SPEECH BREATHING ACROSS TASK IN CHILDREN WITH CEREBRAL PALSY AS COMPARED TO TYPICALLY DEVELOPING CHILDREN

by

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Abstract

PURPOSE: The present study examined how speech task influenced speech breathing in children with cerebral palsy (CP) as compared to typically developing (TD) peers. There is limited research regarding speech breathing in children with CP. Understanding how the respiratory system supports speech production during various speech tasks can help researchers to construct appropriate models of speech production and clinicians to remediate speech disorders effectively.

METHOD: Four children with CP and four age- and sex-matched TD peers completed two speech tasks to simulate differing cognitive-linguistic loads. An extemporaneous speech task represented a higher cognitive load, while an oral reading task represented a lower cognitive load. Respiratory inductive plethysmography was used to collect respiratory kinematic data. Respiratory data were analyzed in a custom, semiautomated MATLAB program. Dependent variables included utterance length, speech rate, sound pressure level, percent vital capacity per syllable (%VC/syll), lung volume initiation (LVI), lung volume termination (LVT), lung volume excursion (LVE), and inspiratory duration.

RESULTS: Results are presented as a case series of pairs, each including one participant from the CP group and one participant from the TD group. The majority of children produced longer utterances and faster speech rates during reading than during extemporaneous speech. Intensity was approximately the same across tasks. The majority of children used a higher %VC/syll, higher LVI, higher LVT, and greater LVE in extemporaneous speech than in reading. All children had longer inspiratory durations for the extemporaneous task than for the reading task.

CONCLUSION: Speech task affects speech breathing. Children with CP demonstrate different speech breathing patterns from TD children, particularly if children with CP have concomitant speech motor impairment.
Keywords: cerebral palsy, speech breathing, speech task
Introduction

Cerebral palsy (CP) is a heterogenous group of disorders characterized by Rosenbaum et al. (2007) as nonprogressive movement and posture disturbances resulting from abnormal fetal or infant brain development and often co-occurring with deficits in sensation, perception, cognition, communication, and behavior. The most common cause of severe motor disability in children, CP is estimated to occur in approximately 3.6 per 1000 children, and 10,000 to 20,000 new cases are reported in the United States each year (Hustad, 2010). The etiology of the disease was previously thought to be due to an anoxic event during birth; however, more recent research indicates that prenatal and postnatal variables may be involved (Hustad, 2010).

The characteristics and the severity of tonal/movement impairment vary considerably. Types of CP are defined by motor characteristics and neurologic lesion site. Spastic CP is the most commonly occurring category, followed by athetoid (dyskinetic) CP, followed by ataxic CP, affecting approximately 70-80%, 10-20%, and 5-10% of individuals with CP, respectively (Stanley et al., 2000). Children with spastic CP generally display “increased muscle tone, hyperactive reflexes, abnormal patterns of posture or movement, and increased resistance to externally imposed movement” (Hustad, 2010, p. 361). Children with athetoid (dyskinetic) CP present with “abnormal patterns of posture or movement, including involuntary, uncontrolled, and recurring movements,” which can affect the entire body (Hustad, 2010, p. 361). Children with ataxic CP demonstrate “loss of coordination, resulting in problems with force, rhythm, and accuracy of movement” (Hustad, 2010, p. 361). CP is further characterized by anatomic or topographical distribution. That is, motor impairment may affect two limbs (hemiplegia or diplegia), three limbs (triplegia), or all four limbs (quadriplegia).
Among the various comorbidities that children with CP may experience are cognitive-linguistic deficits and speech motor involvement. It is important to consider cognitive and linguistic abilities because these factors impact speech production (Nordberg et al., 2014). Determining the prevalence of cognitive-linguistic impairment in individuals with CP has proven difficult, but estimates range from 23% to 60% (Odding et al., 2006; Sigurdardottir et al., 2008; Himmelmann et al., 2010; Nordberg et al., 2012). Hustad (2010) defines speech motor involvement as “any evidence of motor impairment in any one or more of the speech subsystems (articulation, phonation, resonation, respiration) that can be observed at rest, during speech, or during feeding” (p. 367) and includes dysarthria, excessive drooling, and facial asymmetry. Speech motor impairment is estimated to occur in 20-70% of children with CP (Hustad, 2010; Nordberg et al., 2014). Speakers with CP tend to have speech deficits that involve all speech subsystems to varying degrees (Hustad, 2010).

While speech motor involvement may result in deficits in any single or combination of speech subsystems, the present study focused specifically on the respiratory subsystem. The respiratory subsystem provides the driving pressure required to produce speech. Respiration for speech, or speech breathing, is a carefully regulated process. Solomon and Charron (1998) define speech breathing as “the respiratory mechanics used to inhale before speaking and to generate and maintain subglottal air pressure during speech production” (p. 61). Passive and active forces within the respiratory system must be balanced to support speech (Huber & Stathopulos, 2015). At rest, the lung volume is at end expiratory level, or “the point in the respiratory cycle at the end of a tidal expiration” (Huber & Stathopulos, 2015, p. 14). During inspiration, lung volume exceeds end expiratory level, generating a positive recoil force. This positive recoil force helps return the lung volume to end expiratory level during expiration. As one expires below end
expiratory level, negative recoil force is generated. This negative recoil force assists the lungs in inspiring to return to end expiratory level. These recoil forces are passive; that is, they are not produced by muscle contraction, but rather the elasticity of the lung tissue. Respiratory muscles are used to apply active force to the respiratory system during speech production. Active muscular force is necessary when passive recoil forces are not sufficient to generate the necessary pressure needed for the demands of speech production. For example, active muscular forces are solely responsible for pressure generation for speech production below end expiratory level since passive recoil forces are working to expand and not contract the lungs. When more active muscular force is needed to produce speech, the individual performs more work. Doing more work is perceived as more effortful respiration.

