student's (client's) ability to produce correct speech sounds" (Van Riper, 1963, p. 484). The historical roots of using this passage in motor speech evaluation perhaps stem from Darley, Aronson, and Brown's (1969a, 1969b) seminal work on the perceptual characteristics of dysarthria, in which they used a variant of the passage called "The Grandfather Passage" (see Reilly & Fisher, 2012, for a description of the genesis of the passage). Given that the purpose of a reading passage is to allow researchers to observe the integrated performance of the speech production system, best clinical practice would support embedding some of the syllable and word repetition tasks of the motor speech evaluation within the reading passage, to observe differences

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between isolated and connected speech performance. Moreover, the reading passage provides an opportunity to observe motor speech performance on tasks that cannot be assessed in isolation, such as prosodic modulation.

To address the need for a passage tailored to motor speech impairment, we developed a novel reading passage called "The Caterpillar." In this article, we describe the design and development of the passage and document the performance of a group of individuals with motor speech disorders and healthy controls. Speaker-specific profiles are discussed to illustrate the utility of the "The Caterpillar" passage for motor speech evaluation.

Method

Development of "The Caterpillar" Passage

"The Caterpillar" passage was developed for the primary purpose of augmenting current motor speech assessment protocols. Passage formulation followed a multistep process in which we first identified a subset of speech tasks used in motor speech evaluation that would be informative for differential diagnosis and treatment planning. We considered additional tasks to address prosodic disturbances that may not be evident in syllable and word repetition tasks. Next, we conducted a review of passages cited in the clinical and research realms to document the attributes that target motor speech impairments as well as identify potential enhancements. We used the following criteria to design the novel passage:

1. Balance of passage length with breadth of tasks for clinical efficiency
2. Comprehensive phonotactic coverage to examine speech repertoire
3. Inclusion of word and sentence forms that examine respiratory, phonatory, articulatory, resonatory, and prosodic control
4. Insertion of isolated speech motor tasks for comparison within connected speech (e.g., mono- and polysyllabic word forms, words of increasing length, repeated words, etc.)
5. Use of contemporary vocabulary and simple syntax to focus on speech production abilities while minimizing cognitive load

Given the broad clinical use of "My Grandfather" (Reilly & Fisher, 2012), we conducted an analysis of its structural and linguistic properties to ensure that "The Caterpillar" passage was comparable along basic dimensions. (Both passages can be found in the Appendix.) Figure 1 provides a summary of attributes of "My Grandfather" and rationale for modifications and/or additions that were implemented in "The Caterpillar" passage. This comparison suggests that "The Caterpillar" and "My Grandfather" are similar along a number of dimensions. First, they both assess the full phonetic repertoire within a concise passage length for clinical efficiency. Second, both passages are characterized by a syllable-to-word ratio of 1.33, indicating that they are composed of mono- and multisyllabic words. This attribute is important for the motor speech evaluation in that speech production is taxed to a greater degree in multisyllabic words than in monosyllables. Last, the passages are comparable in overall reading level and relatively similar in the number of high frequency words in order to examine motor speech skills rather than cognitive or reading abilities.

"The Caterpillar" passage was designed to systematically build upon "My Grandfather" by including tasks that examine deficits within and across speech subsytems. For example, sentences of varying lengths were included to permit observations of respiratory and phonatory support, tendency to fatigue, and the ability to mark appropriate breath groups. In addition, complex words such as *caterpillar, amusement,* and *memorable* assess a range of sound classes and places of articulation. Similarly, the inclusion of a primarily nasal sentence (e.g., "My most memorable moment ever") affords the opportunity to infer velopharyngeal function when compared with sentences containing only oral phonemes (e.g., "Boy, was I scared").

Tasks requiring prosodic modulation, such as contrastive sentence types (e.g., statements vs. questions) and words with emphatic stress, were also embedded within the passage. We were motivated to include these attributes because of the fact that prosodic disturbances in motor speech disorders are pervasive—yet often overlooked—in assessment protocols (Patel, 2010). For example, there is only one utterance with prosodic emphasis ("Banana oil!") within the "My Grandfather" passage. Yet, *prosodic insufficiency,* characterized by slow rate, abnormal pausing, equalized stress, and restricted or altered pitch, duration, and loudness variation (Duffy, 2005), forms a deviant speech cluster in the Mayo Clinic classification of dysarthria (Darley, Aronson, & Brown, 1969a, 1969b, 1975). Despite the salience of prosodic disturbances in motor speech disorders, there is little standardization in the tasks that clinicians use to assess prosodic function compared with those used to assess segmental control of speech.

