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Perceptual and Acoustic Effects of Dual-Focus Speech Treatment in Children With Dysarthria

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Abstract

Purpose: Children with dysarthria secondary to cerebral palsy (CP) may experience reduced speech intelligibility and diminished communicative participation. However, minimal research has been conducted examining the outcomes of behavioral speech treatments in this population. This study examined the effect of Speech Intelligibility Treatment (SIT), a dual-focus speech treatment targeting increased articulatory excursion and vocal intensity, on intelligibility of narrative speech, speech acoustics, and communicative participation in children with dysarthria. **Method:** American-English speaking children with dysarthria (n = 17) received SIT in a three-week summer camp-like setting at Columbia University. SIT follows motor-learning principles to train the child-friendly, dual-focus strategy, "Speak with your big mouth and strong voice." Children produced a story narrative at baseline (BASE), immediate post-treatment (POST), and at 6-week follow-up (FUP). Outcomes were examined via blinded listener ratings of ease of understanding (n = 108 adult listeners), acoustic analyses, and questionnaires focused on communicative participation. **Results:** SIT resulted in significant increases in ease of understanding at POST, that were maintained at FUP. There were no significant changes to vocal intensity, speech rate, or vowel spectral characteristics, with the exception of an increase in second formant difference between vowels following SIT. Significantly enhanced communicative participation was evident at POST and FUP. Considerable variability in response to SIT was observed between children. **Conclusion:** Dual-focus treatment shows promise for improving intelligibility and communicative participation in children with dysarthria, although responses to treatment vary considerably across children. Possible mechanisms underlying the intelligibility gains, enhanced communicative participation, and variability in treatment effects are discussed.

Key Words: Cerebral Palsy, Dysarthria, Children, Intelligibility, Treatment, Participation

Perceptual and Acoustic Effects of Dual-Focus Speech Treatment in Children With Dysarthria

Cerebral palsy (CP) is the most common neuromotor disorder in children (Centers for Disease Control and Prevention, 2013). The motor speech disorder of dysarthria is present in the majority of children with CP (Mei et al. 2014; Nordberg et al. 2013). Dysarthria may be characterized by articulatory imprecision, rate reduction, strained vocal quality, and decreased vocal intensity, among other variable deficits in this heterogeneous disorder, and often results in reduced speech intelligibility (Allison & Hustad, 2018; Fox & Boliek, 2012; Higgins & Hodge, 2002; Lee et al., 2014; Levy et al., 2013, 2016; Workinger & Kent, 1991). The intelligibility reductions evident in many children with dysarthria secondary to CP often limit the children's ability to communicate and interfere with both social development and quality of life (Dang et al., 2015; Fauconnier et al., 2009). Increasing intelligibility is therefore commonly a primary goal of speech treatment for children with dysarthria. Yet, there have been few studies of the effects of speech treatment upon intelligibility and communication in this population (Pennington et al., 2009). Furthermore, studies thus far have reported limited change in speech production (Fox & Boliek; 2012; Moya-Galé et al., 2020; Pennington et al., 2018).

Two of the primary approaches to speech treatment in childhood dysarthria have been described in the literature: the S*peech Systems Approach* (Pennington et al., 2006, 2010, 2013, 2019) and *Lee Silverman Voice Treatment* (LSVT LOUD®; Boliek & Fox, 2017; Fox & Boliek, 2012). Speech Systems is the more commonly-implemented approach and, while individually tailored to each child, primarily aims to stabilize respiratory and phonatory control and effort. Children receive three 30-45-minute speech treatment sessions per week for 6 weeks. Children with reduced vocal intensity are trained to speak louder, whereas those with inappropriate variability in vocal intensity are trained to use a "nice and easy" or "smooth" voice to regulate respiratory effort within a phrase. Speech rate is also targeted by adjusting phrase length and syllables per breath. A study of 15 children with dysarthria showed that the Speech Systems Approach resulted in improved intelligibility at word level and in narrative speech tasks, with gains maintained at 12 weeks (Pennington et al., 2013). A later study showed small improvements to acoustic measures of speech production, primarily in those reflecting speech breathing and phonatory function (Pennington et al., 2018).

The second treatment approach, LSVT LOUD (Ramig et al., 2001), utilizes a single focus on healthy vocal loudness via four 60-minute treatment sessions per week for four consecutive weeks, plus homework. This treatment has most commonly been employed in adults with Parkinson's disease (PD), resulting in significant intelligibility gains in a randomized controlled trial (Levy, Moya-Galé, Chang, Freeman, et al., 2020). However, improvement in speech production has also been demonstrated when the treatment has been trialed with children with dysarthria secondary to CP. Specifically, in a study of four children with dysarthria, Fox and Boliek (2012) showed that speech-language pathologists (SLPs) exhibited a preference for most of the perceptual characteristics (e.g., voice quality, loudness) of the children's utterances recorded following LSVT LOUD, compared to those recorded pre-treatment, with variable results at 6-week follow-up. When seven children who completed LSVT LOUD were studied, the outcomes were equivocal (Boliek & Fox, 2017). Here, single word intelligibility, as measured by 54 listeners' transcription accuracy, showed an increase at post-treatment; however, the gains were not maintained at 12-week follow-up. Acoustic changes reported by Fox and

Boliek (2012) and Boliek and Fox (2017) following LSVT LOUD were inconsistent and maintenance of gains was variable.

While the Speech Systems and LSVT LOUD approaches show promise for increasing intelligibility in children with dysarthria, the need remains for further research and exploration of alternative approaches. For example, the Speech Systems Approach has shown demonstrable gains in intelligibility for children with dysarthria across a range of speech tasks, including those more "real-world" speech tasks such as narrative speech. Data from narrative tasks such as those implemented in Pennington et al.'s (2006, 2010, 2013, 2019) treatment research provide rich, in-depth information about children's language use, resulting in strong ecological validity (Ebert & Scott, 2014). However, the advantages of individually tailored treatment must be weighed against the challenge of replicating such an approach. In contrast, LSVT LOUD utilizes a consistent single focus and is therefore highly replicable. However, the outcomes of this approach have been measured in single word or repetition tasks, with limited analyses of the effects on intelligibility at the narrative level.

Furthermore, there has been little study of the effects of behavioral speech treatments on communicative participation in the everyday lives of children with CP. Whether treatments make a meaningful difference in clients' lives is a critical consideration in clinical practice (Torrence et al., 2016). Among the limited findings on this topic, following the Speech Systems Approach, children have been reported to communicate more readily in their daily lives (Pennington et al., 2013). Additionally, Boliek and Fox's (2017) parent ratings of the children's speech and communication following LSVT LOUD indicated lower frustration levels and more frequent conversation, suggesting improvements in aspects of communicative participation.

There is a clear need for treatment approaches that are appealing to children, easily replicable, promote gains in speech intelligibility that are evident in more natural speaking tasks, and that result in improved ability for children with dysarthria to interact in their everyday lives. With that in mind, recently, a third treatment approach has been developed, *Speech Intelligibility Treatment* (SIT; Levy, 2013, 2018). The primary goal of SIT is to increase intelligibility in children with dysarthria. Delivered in a summer camp-like setting since 2014, SIT appeals to the playfulness of children and encourages their communicative participation, while considering the visual, cognitive, and mobility limitations often present in CP (Bleyenheuft & Gordon, 2014). The dual-focus strategy of "Speak with your big mouth and strong voice" implemented throughout SIT, is central to treatment and provides a framework that is relatively straightforward for other clinicians to replicate.