Three major findings from a review by Solomon and Charron (1998) indicate that respiratory function is affected in children with CP. First, respiratory muscles may be weak or be poorly controlled in children with CP (Solomon & Charron, 1998). Because of this, it might be difficult for children with CP to generate sufficient force for adequate speech production. Second, children with CP may exhibit inefficient valving of the airstream by the larynx, velopharynx, and orofacial articulators (Solomon & Charron, 1998). Inefficiencies in valving may lead to breath leaking from the respiratory system. Expending greater lung volume during speech might result in shorter utterances or pausing at syntactically inappropriate places. Third, uncoordinated, paradoxical movements of the chest wall are more likely to be present in children with CP (Solomon & Charron, 1998). This means that the chest wall may be expanding outward while lung volume is decreasing, or the chest wall may be compressing inward while lung volume is increasing. This paradoxical movement is highly inefficient for respiration. Additionally, children with CP may have spasticity of the chest wall, making inspiration
difficult. To compensate for the rigidity of the rib cage, children with CP may recruit more respiratory muscles to generate active forces. In turn, respiration may be more effortful in children with CP as they may need to work harder to inspire and expire. Impairments in respiratory physiology may contribute to common auditory-perceptual features of dysarthria in children with CP, including inappropriate phrasing, reduced stress, voice quality changes, and monoloudness (Workinger & Kent, 1991).

Unfortunately, there is a dearth of literature regarding speech breathing in children with cerebral palsy, particularly in ecologically valid tasks like connected speech. It is important to consider speech breathing in a variety of connected speech tasks. In one’s daily life, one may be required to perform various speech tasks that require adjustments in speech production. For example, school age children will need to produce speech when responding to questions in the classroom, reading aloud, or interacting with peers on the playground. A child will need to produce different levels of intensity depending on the context. In the school library, the child will need to use a quiet voice, but during play the child may desire a louder voice. Thus, the demands of the speech task will likely tax the speech production system differently depending on context.

Speech breathing has been examined across different types of connected speech tasks in adults with speech motor impairment that may have similar respiratory subsystem impairments (e.g., respiratory muscle weakness, chest wall rigidity), such as the Parkinson disease (PD) population (Bunton, 2005; Huber & Darling, 2011). As such, clinicians and researchers must look to the adult literature to inform clinical decision making and to drive hypothesis formation regarding this population. Bunton (2005) examined speech measures of speakers with PD compared to healthy controls. The speakers with PD demonstrated differences in utterance length, speech rate, lung volume initiation, and lung volume termination during speech (Bunton,
Differences in speech breathing behavior between individuals with PD and older adults was also exacerbated by tasks with higher cognitive-linguistic load. Huber and Darling (2011) compared extemporaneous speech, representing a high cognitive load, to oral reading, representing a lower cognitive load, in individuals with PD and in healthy controls. Individuals with PD were found to have more difficulty integrating language and respiratory support for speech in the extemporaneous speech task than did the control participants. Huber and Darling (2011) posited that respiration reflects speech planning and that speech production relies on interaction between cognitive-linguistic factors and physiologic factors. This evidence supports that the cognitive-linguistic complexity of the task plays a role in speech breathing patterns.

Given that children with CP may have respiratory physiologic deficits and cognitive-linguistic impairment, it is imperative to examine how these deficits impact speech breathing in connected speech. With such limited research, it is difficult to formulate directional hypotheses regarding speech breathing in children with CP. However, given what is known about speech breathing in PD, children with CP will likely demonstrate utterance length, lung volume initiations, and lung volume terminations that differ from typically developing (TD) peers. It is possible that tasks that increase cognitive-linguistic load might exacerbate aberrant speech breathing patterns in children with CP. In the case of the present study, an oral reading task represents a low cognitive-linguistic load and an extemporaneous speech task represents a high cognitive-linguistic load. Based on what is known from previous studies, it is likely that acoustic and respiratory measures will differ across speech task. Knowing how speech breathing is impacted by speech task in children with CP can give clinicians more insight into how these children function in their daily lives. It is important to understand how the respiratory system adjusts for various speech tasks in order to construct appropriate models of speech production.
and to effectively remediate speech disorders (Huber & Stathopoulos, 2015). The present study addressed the following research question: How does speech task influence speech breathing in children with CP as compared to typically developing peers?

**Methods**

**Participants**

Approval for all study procedures was obtained by the University of Arizona Human Subjects Review Board (Protocol 16055837A005). Eight children were included in the present study: four children with CP and four age- and sex-matched TD peers. These participants appear in Darling-White (2022), but the data presented in the current study are unique. Children with CP were recruited through specialty clinics and public postings. All TD children were recruited through postings in the community and on public websites. Written consent from legal guardians and verbal assent from participants were obtained before data collection was initiated.

