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The Impact of Clear and Loud Speech Cues on Acoustic and Perceptual Features of Speech Production in Adolescents With Down Syndrome

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ABSTRACT

Purpose: There are few evidence-based speech interventions designed to alter speech production in a way that ultimately results in increased speech intelligibility in adolescents with Down syndrome (DS). The primary purpose of this study was to examine the impact of clear and loud speech cues on acoustic and perceptual features of speech production in adolescents with DS.
Method: Eight adolescents diagnosed with DS repeated sentences of varying lengths in three conditions: habitual, big mouth (i.e., clear speech), and strong voice (i.e., loud speech). Four hundred eighty adult listeners (20 listeners per adolescent per condition) provided orthographic transcriptions of adolescent's speech, which were used to calculate intelligibility scores. Acoustic measures of speech rate, articulation rate, proportion of time spent pausing, vocal intensity, and fundamental frequency were calculated for each sentence.
Results: The big mouth condition resulted in significantly increased intelligibility, slowed speech and articulation rates, increased pauses, increased vocal intensity, and increased fundamental frequency. The strong voice condition resulted in significantly increased vocal intensity and fundamental frequency, but no other changes. Speech rate was the only variable that explained any of the variance in intelligibility.
Conclusions: Adolescents with DS respond differently to clear and loud speech cues. In particular, clear speech cues resulted in significant increases in intelligibility, but loud speech cues did not. Clear speech cues hold promise as an intervention strategy for adolescents with DS.

Over half of adolescents with Down syndrome (DS), a genetic disorder caused by trisomy of whole or part of Chromosome 21, demonstrate decreased speech intelligibility (Wilson et al., 2019b). Decreased intelligibility results from a constellation of causes, including anatomic differences (Rodrigues et al., 2019; Sforza et al., 2012), speech motor impairment (Kumin, 2006; Wilson et al., 2019a, 2019b), and hearing loss (Nightengale et al., 2017). While there is considerable individual variability, the factors that contribute to decreased intelligibility are considered part of the clinical phenotype of DS, meaning that the majority of adolescents with DS exhibit these deficits to some degree (Danhauer & Fidler, 2011). As a result, adolescents with DS demonstrate speech production characteristics that are heterogeneous, involving unique combinations of speech subsystem deficits. Almost all commonly rated impairments in auditory-perceptual features of speech production (Darley et al., 1969a, 1969b; Duffy, 2020) have been found in the DS population (Jones et al., 2019; Kent et al., 2021; Kent & Vorperian, 2013; Wilson et al., 2019a, 2019b), and these auditory-perceptual deficits associated with the speech subsystems have been described as “hyper”/“too much,” “hypo”/“too little,” and “adequate.” For example, speech rate can be adequate, too slow, or too fast (Jones et al., 2019; Kent et al., 2021; Kent & Vorperian, 2013; Wilson et al., 2019b), and phonatory symptoms can indicate vocal hyperfunction or vocal hypofunction (Kent et al., 2021; Pebbili et al., 2021). The lack of a

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syndrome-specific speech production profile makes intervention planning and implementation difficult. This heterogeneity is likely one of the reasons why the number of studies examining the efficacy of interventions focused on improving speech production in the DS population is extremely limited (Pennington et al., 2016). This study sought to address this gap in the literature by examining the impact of two types of cues, namely, clear speech cues and loud speech cues, on acoustic and perceptual features of speech production in adolescents with DS.

Establishing evidence-based speech interventions that alter speech production in a way that improves intelligibility in adolescents with DS is critical, given the important role intelligibility plays in communicative participation (i.e., the ability to use communication while engaging in daily life activities; Connaghan et al., 2022). Restrictions in communicative participation are not trivial and limit language development, academic achievement, peer relationships, and quality of life (Hodge & Wellman, 1999). Adolescents with DS are particularly vulnerable to the negative consequences that result from restrictions in communicative participation. Peer relationships and social success assume a more significant role during adolescence than during any other life stage (Jose et al., 2012; Whitmire, 2000). However, there is evidence that adolescents with DS spend the majority of their time with adults (e.g., parents, support staff) or alone (Dolva et al., 2019). Loneliness has both physical (e.g., headache, nausea) and mental health (e.g., depression, anxiety) consequences for adolescents (Lyyra et al., 2018; Stickley et al., 2016). Higher levels of loneliness at age 10 lead to lower levels of self-worth and higher levels of depressive symptoms at age 18 in adolescents with DS (Tillinger, 2013). Adolescents and their parents report that intelligibility deficits directly interfere with the adolescents' ability to initiate and maintain social interactions and make new friends (Connaghan et al., 2022). Despite the overwhelming need for speech intervention services, adolescents with DS are the most underserved population of individuals with DS by speech-language pathologists (Meyer et al., 2017).

The majority of the speech intervention literature involving adolescents with DS has focused on speech sound accuracy as a way of improving intelligibility (Cleland et al., 2009; Rvachew & Folden, 2018; Wood et al., 2009). Unfortunately, improvements in speech sound accuracy have not resulted in statistically or clinically significant[1] intelligibility changes in adolescents with DS (Cleland et al., 2009; Wood et al., 2009). While it is difficult to make definitive conclusions based on a handful of studies that together examined fewer than 10 adolescents with DS, the result (or lack thereof) is unsurprising given the complexity of speech production deficits observed in adolescents with DS. As noted above, almost all commonly rated impairments in auditory-perceptual features of speech production (Darley et al., 1969a, 1969b; Duffy, 2020) have been found in the DS population, and the constellation of deficits within an individual often points to multiple speech subsystem impairments. Thus, speech interventions designed to target multiple speech subsystems as opposed to a single speech subsystem (e.g., articulatory) are likely needed.

Two such intervention approaches found in the speech intervention literature are clear speech and loud speech. These approaches utilize a single cue (e.g., "speak clearly" or "speak loudly") aiming to facilitate speech production changes across multiple speech subsystems, resulting in increased intelligibility while reducing the cognitive load required to remember the speech production strategy. Approaches of this nature are typically examined in one of two ways: (a) In cueing studies, the immediate impact of speech cues (often within one recording session) is examined (e.g., Chang et al., 2024; Lam & Tjaden, 2016; Levy et al., 2017; Levy, Moya-Galé, Chang, Campanelli, et al., 2020; Tjaden et al., 2013), and (b) in treatment studies, the "long-term" impact of participating in multiple weeks of treatment involving a protocol that includes speech cues embedded in therapeutic activities designed to promote a "new" way of speaking is examined (e.g., Levy et al., 2021; Levy, Moya-Galé, Chang, Freeman, et al., 2020; Park et al., 2016; Ramig et al., 1995; Stathopoulos et al., 2014). Cueing studies, often the first step in the process of establishing the efficacy of speech cue use, provide important foundational knowledge for the development and implementation of treatment protocols but do not necessarily predict long-term changes as a response to any specific protocol. The current study will be the first cueing study to examine the acoustic and perceptual consequences of clear and loud speech cues in any age group of individuals with DS.