The "big mouth" instruction was developed to increase the children's articulatory excursion, promoting the hyperarticulation that is characteristic of clear speech (Ferguson & Kewley-Port, 2002; Perkell et al., 2002), with the aim of addressing underlying reductions in articulatory working space often seen in children with dysarthria (Lee et al., 2014; Nip et al., 2017; Workinger & Kent, 1991). "Strong voice," similar to instructions in LSVT LOUD (Boliek & Fox, 2017; Fox & Boliek, 2012; Ramig et al., 2001), is aimed to increase vocal intensity and also reap the concomitant benefit of raising amplitude across the speech production system (Dromey et al., 1995; Sapir et al., 2007). In combining these instructions in the simple dual-focus strategy "Speak with your big mouth and your strong voice," SIT aims to maximize the potential for intelligibility gains in children with dysarthria, while also encouraging communicative participation.

Benefits of big mouth and strong voice cues were documented in Levy et al.'s (2017) examination of immediate responses to cues delivered in one recording session, with no treatment provided. Eight children with dysarthria were cued to speak with their “big mouth” or with their “strong voice.” Significant gains in intelligibility resulted, with some children benefiting more from the big mouth cue and others from the strong voice cue. Consistent, albeit smaller, intelligibility gains were revealed in response to French translations of these cues in a parallel cueing study conducted in Belgium (Levy, Moya-Galé, Chang, Campanelli, et al., 2020).

As in the Speech Systems Approach and LSVT LOUD, SIT follows principles promoting motor learning, including high effort and intensive dosage, through intensive repetitive practice (Kleim & Jones, 2008; Maas et al., 2008), but differences include its dual-focus approach and the 3-week camp-like setting. Additionally, like LSVT LOUD, SIT is easily replicable for SLPs and is designed to promote generalization to new settings and communication partners. The free, child-friendly SIT program was delivered yearly (6.5 hours x 5 days for 3 weeks) in a game- and conversation-filled Hawaii-themed summer camp-like setting at Teachers College, Columbia University in New York. Children from several states, including California, Massachusetts, and North Carolina, participated. A video about the yearly program may be found at https://www.youtube.com/watch?v=sj4Eeu4WFhs. Details regarding SIT are provided in the Methods section.

There is emerging evidence that SIT provides a promising third treatment approach for children with CP. In a small-scale SIT study conducted in French in Belgium (Moya-Galé et al., 2020), 10 French-speaking children with dysarthria were randomized to SIT or to a physical therapy program (Bleyenheuft & Gordon, 2014). Significant intelligibility gains were found in the SIT group, but not in the physical therapy group, suggesting that the gains stemmed from the speech treatment itself, rather than the intensity or social component of the camp-like setting. Larger-scale investigations, with longer-term outcomes, are needed to further examine the effects of this treatment. Therefore, in the current study, we report on the immediate and follow-up outcomes of six years of the SIT program.

The aim of this study was to determine the effects of SIT on speech intelligibility, speech acoustics, and communicative participation of the group of 17 English-speaking children with dysarthria secondary to CP who had participated across the six years. For intelligibility, the focus was on a narrative task, more closely representing everyday speech production than would more controlled tasks. We were also interested to determine if any changes to intelligibility would be observed through relevant objective measures of speech acoustics—articulation rate, vocal sound pressure level (SPL), first formant (F1) and second formant (F2) of vowels, and formant differences between vowels.[1] Finally, the study aimed to determine whether SIT resulted in changes to communicative participation in the group of children with dysarthria and, if so, whether this was related to any intelligibility gain.

It was hypothesized that SIT would result in enhanced intelligibility for the children with dysarthria (Levy et al., 2017; Levy, Moya-Galé, Chang, Campanelli, et al., 2020; Moya-Galé et al., 2020). Furthermore, intelligibility improvements were expected to be accompanied by acoustic changes similar to those found in clear and/or loud speech. Namely, reduced articulation rate, gains in vocal SPL, higher F1, representative of a lower tongue position, and higher F2 of front vowels, reflecting tongue advancement along the anterior-posterior plane (Ansel & Kent, 1992; Ferguson & Kewley-Port, 2002; Levy et al., 2017; Perkell et al., 2002; Stevens & House, 1955; Tjaden et al., 2013), and greater formant differences between vowels, particularly for F2

[1] While examination of further variables and variability of the acoustic speech characteristics would also be of interest in future research, the current initial analyses were intended to more directly reflect acoustic changes expected in response to SIT’s “big mouth and strong voice” instructions.

(Ansel & Kent, 1992; Monsen, 1978), were anticipated immediately after treatment and at follow-up. The acoustic hypotheses were guarded, however, because of the inconsistent and limited acoustic changes reported following speech treatments in dysarthria (Fox & Boliek, 2012; Moya-Galé et al., 2020; Pennington et al., 2018). With regard to communicative participation, we hypothesized that SIT would result in improvements for the children on this measure, and that these changes would be associated with improved intelligibility. Overall, this study was expected to shed light on the effects of the SIT on the everyday communication abilities of children with CP and dysarthria.

Method

Design

This Phase I-Phase II study (Beeson & Robey, 2006) used a group baseline versus post-treatment design. Children's speech and communicative participation were assessed at two baseline timepoints. The group subsequently participated in SIT, which was followed by two post-treatment sessions (immediate post-treatment, 6-week follow-up).

Participants

Children with Dysarthria

Seventeen children, diagnosed with CP by a neurologist, participated in the study. The majority of the children presented with spastic CP. The four females and 13 males ranged in age from 4;8 to 17;5, with a mean age of 10;0. All children exhibited notable dysarthria as determined by three experienced SLPs' independent review of each child's audio and video recordings of a motor speech screening, including sentence repetition and monosyllabic and multisyllabic word repetition tasks, diadochokinesis tasks, conversational speech, and an oral structural-functional screening (Murray et al., 2015; Strand & McCauley, 2008). The determination of diagnosis and severity of dysarthria was based on the presence and degree of observable visual characteristics associated with dysarthria (e.g. abnormal orofacial and/or respiratory movement and tone) and audible speech deficits associated with dysarthria (e.g. imprecise articulation, strained vocal quality, decreased articulation rate and vocal intensity, monotone) in at least two of the speech subsystems (Allison & Hustad, 2018; Fox & Boliek, 2012; Lee et al., 2014). Most of the children presented with decreased vocal intensity and articulation rate. Childhood apraxia of speech, pure phonological disorder, and other diagnoses were ruled out based on the children's responses (Murray et al., 2015; Strand & McCauley, 2008). Analysis of SLPs' independent review data indicated 100% agreement regarding the presence of dysarthria. Further criteria for inclusion were speech as the children's primary communication modality, passing a hearing screening bilaterally at 20 dB HL (American National Standards Institute [ANSI], 2004) at 500, 1000, 2000, and 4000 Hz, ability to follow simple directions, and English as a dominant language. Participant characteristics, including Gross Motor Function Classification System (Palisano et al., 1997) and most salient speech characteristics, are listed in Table 1. Selected subtests from one of two standardized tests, the Clinical Evaluation of Language Fundamentals-Fifth Edition (Wiig et al., 2013) and the Test for Auditory Comprehension of Language-Third Edition (Carrow-Woolfolk, 1999), were used to test receptive language skills. However, because adaptations suggested in the manuals were not always sufficient for this population, the scores are likely to underestimate the skills of the children with dysarthria (Hustad et al., 2010).

