

Voice Disorders and Speech Intelligibility in Developmental Dysarthria: Influence of Speech Task

Micalle Carl, Sapir Amira Shmuel, and Michal Licht, Ariel, Israel

SUMMARY: Background. Impairment of the phonatory subsystem is a common feature of developmental dysarthria and may contribute to reduced speech intelligibility. However, voice quality is known to vary as a function of speech task, and the relationship between phonatory functioning and intelligibility across elicitation contexts remains poorly understood. This study aimed to (1) examine speech task effects on acoustic measures of voice quality, and (2) investigate task-specific relationships between voice quality and intelligibility in children and adolescents with developmental dysarthria.

Methods. Participants with developmental dysarthria ($n = 31$, mean age: 12;3 years) produced speech across three tasks: sustained phonation (/a/), single-word production (picture naming), and spontaneous speech (picture description). Acoustic measures included cepstral peak prominence (CPP), jitter, shimmer, and harmonic-to-noise ratio (HNR), adapted for connected speech contexts. Speech intelligibility was assessed via transcription for single-word productions and listener ratings for connected speech samples. Perceptual voice quality was evaluated using the GRBAS Grade (G) component for sustained phonation. Linear mixed-effects models examined task effects on voice quality and relationships between acoustic measures and intelligibility.

Results. Significant task effects were observed for all acoustic measures. Sustained phonation yielded the most favorable voice quality, followed by connected speech, with single-word productions demonstrating the poorest vocal quality. Acoustic measures of sustained phonation were significantly associated with perceptual ratings, supporting their validity. No significant relationships were found between acoustic voice measures and intelligibility at either the word or connected speech levels.

Conclusions. Voice quality in developmental dysarthria is strongly influenced by speech task, reflecting differences in motor demands and subsystem integration. Perceptual ratings aligned with acoustic measures during sustained phonation; however, acoustic indices across tasks were not directly associated with intelligibility outcomes. These findings underscore the importance of task selection in voice assessment and suggest that phonatory impairment may not directly capture functional communication outcomes in developmental dysarthria.

Key Words: Developmental dysarthria—Voice quality—Speech intelligibility—Speech task effects—Phonatory subsystem.

INTRODUCTION

Dysarthria is a motor speech disorder characterized by impairment to any or all of the speech subsystems, including articulation, phonation, respiration, resonance, and prosody, to varying degrees.¹ Developmental dysarthria, most commonly associated with neurodevelopmental conditions such as cerebral palsy (CP), is marked by reduced speech intelligibility arising from combined subsystem deficits.² However, the type of task used to elicit speech from which voice quality is analyzed may impact the results of these measurements.³ Furthermore, the relationship between phonatory subsystem functioning and speech intelligibility in children with developmental dysarthria has yet to be fully examined. The goal of the current study is therefore twofold: First, to determine the effect of

task elicitation on voice quality measurements. Second, to investigate the relationship between voice quality and speech intelligibility across tasks (eg, sustained phonation, word production, and spontaneous utterances) among children and adolescents with developmental dysarthria. These findings may shed light on the interaction and integration between motor speech subsystems and guide further assessment and intervention procedures within this population.

Developmental dysarthria

The speech disorder and resulting speech intelligibility of children and adults with developmental dysarthria vary in severity across speakers and typically involve impairment to one or more of the speech subsystems.^{4,5} Dysarthria is commonly attributed to impairments in neuromuscular control, including muscle weakness, abnormal muscle tone, and reduced coordination, which collectively disrupt the functioning of the speech subsystems.^{1,6} Perceptual descriptions of speech in individuals with CP frequently include slurred, labored, and/or slow speech,^{7,8} with speech sound errors that include imprecision of both consonants and vowels.^{9,10} With respect to respiratory and phonatory difficulties, often noted are descriptions of a strained or

Accepted for publication June 2, 2026.

From the Department of Communication Disorders, Ariel University, Ariel, Israel.

Address correspondence and reprint requests to Micalle Carl, Department of Communication Disorders, Ariel University, 40700, Israel. E-mail: micallec@ariel.ac.il

Journal of Voice, Vol xx, No xx, pp. xxx–xxx
0892-1997

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<https://doi.org/10.1016/j.jvoice.2026.06.002>

strangled voice quality, breathiness, reduced breath support for phonation, and abnormal pitch and loudness,^{11,12} which are consistent with underlying impairments in respiratory-phonatory control. These voice characteristics are thought to arise from neuromotor deficits affecting laryngeal muscle control, including reduced coordination between respiration and phonation, incomplete or inconsistent vocal fold closure, and impaired regulation of subglottal pressure.^{3,13} Such physiological disruptions result in instability in vocal fold vibration, instability in vocal amplitude, and reduced harmonic organization, as reflected in measures such as jitter, shimmer, and HNR, respectively.^{4,14} Consequently, voice quality abnormalities are not incidental but represent a core component of the motor speech impairment in this population, with potential implications for both speech production and perception.