Without cueing studies involving individuals with DS, we must turn to literature from other potentially similar populations. Clear and loud speech cues have been used to great success with adults with speech motor impairment, with cueing studies and treatment studies documenting similar effects (e.g., Park et al., 2016; Ramig et al., 1995; Stathopoulos et al., 2014; Tjaden et al., 2013; Tjaden, Sussman, & Wilding, 2014). The use of clear speech cues with adults with speech motor impairment commonly results in decreased speech and articulation rate, increased vocal intensity, increased vowel space area, increased spectral change, increased mean fundamental

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[1] Clinical significance can be thought of as the difference in intelligibility between two or more time points that reflects a true change in an individual's speech function. Collectively, studies suggest that a ≥ 10% increase in intelligibility between two time points is clinically significant (Pennington et al., 2013; Stipancic & Tjaden, 2022; Stipancic et al., 2018).

frequency (*F*0), and increased intelligibility (Lam & Tjaden, 2016; Park et al., 2016; Stipancic et al., 2022; Tjaden et al., 2013; Tjaden, Sussman, & Wilding, 2014; Whitfield & Goberman, 2014). The use of loud speech cues with adults with speech motor impairment commonly results in increased vocal intensity, increased *F*0, improved laryngeal aerodynamics, changes in speech breathing patterns, and increased intelligibility (Levy, Moya-Galé, Chang, Freeman, et al., 2020; Ramig et al., 1995, 2018; Sadagopan & Huber, 2007; Schulz et al., 2021; Stathopoulos et al., 2014; Tjaden et al., 2013; Tjaden, Sussman, & Wilding, 2014). One type of approach is not necessarily better than the other. In one study with adults with speech motor impairment, clear speech cues resulted in the same level of intelligibility improvement as loud speech cues (Tjaden, Sussman, & Wilding, 2014).

Despite the many potential differences between developmental and acquired speech motor impairment, there has been an underlying assumption (not based in evidence) that children and adolescents with speech motor impairment (regardless of etiology) would respond to clear and loud speech cues in the same manner as adults with speech motor impairment. In the case of the use of loud (or other) speech cues in the DS population, little is known about responses to cueing. However, there are two Phase I treatment studies examining different aspects of speech production following the Lee Silverman Voice Treatment (LSVT LOUD), an approach focused on increasing loudness developed for individuals with Parkinson's disease, in the same cohort of nine children with DS aged 4–8 years (Boliek et al., 2022; Langlois et al., 2020). Acoustic changes following LSVT LOUD were sparse, with only four out of the nine children with DS demonstrating increased vocal intensity and three out of the nine children with DS demonstrating increased *F*0 at the phrase level (Boliek et al., 2022). Children with DS, as a group, did not demonstrate statistically or clinically significant changes in intelligibility following LSVT LOUD (4% increase; Langlois et al., 2020). Individually, only three out of the nine children with DS demonstrated clinically significant differences in intelligibility following LSVT LOUD (Boliek et al., 2022). Furthermore, increased vocal intensity and *F*0 did not necessarily lead to improvements in intelligibility in individual children with DS. These results are in stark contrast with LSVT LOUD outcomes in adults with speech motor impairment. For example, group results from individuals with Parkinson's disease indicate increases of intelligibility ranging from 11% to 31% post-LSVT LOUD (Levy, Moya-Galé, Chang, Freeman, et al., 2020; Schulz et al., 2021). The differences in these populations highlight the need to conduct cueing studies involving adolescents with DS to first establish the effects of clear and loud speech cues prior to implementing rigorous treatment studies.

Cerebral palsy (CP), a neurodevelopmental disorder that also results in decreased speech intelligibility due to a variety of reasons including speech motor impairment, could be a more appropriate comparison group for DS. CP is similar to DS in that there is no syndrome-specific speech production profile, and the speech production deficits often indicate involvement of multiple speech subsystems (e.g., Allison & Hustad, 2018a, 2018b; Hustad et al., 2010). Cueing studies using child-friendly versions of clear and loud speech cues have been examined within English-, French-, and Korean-speaking children with CP (Chang et al., 2024; Levy et al., 2017; Levy, Moya-Galé, Chang, Campanelli, et al., 2020). Since there may be differential responses to these cues based on language (Chang et al., 2024; Levy, Moya-Galé, Chang, Campanelli, et al., 2020), we will focus on the cueing study conducted with English-speaking children with CP (Levy et al., 2017). To elicit clear speech, children were asked to speak using their "big mouth," and to elicit louder speech, children were asked to speak with their "strong voice." Word and sentence duration significantly increased in response to both clear and loud speech cues, although to a larger extent with clear speech cues. Vocal intensity also significantly increased in response to both clear and loud speech cues, although to a larger extent with loud speech cues. Neither cue significantly impacted formant frequencies. Ease of understanding ratings and word intelligibility significantly increased in response to both clear and loud speech cues, with neither cue necessarily resulting in more improvement than the other. Individual intelligibility results revealed a more mixed picture with some children with CP demonstrating clinically significant increases in intelligibility with clear speech cues, some with loud speech cues, some with both, and some with neither (Levy et al., 2017). Although this same type of variability to clear and loud speech cues may exist within the DS population, etiology-specific differences to speech production challenges (Darling-White & Jaeger, 2023; Darling-White & Polkowitz, 2023) and speech treatments (Langlois et al., 2020) have been found between the DS and CP populations. For example, post-LSVT LOUD children with CP demonstrate more consistent changes in vocal intensity, formant frequencies, and intelligibility than children with DS (Langlois et al., 2020). Furthermore, presence of DS was one of the biggest predictors of successful language treatment outcomes among toddlers with developmental disabilities (Yoder & Warren, 2002).

The primary purpose of this study was to examine the impact of clear and loud speech cues on acoustic and perceptual features of speech production in adolescents with DS. The child-friendly cues of "big mouth" and "strong voice" introduced in Levy et al.'s (2017) study were utilized. Given the lack of a syndrome-specific speech production profile, limited cueing/treatment data, and etiology-specific responses to different treatment protocols, it cannot be assumed that adolescents with DS will perform similarly to adults with speech motor impairment in their responses to clear and loud speech cues, nor can it be assumed that adolescents with DS will respond in the same manner as children with CP. Thus, no directional hypotheses were formed for the following research questions:

1. Do clear and loud speech cues impact intelligibility, speech rate, articulation rate, pauses, vocal intensity, and *F*0 in adolescents with DS?

Intelligibility was examined since the goal of these types of approaches is to alter speech production in such a way that intelligibility increases. The acoustic variables were chosen based on the literature reviewed above describing some of the most common acoustic responses to clear and loud speech cues. All variables were examined across three conditions: habitual, clear speech, and loud speech.

1. To what extent do the acoustic variables contribute to ratings of intelligibility in adolescents with DS?

There is very little information about which speech production alterations improve intelligibility in the DS population, and what is known from other populations may not be applicable. Children with DS who demonstrate increases in vocal intensity and *F*0 post-LSVT LOUD did not necessarily demonstrate improvements in intelligibility (Boliek et al., 2022), a finding that is surprising based on the adult speech motor impairment literature. To more thoroughly understand how acoustic changes in response to clear and loud speech cues may or may not result in changes in intelligibility, a series of linear regressions followed by a forward and backward stepwise regression model were completed.