Table 1

Participant characteristics of children with dysarthria due to cerebral palsy

Child	**Age**	**Sex**	**Diagnosis**	**GMFCS**	**Dysarthria Severity**	**Deviant Speech Characteristics (in order of salience)**	**Language Comprehension**
CP01	4;6	F	spastic hemiplegia	I	moderate-severe	Hypernasality, imprecise articulation, phonological processes	91st, above average[a]
CP02	5;7	M	spastic quadriplegia	IV	moderate	Strained vocal quality, slow rate, monotone	<1st, very poor[a]
CP03	6;8	M	ataxic diplegia	III	mild-moderate	Imprecise articulation, excessive pitch and loudness variation	<1st, very poor[a]
CP04	7;1	M	spastic triplegia	IV	moderate-severe	Phonological processes, imprecise articulation	9th, below average[a]
CP05	7;8	M	spastic diplegia	III	moderate	Decreased vocal intensity, strained vocal quality, phonological processes	9th, below average[a]
CP06	8;3	F	dyskinetic-hypotonia	II	moderate	Voice stoppages, irregular articulatory breakdowns, imprecise articulation	37th, average[a]
CP07	8;8	M	spastic diplegia	II	mild	Imprecise articulation, strained vocal quality	37th, average[a]
CP08	9;6	M	ataxic diplegia	I	moderate	Imprecise articulation, excessive pitch and loudness variation	<1st, very poor[a]
CP09	10;2	M	spastic triplegia	III	moderate	Strained vocal quality, slow rate, imprecise articulation	37th, average[a]
CP10	10;8	M	spastic quadriplegia	V	moderate	Strained vocal quality, monotone, imprecise articulation	0.5th, poor[b]
CP11	11;0	M	spastic quadriplegia	V	mild-moderate	Decreased vocal intensity, monotone, equal stress	<1st, very poor[a]
CP12	11;3	M	spastic hemiplegia	I	moderate	Imprecise articulation	95th, above average[b]
CP13	11;8	M	spastic diplegia	III	severe	Strained vocal quality, slow rate, imprecise articulation	5th, poor[a]
CP14	12;1	M	spastic quadriplegia	IV	mild	Decreased vocal intensity, imprecise articulation	50th, average[a]; 25th below average[b]
CP15	13;4	F	spastic quadriplegia	IV	mild-moderate	Strained vocal quality, slow rate, imprecise articulation	0.4th, poor[b]
CP16	14;11	M	spastic quadriplegia, epilepsy, VP shunt	V	severe	Strained vocal quality, slow rate, imprecise articulation	0.4th, poor[b]
CP17	17;5	F	spastic hemiparesis	I	severe	Imprecise articulation, strained vocal quality, slow rate	50th, average[b]

Note. GMFCS = Gross Motor Function Classification System (Palisano et al., 1997)

[a]Percentile rank obtained from the Test for Auditory Comprehension of Language–Third Edition, Elaborated Phrases & Sentences subtest.

[b]Percentile rank obtained from the Clinical Evaluation of Language Fundamentals–Fifth Edition, Word Classes subtest.

Procedures

Selection of Children with Dysarthria

Recruitment of children with dysarthria was performed through word of mouth and on-line through the Teachers College Center for Cerebral Palsy Research. To determine eligibility for participation, an on-line questionnaire was completed by parents of potential participants, followed by an on-line video screening session with the child. This session included a motor speech screening to 1) determine the presence of dysarthria, 2) rule out childhood apraxia of speech, 3) confirm intelligibility deficits, and 4) assess the child's ability to follow directions required for the study tasks. The study was approved by the Institutional Review Board at Teachers College, Columbia University.

Speech Recording Procedure

Speech recording took place in a quiet room at Teachers College in a different building from the treatment program. Children were seated in their wheelchair or an adaptive chair and were not provided with any instructions on posture. Recording methodology replicated the general approach implemented by LSVT LOUD studies (e.g., Boliek & Fox, 2017; Fox & Boliek, 2012; Ramig et al., 2001) to include the dimension of the (child) participant's vocal intensity in the signal for later playback (Švec & Granqvist, 2018). Specifically, a Countryman EMW Lavalier microphone was secured to the child's forehead by means of a headband and tape, eight centimeters from the child's lips. The mouth-to-microphone distance was verified throughout the recording sessions and the input dial setting remained unchanged throughout the study. Before and after each speech recording session, a calibration tone was played on a tuner (OT120-Korg Orchestral) that was placed eight centimeters away from a sound level meter (Galaxy CheckMate CM140) and the experimenter noted the SPL for later playback purposes. The speech signal was recorded using SoundForge 8.0 software on a Dell Optiplex 760 computer via a Scarlett 2i2 audio interface (Focusrite 2x2 USB2). Speech was recorded on a mono channel with 16-bit resolution at a sampling rate of 22050 Hz.

Speech Task

Children's productions of story narratives were elicited through sequenced picture cards from the School-age Language Assessment Measures (Crowley & Baigorri, 2014). If children did not readily produce narratives, the experimenter asked questions regarding what was occurring in the story. Experimenters were trained in a consistent manner and were blinded to the child's treatment conditions. They were instructed not to provide any speech cues to children throughout the testing. Story narratives were not included as speech practice tasks during treatment.

Speech Intelligibility Treatment

Each child received SIT in a summer camp-like setting at Teachers College for 6.5 hour per day for 5 days per week across 3 weeks. As detailed in the protocol summary in Table 2, three to five children with dysarthria attended the program each year. (Data from two children were not included in this study due to not meeting inclusion criteria for language background and medical diagnosis.) The treatment was delivered by Communication Sciences and Disorders master's student clinicians supervised by the first author (faculty) and second and third authors (doctoral students). The daily program included group and individual activities, during which children were trained intensively with the dual-focus instructions "Speak with your big mouth and your strong voice." A "Hawaiian Lion" puppet served as a mascot, modeling target speech. When the clinician perceived that the children were not intelligible or were not adequately using a "big mouth and strong voice," they instructed the children to use the strategy. Following the next production, the clinician provided positive feedback or further instructions to use a "bigger mouth and stronger voice." No other instructions on speech production were provided. (See Table 2 regarding fade-out of feedback and reminders.) Activities, including barrier tasks and minimal pair vowel tasks, were designed to elicit speech (Levy, 2014). The "camp" was Hawaii-themed, with arts and crafts activities and games such as Hawaii bingo and Hawaii hangman. Over the three weeks, skills were trained hierarchically, from word level to the child's highest linguistic level, culminating in "generalization week" during which children used their new speech strategies to converse with novel communication partners. As one child described, "You get to roll or walk or however you move around, using what you learned in the camp…. in a real-world environment." Feedback was faded out as clinicians encouraged children to use their new strategies for longer periods without reminders, with the goal of forming new speech habits. At a luau (party) at the end of the "camp," each child presented a project they had prepared, and children from past years returned.

Table 2

Speech Intelligibility Treatment Protocol Summary

General Information	
Goal	To increase intelligibility and encourage communicative participation by means of the dual-focus strategy "Speak with your big mouth and strong voice"
Setting	Camp-like setting at Teachers College, Columbia University Group sessions in a large room; individual sessions in individual rooms with one-way mirrors Generalization week: New settings and new communication partners
Number of Children	3 to 5 children per year
Dosage	6.5 hour per day, for 5 days per week, over 3-week period; Total 97.5 hours 2.5 hour of group session, 1 hour of lunch, 3 hours of individual session daily
Clinicians	Two supervised SLP master's students work with each child All clinicians required to have passed a (free) SIT training and certification
Supervision	Supervisors are the first author (faculty) and second and third authors (doctoral students) All three supervisors are licensed SLPs The supervisors ensure the safety and comfort of the children and treatment fidelity

Daily Schedule

Morning Sessions	
Group session (9am – 10:30am)	Children are reminded to use the dual-focus strategy throughout activities Hawaiian Lion puppet serves as a mascot, modeling strategies and providing a visual reminder Examples of group activities: making a volcano, paper boat floating contest, and decorating picture frames
Individual session (10:30am – 12pm)	Children practice 7 lucky phrases while they use the dual-focus strategy Lucky phrases are provided by parents as phrases their children say daily, such as "I'm hungry" or "Can I have my phone?"
Lunch (12pm – 1pm)	Speech training continues as children request help opening containers or commenting or discussing
Afternoon Sessions Individual session (1pm – 2:30pm)	Minimal pair vowel activities and barrier tasks Children are reminded to use the dual-focus strategy through activities
Group session (2:30pm – 3:30pm)	Activities such as Hawaii bingo and hangman (See Levy, 2014) Children are reminded to use the dual-focus strategy through activities
Daily Homework	15 minutes daily Children rewarded with stickers for homework done