Another differentiating characteristic of "The Caterpillar" passage compared to "My Grandfather" is the inclusion of tasks that specifically target motor planning and programming deficits. For instance, individuals with apraxia of speech have been documented to demonstrate increased errors on words of increasing length (e.g., *amuse* vs. *amusement, fast* vs. *faster*) and/or phonetic complexity (Duffy, 2005; McNeil, Robin, & Schmidt, 1997; Ogar et al., 2006; Strand & McNeil, 1996; Yorkston, Beukelman, Strand, & Bell, 1999), produce repeated words inconsistently (McNeil et al., 1997; Wertz, Lapointe, & Rosenbek, 1984), and attempt to revise or self-correct productions (Wertz et al., 1984). "The Caterpillar" includes word pairs of increasing length, complex words, and words that are repeated throughout the passage, thus providing the authors an opportunity to observe these behaviors during the speech assessment.

Participants

Fifteen adults (eight men, seven women; mean age = 51 years) with motor speech impairment, along with seven healthy participants (two men, five women; mean age = 41 years), were recruited to demonstrate the feasibility of using "The Caterpillar" passage to examine motor speech

FIGURE 1. Description of attributes of "My Grandfather" passage and rationale for design decisions for "The Caterpillar" passage. syll = syllable; avg = average.

Passage Attribute	"My Grandfather"	Significance of Attribute/Rationale for Modification	"The Caterpillar"
Repertoire of phonemes	Contains almost all phonemes except glottal stops and /ʒ/	Include breadth of phonemes to gather diverse and representative inventory of phonetic structures	Contains all English phonemes
Passage length and complexity	133 words; 177 syllables; 1.33 word/syll ratio; average of 16.5 words/sentence and 4.2 characters/word	Moderate length passage, long enough to make observations but quickly read. Words of varying length (mono- and multisyllables) desirable to observe if breakdown occurs on longer words	197 words; 261 syllables; 1.33 word/syll ratio; average of 12.1 words/sentence and 4.1 characters/word
Mean length of utterance (MLU)	Contains utterances of varying lengths. Avg. MLU: 15.9 (*SD* 6.5); MLU range: 9–27	Varying length of utterances (e.g., short and long utterances) desirable to compare fatigue and prosodic modulation	Contains utterances of varying lengths. Avg. MLU: 13.4 (*SD* 6.6); MLU range: 4–28
Word familiarity	54% of words are "high frequency" based on Fry (2000)	Familiar words help ensure testing of motor skills and not cognitive, linguistic, or reading skills	64% of words are "high frequency" based on Fry (2000)
Reading level	Flesh-Kincaid Reading grade level: 5.2	Keep reading level relatively simple to test motor skills and not cognitive, linguistic, or reading skills	Flesh-Kincaid Reading grade level: 5.0
Prosodic variations	**Intonation types—** statements and exclamation ("Banana oil!")	Prosodic performance informs assessment, treatment planning, and rating of severity of motor speech disorders	**Intonation types—** statement/interrogative/ exclamation **Contrastive stress—** minimal pairs: *most, memorable, so, scared*
Words of increasing length	Not included	Breakdown on words of increasing length seen in AOS, so can assist with differential diagnosis	Word pairs of increasing length: *amuse/ amusement, fast/faster, ride/riding*
Word repetition (#)	"*Grandfather*" (2)	Inconsistency of repetitions seen in AOS, and can assist with differential diagnosis	"*Caterpillar*" (7), "tick" (3), "*memorable*" (2)
Oral/nasal sounds	*"Banana oil!"*	To assess performance of resonance subsystem through observation on words/utterances containing rapid changes from nasal to oral	Tasks to compare resonance: *Boy was I scared* vs. *It was my most memorable moment ever.*