**Children with Cerebral Palsy**

Four children with CP (two males and two females) were included in the present study. Two of the children with CP (F01CP and M08CP) were 13 years old at the time of data collection, one child with CP (F02CP) was 14 years old, and one child with CP (M04CP) was 11 years old. To be included in the study, children needed to (a) be fluent American English speakers, (b) communicate verbally as the primary mode of communication, and (c) be able to follow basic directions. Children were excluded if they had a history of head, neck, or chest cancer or surgery.

A certified speech-language pathologist determined the presence or absence of a speech motor impairment (i.e., dysarthria) using standard clinical procedures relying on perceptual assessment. Two of the participants with CP (F01CP and M08CP) had a diagnosis of dysarthria.
All participants had normal hearing as evidenced by passing a pure-tone hearing screening at 20 dB HL for 500, 1000, 2000, and 4000 Hz.

Children’s core language score on the Clinical Evaluation of Language Fundamentals-Fifth Edition (CELF-5; Wiig et al., 2013) was used to determine the presence or absence of a language impairment. Participant M08CP, whose first language was Chinese and who had been learning American English for approximately 3 years, was not given the CELF-5 as it was deemed inappropriate. However, there were no parent reports of language impairment, and M08CP was fluent in American English at the time of data collection and was able to follow all directions to participate in the study.

Lung function was examined to ensure the health of the participants’ lungs prior to data collection. To test vital capacity (VC) and forced vital capacity (FVC), each participant completed a maneuver while breathing into a digital spirometer (VacuMed Discovery Handheld Spirometer). For the VC maneuver, participants were instructed to inspire as much air as possible and then expire as much air as possible. For the FVC maneuver, participants were instructed to inspire as much air as possible and then expire as hard and fast as possible. During these maneuvers, a researcher held the digital spirometer and encouraged the participants to produce each task to their maximum capability. Normal lung function was defined as VC and FVC values that were greater than or equal to 80% of expected values based on age, sex, height, and weight coded into the spirometer (VacuMed Discovery Handheld Spirometer).

Children with CP were not required to have normal lung function. Three of the four children with CP demonstrated normal lung function. One participant (F01CP) did not participate in lung function testing, but did not have any reported chronic or acute respiratory illness.
Gross motor function was characterized for the children with CP. Tonal/movement abnormalities (e.g., spastic), topographical distribution (e.g., diplegia and hemiplegia), and scores on the Gross Motor Function Classification System (GMFCS; Palisano et al., 1997) are reported in Table 1. The GMFCS is a standard measurement tool designed for children with CP that classifies gross motor abilities into five levels. GMFCS Level I represents the least impairment (i.e., the child can walk, run, climb stairs, and jump independently, but the child may be limited in speed, balance, and coordination), and GMFCS Level V represents the greatest impairment (i.e., the child requires a manual wheelchair for transport in all settings, and the child is limited in resisting gravity for head and trunk postures and in controlling limb movements). Additional details about the participants can be found in Table 1.
Table 1: Demographics for children with cerebral palsy.

<table>
<thead>
<tr>
<th>Participant</th>
<th>Age (years)</th>
<th>Language impairment</th>
<th>Speech motor impairment</th>
<th>Type of CP</th>
<th>GMFCS</th>
</tr>
</thead>
<tbody>
<tr>
<td>F01CP</td>
<td>13</td>
<td>Severe impairment</td>
<td>Yes</td>
<td>Spastic diplegia</td>
<td>II</td>
</tr>
<tr>
<td>F02CP</td>
<td>14</td>
<td>No impairment</td>
<td>No</td>
<td>Spastic hemiplegia</td>
<td>I</td>
</tr>
<tr>
<td>M04CP</td>
<td>11</td>
<td>No impairment</td>
<td>No</td>
<td>Spastic</td>
<td>I</td>
</tr>
<tr>
<td>M08CP</td>
<td>13</td>
<td>Did not complete</td>
<td>Yes</td>
<td>Spastic quadriplegia</td>
<td>II</td>
</tr>
</tbody>
</table>

Note: F=female; M=male; CP=cerebral palsy; GMFCS=Gross Motor Function Classification System

Age- and Sex-Matched Typically Developing Peers

Four age- and sex-matched TD children were included in the present study. To be included, TD children needed to (a) be fluent American English speakers, (b) have no reported history of speech, language, hearing, or learning problems, (c) have normal speech, language, and hearing, and (d) demonstrate normal lung function based on their age, sex, height, and weight. Children were excluded if they had a history of head, neck, or chest cancer or surgery.

Perceptual assessment by a certified speech-language pathologist determined that all TD children had typical speech production and voice quality. All TD children scored within the average or above average range on the core language section of the CELF-5 (Wiig et al., 2013).
All TD children were determined to have normal lung function based on the procedure described above.

**Equipment and Data Collection**

Data collection took place over two sessions, roughly 1 week apart, as part of a larger study. Respiratory and acoustic data were collected at the Motor Speech Research Laboratory at the University of Arizona during one of these sessions. Data collection took approximately 60 minutes. Frequent breaks were provided to prevent fatigue. At the time of data collection, participants were free of allergies or cold symptoms.