Method

Participants

Adolescents With DS

Eight adolescents (two male, six female) diagnosed with DS participated in the current study. The mean age of the adolescents was 13;2 (years;months) with a range of 10;7–17;11. These adolescents appear in previous publications from the Darling-White research team. Specifically, the intelligibility and rate-related measurements from the habitual condition have been examined in relation to sentence length (Darling-White & Jaeger, 2023; Darling-White & Polkowitz, 2023). All other data are unique to this study. Prior to data collection, legal guardians provided written consent and adolescents provided verbal assent. Study procedures were approved by the University of Arizona Human Subjects Review Board (Protocol 16055837A005).

Adolescents were recruited via specialty clinics, community events, and online forums. Inclusionary criteria for this study were as follows: (a) speak fluent English and (b) be able to repeat sentences up to seven words in length. Demographic characteristics of the adolescents with DS, including age, race, ethnicity, native language, language impairment status, speech motor impairment severity, and adaptive behavior skills, are presented in Table 1. These demographic characteristics were not used as inclusionary or exclusionary criteria but, rather, are a way to characterize our sample to allow for cross-study comparison.

F03DS and M09DS were bilingual (i.e., regularly used two languages; Grosjean, 1992). These adolescents

Table 1. Participant demographic information.

Participant	Age (years; months)	Race/ethnicity	Native language	Language impairment	Speech motor impairment severity	Adaptive behavior composite of Vineland-3
F01DS	16;1	White/Hispanic Latino	American English	Severe impairment	Moderate	75
M02DS	11;10	Did not report/ Hispanic Latino	American English	Severe impairment	Moderate	74
F03DS	17;11	White/Hispanic Latino	Spanish and American English	Severe impairment	Severe	68
F04DS	10;7	White/non-Hispanic	American English	Severe impairment	Severe	78
F05DS	13;6	White/non-Hispanic	American English	Severe impairment	Moderate	67
F06DS	12;2	White/non-Hispanic	American English	Impairment[a]	Severe	65
F07DS	11;9	White/Hispanic Latino	American English	Severe impairment	Moderate	63
M09DS	10;7	White/Hispanic Latino	Spanish and American English	Impairment[a]	Severe	62

Note. Language impairment classifications are based on the core language score of the Clinical Evaluation of Language Fundamentals–Fifth Edition (Wiig et al., 2013). Higher scores on the Vineland-3 indicate better functioning. F = female; M = male; DS = Down syndrome; Vineland-3 = Vineland Adaptive Behavior Scales–Third Edition (Sparrow et al., 2016).

[a] Parent-reported language impairment that did not include a severity rating.

were early bilinguals (learned both languages when they were younger than 5 years of age; Paradis et al., 2021) and primarily spoke Spanish at home and English at school. No differences have been found between bilingual and monolingual adolescents with neurodevelopmental disorders on measures of language, cognition, or adaptive functioning when tested in the majority language (i.e., English) regardless of age of acquisition (Edgin et al., 2011; Kay-Raining Bird et al., 2005, 2016). The core language score of the Clinical Evaluation of Language Fundamentals–Fifth Edition (Wiig et al., 2013) was used to determine the presence or absence of language impairment. Two adolescents, F06DS and M09DS, did not participate in standardized language testing due to time constraints. In these cases, language impairment was based on parent report and was not given a severity rating. All adolescents exhibited speech motor impairment as determined by the first author, a certified speech-language pathologist, using perceptual assessment during a variety of connected speech tasks (e.g., conversation, reading, single-sentence production). The severity of speech motor impairment was indexed by speech intelligibility scores obtained from the habitual condition (Allison & Hustad, 2018b; Kent et al., 1989; Kim et al., 2011; Natzke et al., 2020). High levels of intelligibility, 81%–100%, indicated mild speech motor impairment. Moderate levels of intelligibility, 61%–80%, indicated moderate speech motor impairment. Low levels of intelligibility, 0%–60%, indicated severe speech motor impairment. Severity categories were based on those reported in Natzke et al.'s (2020) study. The Vineland Adaptive Behavior Scales–Third Edition (Vineland-3; Sparrow et al., 2016) was used to describe adaptive behavior. The Vineland-3 is a standardized parent report measure that examines adaptive behavior across three domains: communication, daily living skills, and socialization. The composite score is expressed as a standard score with a mean of 100 and an *SD* of 15. Higher scores indicate better adaptive behavior skills.

Only one of the adolescents with DS participated in the hearing screening due to time constraints. F05DS had an elevated threshold of 25 dB at 500 Hz in the right ear but passed at all other frequencies. F01DS and M09DS wore bilateral hearing aids, and their parents had no concerns about their hearing that were not addressed by the hearing aids. No parent concerns regarding hearing status were reported for the remaining adolescents.

Adult Listeners

Four hundred eighty adult listeners (20 listeners per adolescent per condition; 20 × 8 × 3) participated in this study. Listeners provided orthographic transcriptions of the speech tasks described below as the basis for intelligibility measures. Listeners were recruited from Amazon Mechanical Turk (MTurk), an online crowdsourcing platform. The use of crowdsourcing platforms for auditory-perceptual studies in the speech sciences has been validated (Lansford et al., 2016; McAllister Byun et al., 2015; Ziegler et al., 2021) and is becoming more frequent in the literature (e.g., Borrie et al., 2017; Jiao et al., 2019; McAllister Byun, 2017; McAllister Byun et al., 2016; Nightingale et al., 2020). Participation was limited to MTurk workers designated by Amazon as Masters (i.e., have high approval ratings) with a U.S.-based IP address. Participation requirements were as follows: (a) use of Firefox, Chrome, or Safari browsers; (b) between the ages of 18 and 45 years; (c) native speaker of American English; (d) no history of speech, language, learning, or hearing disorders; (e) no more than incidental experience listening to adolescents with speech sound disorders; and (f) a pair of headphones to wear while completing the task. Confirmation of these requirements was based on self-report.

Acquisition of Speech Samples

Equipment

Adolescents wore an omnidirectional headset microphone (Shure WBH53) with a mouth-to-microphone distance of 6 cm during the completion of the speech tasks detailed below. The acoustic signal was recorded via a digital audio recorder (Marantz PMD-671) with a compact flash card, then transferred to a computer, and resampled at 18 kHz with a low-pass filter at 9 kHz for anti-aliasing using GoldWave. The microphone was calibrated before each data collection session using a pure-tone generator and sound-level meter (Method 2B; Švec & Granqvist, 2018). The difference between the measured intensity of the calibration signal in Praat (Boersma & Weenink, 2016) versus from the sound-level meter was calculated and added to the intensity measures detailed below.