performance. The individuals with speech impairment included 10 participants diagnosed with dysarthria (DYS) and five participants diagnosed with apraxia of speech (AOS; see Table 1 for participant characteristics). All participants were native English speakers who had adequate hearing, vision, and cognitive skills and read at a fifth-grade level or higher. The speakers with DYS or AOS were recruited from various hospitals and skilled nursing facilities. Their speech impairments were diagnosed by an experienced speech-language pathologist (last author) using conventional diagnostic methods, and confirmed by a second speech-language pathologist (second author). The acoustic data from one female participant with AOS (AOS5) were not usable due to recording artifacts and therefore are not reported. Thus, the final participant pool included four participants with AOS, 10 participants with DYS, and seven healthy controls. Approval for all procedures was granted by the Institutional Review Board at Northeastern University.

TABLE 1. Participant characteristics.

Participant	Gender	Age (years)	Etiology	Time post onset	Speech diagnosis	Severity of speech impairment
AOS1	F	44	CVA	1 week	AOS	Mild–moderate
AOS2	M	56	CVA	6 months	AOS	Mild–moderate
AOS3	M	59	CVA	2 months	AOS	Moderate–severe
AOS4	M	33	CVA	3 days	AOS	Severe
AOS5	F	51	Left craniotomy	4 months	AOS	Mild–moderate
Flaccid1	M	50	Head and neck cancer	2 days	Flaccid DYS	Mild
Flaccid2	M	58	CVA	2 days	Flaccid DYS	Moderate
Mixed1	M	53	Myasthenia gravis	2 years	Mixed DYS	Mild
Mixed2	F	54	CP & oral cancer	1 year	Spastic DYS	Moderate–severe
Mixed3	M	54	CVA	1 month	Mixed DYS	Severe
Mixed4	M	48	Spinal cord ataxia	5 years	Mixed DYS	Severe
Mixed5	F	59	Anoxia	1 month	Mixed DYS	Severe
Spastic1	F	62	CVA	2 months	Spastic DYS	Mild
Spastic2	F	50	CVA	1 week	Spastic DYS	Moderate
Spastic3	F	45	CVA	2 months	Spastic DYS	Moderate–severe
HC1	M	32				
HC2	F	24				
HC3	F	38				
HC4	F	57				
HC5	M	53				
HC6	F	40				
HC7	F	46				

Note. AOS = apraxia of speech; CVA = cerebrovascular accident; DYS = dysarthria; HC = healthy control speaker.

Procedure

We audio-recorded each participant reading "The Caterpillar" passage by using a digital recorder (Olympus WS-133M) placed at a 45-degree angle, 6–8 in. from the left corner of the participant's mouth. The participants had no previous experience with the reading passage, nor did they have an opportunity to rehearse the passage orally or silently prior to the recording. Recordings took place in a quiet room within the participant's home or residential facility. Audio recordings were analyzed off-line using Praat (Boersma & Weenink, 2009) so that we could examine a subset of variables amenable to analysis for illustrative purposes. We gave priority to measures that were quick and easy to administer by clinicians using perceptual techniques. These variables included overall passage reading rate (words/second), frequency of pauses, and variation of fundamental frequency and intensity. Additional analyses were conducted on tokens designed specifically to assess motor speech performance. For example, words produced with contrastive stress were analyzed along with changes in fundamental frequency (F0) and intensity; and complex words were analyzed for segmental errors, consistency of production, and revisions/attempts at self-correction (see Table 2 for operational definitions of variables). Interjudge reliability ratings were obtained through recoding of 10% of acoustic tokens ($r = 92.3$) and 13% of perceptual tokens (agreement = 97.6%) by a second investigator.

Results and Discussion

The performance of each speaker with motor speech disorders and the group average of the healthy control speakers on variables measured across "The Caterpillar" passage are reported in Figure 2. Specifically, the top two panels illustrate the F0 range (i.e., maximum F0 – minimum F0) and intensity range (i.e., maximum intensity – minimum intensity) for each participant across the passage. The third and fourth panels from the top show the number of pauses inserted by each participant during reading and the rate of reading (words/second).