**Acoustic Signal**

An omnidirectional headset microphone (Shure WBH53) with a flat frequency response up to 20 kHz was used to transduce the acoustic signal. The microphone was held at a constant distance of 6 cm from the participant’s mouth. The microphone signal was recorded to a digital audio recorder (Marantz PMD-671) with a compact flash card and was later transferred to a computer. Goldwave was used to resample the acoustic signal at 18 kHz with a low-pass filter at 9 kHz for anti-aliasing.

**Respiratory Kinematic Data**

Respiratory inductive plethysmography (Inductotrace system, formerly Respitrace, Ambulatory Monitoring Inc.) was used to collect respiratory kinematic data. Two elastic bands, one placed around the rib cage inferior to the axilla, and one placed around the abdomen at the level of the navel, inferior to floating ribs, were used to transduce the movement of the rib cage and the abdomen. LabChart (ADInstruments) digitized the respiratory kinematic data using a sampling rate of 1 kHz/s. The acoustic and respiratory kinematic signals were time-locked via LabChart.
Once the bands were placed appropriately, participants engaged in a series of calibration tasks. Performance during the calibration tasks is described in detail in Darling-White (2022). Correction factors for the rib cage (RC) and abdomen (AB) were calculated from the rest breathing calibration task using the least squares method (LsqRC/AB). For the rest breathing calibration task, participants wore nose clips and breathed quietly through a digital spirometer over two 45-s trials for a total of 1.5 mins. The correction factors for the RC signal (k1) and the AB signal (k2) are solved for using a Moore-Penrose pseudoinverse function in the following formula:

\[ \text{Spirometer (L)} = k1 \text{ (RC)} + k2 \text{ (AB)} \]

The correction factors for the RC and AB signal were then used to estimate lung volume during speech tasks. This method has been validated for children with CP and typically developing children (Darling-White, 2022).

All respiratory kinematic measurements described below were measured as a % of VC. Participants performed one to three VC maneuvers while wearing the Respitrace bands. VC was measured from the peak of the inspiratory phase of the maneuver to the trough of the expiratory phase of the maneuver using a customized MATLAB program. The program chooses the best maneuver to use for further calculations.

**Speech Stimuli**

Each participant completed two speech tasks: a reading task and an extemporaneous speech task. For the reading task, children were asked to read “The Caterpillar” (Patel et al., 2013) aloud. For the extemporaneous speech task, children were asked to speak about a topic of their choice for about 2 min.

**Measurements**
Speech Measures

The speech measures used were utterance length, speech rate, and sound pressure level. Utterance length was defined as the number of syllables per breath. Praat (version 6.1.16; Boersma & Weenink, 2020) was used to visually inspect the acoustic data and to determine the number of syllables. A syllable had to contain one vowel to be counted as a syllable. Diphthongs were counted as one syllable. Prolonged vowels were determined to be one syllable if the vowel remained constant or part of a diphthong. Single vowels that were repeated (e.g., “e-e-e-even”) were counted as separate syllables. Syllabic /n/ and /l/ were counted as syllables. Speech rate was defined as the number of syllables per utterance divided by utterance duration (syllables/second). Syllables were manually entered in the custom, semiautomated MATLAB program used to measure the respiratory kinematic measures described below. Utterance length and speech rate were calculated using this program.

Sound pressure level was calculated as the mean intensity (dB) of each speech segment produced during the task exclusive of pauses. The spectrogram displayed in Praat was used to identify when the participant was speaking and when they were pausing. A pause was defined as a period of silence 0.15 seconds or longer. Each pause and speech segment were marked in the textgrid. A customized MATLAB program was used to extract the mean intensity (dB) from each speech segment based on the labels from the textgrid.

Respiratory Kinematic Measures

Respiratory data was analyzed in a custom, semiautomated MATLAB program. Prior to all measurements, the program prompted the user to mark the end expiratory level, the rest position of the lung-thorax unit, from three rest breaths collected prior to the start of the speech task. All respiratory measurements were measured relative to end expiratory level, such that
positive values indicate lung volumes above end expiratory level and negative values indicate lung volumes below end expiratory level. End expiratory level was defined as the average of the troughs of three rest breaths. Any utterance with a cough or laugh was not included in the measurements.

The respiratory kinematic measures used were inspiratory duration, lung volume initiation, lung volume termination, lung volume excursion, and percent vital capacity per syllable. Inspiratory duration was defined as the amount of time in seconds spent inspiring before each utterance. This was manually measured as the trough of the previous expiration to the peak of the inspiration of the utterance being measured. Lung volume initiation (LVI) was defined as the lung volume at the onset of speech for a particular utterance. Lung volume termination (LVT) was defined as the lung volume at the offset of speech for a particular utterance. The time-locked acoustic signal was used as a guide for these measures. Lung volume excursion (LVE) was defined as the difference between LVI and LVT. Lung volume measures were expressed as a percent of vital capacity. Percent vital capacity per syllable (%VC/syll) was defined as the amount of lung volume used for each syllable and was calculated by dividing LVE by the number of syllables in a given utterance.

**Statistical Analysis**

Means and standard errors for each measure were calculated for each participant and are presented below. No inferential statistics were calculated for the present study.

**Results and Discussion**

Results are reported below in pairs of CP participants and their age- and sex-matched TD peers. For each pair, a table and figures report the means and standard errors for speech and respiratory kinematic measures.
Pair 1: F01CP and F17TD

**Figure 1:** Mean utterance length for F01CP and F17TD.

![Mean Utterance Length Chart]

**Figure 2:** Mean speech rate for F01CP and F17TD.

![Speech Rate Chart]
Figure 3: Mean %VC/syllable for F01CP and F17TD.