Weekly Progression

Week	Theme	Progression	Lucky Phrases	Reminders and Feedback
1	Get systematic! Learn the behaviors	Word level: Activities targeting words	Blocked: 6x7 phrases in first individual session	Frequent: Reminders and feedback regarding dual-focus strategy as needed until mastered with reminders
2	Practice, practice! Increase number of trials	Sentence level: Activities targeting sentences	Shorter, more frequent blocks: 3x7 phrases in each of 2 individual sessions	Less frequent: Transition to child's self-monitoring; Ask how clinician and child sound with "big/small" mouth and "strong/weak" voice
3	Generalize! Speak with new people	Conversational level: Activities targeting conversation or child's highest linguistic level e.g. treasure hunt, purchase items, conduct survey	Random: 6x7 phrases distributed across individual sessions	Fade out: Ask child how they sound, then fade out

Intelligibility Assessment

Three sentences from each of the three timepoints, i.e. baseline[2] (BASE), immediate post-treatment (POST), and 6-week follow-up (FUP), were selected from each child's narrative

[2]As described in the Design section, the children's speech data were collected at two baselines. Ease of understanding ratings of sentences from baseline 1 and baseline 2 were compared in a preliminary study with different listeners from those included in the experimental study, in order to assess baseline stability and for data

speech sample – to a total of nine sentences per child. The chosen sentences were always the first three sentences produced by the child, with the average number of syllables per sentence differing by less than one syllable across the three timepoints. These speech stimuli were used in the ease of understanding (EoU) rating task.[3] One hundred and thirty healthy American-English (AE)-speaking listeners participated in the task. Results from 22 of these listeners were excluded due to technical (software) difficulties (n = 20), attention deficit hyperactivity disorder (n = 1), and failing hearing screening (n = 1). In total, data from 108 listeners were included in the analysis. The 86 women and 22 men ranged in age from 18;7 to 36;8 years, with an average age of 24;7 years. Listeners were recruited from New York City and its surroundings. These listeners reported no history of cognitive, language or learning disability and no significant experience with individuals with motor speech disorders. They passed a hearing screening at 25 dB HL (ANSI, 2004) bilaterally at 500, 1000, 2000, and 4000 Hz. Listeners were entered into a raffle for a gift card, as a token of appreciation for their participation.

The EoU rating task was conducted free-field in a sound-attenuated IAC booth. It took approximately 45 minutes. Listeners were seated by a desk, 85 cm from loudspeakers, a typical conversational distance for AE speakers (Hall, 1966). They were encouraged to sit with comfortable access to a MacBook Air laptop computer (Model A1466) on the desk and to not lean forward toward the loudspeakers (Altec Lansing ADA 215), which were connected to the laptop. To ensure that the speech samples were presented at a level representative of the children's vocal intensity, the SPL of the calibration tone measured before the children's recording sessions was reproduced at an eight centimeter distance from the loudspeakers. Custom-developed software (Chang & Chang, 2015), programmed in MATLAB (Version R2015b, The MathWorks, Inc., 2015), presented the children's speech samples and recorded listener responses on a visual analog scale.

After hearing a sentence, each listener was asked to rate on the visual analog scale how easy the sentence was to understand. The anchor points provided were "difficult" and "easy" (Levy et al., 2017). (Orthographic transcriptions were also collected, but not reported here.) The experimental task was preceded by task familiarization, which utilized speech of children with dysarthria not included in the experimental task. Instructions were provided in written form and verbally. For the experimental task, the 108 listeners were divided into 6 groups, with 18 listeners in each group. Each listener group was assigned to sentences produced by three children. The sentences were blocked by child, with three sentences at each timepoint (BASE, POST, and FUP) randomized within the child block. Children's blocks (of 9 sentences) were presented in random order to the listener. Listeners also provided ratings on an additional three sentences (approximately 10%) for reliability at the end of the assessment. In total, each listener

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reduction purposes (Beeson & Robey, 2006; Pennington et al., 2019). Two groups of listeners ($n_{group1} = 41$, $n_{group2} = 40$) rated the ease of understanding of 8 and 9 children, respectively, on a visual analog scale. A linear mixed models analysis with fixed effects of time and random effects of listeners found no significant rating differences between the baselines (F (1, 4031.43) = 1.38, p = .240). Therefore, only Baseline 2 responses, collected in the week prior to treatment commencement, were included to represent baseline performance.

[3] While listener ratings are a valid and widely-used measure to quantify intelligibility in dysarthria (e.g., Kim et al., 2011; Stipancic et al., 2016; Tjaden et al., 2014; Yunusova et al., 2005), and EoU ratings were selected as the intelligibility measure for this study, ratings are more subjective than is transcription accuracy (Hustad, 2006), for example, as considered further in the Discussion section. The term "EoU" is used interchangeably with "intelligibility" here, although EoU has a connotation of effort in decoding speech.

rated 30 sentences (27 experimental sentences + three sentences for reliability). The final data file included 162 listener ratings for each of the 17 children, totaling 2754 ratings for 153 sentences. The listeners were not provided any information about the children or treatment conditions.

Acoustic Analysis

Across the three timepoints, six acoustic measures were examined: (a) articulation rate, (b) SPL, (c) F1 frequencies, (d) F2 frequencies, and (e) F1 difference and (f) F2 difference between vowels. Articulation rate is considered a global index of children's speech production skills (Allison & Hustad, 2018; Darling-White et al., 2018). Additionally, articulation rate and SPL measures were expected to verify the presence of production changes post-treatment (Fox & Boliek, 2012; Pennington et al., 2018) in response to the "big mouth and strong voice" instructions. We followed the criteria of Allison and Hustad (2018) in defining articulation rate as the speech rate (in syllables per second) excluding silent periods of greater than 200 ms within a sentence. To calculate articulation rate via this measure, each sentence was segmented from the beginning of the first syllable to the end of the last syllable, with the boundaries determined by the appearance (beginning) and cessation (end) of acoustic energy (Klatt, 1975; Levy & Law, 2010). Any pauses greater than 200 ms between these boundaries were marked and removed in the calculation of sentence duration. This sentence duration was then divided by the number of syllables in the sentence to arrive at an articulation rate value in syllables per second (Allison & Hustad, 2018; Darling-White et al., 2018). These same sentences were used to calculate average SPL (i.e., vocal intensity) per sentence (Tjaden et al., 2013). Measures were obtained with a combination of the waveform and wideband spectrogram in Praat (Boersma & Weenink, 2020).

In addition, F1 and F2 of the low back vowel /ɑ/[4] in the word "dog" and the low front vowel /æ/ in the word "bath" were examined. These vowels and their formant differences representing their distance in acoustic vowel space were selected based upon the prior finding that the back-front vowel dimension is one of four parameters accounting for a great degree of variance in the intelligibility in adults with dysarthria due to CP (Ansel & Kent, 1992) and in children with hearing impairment (Monsen, 1978), as well as reports of vowel dispersion measures associated with intelligibility (e.g., Hustad et al., 2010; Mou et al., 2019).

The words representing the /ɑ/ and /æ/ vowels were selected based on their frequency of occurrence in the children's narratives. The formant frequencies were determined by the second author and a research assistant by means of the wideband spectrographic display and linear predictive coding spectrum for a 25-ms window that was centered at the temporal midpoint of the steady state portion of the vowel. Formant tracks were visually inspected and hand-corrected if needed. The formant differences between vowels were calculated by subtracting the F1 value of /ɑ/ from the F1 of /æ/ (i.e., F1 difference), and subtracting the F2 of /ɑ/ from the F2 of /æ/ (i.e., F2 difference), similar to the methodology of Metz et al. (1990) and Monsen (1978).