Speech Task

Acoustic data were collected during a 30- to 45-min session held in a quiet space at the University of Arizona or at the adolescent's home depending on parent preference. Adolescents completed the sentence-level Test of Children's Speech (TOCS+; Hodge & Daniels, 2009) in three different conditions: habitual, big mouth (i.e., clear speech), and strong voice (i.e., loud speech). The habitual condition was always collected first to prevent carryover effects. The order of the big mouth and strong voice conditions was counterbalanced across adolescents. Frequent breaks were provided to prevent fatigue and increase compliance.

Prior to data collection, the TOCS+ software (Hodge & Daniels, 2009) was used to create 30 unique lists. Each TOCS+ list consisted of 34 sentences varying in length from two to seven words. The software randomly pulled sentences from a pool of 2,000 phrases and randomized the order of sentence length presentation. Sentences in the TOCS+ were developed to include a representative sample of phonemes and to be lexically valid for individuals with a developmental language age as young as 3 years. To minimize the effects of listener familiarity, the software does not allow content words to be repeated within the same test administration. Each list of sentences had different numbers of sentences at each length, but a representative TOCS+ list contained four 2-word sentences, five 3-word sentences, six 4-word sentences, seven 5-word sentences, six 6-word sentences, and six 7-word sentences. Each adolescent was presented with a different TOCS+ list for each condition (i.e., three different lists per adolescent). No TOCS+ lists were repeated within a condition. The TOCS+ has good test–retest reliability (Hodge & Gotzke, 2010).

Per TOCS+ protocols, adolescents repeated each stimulus sentence following a prerecorded adult model. Each TOCS+ list was prerecorded and presented in a manner consistent with the testing condition: habitual, big mouth, or strong voice (Levy et al., 2017). This served as a reminder for the adolescents of the task requirements. Stimulus sentences were prerecorded by the first author in a sound-attenuating booth using a comfortable loudness and pitch (i.e., habitual condition) and clear speech (i.e., big mouth condition). To ensure consistency of audibility across the habitual and clear speech conditions, the prerecorded stimulus sentences were scaled such that the average intensity was 60 dB using Praat (Boersma & Weenink, 2016). To simulate loud speech (i.e., strong voice condition), the prerecorded sentences from the habitual condition were scaled such that the average intensity was 80 dB using Praat (Boersma & Weenink, 2016). The text and accompanying audio of each stimulus sentence were presented via a laptop computer situated approximately 1 ft in front of each adolescent. The volume on the laptop was not adjusted during the presentation of the stimulus sentences, resulting in a 20-dB difference between the prerecorded sentences for the habitual and clear speech conditions and the prerecorded sentences for the loud speech condition.

In the habitual condition, adolescents were asked to repeat each sentence using their comfortable loudness and pitch. In the big mouth condition, adolescents were asked to repeat each sentence using their "big mouth." In the strong voice condition, adolescents were asked to repeat each sentence using their "strong voice." Prior to the initiation of each therapeutic condition, the first author, who collected these data, provided a model of a big mouth and a strong voice using the phrase "Hawaiian lion" (Levy et al., 2017). Adolescents were asked to repeat that practice phrase using the appropriate cue and were given feedback on their performance. Care was taken not to use the word "loud" when providing feedback for the strong voice condition to discourage yelling. The only feedback provided during the performance of the therapeutic conditions was verbal reminders to use a big mouth or strong voice. Adolescents were occasionally asked to produce more than one trial of a stimulus sentence. This was typically due to issues such as laughing or coughing during the sentence, difficulty remembering the sentence, overlap with the prerecorded adult model, or background noise.

Acquisition of Listener Data

Stimulus sentences were orthographically transcribed by adult listeners. Twenty adult listeners were collected for each adolescent in each condition (20 × 8 × 3). Each listener heard the 34 sentences produced by one adolescent in one condition. Stimulus sentences were presented via a Qualtrics survey, which randomized the presentation of the stimulus sentences for each listener. Each stimulus sentence was separated into its own .wav file, and amplitude normalized via a customized MATLAB script (B. Story) prior to presentation. Amplitude normalization is a common practice in perceptual studies involving clear and/or loud speech cues and assists in interpreting the source of potential variations in intelligibility by minimizing the influence of audibility (see Ferguson & Kewley-Port, 2002; Stipancic et al., 2022; Tjaden et al., 2013; Tjaden, Kain, & Lam, 2014; Tjaden, Sussman, & Wilding, 2014). Stimulus sentences were processed by low-pass filtering the signals with a cutoff frequency of 8500 Hz (Ferguson & Kewley-Port, 2002). Each sentence was then amplitude-normalized by first determining the overall root-mean-square (RMS) amplitude (excluding pauses) and then multiplying each sentence by a scale factor such that the overall RMS value of the normalized signal was 30 dB below full scale. This scaling prevented clipping of any transient high-intensity segments in an utterance and allowed for normalization of intensity across utterances and conditions.

Listeners were instructed to wear headphones during the task and set the volume to a comfortable listening level. Listeners were asked to listen to each sentence and type the words that they heard (without the use of abbreviations) in the textbox provided. Listeners were told they would only hear real English words and were encouraged to guess if they were unsure. Stimulus sentences were presented to each listener one time. The task took less than 30 min.

Dependent Variables

Three sentences across all adolescents and conditions were discarded because of significant disfluency (one from the habitual condition and two from the strong voice condition). F06DS exhibited sensory defensiveness with the microphone and did not have a stable mouth-to-microphone distance. Her data were included in the intelligibility measurements but excluded from the SPL and *F*0 measurements. A total of 813 sentences were included in the intelligibility measurements described below (271 sentences in the habitual condition, 272 sentences in the big mouth condition, and 270 sentences in the strong voice condition), and 712 sentences were included in the SPL and *F*0 measurements (238 sentences in the habitual condition, 238 sentences in the big mouth condition, and 236 sentences in the strong voice condition).

Intelligibility Data

A scoring key was created for each adolescent by listening to the stimulus sentence, comparing it to the target sentence, and writing down the words the adolescent produced. If the adolescent was unintelligible, the target word or sentence was used. Listener responses were scored as correct if they were an exact phonemic match with the scoring key. Homonyms and misspellings were counted as correct. A team of two to four undergraduate research assistants scored the listener responses. Team members scored a response set individually, and then the group met to discuss their scores. If discrepancies arose, the team would make a group decision about the final score based on the scoring rules. Discrepancies were primarily due to human error (e.g., typos, miscalculations). A percent intelligibility score was calculated by dividing the total number of words correctly identified by the total number of words produced and multiplying by 100.