Figure 4: Mean inspiratory duration for F01CP and F17TD.
Figure 5: Mean percent lung volume excursion for F01CP and F17TD.
Table 2: Pair 1 Data

<table>
<thead>
<tr>
<th>Participant</th>
<th>Utterance Length</th>
<th>Speech Rate</th>
<th>SPL</th>
<th>%VC/syll</th>
<th>%LVI-EEL</th>
<th>%LVT-EEL</th>
<th>%LVE</th>
<th>Inspiratory duration</th>
</tr>
</thead>
<tbody>
<tr>
<td>F01CP read</td>
<td>9.92(0.89)</td>
<td>3.35(0.11)</td>
<td>77.13(0.43)</td>
<td>1.10(0.08)</td>
<td>-16.06(1.63)</td>
<td>-26.73(1.48)</td>
<td>10.67(0.99)</td>
<td>0.74(0.07)</td>
</tr>
<tr>
<td>F01CP ex</td>
<td>6.83(1.01)</td>
<td>3.29(0.21)</td>
<td>77.04(0.68)</td>
<td>2.32(0.31)</td>
<td>8.69(3.97)</td>
<td>-6.34(3.19)</td>
<td>15.02(2.41)</td>
<td>0.88(0.06)</td>
</tr>
<tr>
<td>F17TD read</td>
<td>22.55(3.09)</td>
<td>4.94(0.25)</td>
<td>78.60(0.45)</td>
<td>0.82(0.10)</td>
<td>17.08(1.36)</td>
<td>-2.92(2.32)</td>
<td>20.00(3.03)</td>
<td>0.55(0.04)</td>
</tr>
<tr>
<td>F17TD ex</td>
<td>14.71(1.74)</td>
<td>3.97(0.22)</td>
<td>77.10(0.32)</td>
<td>1.75(0.26)</td>
<td>20.40(1.67)</td>
<td>1.61(1.40)</td>
<td>18.79(1.58)</td>
<td>0.82(0.08)</td>
</tr>
</tbody>
</table>

Note: CP=cerebral palsy; TD=typically developing; read=reading task; ex=extemporary task
F01CP: Reading vs. Extemporaneous Speech

This child was a 13-year-old female with spastic, diplegic cerebral palsy and concomitant dysarthria. Additional demographic information is reported in Table 1. Data for speech and respiratory kinematic measures can be found in Table 2 and Figures 1-5.

F01CP produced longer utterances in the reading task than in the extemporaneous speech task. She used approximately the same rate for both tasks. The difference in utterance length may reflect planning time. During a reading task, the content is already provided, so the individual does not have to allocate cognitive resources to generating content and can instead plan to continue speaking through the end of a sentence or paragraph. During extemporaneous speech, one must allow for planning the content. If the content is uncertain, then planning must occur simultaneously with speech production. F01CP likely produced shorter utterances in this task because she did not plan the content ahead of speech. The fact that speech rate was approximately the same for both tasks supports that utterance length is a reflection of cognitive-linguistic planning rather than a product of rate. Across both tasks, F01CP produced almost the same sound pressure level. Thus, lung volume changes did not reflect changes in sound pressure level.

F01CP used higher %VC/syll during extemporaneous speech than in reading. She also demonstrated greater LVE for the extemporaneous speech task than for the reading task. Taken together, these findings indicate an inefficiency in valving of the upper respiratory tract, which is again suggestive of planning. Reading is such a highly regulated task because the content is already available. The reader can plan for how much air to use and when to adduct or abduct the vocal folds. In extemporaneous speech, the speaker is unsure of the exact content, so the motor plan must be developed on-line and laryngeal valving is not as efficient. This valving
inefficiency then leads to greater LVE in the extemporaneous speech task because more air is lost with loose valving than in the reading task. F01CP had longer mean duration of inspiration for extemporaneous speech than for reading. Again, this is thought to reflect planning time. In extemporaneous speech, the individual must plan what to say, and so requires more time during inspiration to allow for this planning. Alternatively, a longer inspiratory duration may allow for greater inspiratory volume, which would allow the speaker to take advantage of greater passive forces during speech production. If so, the speaker may not need to work as hard to produce speech. However, in the reading task, F01CP started speaking below end expiratory level and ended far below end expiratory level. This seems inefficient in terms of the amount of effort it takes to produce speech. She was not inspiring much to prepare for speech, so she had to rely on mostly active forces for speech production. It is possible that the spasticity or stiffness of F01CP’s respiratory musculature prevented her from taking large inspiratory breaths. This would explain why she did not appear to prepare for speech with inspirations greatly above end expiratory level. Similarly, during extemporaneous speech, she began her utterances above but close to end expiratory level and terminated her utterances below end expiratory level. So, there were more active forces involved in reading than in extemporaneous speech, but overall F01CP appears to be using mostly active forces rather than passive recoil of the lungs to drive speech.