Assessment of Communicative Participation

A parent of each child completed a Focus on the Outcomes of Communication Under Six (FOCUS) questionnaire regarding their child's communication at BASE, POST, and FUP. This FOCUS outcome tool was developed by Thomas-Stonell et al. (2013) in alignment with the International Classification of Functioning, Disability and Health (World Health Organization,

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[4] The vowel in the word "dog" may be pronounced as the low back /ɑ/ or the more mid-central /ɔ/, depending on the AE dialect. For simplicity, we refer to /ɑ/ as the vowel in "dog", as children came from various states, not just the New York area, where /ɔ/ is prevalent.

2001) framework, to measure changes in children's communicative participation. Although designed for young children, the FOCUS has also been implemented for older children (e.g., Pennington et al., 2018) as a single tool to gather relatively comprehensive information across children. Parents responded to questions such as "My child joins in conversations with her/his peers." Responses are rated on a scale from 1 to 7, with 1 corresponding to "not at all like my child" and 7 corresponding to "exactly like my child."

Statistical analysis

Intelligibility and Acoustic Measures

Separate linear mixed effects models were employed to analyze the effect of time (BASE, POST, FUP) upon the dependent variables of EoU rating and the acoustic measures of articulation rate, SPL, F1, F2, F1 difference and F2 difference between vowels. For EoU, the dependent measure was maintained at its original scale (from 0 = "difficult to understand" to 100 = "easy to understand") as it showed approximately normal distribution and no extreme values or outliers were detected. Random effects of child and listener were also included in the EoU modelling. For the acoustic parameters, a random effect of child was included in the modelling. All models included the maximal random effects structure justified by the design.

Communicative Participation

Total and subcategory scores of the FOCUS questionnaire (Thomas-Stonell et al., 2013), completed by parents at each timepoint, were calculated to assess changes in communicative participation. One child was excluded from the analysis because of incomplete questionnaires. To determine effects of SIT on FOCUS scores, non-parametric Friedman tests were conducted, followed by post-hoc Wilcoxon signed-rank tests with Bonferroni correction. A Spearman rank-order correlation was performed to examine associations between gains in EoU and gains in FOCUS total scores.

Reliability

Intelligibility: Intra- and inter-listener reliability of EoU were calculated by means of intraclass correlation coefficient (ICC), determined from a two way mixed-model (with random listener effects and fixed measure effects) for absolute agreement and consistency of ratings among listeners, respectively. For intra-listener reliability, 10% of the sentences were randomly selected for presentation to each listener at the end of the task. The single measures ICC was .81 (95% CI [.77, .85]) and the average measures ICC was .90 (95% CI [.87, .92]), both suggesting good intra-listener reliability.

For the inter-listener reliability of EoU, the average ICC was considered the primary measure of agreement among listeners, as aggregate listener performance has been of focus in previous studies (e.g., Tjaden et al, 2014). Because 18 listeners were grouped together to rate three children's speech, ICC was determined for each group of 18 listeners (total of six groups). The average ICC ranged from .87 (95% CI [.67, .98]) to .99 (95% CI [.97, .99]), suggesting good to excellent inter-listener reliability. All of the ICCs were statistically significant ($p < .001$).

Acoustic measures: 20% of the original sentences, as well as vowels in the words "dog" (/ɑ/) and "bath" (/æ/) were randomly selected and re-measured by a second judge. Reliability was indexed using Pearson product–moment correlations and absolute measurement errors. For the narrative sentences, the correlation between the first and second measurements of SPL was .99 (mean absolute difference measure = 0.03 dB, SD = 0.14 dB). The correlation between the first and second articulation rate measures was .99 (mean absolute difference measure = 0.06 s, SD = 0.06 s). For F1 and F2 measurements, the correlation between values determined by the first and second judges was .95 for F1 (mean absolute difference measure = 36 Hz, SD = 44 Hz) and .97 for F2 (mean absolute difference measure = 49 Hz, SD = 59 Hz).

Results

All 17 children with dysarthria completed the treatment, with no adverse effects reported.

Changes in Intelligibility

The average EoU ratings for the group of children at each of the three timepoints are presented in Figure 1. Linear mixed effect models revealed a significant main effect of time on the listeners' EoU (F (2, 2794) = 9.41, $p < .001$). Post-hoc Bonferroni-corrected pairwise comparisons indicated a significant increase in EoU from BASE to POST (mean difference = 3.54, 95% CI [1.33, 5.76], $p < .001$) and BASE to FUP (mean difference = 3.39, 95% CI [1.18, 5.61], $p = .001$). No significant differences were found between POST and FUP (mean difference = 0.15, 95% CI [-2.06, 2.36], $p > .05$).

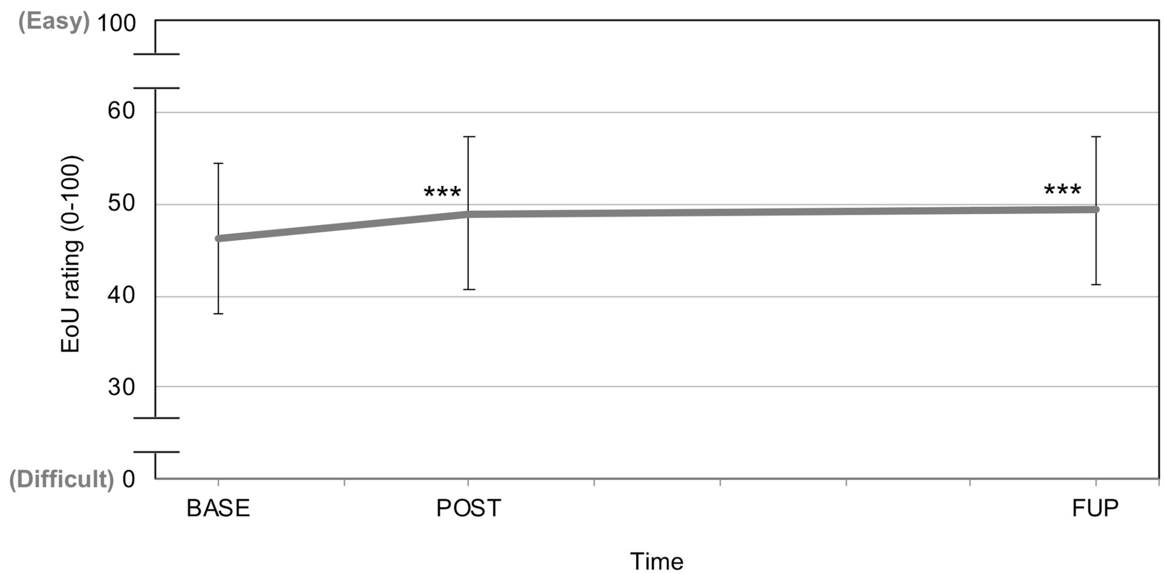

Figure 1. Average ease of understanding (EoU) rating across 17 children with dysarthria at baseline (BASE), immediate post-treatment (POST), and 6-week follow-up (FUP). Standard error bars are included. ***$p \leq .001$.

Given the considerable variability in EoU change across children, individual data are also displayed (see Figure 2). Data are presented in order of severity of dysarthria at baseline. As can be seen, 10 children exhibited some increase in EoU immediately following treatment. However, 7 showed decreases. Closer examination revealed that children who exhibited an increase in EoU immediately after treatment experienced an average of 21% EoU increase post-treatment (range:

1.32 – 78.46%), and those whose EoU decreased experienced a 13% EoU decrease post-treatment (range: -35.16 – -2.40%).