Acoustic Data

Members of the research team listened to each sentence to determine the number of syllables produced. Using the spectrographic display in Praat (Boersma & Weenink, 2016), a research team member created a text grid denoting the initiation and termination of each sentence and each pause (defined below). Text grids were created by hand and not via automation. Sentence duration was defined as the amount of time (in seconds) between the initiation (i.e., onset of acoustic energy) and termination (i.e., offset of acoustic energy) of the sentence. Speech rate was calculated by dividing the number of syllables produced in the sentence by the sentence duration. Articulation rate was calculated by dividing the number of syllables produced in the sentence by the sentence duration minus pause time. A pause was defined as a between-words silent interval greater than or equal to 0.150 s (e.g., Darling-White & Banks, 2021; Darling-White & Jaeger, 2023). There were five instances in which M02DS produced perceptually and acoustically evident breath pauses that were shorter in duration than the minimum pause threshold (range: 0.121–0.147 s). These instances were counted as pauses and removed from articulation rate calculations. A within-word silent interval greater than or equal to 0.150 s was only counted as a pause if there was perceptual and acoustic evidence of a breath. No within-word silent intervals meeting our pause threshold coincided with a breath and were therefore considered to be part of articulation rate. The proportion of time spent pausing was calculated by dividing the total pause time in a sentence by the sentence duration. Values closer to 1 indicate the sentence contained mostly pauses, whereas values closer to 0 indicate the sentence contained mostly speech. A customized MATLAB program (B. Story) was used to extract mean intensity (SPL) and mean *F*0 from each sentence exclusive of pauses based on the labels from the text grid (Kovacs & Darling-White, 2022).

Reliability

We calculated the interrater reliability of intelligibility measurements by examining the agreement between percentages of words correctly transcribed for each listener of each adolescent via the intraclass correlation coefficient (ICC) using SPSS. Using an average score, one-way random-effects model, we found strong agreement among listeners in each condition (habitual: ICC = .99, 95% confidence interval (CI) [.98, 1]; big mouth: ICC = 1, 95% CI [.98, 1]; strong voice: ICC = 1, 95% CI [.99, 1]).

Sentence and pause durations from each sentence produced by two participants in each condition (a total of 204 sentences) were randomly chosen to be reanalyzed by a second measurer. Intermeasurer reliability was evaluated by computing the Cronbach's α between the two sets of measurements for sentence duration and total pause time. Cronbach's α was not calculated for intensity and *F*0 measures since these were extracted based on the sentence and pause durations marked in the text grid via a customized MATLAB program. The Cronbach's α was 1 for both sentence duration and total pause time, indicating high intermeasurer reliability.

Statistical Analysis

All statistical analyses were completed in SAS (Version 9.4).

Research Question 1: Do Clear and Loud Speech Cues Impact Intelligibility, Speech Rate, Articulation Rate, Pauses, Vocal Intensity, and *F*0 in Adolescents With DS?

A general linear mixed-model analysis of variance was used to examine the change in each dependent variable as a result of condition (habitual, big mouth, strong voice). For each adolescent, the percent intelligibility score obtained from each listener across all sentences in each condition and the acoustic data from each sentence in each condition were used in the statistical model (as opposed to a single average for each condition). Subject was modeled as a random effect. Condition was modeled as the fixed effect. Tukey's honestly significant difference post hoc tests were used to examine statistically significant pairwise comparisons. The significance level was set as $p \leq .01$ for all statistical tests.

Research Question 2: To What Extent Do the Acoustic Variables Contribute to Ratings of Intelligibility in Adolescents With DS?

For each adolescent, a mean percent intelligibility score (average across 20 listeners) was calculated for each sentence in each condition. The mean percent intelligibility score and the acoustic data from each sentence in each condition were used in the regression models described below. Since intensity was not an available cue for listeners given the amplitude normalization procedures, intensity was excluded from this analysis. F06DS was not included in the regression analyses given her lack of SPL and $F0$ data.

Linear regressions were completed to assess the relationship between intelligibility and each dependent variable. The significance level was set as $p \leq .01$ for all statistical tests. Dependent variables found to have a significant relationship with intelligibility were entered into a forward-and-backward stepwise regression model. Variables were added one at a time according to an "entry" threshold of $p = .3$ and were removed if they did not meet the "stay" threshold of $p = .01$. This process was repeated until none of the variables outside the model met the "entry" threshold and every variable in the model met the "stay" threshold.

Results

Group means and standard deviations for each dependent variable by condition are presented in Table 2. Post hoc comparisons are reported in Table 3. Individual means and standard deviations for each dependent measure by condition are presented in the Appendix.

Intelligibility

There was a significant main effect of condition on intelligibility, $F(2, 14) = 104.25$, $p < .0001$. Post hoc testing revealed that intelligibility was significantly higher in the big mouth condition than both the habitual and strong voice conditions. The habitual and strong voice conditions were not significantly different from one another. This result is paralleled in the clinical significance as well. The habitual-to-big contrast resulted in a 13% mean difference, but the habitual-to-strong contrast yielded a 3% mean difference. Six out of the eight adolescents with DS demonstrated clinically significant increases in the big mouth condition (see Figure 1). Only two out of the eight adolescents with DS, F05DS and F07DS, demonstrated clinically significant increases in the strong voice condition (see Figure 1).

Speech Rate

There was a significant main effect of condition on speech rate, $F(2, 14) = 241.94$, $p < .0001$. Post hoc testing revealed that speech rate was significantly slower in the big mouth condition than both the habitual and strong voice conditions. The habitual and strong voice conditions were not significantly different from one another.

Articulation Rate

There was a significant main effect of condition on articulation rate, $F(2, 14) = 186.02$, $p < .0001$. Post hoc testing revealed that articulation rate was significantly slower in the big mouth condition than both the habitual and strong voice conditions. The habitual and strong voice conditions were not significantly different from one another.

Proportion of Time Spent Pausing

There was a significant main effect of condition on the proportion of time spent pausing, $F(2, 14) = 94.48$, $p < .0001$. Post hoc testing revealed that the proportion of time spent pausing was significantly higher in the big mouth condition than both the habitual and strong voice

Table 2. Means (standard deviations) for each dependent measure by condition.

Condition	Intelligibility (%)	Speech rate (syll/s)	Articulation rate (syll/s)	Pausing	SPL (dB)	*F*0 (Hz)
Habitual	56% (1.73%)	3.18 (0.05)	3.30 (0.05)	0.04 (0.005)	79.29 (3.88)	215.56 (42.65)
Big mouth	69% (1.76%)	2.01 (0.04)	2.29 (0.03)	0.13 (0.007)	85.94 (4.56)	229.30 (39.28)
Strong voice	59% (1.89%)	3.09 (0.05)	3.23 (0.05)	0.04 (0.005)	88.85 (4.90)	236.51 (46.67)

Note. syll/s = syllables per second; Pausing = proportion of time spent pausing.

Table 3. Pairwise comparisons for the main effect of sentence length.