To examine the utility of the targeted motor speech tasks, we conducted an additional set of perceptual and acoustic analyses on recordings of "The Caterpillar." The performance of each participant with motor speech disorders and average of the control participants are shown in Figure 3. The upper panels of Figure 3 include the difference between the F0 (top panel; e.g., F0 of stressed word – F0 of unstressed word) and intensity (panel second from top; i.e., intensity of stressed word – intensity of unstressed word) for the stressed and unstressed productions of *memorable, so,* and *scared.* The third panel of Figure 3 includes a tally of the complex words (i.e., multisyllabic words containing phonemes with variable places and manners of articulation) *gigantic, rollercoaster, bright blue, unfortunately, Caterpillar,* and *memorable* produced with at least one error. For the words that were repeated in the passage (the latter two), only the first occurrence in the passage was analyzed. The fourth panel (second from the bottom) shows the number of complex words upon which participants revised or attempted to correct their initial production. The bottom panel shows the number of words with inconsistent repetitions on the words *tick, Caterpillar,* and *memorable,* which are repeated throughout the passage. It is notable that no participant made errors on any productions of the word *tick.*

A comparison of the occurrence of errors on the short and long version of words of increasing length (e.g., *amuse/amusement, fast/faster,* and *ride/riding*) was also

TABLE 2. Operational definitions.

Variable	Operational definition
Passage reading rate (words/second)	Total length of passage from onset of the first utterance to offset of the last utterance. Extended pauses or breaks in recording were omitted to ensure accuracy. Individual recordings were transcribed to obtain total number of words spoken. The ratio of words spoken per second was calculated for each speaker.
Number of pauses	Total number of pauses tallied based on perceptual judgment.
Average F0 (intensity) across passage	Mean F0 (intensity) calculated per utterance and averaged over all sentences in the passage. Acoustic analysis conducted using Praat software (Boersma & Weenink, 2009).
F0 (intensity) range across passage	Difference between maximum F0 (intensity) and minimum F0 (intensity) across the entire passage. Acoustic variables analyzed using Praat.
Peak F0 (intensity) of stressed words	Peak F0(intensity) extracted using Praat for contrastive pairs of stressed and unstressed words, e.g., MEMORABLE/memorable, SCARED/scared, SO/so.
Number of multisyllabic/complex words with error	Total number of multisyllabic words produced with at least one segmental error based on perceptual judgment. Complex words or phrases analyzed included *gigantic, rollercoaster, bright blue, Caterpillar, unfortunately, and memorable.* Vowel, consonant, and consonant cluster errors were tallied.
Number of words of increasing length with error	Total number of short and long word forms produced with at least one segmental error on the words *fast/faster, amuse/amusement,* and *ride/riding,* based on perceptual judgment.
Number of words with attempted revisions	Tally of words with at least one revision after initiation of the following words: *gigantic, rollercoaster, bright blue, Caterpillar, unfortunately, memorable, faster, amusement* and *riding,* based on perceptual judgment.
Number of words inconsistently repeated	Tally of inconsistent productions on the repeated words *tick, memorable,* and *Caterpillar,* based on perceptual judgment.

made for each participant. Although these words elicited errors from both AOS and DYS speakers, only one AOS and one DYS speaker had greater difficulty with the longer word forms.

Within this limited sample of participants and subset of variables examined, a number of generalizations can be made across participants and across subgroups. For instance, all participants with motor speech disorders were observed to produce errors on complex words, regardless of disorder type or severity. In comparing the AOS and DYS groups, we found that three of the four participants with AOS attempted to revise their productions of complex words, whereas few of the DYS participants demonstrated this behavior. Similarly, the AOS participants appeared more apt to produce inconsistent word repetitions than their DYS counterparts.

Given the preponderance of individual differences in presentation of motor speech disorders, it is not surprising that any one measure did not cleanly cluster subtypes. However, patterns of performance across segmental and prosodic variables (Figures 2 and 3) were evident when we analyzed individual speaker performance on "The Caterpillar" passage. Examples of the types of patterns observed and resulting clinical implications are discussed below. It should be noted that these examples are based on a small subset of variables gathered in readings of "The Caterpillar" for illustrative purposes and thus are not an exhaustive account of motor speech performance; they should be considered within the context of a full assessment battery.