Acoustic studies have detailed the acoustic correlates of these perceptual features across speaker ages and often discuss the impact of these characteristics on speech intelligibility. Speakers with developmental dysarthria demonstrate atypical acoustic features of fricatives and affricates,¹⁰ a smaller vowel space area,^{15,16} as well as reduced vowel contrasts¹⁷ and a slower speech rate.¹⁸ Furthermore, acoustic characteristics of voice quality include increased perturbation measures (jitter and shimmer), reduced harmonic-to-noise ratio (HNR),^{4,14} and altered cepstral peak prominence (CPP).³ Although articulatory impairments are typically considered the primary contributors to intelligibility limitations in this population,^{4,5,16} there is evidence to suggest that phonatory subsystem dysfunction may also contribute to the intelligibility impairment.^{4,16}

Speech task effects on voice quality

Speech production tasks place different demands on the speech motor system, particularly with respect to coordination, timing, and subsystem integration.¹⁹ Sustained phonation tasks primarily reflect respiratory-phonatory control under relatively stable articulatory conditions, whereas speech tasks (eg, words, sentences, and spontaneous speech) require rapid and flexible coordination across articulatory, phonatory, respiratory, and prosodic subsystems. Several studies have demonstrated that voice quality measures are task-dependent, even in typically developing speakers,^{20,21} although others have failed to demonstrate any stimulus differentiation in the typical population.²² When task differentiation was demonstrated, sustained phonation tasks often yielded more stable and extreme estimates of phonatory function than connected speech tasks.²¹

In developmental dysarthria, where motor impairments are typically present from the early stages of development, task-related demands may be particularly influential. Children and adolescents with CP often demonstrate limited capacity to adapt motor output across speech contexts, reflecting constraints in neuromotor planning, execution, and sensory-motor integration.^{5,16} Consistent with this

view, increased task demands in motor speech disorders have been associated with greater breakdowns in motor control, resulting in increased variability and reduced speech precision.^{23–25} This is also reflected in the articulatory and intelligibility characteristics of utterances of varying lengths, in which longer stimuli are judged to be less intelligible than shorter ones among children with CP.^{24,26,27} Consequently, speech and voice characteristics observed in simple or highly constrained tasks may not generalize to more complex or ecologically valid speech conditions, underscoring the importance of examining motor speech performance across a range of elicitation tasks.

A relatively small number of studies have investigated task-related effects in measures of voice quality in this population. Nip and Garellek³ demonstrated task effects on phonatory measures among children with CP, with isolated vowels showing reduced voice quality compared with connected speech contexts. In contrast, group differentiation for voice characteristics between individuals with CP and typically developing peers has been demonstrated for connected speech contexts,¹⁶ although not consistently for single-word contexts.^{4,5} These results suggest that phonatory control may deteriorate as articulatory and linguistic demands increase.²⁸ Notably, much of the existing literature describing phonatory characteristics among individuals with developmental dysarthria has relied on a limited variation of task types, thus precluding conclusions about voice function during varied communicative contexts. Systematic comparisons of voice quality across multiple tasks in developmental dysarthria, therefore, remain scarce, despite their clinical relevance.

Phonatory impairment and speech intelligibility

Phonatory subsystem impairment may contribute to reduced speech intelligibility both directly and indirectly. As a direct influence on speech, phonatory impairment may compromise speech intelligibility through its effects on the harmonic structure of the voiced signal, which can subsequently alter the acoustic properties of sonorant speech sounds, including formant-related information.^{29,30} In addition, degraded phonatory control may attenuate acoustic contrasts between voiced and voiceless segments and disrupt the transmission of suprasegmental information.²⁹ Indirectly, reduced vocal intensity, increased noise, phonatory instability, and abnormal voice quality can diminish the acoustic salience of speech overall, compromising listeners' ability to detect phonetic contrasts and segment speech signals.⁴ In developmentally typical speakers, phonatory impairment is often associated with reduced speech intelligibility, although not consistently so (for a review, see Gao and Ma³¹).

For individuals with developmental dysarthria, preliminary findings suggest that reduced vocal quality may limit intelligibility, especially in tasks requiring sustained phonatory control or increased speech length.^{4,16,32} Nonetheless, the extent to which phonatory impairment

contributes to intelligibility across different speech tasks in this population remains understudied. Although Nip and Garellek³ found task differentiation for various phonatory measures, speech intelligibility was not included in the analyses. Chen et al⁴ reported that phonatory measures were correlated with sentence-level speech intelligibility, but not with single-word intelligibility. In contrast, Schölderle et al¹² demonstrated that primary predictors of speech intelligibility included articulatory, respiratory, and prosodic, but not phonatory characteristics of speech, among adults with CP. Taken together, further investigation into task effects on measures of vocal quality and their impact on speech intelligibility is necessary within the study of developmental dysarthria. Examining task-specific relationships between voice quality and intelligibility may provide critical insight into subsystem interactions and inform targeted assessment and intervention strategies.

Research questions and hypotheses:

1. How does speech task type affect acoustic measures of voice quality in developmental dysarthria? It was hypothesized that acoustic measures of voice quality will differ across speech tasks, although no *a priori* assumptions were made regarding the direction of vocal quality between tasks.
2. Are acoustic measures of voice quality associated with speech intelligibility in a task-dependent manner? It was hypothesized that associations between voice quality and speech intelligibility would be task-dependent, emerging more strongly in connected speech than in single-word production.

METHODS

Ethical approval for the study was obtained from the University Ethics Review Board (approval #AU-HEA-MI-20211201). Informed consent was obtained from parents or legal guardians, and children provided verbal assent prior to the initiation of the recording procedures.