Measure	**Contrast**	**Mean difference**	***SE***	***p***
Intelligibility (%)	Habitual vs. big mouth	13	0.97	< .0001*
	Habitual vs. strong voice	3	0.97	.02
	Big mouth vs. strong voice	10	0.97	< .0001*
Speech rate (syllables per second)	Habitual vs. big mouth	1.18	0.06	< .0001*
	Habitual vs. strong voice	0.09	0.06	.28
	Big mouth vs. strong voice	1.08	0.06	< .0001*
Articulation rate (syllables per second)	Habitual vs. big mouth	1.01	0.06	< .0001*
	Habitual vs. strong voice	0.08	0.06	.19
	Big mouth vs. strong voice	0.93	0.06	< .0001*
Proportion of time spent pausing	Habitual vs. big mouth	0.09	0.007	< .0001*
	Habitual vs. strong voice	0.0004	0.007	1
	Big mouth vs. strong voice	0.09	0.007	< .0001*
SPL (dB)	Habitual vs. big mouth	6.65	0.28	< .0001*
	Habitual vs. strong voice	9.53	0.28	< .0001*
	Big mouth vs. strong voice	2.88	0.28	< .0001*
*F*0 (Hz)	Habitual vs. big mouth	13.74	2.28	.0002*
	Habitual vs. strong voice	21.12	2.28	< .0001*
	Big mouth vs. strong voice	7.38	2.28	.02

Note. *SE* = standard error; *F*0 = fundamental frequency.
**p* ≤ .01.

conditions. The habitual and strong voice conditions were not significantly different from one another.

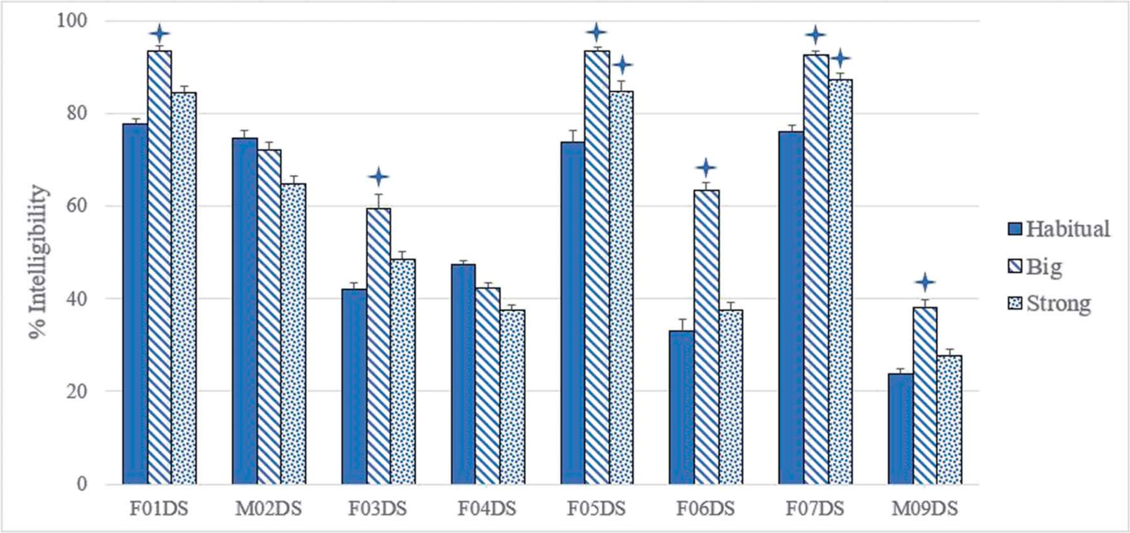
SPL

There was a significant main effect of condition on SPL, $F(2, 12) = 593.65$, $p < .0001$. Post hoc testing revealed that SPL was significantly different in each condition, with SPL being highest in the strong voice condition and lowest in the habitual condition.

*F*0

There was a significant main effect of condition on *F*0, $F(2, 12) = 44.17$, $p < .0001$. Post hoc testing revealed that *F*0 was significantly higher in the big mouth and

Figure 1. Intelligibility values (with standard errors) by participant and condition.



Note: ✦ indicates a clinically significant change (≥10%) in intelligibility from habitual. DS = Down syndrome.

strong voice conditions than the habitual condition. The big mouth and strong voice conditions were not significantly different from one another.

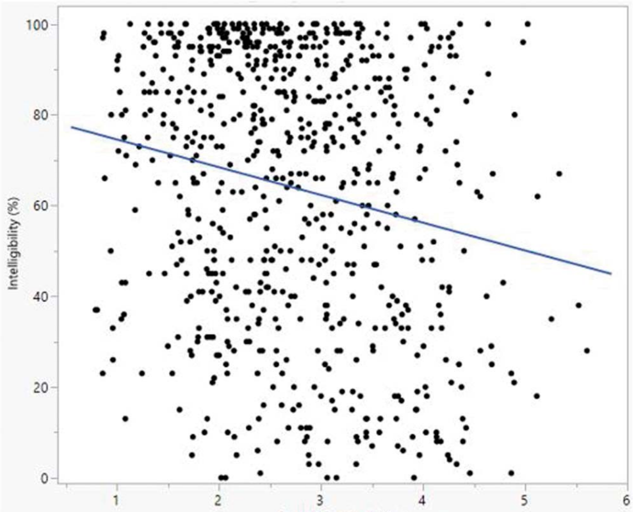
Linear Regressions

There was a significant negative relationship between intelligibility and speech rate (R^2 = .037, p < .0001) and articulation rate (R^2 = .029, p < .0001). Intelligibility decreased as speech rate and articulation rate increased. There was a significant positive relationship between intelligibility and the proportion of time spent pausing (R^2 = .014, p = .002). Intelligibility increased as the proportion of time spent pausing increased. There was no relationship between intelligibility and $F0$ (R^2 = .005, p = .051).

Stepwise Regression

The dependent variables that were significantly related to intelligibility were considered in the stepwise model: speech rate, articulation rate, and the proportion of time spent pausing. The first step (R^2 = .037) included speech rate (F = 26.92, p < .0001). The second step (R^2 = .039) included speech rate (F = 6.98, p = .008) and articulation rate (F = 1.58, p = .209). However, articulation rate did not meet the "stay" threshold (p = .01) and was removed from the model. The proportion of time spent pausing did not meet the "entry" threshold (p = .3). Thus, the final model (R^2 = .037) included speech rate (F = 26.92, p < .0001). Figure 2 depicts the linear relationship between intelligibility and speech rate across conditions for adolescents with DS.

Figure 2. The linear relationship between intelligibility and speech rate across conditions for adolescents with Down syndrome.



Discussion

The purpose of this study was to examine the impact of clear and loud speech cues on speech production in adolescents with DS. Adolescents with DS alter their speech production in response to both types of cues, but the impact of those speech production changes on intelligibility is very different. For the remainder of this section, "clear speech" refers to the speech produced in response to the big mouth cue and "loud speech" refers to the speech produced by the strong voice cue. This is the first study of clear speech in any age group of individuals with DS. Clear speech resulted in significantly increased intelligibility, decreased speech and articulation rate, increased pauses, increased intensity, and increased $F0$. Individual data for most of the adolescents with DS included in this study followed these statistical findings (see the Appendix). Six out of the eight adolescents with DS demonstrated clinically significant intelligibility increases in response to the clear speech cue (see Figure 1). These results are generally consistent with the literature involving adults with speech motor impairment (Lam & Tjaden, 2016; Park et al., 2016; Stipancic et al., 2022; Tjaden et al., 2013; Tjaden, Sussman, & Wilding, 2014) and the literature involving children with CP, although the intelligibility increases were more consistent in our study than previously published work in the CP population (Levy et al., 2017).