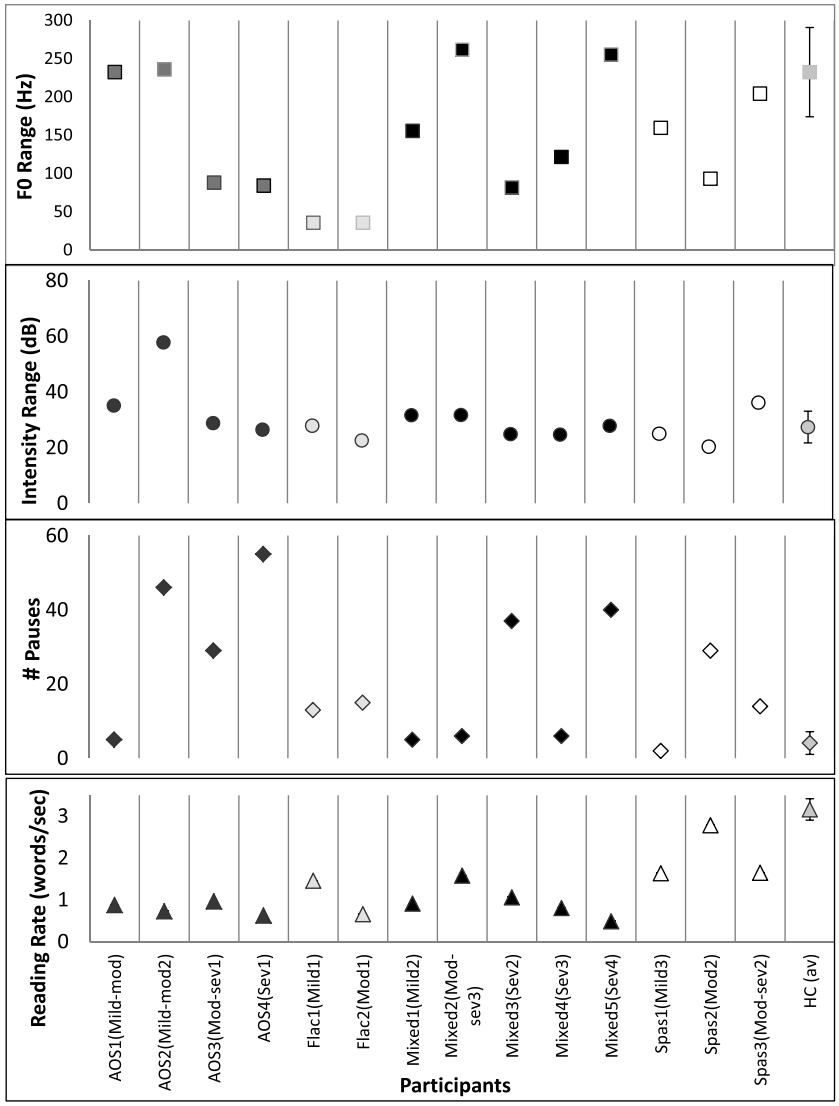
Profiles of Performance

Substantial segmental errors with variable prosodic modulation. Participant Mixed5 demonstrated substantial segmental impairment with errors on all six complex words. In contrast, although her F0 and intensity ranges across the passage were similar to the control group, she had difficulty targeting prosodic control within an utterance, as demonstrated by large F0 variability on stressed and unstressed word pairs. Clinically, this profile may reflect the need to prioritize segmental deficits over prosodic deficits. On the other hand, perhaps her prosodic range could be shaped at the word level to improve intelligibility (Hartelius, Wising, & Nord, 1997; Liss, 2007; Patel & McNab, 2008).

Moderate segmental errors with relatively impaired prosody. Participant Mixed3 demonstrated moderate difficulty with segmental production, in that three of the six complex words contained errors. It is interesting to note that he was one of few DYS participants who attempted to revise productions and was inconsistent on word repetitions. This profile may lead a clinician to further probe motor planning/programming. Mixed3 also used a restricted F0 range across the passage, as well as relatively smaller F0 and intensity distinctions between stressed and unstressed word pairs. Furthermore, his reading rate was moderately slow, due in part to frequent pausing. One possible treatment approach for this profile would be to target both segmental and prosodic skills simultaneously.