Participants

Speakers

A total of 31 children with developmental dysarthria participated in the current study. It should be noted that this sample represents a subset of a larger participant cohort involved in a longer recording procedure examining speech production in children with developmental dysarthria. The current sample was selected based on the availability of complete data across all speech tasks and measures relevant to the present analyses. Information regarding participant age, gender, diagnosis, and dysarthria severity level was obtained from academic records and is presented in Appendix A. Participants ranged in age from 8;8 to 15;0 years ($M = 12;2$ years). The sample included 15 females and 16 males with a clinical diagnosis of developmental dysarthria. Dysarthria severity was classified as mild ($n = 11$), moderate ($n = 12$), or severe ($n = 8$), based on the Pediatric Radboud Dysarthria

Assessment,³³ as part of the clinical speech evaluation reported in the academic records of each participant. The majority of participants were diagnosed with CP ($n = 23$) or a joint diagnosis of CP with an additional neurodevelopmental condition. The remaining participants presented with other neurodevelopmental or genetic conditions associated with motor speech impairment ($n = 8$). As per academic records, the cognitive functioning of all participants was reported to be within limits for the child's chronological age. All participants were native Hebrew speakers, and Hebrew was both their primary language and the language of instruction within their educational setting. Participants were reported to have normal or corrected-to-normal hearing.

Listeners

A total of 71 naive listeners participated in the speech intelligibility tasks. Listeners volunteered to take part in the study and were recruited via word of mouth; some were undergraduate students at the University who participated in exchange for academic course credit. All listeners were native speakers of Hebrew and reported normal hearing, no history of speech, language, learning, or neurological disorders, and no prior experience working with individuals with speech disorders, to minimize potential bias related to familiarity with dysarthric speech. All were between the ages of 18 and 50, of which 23 were men, and 48 were women.

Speech tasks and measures

Participants completed three speech tasks: production of sustained phonation of the vowel /a/, single words, and spontaneous speech elicited during a picture description task, designed to sample phonatory, articulatory, and connected speech performance. From these tasks, acoustic, perceptual, and intelligibility measures were derived, as detailed below. All recordings were reviewed by the authors to ensure adequate quality of the recordings for voice analyses.

Sustained vowel task

Phonatory performance was assessed using a sustained vowel task. Participants were instructed to sustain the vowel /a/ for as long as possible at a comfortable pitch and loudness. Recordings were analyzed acoustically using *Praat* software.³⁴

Articulation and naming task

Single-word productions were elicited using the Articulation and Naming Test.³⁵ The original test includes 35 picturable common nouns; six additional noun stimuli were added to ensure balanced representation of Hebrew consonants and vowels within varying word positions, resulting in a total of 41 target words. To minimize order effects, six versions of the test with different word sequences were created, and participants were randomly assigned to one version. A total of 10 words, chosen from the

TABLE 1.
Single Words Used for Acoustic Analyses

Hebrew Word	English Translation
/agas/	"pear"
/baʁvaz/	"duck"
/gezex/	"carrot"
/dag/	"fish"
/χultsa/	"shirt"
/kadux/	"ball"
/limon/	"lemon"
/matana/	"gift"
/ipaʁon/	"pencil"
/ʁaglajim/	"feet"

total sampling, were further used for the acoustic analysis (Table 1).

Picture description task

Connected speech samples were elicited using a picture description task. The picture used for this task consisted of a black-and-white illustration depicting a complex seaside scene, including multiple characters engaged in various everyday activities (eg, playing, reading, filming, swimming, and interacting socially). The image was designed to elicit spontaneous connected speech by providing a rich, dynamic context with multiple events occurring simultaneously. Participants were instructed to look at the image and asked to freely describe what was happening in the scene. Utterances varied in length across participants and included utterances consisting mostly of two words or more (average utterance length = 3 words per utterance; range: 1–8 words per utterance).

Dependent measures

Acoustic measures

Analysis of voice quality was conducted with the following acoustic measures calculated from stimuli across each of the tasks:

1. Jitter/jitter ppq (%), reflecting cycle-to-cycle variability in fundamental frequency. Lower jitter values indicate greater phonatory stability. Jitter was applied to the sustained phonation task, while jitter ppq was applied to word and connected speech tasks.
2. Shimmer/Shimmer apq (%), reflecting cycle-to-cycle variability in amplitude. Lower shimmer values indicate greater phonatory stability. Shimmer was applied to the sustained phonation task, while Shimmer apq was applied to word and connected speech tasks.
3. Harmonic-to-Noise Ratio (HNR; dB), an index of voice clarity, with higher values indicating reduced noise. HNR was applied to both sustained phonation and speech (word, connected speech) contexts.
4. Cepstral Peak Prominence (CPP, dB), reflecting the relative dominance of the harmonic structure in the voice signal. CPP is considered to be a reliable and

robust acoustic measure of voice quality across both sustained and connected speech contexts,^{32,36,37} with higher CPP values indicating more periodic and stable phonation.

Acoustic measures of jitter, shimmer, and HNR were calculated in *Praat*,³⁴ using an automated script³⁸ to ensure consistency of measurement, whereas CPP was calculated via *VoiceSauce*³⁹ a *MATLAB*-based program,⁴⁰ in order to facilitate comparability with prior studies using the same software (eg, ³).

Speech intelligibility

Speech intelligibility was measured using both transcription-based and rating-based measures, derived from single-word and spontaneous speech stimuli, respectively. Single-word intelligibility provides a controlled measure of segmental accuracy^{10,41,42}, whereas intelligibility derived from connected speech is considered more ecologically valid, reflecting functional communication in naturalistic contexts.^{16,43}

Word intelligibility was measured as transcription accuracy, whereas intelligibility of spontaneous speech was evaluated using Ease of Understanding (EoU) ratings. For the EoU measure, listeners rated overall speech intelligibility on a numerical scale ranging from 1 (speech not understood at all/very poor intelligibility) to 10 (very good intelligibility/fully understood speech). For the single-word productions, each recording was independently rated by two listeners (see also Icht and Carl⁴⁴ for a similar rating procedure), whereas each connected speech sample was judged by three listeners. For both speech tasks, the averaged score was used as a measure of speech intelligibility.