Of note, F01CP had concomitant language impairment, which may have played a role in her breathing patterns. It is possible that the reading task was more challenging for her than the extemporaneous speech task. During extemporaneous speech, F01CP could select a comfortable topic and familiar vocabulary. During reading, she may have been unfamiliar with the topic and/or some vocabulary words. Cognitive resources would have been allocated to reading difficult words, and so planning for speech was affected.
**F17TD: Reading vs. Extemporaneous Speech**

This child was a 13-year-old typically developing female. Data for speech and respiratory kinematic measures can be found in Table 2 and Figures 1-5.

F17TD produced longer utterances in reading than in her extemporaneous task. She also had a faster speaking rate during reading than during extemporaneous speech. The increased speaking rate allowed her to produce longer utterances in the reading task. The faster rate in reading was likely a result of reduced planning. Again, the content is available during a reading task, so a reader does not need to take additional time to think about the content and can therefore produce speech at a faster rate. Intensity across tasks was approximately the same.

F17TD did not manage her air differently across tasks to change intensity. Differences across tasks are attributed to cognitive-linguistic planning rather than increased or decreased intensity.

F17TD used higher %VC/syll during extemporaneous than in reading, and she had greater LVE during extemporaneous speech than in reading. This reflects inefficient valving due to planning. Reading is a highly regulated task in which the content is available, so it is easy to plan how much air to use and when to adduct/abduct the vocal folds. In a monologue, when the content is uncertain, the valving is less precise. Greater LVE is a result of inefficient valving.

F17TD demonstrated longer inspirations during the extemporaneous task than for the reading task. The longer inspiration duration allows for time to plan what to say. Alternatively, taking more time to inspire may have allowed for greater volume inspired, which would allow the speaker to take advantage of passive recoil forces and reduce effort while speaking. F17TD began her utterances at a higher LVI in the extemporaneous task than in the reading task. Again, for extemporaneous speech, the content is yet to be planned. Inspiring to a greater LVI allows for
greater passive recoil and reduced effort to drive speech. The element of planning is once again
reflected in taking a larger breath to prepare for an utterance of length yet unknown.

**Comparison of F01CP to F17TD**

F01CP and F17TD demonstrated breathing patterns that were similar and different. Both
produced longer utterances in reading than in extemporaneous speech. Both used higher
%VC/syll during extemporaneous speech than reading and had greater LVE for the
extemporaneous task than for reading. Both had longer inspiration times for extemporaneous
speech than for reading. Both participants maintained their intensity across tasks.

F01CP used approximately the same rate for both tasks, but F17TD had a faster rate in
the reading task than the extemporaneous task. It is possible that F01CP was unable to adjust her
speaking rate due to dysarthria. F01CP had lower LVI/LVT in both tasks than did F17TD. The
mean difference for LVI change across tasks was much larger for F01CP than F17TD. It may be
that F01CP could not take large breaths due to spasticity/stiffness of her chest wall.

**Pair 2: F02CP and F38TD**

**Figure 6:** Mean utterance length for F02CP and F38TD.
**Figure 7:** Mean speech rate for F02CP and F38TD.

**Figure 8:** Mean %VC/syllable for F02CP and F38TD.
**Figure 9:** Mean inspiratory duration for F02CP and F38TD.

**Figure 10:** Mean lung volume excursion for F02CP and F38TD.
Table 3: Pair 2 Data

<table>
<thead>
<tr>
<th>Participant</th>
<th>Utterance Length</th>
<th>Speech Rate</th>
<th>SPL</th>
<th>%VC/syll</th>
<th>%LVI-EEL</th>
<th>%LVT-EEL</th>
<th>%LVE</th>
<th>Inspiratory duration</th>
</tr>
</thead>
<tbody>
<tr>
<td>F02CP read</td>
<td>13.55(1.41)</td>
<td>4.98(0.22)</td>
<td>78.42(0.46)</td>
<td>0.89(0.03)</td>
<td>15.57(0.97)</td>
<td>3.60(0.91)</td>
<td>11.97(1.29)</td>
<td>0.47(0.04)</td>
</tr>
<tr>
<td>F02CP ex</td>
<td>10.19(1.02)</td>
<td>3.14(0.23)</td>
<td>77.36(0.43)</td>
<td>1.59(0.25)</td>
<td>24.81(0.98)</td>
<td>12.12(1.00)</td>
<td>12.69(1.02)</td>
<td>0.69(0.06)</td>
</tr>
<tr>
<td>F38TD read</td>
<td>7.41(0.57)</td>
<td>4.85(0.21)</td>
<td>84.82(0.29)</td>
<td>0.93(0.08)</td>
<td>8.30(0.52)</td>
<td>1.78(0.61)</td>
<td>6.52(0.67)</td>
<td>0.28(0.02)</td>
</tr>
<tr>
<td>F38TD ex</td>
<td>11.00(1.24)</td>
<td>4.05(0.23)</td>
<td>80.44(0.27)</td>
<td>1.25(0.13)</td>
<td>2.06(0.58)</td>
<td>-8.04(0.98)</td>
<td>10.10(0.91)</td>
<td>0.46(0.03)</td>
</tr>
</tbody>
</table>

Note: CP=cerebral palsy; TD=typically developing; read=reading task; ex=extemporaneous task
**F02CP: Reading vs. Extemporaneous Speech**

F02CP was a 14-year-old female with spastic, hemiplegic cerebral palsy. Additional demographic information is reported in Table 1. Data for speech and respiratory kinematic measures can be found in Table 3 and Figures 6-10.