Limited prosodic modulation across passage, yet an ability to convey stress contrasts. Participant AOS4 demonstrated errors on complex words, frequently attempted self-corrections, and showed some inconsistency on repeated words. He read at a slow rate and inserted many pauses. Most notable, however, was the fact that although he had a relatively restricted F0 range across the reading passage, he was able to produce stress contrasts with substantial F0 differences. Interventions aimed at leveraging his ability to modulate word-level prosody on demand may be beneficial for improving communication. For example, stressing the most salient words within an utterance may promote comprehensibility.

FIGURE 2. Profile from each participant with motor speech disorders and average of HC group derived from reading of "The Caterpillar," including mean F0 (top panel) and mean intensity (panel second from top) across the passage, number of pauses inserted (panel third from top), and speaking rate (words/second; bottom panel).



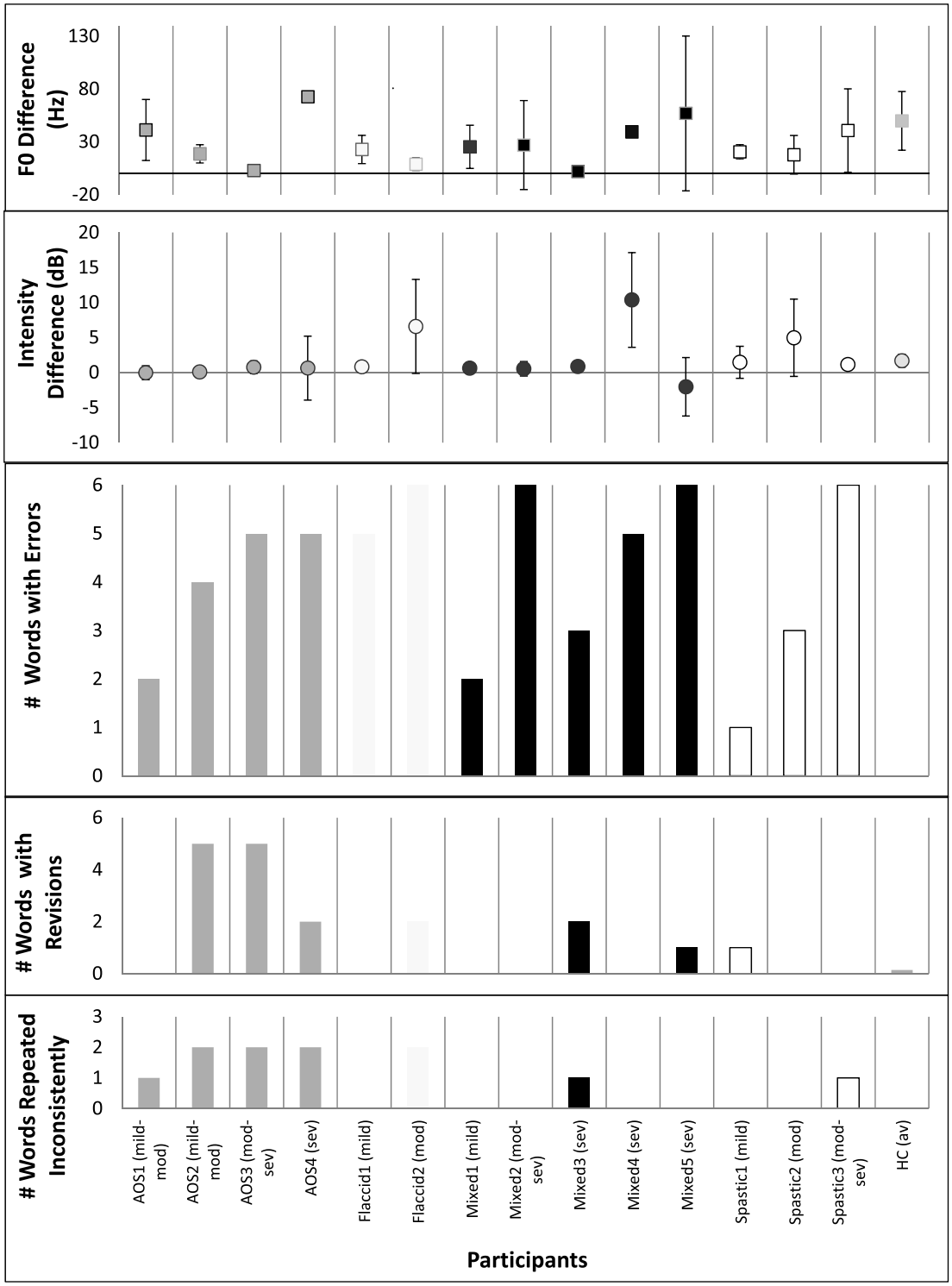
Limitations and Future Directions

Although the sensitivity and specificity of "The Caterpillar" passage was not directly measured, this initial feasibility study provides illustrative profiles demonstrating clinical utility for the sample studied herein. This work did not aim to, nor can it, substantiate claims of improved differential diagnosis of motor speech disorders using "The Caterpillar" versus "My Grandfather" passage. However, given that "The Caterpillar" is grounded in the motor speech literature, it is more likely to yield more clinically relevant information than "My Grandfather," which was not developed in this way. Increased use of "The Caterpillar," both clinical and in research protocols, will provide opportunities to validate the passage on a larger group of individuals with motor speech disorders and ultimately judge its clinical impact. Extensions of the current work include coupling tokens in word- and utterance-level assessment tasks of the motor speech evaluation with tokens in "The Catepillar" passage to assess task-level changes in performance, and adapting the passage for other language, cultural, and clinical groups, as well as for young children.

Conclusion

The motor speech evaluation is used to diagnose, characterize, and differentiate between impairments, as well as determine targets for treatment planning. In an effort to augment current assessment tools, we developed a novel

FIGURE 3. Profile from each participant with motor speech disorders and average of HC group derived from reading of "The Caterpillar," including difference in peak F0 (top panel) and peak intensity (panel second from top) between stressed and unstressed minimal pairs; number of complex words containing at least one segmental error (third panel from top); number of complex words with attempted revision (fourth panel from top); and number of inconsistent productions on repeated words (bottom panel).