Perceptual voice assessment

Perceptual voice quality was assessed using the GRBAS scale for sustained vowel production. A total of three raters independently rated all sustained phonation recordings; of these raters, two were certified speech pathologists, and the third was a trained research assistant (undergraduate SLP student). The score of the G (Grade) component for each participant, averaged across all three raters, was included in the analyses. Interrater reliability between the three raters is reported below. This measure was collected in order to provide a basis for comparison for acoustic measures and thus confirm the reliability of these measures.

Procedures

Prior to participation, parents or legal guardians provided written informed consent and received an information sheet describing the study procedures and aims. Children provided verbal assent before the assessment session. Only participants for whom both parental consent and child assent were obtained were included in the study.

All assessments were conducted individually and audio-recorded using a Philips DVT4010 digital recording device. One of the authors (SAS, an experienced speech-language

pathologist [SLP]), accompanied by a trained research assistant (an undergraduate SLP student), met each participant in a quiet room within the educational setting. The participant, examiner, and research assistant were seated comfortably at a table, with the recording device positioned approximately 7 cm from the participant's mouth. Participants were instructed to complete three speech tasks, administered in a random order: (1) sustained vowel production, (2) articulation and naming task, and (3) picture description task. The pictures for the articulation and naming task and picture description task were displayed on a laptop positioned on a table at a height appropriate for each participant. For the picture description task, participants were instructed to look at the image and describe what was happening in the scene. If the participant provided only limited productions, the examiner provided minimal prompts (eg, "Do you see anything else?") to encourage further elaboration. Short breaks were provided as needed to minimize fatigue.

The listening task took place via Gorilla, the online experiment builder.⁴⁵ Prior to the listening task, listeners provided informed consent, followed by a brief questionnaire collecting demographic and background information, including age, gender, native language, self-reported hearing status, general health status, and prior experience with individuals with speech disorders. Listeners were instructed to perform the task in a quiet room; the task only opened on a laptop or tabletop computer (not tablet or smartphone).

For the single-word transcription task, each listener was presented with recordings from a maximum of three different speakers. Listeners were instructed to orthographically transcribe each word they heard using standard Hebrew spelling. Word intelligibility scores were calculated as the percentage of correctly transcribed words per speaker, averaged across the two listeners. For the connected speech listening task, listeners were presented with recordings obtained from the picture description task and were asked to rate speech intelligibility using a numerical rating scale based on overall ease of understanding, from 1 (not understood at all) to 10 (understood completely). Each listener heard approximately half of all the speakers, and ratings were completed independently for each utterance. A total of three listeners rated each production, and scores were averaged across listeners.

Statistical analysis

All statistical analyses were conducted in R.⁴⁶ In order to determine correlations between perceptual measures of voice quality and acoustic measures for the sustained phonation task, Pearson product-moment correlations were calculated, separately for each acoustic measure. Correlations between perceptual measures on this task and acoustic measures for the speech-level tasks (word and connected speech) were also calculated.

To determine the presence of any differences in acoustic measures between tasks, linear mixed-effects (LME)

models were applied to the acoustic data, with models calculated separately for each acoustic measure. The LME analysis was used in light of its strength in dealing with unbalanced data sets⁴⁷ and potentially nonnormal data distributions.^{48,49} LME models included individual trials for each acoustic measure (outcome measure), namely sustained phonation (a single production of the vowel /a/), single-word productions (10 total), and connected speech (four multiword utterances, on average), per speaker.

LME models were also applied to the acoustic-intelligibility correlations for single-word and connected speech data. For these analyses, both words and connected speech utterances were each averaged across trials, resulting in a single acoustic value for each acoustic measure, per speaker. In each model, the intelligibility score served as the outcome measure, while the speech task, the acoustic measure, and their interaction served as predictor variables. Participant was included in the model as the random intercept, in order to account for between-speaker differences. Task-specific slopes between intelligibility score and acoustic measure were calculated in order to determine the relationship between the two, within each speech task (single words, connected speech).

Interrater reliability

Interrater reliability between the listeners for both the single-word and connected speech intelligibility scores was calculated in R. The intraclass correlation analysis (ICC) was applied using the one-way random-effects model and absolute agreement.⁵⁰ The results revealed an ICC of 0.95, $F(30, 31) = 18$, $P < 0.001$, for single words and an ICC of 0.86, $F(147, 294) = 7.3$, $P < 0.001$ for connected speech, indicating good-to-excellent agreement between listeners.

Interrater reliability was also calculated for the perceptual ratings of the sustained phonation across the three raters. The intraclass correlation analysis (ICC) was applied using the two-way mixed-effects model for average fixed raters. The results revealed an ICC of 0.75, $F(30, 60) = 4$, $P < 0.001$, indicating good agreement between raters.

RESULTS

Descriptive statistics for the acoustic measures of voice quality across the three speech tasks, sustained phonation, single-word production, and connected speech, are presented in Table 2. Results from select measures are visually demonstrated in Figure 1. Across all measures, sustained phonation yielded the most favorable voice quality, reflected by lower jitter and shimmer values and higher HNR and CPP values. Single-word productions demonstrated the poorest voice quality, whereas connected speech values generally fell between sustained phonation and single-word production. Speech intelligibility scores for both single-word and connected speech productions are presented in Table 3.