Loud speech resulted in significantly increased intensity and $F0$ but did not significantly impact intelligibility, speech and articulation rate, or pauses. Again, individual data for most of the adolescents with DS included in this study followed these statistical findings (see the Appendix). Only two out of the eight adolescents with DS, F05DS and F07DS, demonstrated clinically significant intelligibility increases in response to the loud speech cue (see Figure 1). Significant increases in intensity and/or $F0$ are consistent with the literature involving adults with speech motor impairment (Ramig et al., 1995, 2018; Sadagopan & Huber, 2007; Stathopoulos et al., 2014; Tjaden et al., 2013; Tjaden, Sussman, & Wilding, 2014) and the literature involving children with CP (Chang et al., 2024; Levy et al., 2017; Levy, Moya-Galé, Chang, Campanelli, et al., 2020). Despite this similarity, adolescents with DS demonstrated etiology-specific differences in their response to the loud speech cue.

One etiology-specific difference is the lack of meaningful change in intelligibility in response to the loud speech cue despite significant increases in intensity and $F0$. Individuals with Parkinson's disease and multiple sclerosis demonstrate significantly increased intelligibility with loud speech cues (Levy, Moya-Galé, Chang, Freeman, et al., 2020; Schulz et al., 2021; Tjaden et al., 2013;

Tjaden, Sussman, & Wilding, 2014), although individual data are often not reported so it is difficult to examine this effect on the individual level. Children with CP seem to be less consistent than adults, but typically, at least 40%–50% of a given sample demonstrates clinically significant increases in intelligibility in response to loud speech cues regardless of language spoken (Chang et al., 2024; Levy et al., 2017; Levy, Moya-Galé, Chang, Campanelli, et al., 2020) as opposed to only 25% of the adolescents with DS in this study.

Another etiology-specific difference between previously published literature and the current study is the impact of loud speech cues on speech and articulation rate in adolescents with DS. Adults with speech motor impairment and children with CP demonstrate decreased speech and articulation rate in response to loud speech cues (Chang et al., 2024; Levy et al., 2017; Levy, Moya-Galé, Chang, Campanelli, et al., 2020; Levy, Moya-Galé, Chang, Freeman, et al., 2020; Tjaden, Sussman, & Wilding, 2014), but the adolescents with DS in this study did not. This null result is a potential explanation for the lack of meaningful intelligibility change. Speech rate, articulation rate, and pausing were the only variables significantly related to intelligibility in adolescents with DS, and speech rate was the only one of the three to significantly explain some of the variance in intelligibility.

It could also be hypothesized that the reason behind our lack of meaningful change in intelligibility using the loud speech cue is that intensity and $F0$ were not actually impaired in our participants. Comparing the mean data from this study with other studies involving typically developing adolescents reveal little to no mean differences in intensity or $F0$ (see Smiljanic & Gilbert, 2017a). While this is important to note, typically developing individuals across the lifespan as well as adults with speech motor impairment who do not demonstrate atypical intensity and $F0$ consistently demonstrate increased intelligibility when using loud speech cues (Lam & Tjaden, 2016; Smiljanic & Gilbert, 2017b; Tjaden et al., 2013; Tjaden, Sussman, & Wilding, 2014). Furthermore, our results mirror the results from the treatment articles examining LSVT LOUD in young children with DS, even though the children with DS in those studies did have atypical intensity and $F0$. LSVT LOUD did not result in statistically or clinically significant increases in intelligibility, and individual children with DS who demonstrated increases in intensity and $F0$ did not necessarily demonstrate improvements in intelligibility (Boliek et al., 2022; Langlois et al., 2020). Our results also support data from adults with and without Parkinson's disease that indicate changes in intensity are not necessarily associated with significant improvement in intelligibility, especially once audibility is controlled (Kim & Kuo, 2012; Neel, 2009). A stronger hypothesis that could explain these data is that the expected upstream effects of increased intensity (Traunmüller & Eriksson, 2000), such as formant frequency shifts and spectral changes, either are not exhibited or do not impact intelligibility in the same way in adolescents with DS. This is supported by the fact that intensity itself was controlled by amplitude normalization and, thus, not an available cue for listeners.

The question of which variables make the most difference in intelligibility ratings for adolescents with DS must still be explored. Speech rate only accounted for 3.7% of the variance of intelligibility in adolescents with DS, leaving a large portion of the variance in intelligibility ratings unexplained. It is difficult to place these results in context given the lack of previously published cueing and treatment literature in the DS population. The treatment work available in the DS population has not examined the extent to which any of the dependent variables impacted the intelligibility results. There has been one study that examined how different acoustic and perceptual features contributed to intelligibility in adolescents with DS. Lower intelligibility was significantly associated with across-the-board phonemic and phonetic errors, slow articulation rate and/or increased pause time (i.e., speech rate), inappropriate prosody, and atypical voice quality (Wilson et al., 2019b). Speech rate is, thus, a consistent factor associated with intelligibility in adolescents with DS. It is counterintuitive to want to slow speech rate in an adolescent with DS if slow speech rate is related to low intelligibility. However, slowing speech rate in the clear speech condition contributed to increased speech intelligibility in this study. Therefore, the acoustic features that contribute to an individual exhibiting low intelligibility in a habitual condition are not necessarily the features that can predict success in intervention, emphasizing the importance of adding this type of analysis to future cueing and treatment work.

Taken together, these results preliminarily indicate that clear speech cues are superior to loud speech cues in terms of increasing intelligibility for adolescents with DS. Clear speech resulted in statistically and clinically larger increases in intelligibility than loud speech. Even the two adolescents with DS who responded to the loud speech cue with clinically significant increases in intelligibility exhibited much larger increases in intelligibility in response to the clear speech cue (F05DS: 20% increase for big mouth vs. 11% increase for strong voice; F07DS: 30% increase for big mouth vs. 11% increase for strong voice). Clear speech may have been more effective than loud speech due to the variety of speech subsystems that were impacted. Based on the acoustic changes measured in this study, clear speech impacted the respiratory/phonatory and articulatory subsystems, while loud speech only impacted the respiratory/phonatory subsystem in adolescents with DS. Furthermore, speech rate, the only variable that significantly explained some of the variance in intelligibility, is a measure that provides an overall index of speech production capability and inherently involves the integration of all speech subsystems. Therefore, speech intervention designed to improve intelligibility in adolescents with DS must address deficits across multiple speech subsystems.

Limitations and Future Directions

Additional studies are needed to validate these results. This is particularly important, given our small sample size, the heterogeneity of the DS population, our inclusion of bilingual speakers, the inclusion of only a handful of potential acoustic responses to these cues, and the way in which we controlled for audibility in the perceptual task (i.e., amplitude normalization). Additionally, there were two adolescents in our data set (M02DS and F04DS) who demonstrated intelligibility decreases in response to the clear and loud speech cues. It is unclear why this happened given that these adolescents demonstrated acoustic changes in line with the statistical findings in response to the clear and loud speech cues. Future large-scale studies should include physiologic and aerodynamic measures as well as expand the acoustic measures to include variables such as vowel space area and first and second formant frequencies in an effort to fully characterize the impact of clear and loud speech cues on speech production. These variables must then be examined relative to the contributions to intelligibility.