reading passage, "The Caterpillar." This passage was specifically designed to include contemporary themes with relatively simple reading requirements, and to examine segmental and prosodic skills targeted to inform diagnosis and treatment planning of motor speech disorders.

Linguistic and structural analyses confirmed that "The Caterpillar" passage was comparable to "My Grandfather" in passage length, phonotactic breadth, and reading level. Acoustic and perceptual analyses of recordings of "The Caterpillar" by speakers with motor speech disorders further demonstrated its value in yielding insights into the nature of impairment through its inclusion of targeted motor speech tasks. The passage was informative across a range of severity levels and disorder (sub)types, suggesting its potential to strengthen clinical practice in motor speech disorders when coupled with traditional assessment protocols.

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Appendix

"The Caterpillar" and "My Grandfather" Passages

"The Caterpillar"

Do you like amusement parks? Well, I sure do. To amuse myself, I went twice last spring. My most MEMORABLE moment was riding on the Caterpillar, which is a gigantic rollercoaster high above the ground. When I saw how high the Caterpillar rose into the bright blue sky I knew it was for me. After waiting in line for thirty minutes, I made it to the front where the man measured my height to see if I was tall enough. I gave the man my coins, asked for change, and jumped on the cart. Tick, tick, tick, the Caterpillar climbed slowly up the tracks. It went SO high I could see the parking lot. Boy was I SCARED! I thought to myself, "There's no turning back now." People were so scared they screamed as we swiftly zoomed fast, fast, and faster along the tracks. As quickly as it started, the Caterpillar came to a stop. Unfortunately, it was time to pack the car and drive home. That night I dreamt of the wild ride on the Caterpillar. Taking a trip to the amusement park and riding on the Caterpillar was my MOST memorable moment ever!

"My Grandfather"

You wished to know all about my grandfather. Well, he is nearly 93 years old; he dresses himself in an ancient black frock coat, usually minus several buttons; yet he still thinks as swiftly as ever. A long, flowing beard clings to his chin, giving those who observe him a pronounced feeling of the utmost respect. When he speaks, his voice is just a bit cracked and quivers a trifle. Twice each day he plays skilfully and with zest upon our small organ. Except in the winter when the ooze or snow or ice prevents, he slowly takes a short walk in the open air each day. We have often urged him to walk more and smoke less, but he always answers, "Banana oil!" Grandfather likes to be modern in his language.