TABLE 2.
Descriptive Statistics (Means and Standard Deviations (SD)) for Each of the Acoustic Measures, Across Tasks

Measure	Sustained Phonation	Single Words	Connected Speech
	Mean (SD)		
Jitter (local/ppq5)	0.008 (0.004)	0.012 (0.010)	0.010 (0.007)
Shimmer (local/apq5)	0.063 (0.031)	0.067 (0.043)	0.058 (0.032)
Harmonic-to-Noise Ratio (HNR)	15.716 (5.686)	11.611 (4.598)	12.737 (4.411)
Cepstral Peak Prominence (CPP)	21.242 (3.533)	17.054 (1.759)	17.307 (1.863)

Relationship between perceptual and acoustic measures of sustained phonation

Pearson product-moment correlations were conducted to examine associations between the averaged perceptual ratings of voice quality (GRBAS (G)) and acoustic measures derived from sustained phonation. Significant correlations were observed for all acoustic measures, jitter ($r = 0.68$, $P < 0.001$), shimmer ($r = 0.5$, $P = 0.005$), HNR ($r = -0.66$, $P < 0.001$), and CPP ($r = -0.55$, $P = 0.001$), indicating that poorer perceptual voice quality was associated with increased perturbation and reduced harmonic structure (Figure 2).

The correlation between averaged GRBAS (G) scores and measures of speech intelligibility, for both word-level and connected speech productions, did not reach statistical significance: single-word intelligibility ($r = -0.02$, $P = 0.92$), connected speech EOU ratings ($r = 0.2$, $P = 0.93$).

Effects of speech task on acoustic measures of voice quality

LME models were used to examine the effect of speech task on acoustic measures of voice quality. Fixed-effects estimates are presented in Table 4, and pairwise task contrasts from estimated marginal means (emmeans) are shown in Table 5. A significant main effect of task was observed for all acoustic measures: CPP, HNR, jitter (ppq), and shimmer (apq). For measures of CPP and HNR, sustained phonation was significantly lower than both single words and connected speech ($P < 0.001$). Between the two speech stimuli, single words demonstrated significantly lower HNR than connected speech ($P = 0.005$), while no significant difference was noted between the two for CPP ($P = 0.14$). Both jitter (ppq) and shimmer (apq) were higher for single words in comparison to connected speech (jitter, $P = 0.03$; shimmer, $P = 0.002$).

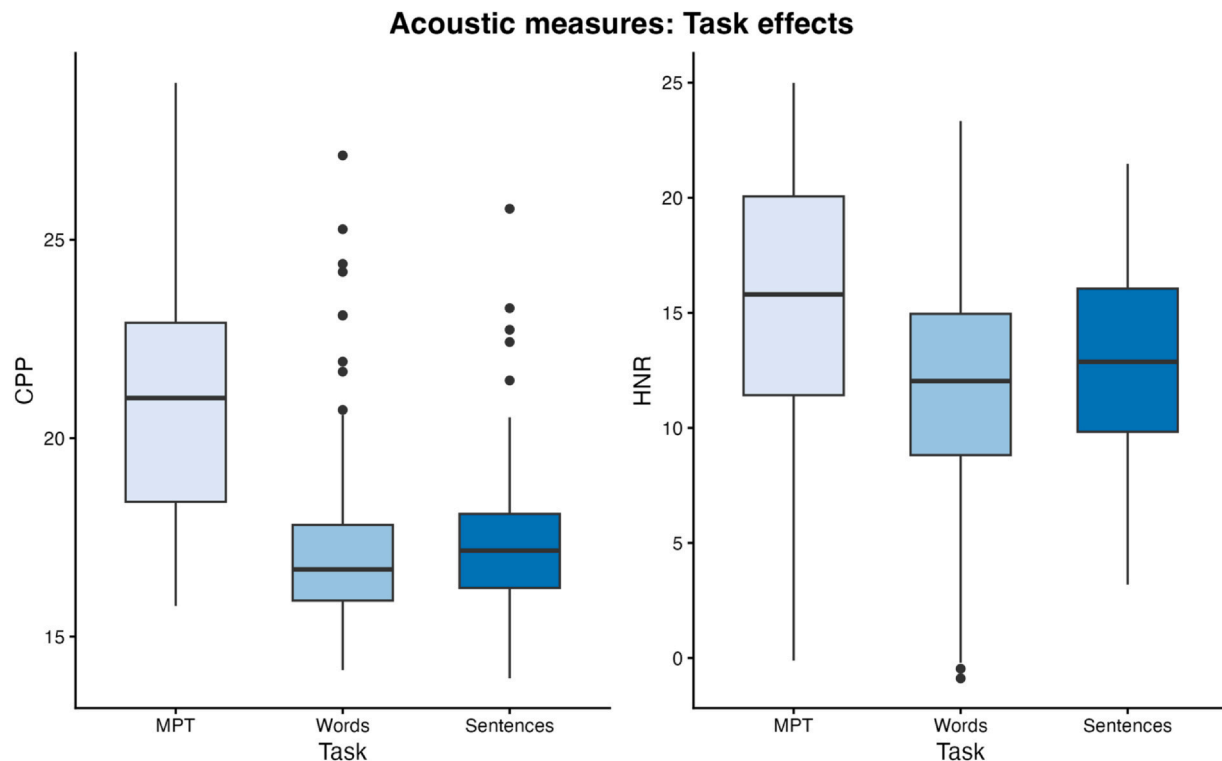
**FIGURE 1.** Results of two acoustic measures, Cepstral Peak Prominence (CPP) and Harmonic-to-Noise Ratio (HNR), across the three tasks (sustained phonation, word production, and connected speech).