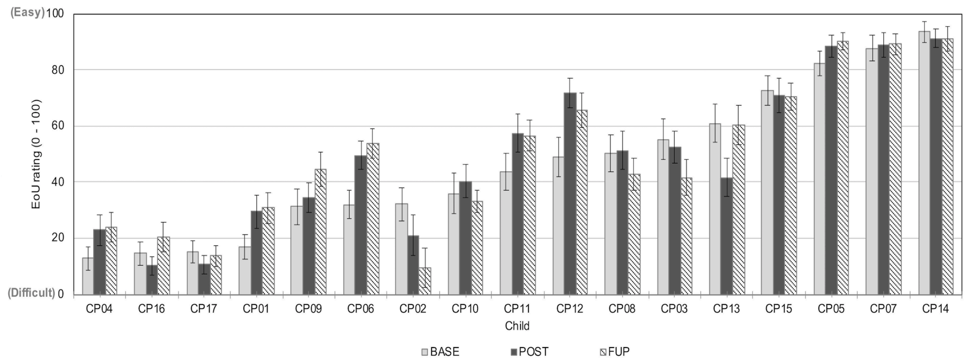

Figure 2. Average ease of understanding (EoU) rating for each of the 17 children with dysarthria at baseline (BASE), immediate post-treatment (POST), and 6-week follow-up (FUP). Children are listed in order of severity of dysarthria at baseline. Standard error bars are included.

Further analysis was performed on the changes in EoU across categories of severity of dysarthria (as judged by the three SLPs). The children were divided into three groups—mild, moderate, and severe reductions in intelligibility at baseline, as can be seen in Figure 3. Statistical analysis showed a significant increase in EoU at POST in the Mild and the Moderate groups (both with $p < .001$). The significant improvement was maintained for 6 weeks in the Moderate group only. In contrast, there was a significant decrease in EoU immediately after treatment in the Severe group ($p < .001$), followed by a significant increase from POST to FUP ($p < .001$). The remaining comparisons, including the Severe group's BASE to FUP change, were not significant ($p > .05$). Generally, no clear pattern could be ascertained regarding the influence of other possible factors (e.g., age or salient speech characteristics) that may have contributed to the gains.

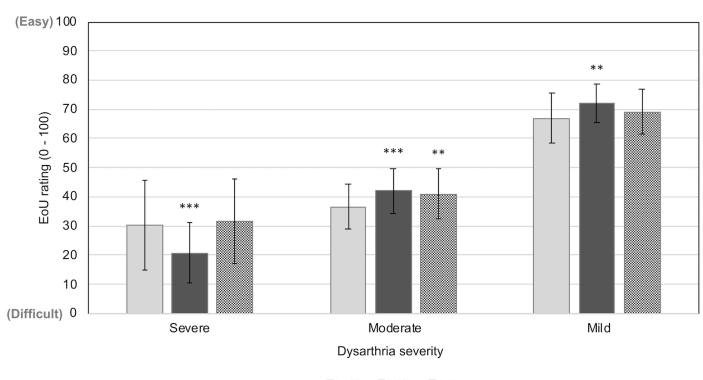

Figure 3. Average ease of understanding (EoU) rating for the 17 children with dysarthria divided into 3 subgroups (Severe (n = 3), Moderate (n = 8), Mild (n = 6)) based on baseline dysarthria severity as assessed by 3 speech-language pathologists. EoU at baseline (BASE), immediate

post-treatment (POST), and 6-week follow-up (FUP) are shown. Standard error bars are included. ***$p < .001$, **$p < .01$.

Changes in Acoustic Measures

Table 3 presents mean group acoustic data for the children's articulation rate (in syllables per second), SPL, vowel formants F1 and F2, and the formant differences between the vowels /æ/ and /ɑ/ across the three timepoints. Linear mixed effects analysis revealed no significant main effect of time on articulation rate ($F(2, 134) = 0.15$, $p = .862$) or SPL ($F(2, 134) = 1.07$, $p = .345$). F1 and F2 of the vowels (/ɑ/) in "dog" and (/æ/) in "bath" varied in degree and direction of change across the three timepoints. There was no statistically significant main effect of time for the vowel /ɑ/ (F1: $F(2, 32) = 1.38$, $p = .265$; F2: $F(2, 32) = 2.41$, $p = .106$) or /æ/ (F1: $F(2, 30.98) = 0.51$, $p = .604$; F2: $F(2, 31.40) = 0.98$, $p = .388$). For the formant differences between /æ/ and /ɑ/, a significant main effect of time was found for F2 ($F(2, 31.6) = 3.37$, $p = .047$) but not for F1 ($F(2, 30) = 0.70$, $p = .504$). Bonferroni-corrected post-hoc pairwise comparison revealed a significant increase in F2 difference at POST (mean difference = 229 Hz, 95% CI [36, 422], $p = .021$) and a marginally significant increase at FUP (mean difference = 192 Hz, 95% CI [4, 388], $p = .054$) relative to BASE. All other comparisons were not statistically significant ($p > .05$), Varying degree and direction of acoustic change were observed at the individual level.

A subsequent analysis of the acoustic changes was performed on the subgroup of 10 children who exhibited an increase in EoU at POST. A significant main effect of time was found for F2 difference between /æ/ and /ɑ/ ($F(2, 17.7) = 4.49$, $p = .027$), with the post-hoc analysis showing significantly greater F2 difference at POST compared to BASE (mean difference = 392 Hz, 95% CI [23, 761], $p = .035$). All other comparisons were not significantly different across the three timepoints. Furthermore, in the 7 children whose EoU declined at POST, there was no significant change in the articulation rate, SPL, or F1 or F2 difference between /æ/ and /ɑ/ after treatment (all *p*s > .05).

Table 3
Average articulation rate (syllables per second), sound pressure level (SPL), first formant (F1), second formant (F2), and formant differences between /æ/ and /ɑ/ (/æ-ɑ/), for the 17 children with dysarthria at the three timepoints.

	BASE Mean (SD)	POST Mean (SD)	FUP Mean (SD)
Rate (syllables/sec)	2.45 (0.88)	2.50 (0.90)	2.48 (0.75)
SPL (dB)	56.58 (4.17)	57.42 (5.11)	56.56 (6.65)
F1 (Hz)			
dog /ɑ/	739 (123)	719 (145)	792 (184)
bath/æ/	954 (208)	938 (193)	911 (193)
/æ-ɑ/	215 (194)	218 (221)	166 (185)
F2 (Hz)			
dog /ɑ/	1469 (362)	1333 (181)	1343 (211)
bath/æ/	1728 (269)	1821 (261)	1779 (281)
/æ-ɑ/	259 (432)	488* (289)	451 (221)

Note. BASE= baseline; POST= immediate post-treatment; FUP= 6-week follow-up; SD= standard deviation. Mean and SD at FUP for /æ/ and /æ-ɑ/ are calculated based on 16 children's data because one child did not produce the target word "bath" at FUP.

*$p < .05$.

Changes in Communicative Participation

Figure 4 reveals the FOCUS scores (Thomas-Stonell et al., 2013) yielded by parent ratings for each of the nine subcategories across the three timepoints, reflecting their children's communicative participation. The scores increased from BASE to POST for all children. For all children except one, gains were maintained at FUP. A non-parametric Friedman test revealed a statistically significant increase in FOCUS total score following SIT, $\chi^2(2) = 21.81$, $p < .001$. Post-hoc analyses with Wilcoxon signed-rank tests were conducted with Bonferroni correction, resulting in a significance level set at .025 (.05/2), as FOCUS scores were each analyzed at two timepoints. The total score increased significantly from BASE to POST ($Z = 3.41$, $p < .001$) and from BASE to FUP ($Z = 3.47$, $p < .001$). Median total score was 205.5 at BASE, 240.5 at POST, and 258 at FUP. Eight of the 9 FOCUS subcategories showed significant gains at POST (all *p*s < .05), with the greatest increases found in the intelligibility, speech, and expressive-language subcategories (43.04%, 31.08%, and 18.55% increase, respectively). Only the independence subcategory showed no significant differences between BASE and POST ($\chi^2(2) = 1.59$, $p = .451$).