F02CP produced longer utterances in reading than in extemporaneous speech, and she used a faster rate in reading than in extemporaneous speech. Increasing speech rate for the reading task allowed her to produce more syllables per breath, or longer utterances. She likely produced a faster rate of speech in reading because she did not need to delegate cognitive resources to creating the content of speech. She could speak more quickly in the reading task because the content was already provided. F02CP produced approximately the same intensity across tasks. The difference in utterance length can be attributed to rate of speech rather than management of air for intensity.

F02CP used higher %VC/syll for extemporaneous speech than for reading. She also produced greater LVE for extemporaneous speech than for reading. This reflects inefficient valving during extemporaneous speech, again due to planning. Loose valving then leads to greater LVE in this speech task. F02CP had a longer inspiratory duration for her extemporaneous speech than in reading. This reflects planning time. She also had a higher LVI for extemporaneous speech than for reading. Starting with a greater LVI would allow her to take advantage of passive recoil to reduce effort. It would also allow her to plan for a longer utterance if she needed to produce one.

**F38TD: Reading vs. Extemporaneous Speech**

F38TD was a 13-year-old typically developing female. Data for speech and respiratory kinematic measures can be found in Table 3 and Figures 6-10.
F38TD produced shorter utterances in reading than in extemporaneous speech. She used approximately the same speaking rate for both tasks. This reflects planning time. During a reading task, F38TD could plan ahead because the content is already given, so she could plan to continue through the end of a sentence. She might plan shorter sentences in reading because content is provided that is shorter in length than natural speech for the child. Longer utterances in extemporaneous speech could mean that the child is not taking time to stop as frequently as is denoted in written sentences by punctuation. Perhaps it is more natural for the child to produce multiple sentences per utterance during extemporaneous speech but pauses to breathe after each sentence in reading because punctuation is denoted for her. F38TD had slightly lower intensity during extemporaneous speech than during reading. It is possible that the difference in utterance length could be due to management of air for intensity regulation.

F38TD used higher %VC/syll for extemporaneous speech than for reading, and she had greater LVE for extemporaneous speech than for reading. This reflects inefficient valving during the monologue, again due to planning. Reading is so highly regulated because the content is already available, so it is easy to plan for how much air to use and when to adduct/abduct the vocal folds. In extemporaneous speech, the content is unknown, so the valving is not as tight. Greater LVE follows because more air is lost with the loose valving. F38TD had a longer inspiration time for extemporaneous speech than for reading. Taking extra time during inspiration allows the individual to plan what to say. F38TD had lower LVI in extemporaneous speech than in reading. This suggests that F38TD was using more active forces during extemporaneous speech than in reading. She can plan ahead for reading by taking a bigger breath to continue through the whole written sentences. In extemporaneous speech, she did not take big breaths to prepare. This reflects poor planning for extemporaneous speech. During reading,
however, she terminated her utterances before she had to produce more effort. Further, lower LVI and LVT in extemporaneous speech explains why intensity was reduced in this task.

**Comparison of F02CP to F38TD**

F02CP and F28TD demonstrated speech characteristics that were both similar and different. Both used higher %VC/syll for extemporaneous speech than for reading. Both had greater LVE for extemporaneous speech than for reading. Both had longer inspiratory durations for extemporaneous speech than for reading.

F02CP had longer utterances in reading than in extemporaneous speech, but F38TD had shorter utterances in reading than in extemporaneous speech. F02CP used a faster rate in reading than in extemporaneous speech, but F38TD used approximately the same rate for both tasks. The faster reading rate employed by F02CP would explain why her utterances were longer in the reading task than in the extemporaneous task. It may be easier to use a faster rate in reading when the content is planned. Perhaps F38TD was already using a comfortable rate and did not modify it across task.

F02CP had a higher LVI for extemporaneous speech than reading, but F38TD had a lower LVI for extemporaneous speech than reading. Both patterns reflect the effect of planning speech content. F02CP had a higher LVI likely because she was planning to need more air for extemporaneous speech. F38TD did not plan to need more air during extemporaneous speech, and so she did not take big breaths to prepare. Taken together with intensity, it seems that F38TD planned for more air during reading in order to increase intensity. F02CP had approximately the same intensity across tasks, but F38TD had lower intensity in extemporaneous speech than in reading. It is possible that intensity reflects her confidence level secondary to cognitive planning.
in that reading provides the content, so the speaker is confident about what to say, but extemporaneous speech must be generated, so the speaker is less confident about what to say.

**Pair 3: M04CP and M43TD**

**Figure 11:** Mean utterance length for M04CP and M43TD.

![Utterance Length Graph](image1)

**Figure 12:** Mean speech rate for M04CP and M43TD.

![Speech Rate Graph](image2)
Figure 13: Mean %VC/syllable for M04CP and M43TD.