TABLE 3.
Intelligibility Scores (in Percentages) for Single-Word and Connected Speech Tasks Across Participants

Participant	Speech Intelligibility (%)	
	Words	Connected Speech
1	64	33
2	36	54
3	98	88
4	21	38
5	27	34
6	95	83
7	61	59
8	66	23
9	90	70
10	76	83
11	94	94
12	86	83
13	50	73
14	82	66
15	57	14
16	38	17
17	90	85
18	57	77
19	26	23
20	86	67
21	92	83
22	93	99
23	67	39
24	94	77
25	95	78
26	100	99
27	42	45
28	72	59
29	37	25
30	68	30
31	74	69

Relationship between acoustic measures of voice quality and speech intelligibility

Results of LME models, examining the relationship between acoustic measures of voice quality and speech intelligibility for single-word and connected speech tasks, yielded no significant associations between any acoustic measure (CPP, HNR, jitter ppq, or shimmer apq) and intelligibility scores for either task. Specifically, CPP, HNR, jitter ppq, and shimmer apq did not significantly predict word intelligibility or connected speech intelligibility scores (all P values > 0.26). Simple slope analyses confirmed the absence of significant task-specific relationships between acoustic voice quality measures and intelligibility outcomes: CPP: single-word task, $b = 1.43$, $t(56.9) = 0.538$, $P = 0.59$, and connected speech task, $b = 2.70$, $t(56.9) = 1.325$, $P = 0.19$; HNR: single-word task, $b = 0.25$, $t(54.6) = 0.24$, $P = 0.81$, and connected speech task, $b = 0.69$, $t(54.6) = 0.74$, $P = 0.46$; Jitter (ppq5): single-word task, $b = -650$, $t(53.1) = -1.182$, $P = 0.24$, and connected speech task, $b = -860$, $t(53.1) = -1.37$, $P = 0.18$; and Shimmer (apq5):

single-word task, $b = -135$, $t(52.3) = -1.09$, $P = 0.28$, and connected speech task, $b = -190$, $t(52.3) = -1.31$, $P = 0.2$.

In sum, significant task effects were observed for all acoustic measures of voice quality, demonstrating systematic differences across sustained phonation, single-word production, and connected speech. In contrast, acoustic measures of phonatory function were not significantly associated with speech intelligibility for either single-word or connected speech tasks.

DISCUSSION

The present study examined the influence of speech tasks on acoustic measures of voice quality and speech intelligibility in children and adolescents with developmental dysarthria, as well as the relationship between these domains across tasks. By comparing sustained phonation, single-word production, and connected speech, this study sought to clarify how task-related motor and linguistic demands shape phonatory output and its functional consequences. Overall, the findings demonstrate robust task effects on acoustic indices of voice quality, while revealing no systematic effects of task on speech intelligibility and no task-dependent associations between voice quality and intelligibility. Together, these findings highlight the task-sensitive nature of phonatory measures and underscore the complex and often indirect role of phonation in supporting intelligible speech in developmental dysarthria.

Effects of speech task on acoustic measures of voice quality

The first research question examined whether acoustic measures of voice quality differ across speech tasks. Consistent with prior literature,³ significant task-related differences were observed across all acoustic measures. Sustained phonation yielded the most stable phonatory profiles, characterized by lower jitter and shimmer values and higher HNR and CPP values, whereas single-word production demonstrated the least favorable voice quality. Connected speech generally showed intermediate values between these two task types. Importantly, acoustic measures derived from sustained phonation were significantly associated with perceptual ratings of overall voice severity (GRBAS Grade) for all acoustic measures, indicating convergence between perceptual and acoustic indices of phonatory function⁵¹ and supporting their interpretive validity in this context.

The observed task differentiation is consistent with prior work among individuals with motor speech disorders, eg, those with Down syndrome,⁵² demonstrating that sustained phonation minimizes articulatory and linguistic demands and therefore provides relatively optimal conditions for phonatory control. Speech tasks require rapid coordination across multiple subsystems and place greater demands on neuromotor control in comparison to nonspeech tasks,^{53,54} which may exacerbate underlying phonatory instability in developmental dysarthria. The present findings extend this literature by demonstrating task differentiation across