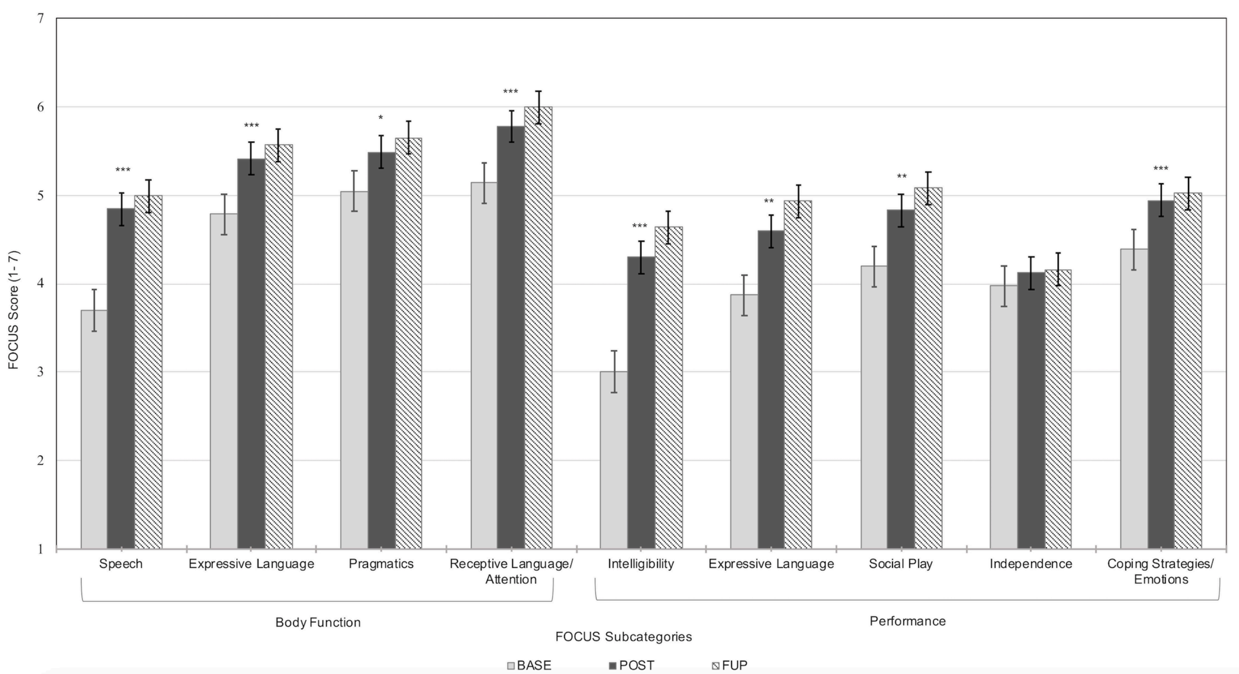

Figure 4. Focus on the Outcomes of Communication Under Six (FOCUS) score for each subcategory at baseline (BASE), immediate post-treatment (POST), and 6-week follow-up (FUP). FOCUS score ranges from 1 to 7, with 7 indicating greatest communicative participation. Standard error bars are included. ***$p \leq .001$, **$p < .01$, *$p < .05$.

A Spearman rank-order correlation was conducted to determine the relationship between changes in FOCUS total score and changes in EoU. No significant correlation was found between the two measures from BASE to POST ($r = .13$, $p = .625$) or from BASE to FUP ($r = -.02$, $p = .931$).

Discussion

The current study examined the outcomes of SIT provided to a group of 17 children with dysarthria secondary to CP over a period of six years. Following three weeks of SIT, the children exhibited significant improvements in narrative intelligibility and communicative participation overall, although there was minimal change to acoustic measures of speech production. Considerable variability in response to SIT was observed across the children. Taken together, results indicate that the dual-focus treatment shows promise for improving everyday communication of children with CP and dysarthria, but responses to treatment may vary across children. As discussed below, these findings add to the limited existing knowledge on the effects of speech treatment in this population.

Intelligibility Changes

Consistent with the study hypotheses, SIT yielded improvements in the children's narrative speech intelligibility that were maintained until at least six weeks post-treatment. While small, the 6% and 7% increase in EoU rating to immediate post-treatment and to 6-week follow-up, respectively, may suggest clinically meaningful improvements in this population with significant motor limitations (Stipancic et al., 2016). A subgroup analysis of the children whose EoU improved after treatment revealed 20% and 21% EoU increases at post-treatment and follow-up, respectively, further supporting meaningful intelligibility improvement in the children who benefit from SIT. These results are in line with Moya-Galé et al.'s (2020) findings of gains in narrative intelligibility in French-speaking children with dysarthria immediately following SIT. The present study included more children with dysarthria than most previous studies and examined narrative intelligibility with the important dimension of vocal SPL included in intelligibility assessment (Švec & Granqvist, 2018). The current findings demonstrate that the improvements in intelligibility following SIT can be maintained for at least six weeks. These results are consistent with the outcomes of Pennington et al. (2010, 2013), who demonstrated maintenance of intelligibility improvements for 6 to 12 weeks following the Speech Systems Approach. With regard to LSVT LOUD, findings are also in line with Fox and Boliek's (2012) results from the sentence level preference task and Boliek and Fox's (2017) word transcription results at immediate post-test, although maintenance of gains has been variable (Boliek & Fox, 2017; Fox & Boliek, 2012).

Further examination of the results in terms of the children's dysarthria severity revealed a significant improvement in EoU following treatment in children with mild to moderate dysarthria, with the improvement maintaining for at least 6 weeks in the moderate group. These results suggest a relationship between dysarthria severity and treatment effects, with children with moderate dysarthria benefiting the most from SIT, perhaps due to greater capacity for improvement. In contrast, children with severe dysarthria prior to treatment evidenced a significant decrease in EoU immediately after treatment, and recovered to baseline EoU 6 weeks later. We speculate that for those who have very poor motor control, the intensive treatment may cause fatigue at first, and, therefore, a less intensive approach might be more appropriate for children with more severe dysarthria. Fatigue has been suggested as a factor in intelligibility reductions in CP (e.g., Hodge, 2013; Moya-Galé et al., 2020), including for Moya-Galé et al.'s finding of intelligibility decreases in French-speaking children with dysarthria who were randomized to the intensive physical therapy treatment. Results from the current analysis need to be interpreted with caution, however, due to the small numbers in the subgroups. These patterns among subsets of children underscore the need to ascertain predictors of treatment-related intelligibility gains for the provision of the appropriate treatment for a particular child.

Acoustic Changes

The current study revealed increases in intelligibility following SIT; however, these were not accompanied by salient change in acoustic measures. Indeed, there was no change to articulation rate, SPL, individual vowel formants, or F1 difference between vowels post-treatment. Only one significant change in acoustic measurement was noted—an increase in F2 difference between vowels (i.e. the difference between the F2 of /æ/ and F2 of /ɑ/) immediately after treatment, with the change from baseline maintaining at six weeks post-treatment.

When data from the subgroup of 10 children who experienced an increase in EoU immediately after treatment were analyzed, these children exhibited greater F2 difference between vowels post-treatment than at baseline, whereas the children with a decrease in EoU after treatment did not. Consistent with the association found between intelligibility and F2 changes in non-treatment studies (e.g., Ansel & Kent, 1992; Ferguson & Kewley-Port, 2002; Levy et al., 2017; Monsen, 1878; Perkell et al., 2002; Stevens & House, 1955; Tjaden et al., 2013), these findings suggest greater tongue excursion along the anterior-posterior plane and, therefore, a greater contrast between front and back low vowels, post-SIT. That vowel height, as reflected by F1 within and between /æ/ and /ɑ/, did not change was not surprising, given that both are low vowels.