Although cueing studies provide important foundational knowledge for the development and implementation of treatment protocols, they do not necessarily predict long-term changes as a response to any specific protocol. There are also many ways to cue clear and loud speech. In adults with speech motor impairment, the type of cue affects an individual's response, physiologically, acoustically, and perceptually (Lam & Tjaden, 2013, 2016; Lam et al., 2012; Sadagopan & Huber, 2007). Future studies should seek to investigate the impact of different types of cues for clear and loud speech in large numbers of adolescents with DS in both cueing and treatment studies.

Cueing studies involving children and adolescents with speech motor impairment often rely on repetition paradigms in which children and adolescents repeat the stimuli following an adult model. Previous studies indicate that children with and without speech motor impairment modify their speech in a manner independent of an adult model (Darling-White & Banks, 2021; Levy et al., 2017). Although previous data are limited, data from the current study support this finding. For example, sentences produced by the adult model for the habitual and strong voice conditions did not contain any pauses, but every adolescent with DS produced sentences containing pauses in both the habitual and strong conditions. Despite this, it is possible that exposure to the sentences produced by the adult model may have impacted adolescents' responses. In this study, sentences produced by the adult model for the big mouth condition were produced using a "big mouth," while sentences produced by the adult model for the strong voice condition were produced in a habitual manner, and then intensity was scaled to represent a "strong voice." Thus, sentences produced by the adult model did not demonstrate slowed speech and articulation rate in the strong voice condition, a commonly observed effect of loud speech in adults. Since the adolescents with DS did not alter speech and articulate rate in the strong voice condition either, future studies involving larger numbers of adolescents with DS should be designed to examine the impact of an adult model by using sentences produced with a "strong voice" in a naturalistic context rather than using intensity scaling and/or by using a task that does not require the adolescents to repeat an adult model.

Clinical Implications

This study contributes meaningfully to the evidence base necessary for the development and implementation of interventions to improve intelligibility in adolescents with DS. When considering these data alongside the available intervention literature in DS, as sparse as it is, the following clinical conclusions can be made about speech intervention involving adolescents with DS: (a) Clear speech cues may be superior to loud speech cues for increasing intelligibility, (b) speech intervention must address deficits across multiple speech subsystems to increase intelligibility, (c) speech rate reduction may be a critical component of speech intervention designed to increase intelligibility, and (d) adolescents with DS respond differently than adults with speech motor impairment and children with CP to the same types of speech cues and likely require etiology-specific intervention strategies.

Data Availability Statement

The data supporting the conclusions of this article can be found in the tables, figures, and Appendix. Any further data requests should be made to the corresponding author, Meghan Darling-White.

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Appendix

Individual Means (Standard Deviations) for Each Dependent Measure by Condition

Participant	Condition	Intelligibility (%)	Speech rate (syll/s)	Articulation rate (syll/s)	Pausing	SPL (dB)	*F*0 (Hz)
F01DS	Habitual	77.66 (6.03)	3.23 (0.80)	3.32 (0.78)	0.03 (0.06)	80.65 (1.89)	208 (11.16)
	Big mouth	93.47 (4.72)	2.08 (0.54)	2.38 (0.59)	0.13 (0.08)	89.38 (1.89)	238.44 (8.84)
	Strong voice	84.62 (5.67)	2.98 (0.43)	3.08 (0.41)	0.03 (0.05)	91.82 (2.47)	263.82 (40.98)
M02DS	Habitual	74.72 (6.82)	3.11 (0.71)	3.32 (0.74)	0.06 (0.07)	82.35 (2.47)	177.09 (9.64)
	Big mouth	72.28 (7.22)	1.22 (0.35)	1.70 (0.39)	0.28 (0.11)	89.68 (4.56)	191.24 (9.22)
	Strong voice	64.97 (6.79)	3.16 (0.94)	3.65 (0.90)	0.14 (0.11)	93.74 (2.87)	191.15 (15.41)
F03DS	Habitual	42.08 (6.13)	3.66 (0.62)	3.70 (0.62)	0.01 (0.03)	77.76 (1.42)	173.12 (6.80)
	Big mouth	59.64 (13.85)	1.99 (0.38)	2.39 (0.50)	0.16 (0.09)	79.38 (2.19)	172.32 (7.79)
	Strong voice	48.59 (6.69)	3.51 (0.81)	3.58 (0.77)	0.02 (0.07)	85.24 (7.89)	183.47 (7.89)
F04DS	Habitual	47.42 (4.38)	2.11 (0.58)	2.34 (0.49)	0.10 (0.13)	76.62 (1.56)	222.56 (41.32)
	Big mouth	42.47 (3.94)	1.81 (0.44)	2.16 (0.46)	0.16 (0.11)	87.09 (2.52)	246.32 (17.86)
	Strong voice	37.67 (4.81)	2.44 (0.57)	2.50 (0.57)	0.03 (0.04)	87.24 (2.61)	248.58 (16.65)
F05DS	Habitual	73.91 (11.43)	2.87 (0.73)	2.99 (0.62)	0.05 (0.09)	78.06 (2.01)	208.18 (22.25)
	Big mouth	93.47 (3.53)	2.23 (0.48)	2.39 (0.54)	0.06 (0.08)	85.41 (2.55)	211.21 (7.10)
	Strong voice	84.94 (9.62)	3.12 (0.74)	3.17 (0.71)	0.02 (0.04)	89.59 (2.63)	218.85 (12.83)
F06DS	Habitual	33.02 (11.07)	3.44 (0.82)	3.64 (0.79)	0.06 (0.09)	—	—
	Big mouth	63.47 (7.27)	2.21 (0.58)	2.56 (0.51)	0.14 (0.13)	—	—
	Strong voice	37.61 (6.77)	3.18 (0.77)	3.43 (0.70)	0.08 (0.11)	—	—
F07DS	Habitual	76.22 (5.22)	3.31 (0.58)	3.34 (0.57)	0.01 (0.03)	74.76 (1.39)	242.18 (32.07)
	Big mouth	92.59 (4.64)	2.01 (0.49)	2.18 (0.52)	0.08 (0.09)	83 (3.15)	271.21 (16.02)
	Strong voice	87.40 (5.91)	2.84 (0.73)	2.90 (0.75)	0.02 (0.05)	82 (2.47)	255.36 (39.15)
M09DS	Habitual	23.88 (5.04)	3.73 (0.66)	3.78 (0.69)	0.01 (0.04)	84.85 (3.47)	277.59 (36.53)
	Big mouth	38.18 (7.29)	2.51 (0.47)	2.58 (0.44)	0.03 (0.05)	87.65 (3.64)	274.38 (27.74)
	Strong voice	27.63 (7.10)	3.45 (1.07)	3.49 (1.04)	0.01 (0.04)	92 (4.94)	295.24 (38.11)

Note. syll/s = syllables per second; Pausing = proportion of time spent pausing; *F*0 = fundamental frequency.