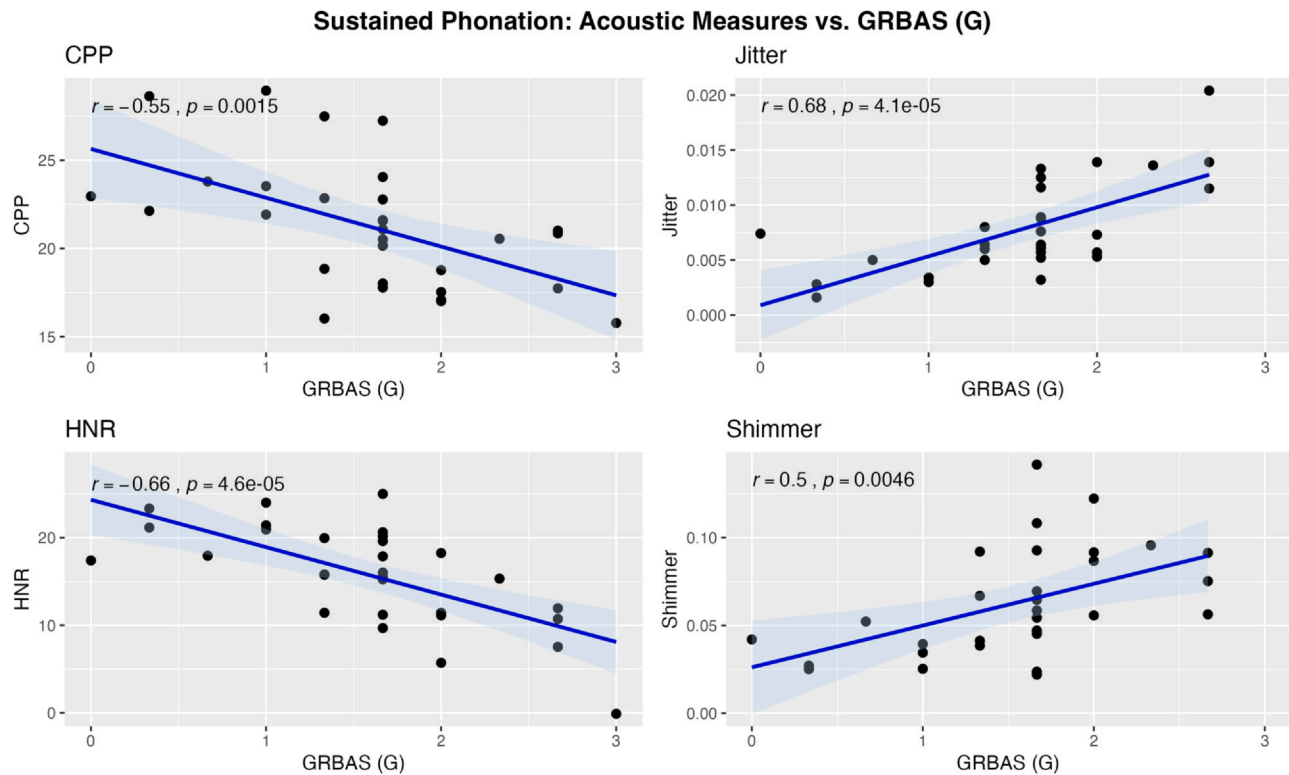


FIGURE 2. Pearson product-moment correlations between perceptual ratings of voice quality (GRBAS —G) and acoustic measures derived from sustained phonation.

multiple acoustic indices within the same cohort. This pattern may reflect increased initiation demands, reduced coarticulatory support, or disrupted coordination between phonation and articulation at word onset.⁶

However, these findings contrast with those of previously reported findings among children with CP,³ in which sustained phonation demonstrated less stable phonatory control than within connected speech production. The differences between these findings may be attributed to participant characteristics (eg, severity of the dysarthria), familiarity of the participant with the task (eg, if one is habitual or preferred³), or differing recording and analysis procedures between the studies.

Notably, single-word production yielded poorer voice quality than connected speech, suggesting that phonatory degradation does not increase linearly with utterance length. The differences between single-word production and connected speech, for most of the acoustic measures, may point to task-specific demands in the current study. The single words were elicited within a structured picture-naming task, in which participants produced a variety of speech sounds and syllable structures. In contrast, spontaneous connected speech may have been experienced as less complex for some participants, as it is less structured and places fewer explicit lexical retrieval or naming demands on production. Alternatively, task differences between single words and

TABLE 4.
Fixed-Effects Estimates Calculated From Linear Mixed-Effects Models Examining the Effect of Speech Task on Acoustic Measures of Voice Quality

	Term	Estimate	Std.Error	Statistic	df	P Value	CI (Low)	CI (High)
CPP	(Intercept)	21.24	0.35	60.04	79.46	< 0.001	20.53	21.95
	Task: Words	-4.18	0.24	-17.24	407.07	< 0.001	-4.66	-3.71
	Task: Sentences	-3.91	0.26	-15.02	407.3	< 0.001	-4.42	-3.4
HNR	(Intercept)	15.72	0.83	18.98	93.97	< 0.001	14.06	17.37
	Task: Words	-4.04	0.61	-6.65	408.16	< 0.001	-5.22	-2.84
	Task: Sentences	-2.91	0.65	-4.47	408.41	< 0.001	-4.19	-1.63
Jitter (ppq5)	(Intercept)	0.01	0.00	11.14	32.74	< 0.001	0.01	0.01
	Task: Sentences	-0.00	0.00	-2.18	376.05	0.03	-0.00	-0.00
Shimmer (apq5)	(Intercept)	0.07	0.00	14	32.6	< 0.001	0.06	0.08
	Task: Sentences	-0.01	0.00	-3.13	373	0.002	-0.02	-0.00

TABLE 5.
Emmeans Pairwise Comparisons of Task Effects for Each Acoustic Measure

	MPT-Words			MPT-Sentences			Words-Sentences		
	estimate	<i>t</i> ratio, <i>P</i> value		estimate	<i>t</i> ratio, <i>P</i> value		estimate	<i>t</i> ratio, <i>P</i> value	
CPP	4.18	17.24 < 0.001		3.91	15 < 0.001		-0.27	-1.9	<i>P</i> = 0.14
	CI	(3.61-4.75)			(3.3-4.52)			(-0.61-0.06)	
HNR	4.03	6.65 < 0.001		2.91	4.47 < 0.001		-1.13	-3.17	0.005
	CI	(2.61-5.46)			(1.37-4.44)			(-1.96--0.29)	
Jitter (ppq)							-0.00	-2.18	0.03
							CI	(-0.00--0.00)	
Shimmer (apq)							0.01	3.13	0.002
							CI	(0.00-0.02)	

connected speech may be minimal when linguistic and cognitive demands are not substantially different.⁵⁵ A limitation relevant to this finding is that spontaneous speech samples in the current study were relatively short, which may have constrained variability in acoustic measures and attenuated task differences. Future studies should examine connected speech samples that feature sentences differing in length and linguistic complexity to better disentangle the effects of motor, linguistic, and cognitive demands on voice quality in developmental dysarthria.