Furthermore, no pattern of acoustic change, other than the increase in F2 difference between vowels, could be ascertained from inspection of the individual data. Thus, despite the articulatory- and phonatory-focused treatment, our acoustic findings provide few clues regarding the sources of the intelligibility improvement, as has also been the case in previous studies (Fox & Boliek, 2012; Moya-Galé et al., 2020; Pennington et al., 2018).

The minimal change and variability in acoustic measures may reflect the more complex task of self-generated narrative sentences than, for example, single word naming or sentence repetition tasks. Narrative sentences vary in semantics, syntax, and phonetic complexity, among other characteristics, all of which could affect the children's speech production and intelligibility (Allison & Hustad, 2014; van Brenk & Kuschmann, 2018). Additionally, as Moya-Galé et al. (2020) suggest, the amplitude envelope of the speech signal included whispered speech, which is common in dysarthria and may have affected SPL measurement variably (Duffy, 2019; Fox & Boliek, 2012). Clearly, unanswered questions remain regarding the nature of the acoustic changes that trigger the perceptual gains. Improvements in prosody and articulatory precision have been suggested as possible factors in treatment-related intelligibility gains in children with dysarthria (Miller et al., 2013; Pennington et al., 2018).

Communicative Participation

Communicative participation was measured in terms of parents' ratings on the FOCUS questionnaire (Thomas-Stonell et al., 2013). FOCUS scores improved significantly in the children with dysarthria, as indicated immediately and six weeks after treatment, suggesting greater communicative participation. Because a primary goal for many children with dysarthria is to increase their participation in life situations, including sharing knowledge, ideas, and feelings, improvements in communicative participation have meaningful implications for the children and their families (Eadie et al., 2006; Torrence et al., 2016). All subcategories of participation improved significantly, except for the subcategory of independence. Given that each child was typically with at least two adult clinicians at all times for safety, it was not surprising that independence did not improve. The participation gains found in the present study were expected and are consistent with previous studies (e.g., Boliek and Fox, 2017; Pennington et al., 2013).

It is important to note that parents were not blinded to treatment conditions; thus, the FOCUS scores may also reflect factors beyond communicative participation, including the parents' perspective on their children's SIT experience. This may also have contributed to the finding of no significant association between speech intelligibility gains and communicative participation. Similarly, Pennington et al. (2013) report an overall participation increase for some children, but no relationship between intelligibility and participation gains. Unlike for intelligibility assessment, because the respondents to questionnaires in Pennington et al. (2013) and in the current study were not blinded, placebo effects of participation cannot be ruled out, in part because parents are keen on having their children in treatment. As could also be speculated for the present study, Pennington et al. (2013) suggest that their nonsignificant relationship between intelligibility and participation gains might also be attributable to other therapeutic effects such as the children's improved confidence, as was also reported anecdotally by parents in the present study. Blinding of parents in future studies could follow a model similar to that of Maas et al.'s (2020) childhood apraxia of speech treatment program. Their design involves treatment and non-treatment phases, with parents not informed of the phase in which their child is.

Limitations and Future Research

This study has the advantage of focusing on more real-life communication skills through the assessment of narrative speech; however, this does come with its limitations. That is, while the children generated a narrative, a cognitively and linguistically complex task similar to tasks in everyday communication (Ebert & Scott, 2014), our use of narrative stimuli resulted in a relinquishment of control over variables such as sentence length and complexity, which may have affected our acoustic results (Allison & Hustad, 2014; Sakash et al., 2020). Non-treatment studies, such as Hodge and Gotzke's (2014) validity investigation, have found comparable intelligibility between repeated utterances and narrative speech. However, it is conceivable that pre- and post-treatment, children might also imitate speech characteristics of the stimuli, including rate and loudness characteristics, thereby confounding or obscuring any treatment effects. Thus, self-generated narrative speech was presumed to more closely approximate the children's everyday speech, with the disadvantage that it was less experimentally controlled than repeated utterances would be. Nonetheless, the number of syllables per sentence and the story told were equivalent across timepoints, limiting variability to some extent. Moreover, reliability of listeners was high. Clues to sources of the children's post-treatment intelligibility increases and the limited acoustic changes might be gleaned from further examinations of the data in relation to linguistic factors and in comparison to the children's data from more controlled tasks. Additional acoustic variables that require exploration in treatment studies of this population include consonant measures, further measures of vowel formant trajectories and dispersion, prosody, as well as measures of acoustic variability (Higgins & Hodge, 2002; Hustad et al., 2010; Kent & Vorperian, 2018; Lee et al., 2014; Mou et al., 2019; Tjaden et al., 2013; Weismer et al., 1992).

Furthermore, this study focused on children with dysarthria who had received treatment, without comparison to a control group. It was determined that the two baselines were not significantly different from each other, suggesting that the post-treatment changes were not simply a reflection of day-to-day variation (Pennington et al., 2019). Still, without a control group, confounding factors could include positive effects of the camp-like environment and greater comfort speaking to new people. Results may be compared to those of Moya-Galé et al.'s (2020) study of French-speaking children with dysarthria, who were randomized to SIT or to a physical therapy program (Bleyenheuft & Gordon, 2014) with similar dosage and intensity. Their finding of significant intelligibility gains in only the SIT group may point to SIT, rather than to the intensity or social component of the camp-like setting, as the source of the intelligibility improvements. Nevertheless, differences in variables such as language (French vs. English), the children, and the clinicians, render it imperative to follow up with larger studies, with controls to verify the conclusions drawn from the current findings.

Additionally, the listeners' EoU rating implemented here as a measure of intelligibility may be considered less objective than transcription accuracy (Hustad, 2006). It is possible, for example, that a child with fewer dysarthric characteristics, but more speech errors, might be rated as easier to understand than a child whose message can be understood, but who has more salient or distracting dysarthric characteristics. Still, transcription accuracy score and EoU rating comparisons within the same individuals with dysarthria show similar patterns (Levy et al., 2017; Stipancic et al., 2016), suggesting EoU as a valid alternative to orthographic transcription for documenting intelligibility in dysarthria (Kim et al., 2011; Stipancic et al., 2016; Tjaden et al., 2014; Yunusova et al., 2005). Ratings may, in fact, be considered more nuanced than transcription alone when two sentences are identified or transcribed accurately, but one with more ease and confidence than the other. However, listeners' transcriptions can provide not only a more objective lens, but also insight on any segmental-level effects of the treatment. Therefore, analyses of listeners' accuracy and error patterns in transcribing the children's speech are a direction of future research.

Conclusion and Clinical Implications

Our findings suggest promising effects of the dual-focus treatment, SIT, on communication in children with dysarthria secondary to CP. No adverse outcomes occurred, thus establishing the safety of the program (Beeson & Robey, 2006). Small but significant improvements were found in the children's intelligibility, using a narrative speech task with high external validity, alongside gains in communicative participation. Overall, the present findings suggest that implementing SIT may improve the daily communication of children with dysarthria. However, there are caveats: The children's intelligibility results were highly variable. It appears likely that this approach may work for some, but not all, children, with children with severe dysarthria benefiting less from the treatment. Future research could assess whether specific patterns of speech deficits, language skills, age, or other factors are more likely to result in improved speech production with SIT.

Benefits of SIT include that it is an easily replicable treatment, free of charge, with a simple strategy and progression designed specifically for children with dysarthria. Clinically-relevant questions remain, however, regarding translation of the camp-like environment and treatment dosage to SLPs' settings and schedules, as well as whether more than one treatment focus might impair the attention needed to optimize motor learning (Kleim & Jones, 2008). High variability among children was evident on all measures and small changes were found in the acoustic outcomes measured. Thus, follow-up studies will address further clinical questions such as which candidates with dysarthria may benefit most from SIT, in addition to testing a larger cohort of children, refining the treatment dosage and maintenance protocol, as well as measuring longer-term treatment outcomes.

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