Task-dependent associations between voice quality and speech intelligibility

The second research question examined whether acoustic measures of voice quality are associated with speech intelligibility in a task-dependent manner. Contrary to the stated hypothesis, no significant associations were observed between acoustic indices of voice quality and intelligibility for either single-word or connected speech tasks. The absence of task effects at the word level is consistent with previous findings indicating minimal influence of phonatory characteristics on single-word intelligibility in developmental dysarthria.⁴ These studies suggest that articulatory accuracy remains the primary determinant of intelligibility for isolated words, whereas phonatory factors may play a more limited role. In contrast, prior work has demonstrated associations between voice characteristics and intelligibility in sentence or connected speech contexts, where task demands are higher, and sustained coordination is required.⁴

Nevertheless, the lack of association between phonatory measures and intelligibility scores in the current study aligns with Schölderle et al,¹² who demonstrated that phonatory measures primarily influenced listeners' perceptions of speaker characteristics such as age and gender, but had only minimal effects on speech intelligibility or naturalness in adults with CP. Together with the present findings, this body of evidence suggests that phonatory impairment alone may be insufficient to constrain intelligibility in developmental dysarthria, particularly in the absence of severe articulatory or prosodic disruption. Although some studies have reported task-specific associations between voice quality and intelligibility, particularly for sentence-level speech⁴ differences in

task complexity, stimuli, and participant characteristics likely contribute to these discrepancies. The present results also suggest that while phonatory control is sensitive to task demands, its contribution to intelligibility may be indirect and mediated by interactions with other speech subsystems.

It is important to note that perceptual and acoustic assessments of voice quality derived from sustained phonation may not fully generalize to connected speech. Previous research has demonstrated that judgments of voice quality based on prolonged vowels often show limited correspondence with those obtained from continuous speech, likely due to differences in articulatory-phonatory coordination, prosodic variation, and contextual influences.^{20,22} Thus, while sustained phonation provides a controlled and clinically useful measure of phonatory function, it may not fully reflect the characteristics of voice as used in everyday communication. This consideration is particularly relevant in developmental dysarthria, where task demands and subsystem interactions may differentially influence voice production across speaking contexts. The lack of correlation between perceptual voice assessment of the sustained vowel and measures of speech intelligibility, as found in the current analyses, further supports this notion.

Clinical implications and future directions

Despite the lack of direct associations between acoustic voice measures and intelligibility, the present findings do not diminish the clinical relevance of targeting phonation in intervention. Previous work has demonstrated that "loud speech" interventions in children with CP improve not only voice quality but also increase the magnitude, speed, and coordination of lip and jaw movements relative to habitual speech.³ Such findings suggest that phonatory-focused interventions may exert broader motor benefits that indirectly support speech clarity. Moreover, improving voice quality may enhance the salience of speech in noisy, real-world communicative environments,⁴² even if intelligibility scores in controlled settings remain unchanged. This distinction highlights the importance of considering functional communication outcomes beyond lab-based intelligibility measures.

Nonetheless, several limitations in the current study should be acknowledged. The sample size was relatively modest, although it is comparable to previous studies in

developmental dysarthria, which often involve small and clinically heterogeneous cohorts.^{3,4,16} The requirement to produce connected speech (eg, utterances at least two words in length) necessarily excluded individuals for whom continuous speech is not yet functional, limiting generalizability to speakers with more severe motor impairment. Additionally, further studies may wish to include perceptual analysis (eg, GRBAS ratings) across all speech tasks and report intrarater reliability alongside between-rater agreement to further strengthen the robustness of perceptual measures. Future research should also examine voice characteristics across a wider range of communicative abilities and task demands, including utterances differing in length, alternative communication contexts, and more cognitively and linguistically complex speech tasks.

CONCLUSION

The present study demonstrates that acoustic measures of voice quality in developmental dysarthria are strongly task-

dependent, whereas speech intelligibility may not be directly related to phonatory measures. These findings underscore the importance of task selection in voice assessment, support a multidimensional view of speech intelligibility, and emphasize the need for integrative models of motor speech production that account for compensatory mechanisms and subsystem interactions across speaking contexts.

Disclosures

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

The authors report that there are no competing interests to declare.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A: Participant Details

Participant #	Age	Gender	Dysarthria Severity ¹	Diagnosis [†]
	(Year; Month)			
1	8;8	F	2	CP-A
2	9;10	M	1	CP-S
3	10;3	F	1	Dravet syndrome
4	10;6	M	3	CP-D
5	10;6	M	2	Prader Willi syndrome
6	10;6	M	2	CP-S
7	10;7	F	2	Joubert syndrome
8	10;9	F	3	Joubert syndrome
9	10;9	M	2	CP-S
10	11;2	M	1	CP-A
11	11;4	F	1	West syndrome and CP-A
12	11;5	M	2	CP-S
13	11;5	M	3	CP-S+D
14	11;6	M	1	VACTERL syndrome and CP-A
15	11;9	F	2	CP-S
16	12;1	F	3	Costeff syndrome
17	12;2	F	2	Dandy-Walker syndrome
18	12;6	F	3	CP-S+A
19	13;3	M	3	CP-S+A
20	13;5	F	2	CP-S
21	13;5	F	3	CP-S
22	13;6	M	1	CP-S
23	13;8	M	2	CP-S
24	14;0	M	1	CP-S
25	14;1	M	1	Spondylo-epiphyseal dysplasia (SED)
26	14;1	M	2	CP-S
27	14;2	F	2	CP-S
28	14;3	F	1	CP-S
29	14;7	F	1	CP-A
30	14;9	F	1	Wolfram syndrome
31	15;0	M	3	CP-S

[†] CP-S = cerebral palsy—spastic; CP-A = cerebral palsy—ataxic.

¹ Dysarthria severity: 1= light, 2 = moderate, 3 = severe.

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