Figure 14: Mean inspiratory duration for M04CP and M43TD.
Figure 15: Mean lung volume excursion for M04CP and M43TD.
Table 4: Pair 3 Data

<table>
<thead>
<tr>
<th>Participant</th>
<th>Utterance Length</th>
<th>Speech Rate</th>
<th>SPL</th>
<th>%VC/syll</th>
<th>%LVI-EEL</th>
<th>%LVT-EEL</th>
<th>%LVE</th>
<th>Inspiratory duration</th>
</tr>
</thead>
<tbody>
<tr>
<td>M04CP read</td>
<td>20.00(2.08)</td>
<td>4.48(0.22)</td>
<td>78.05 (0.36)</td>
<td>1.12(0.10)</td>
<td>12.76(3.60)</td>
<td>-9.54(2.50)</td>
<td>22.30(2.92)</td>
<td>0.60(0.16)</td>
</tr>
<tr>
<td>M04CP ex</td>
<td>19.04(1.93)</td>
<td>3.67(0.18)</td>
<td>80.92 (0.32)</td>
<td>0.90(0.08)</td>
<td>13.77(1.97)</td>
<td>-4.86(2.29)</td>
<td>18.63(2.23)</td>
<td>0.63(0.04)</td>
</tr>
<tr>
<td>M43TD read</td>
<td>11.14(1.10)</td>
<td>3.88(0.23)</td>
<td>79.37 (0.42)</td>
<td>1.01(0.12)</td>
<td>12.65(1.45)</td>
<td>1.38(1.46)</td>
<td>11.27(1.48)</td>
<td>0.51(0.06)</td>
</tr>
<tr>
<td>M43TD ex</td>
<td>9.05(1.07)</td>
<td>3.45(0.17)</td>
<td>79.16(0.19)</td>
<td>1.23(0.13)</td>
<td>18.00(1.22)</td>
<td>7.63(1.23)</td>
<td>10.37(1.28)</td>
<td>0.75(0.07)</td>
</tr>
</tbody>
</table>

Note: CP=cerebral palsy; TD=typically developing; read=reading task; ex=extemporaneous task
**M04CP: Reading vs. Extemporaneous Speech**

This child was an 11-year-old male with spastic cerebral palsy. Additional demographic information is reported in Table 1. Data for speech and respiratory kinematic measures can be found in Table 4 and Figures 11-15.

M04CP had approximately the same utterance length for each task. He had a faster rate in the reading task than in the extemporaneous speech task. He likely was able to read faster than he could produce extemporaneous speech because he did not need extra time to plan the content. The same utterance length could be due to the expenditure of air as the limiting factor. M04CP maintained approximately the same intensity across tasks, though he produced slightly greater intensity in the monologue task. This difference in intensity may reflect the child’s possible excitement about his chosen topic. One of the ways to increase intensity is to use more air, but he demonstrated greater LVE during reading than during extemporaneous speech, which is interesting. He may have produced greater intensity through valving the upper respiratory tract rather than by using more air.

M04CP used higher %VC/syll for reading than extemporaneous speech, and he had greater LVE during the reading task than during the extemporaneous speech task. Using higher %VC/syll in reading might explain why utterance length is the same for both tasks. If he is expending more air but ending up with the same utterance length, he could be limited by the amount of breath he is using. Greater LVE for reading than for extemporaneous speech is interesting because it does not follow the patterns of other individuals. Taking bigger breaths and using more air during reading is perhaps due to the planning component. The child can plan for sentences that are longer in reading than for his natural speech patterns. M04CP had a longer inspiration for extemporaneous speech than for reading, but the inspiratory duration was almost
the same across tasks. He took a little longer to plan for extemporaneous speech. However, the difference is slight. It is possible that the spasticity/rigidity of his chest wall prevented him from taking big breaths. To this point, he demonstrated higher LVI in extemporaneous speech than reading, but again the measures were nearly the same. If he is unsure what the content will be, he will need to plan to take advantage of passive recoil forces to reduce effort by taking larger breaths to prepare. But if the rigidity of the chest wall is preventing the child from taking big breaths, then he may not be able to use those passive forces and instead may rely on active forces for expiration. Alternatively, M04CP may not need too much additional planning for the extemporaneous speech task, or he may be taking extra time to plan during the reading task as well.

**M43TD: Reading vs. Extemporaneous Speech**

This child was an 11-year-old typically developing male. Data for speech and respiratory kinematic measures can be found in Table 4 and Figures 11-15.

M43TD had longer utterances in reading than in extemporaneous speech. He had approximately the same rate and intensity for both tasks. The difference in utterance length can be attributed to the difference in cognitive planning rather than using air differently to change intensity.

M43TD used higher %VC/syll during extemporaneous speech than during reading, but the measures were approximately the same. This reflects slightly less efficient valving in extemporaneous speech. However, he has good control of valving for both tasks. He demonstrated greater LVE for reading than for extemporaneous speech. This, coupled with longer utterances in reading, reflects that he is using more air per utterance because due to the effect of utterance length, rather than using higher %VC/syll. Using approximately the same rate
for both tasks supports this because it really is due to longer utterances and longer breaths and
not because there were more syllables produced within the same length of time.

M43TD had longer inspiratory duration for extemporaneous speech than for reading. This
reflects planning time. This also reflects that M43TD was potentially taking in more air to
prepare for speech and to take advantage of passive recoil forces so speech could be less
effortful. Indeed, M43TD’s LVI was higher in the extemporaneous task than in the reading task.
As the content was yet uncertain, he took a larger breath to prepare for the possibility of a longer
utterance.

Comparison of M04CP to M43TD

M04CP and M43TD demonstrated speech characteristics that were both similar and
different. Both had greater LVE for reading than for extemporaneous speech. Interestingly, this
is the opposite trend of the female participants. Both M04CP and M43TD had longer inspiratory
durations for extemporaneous speech than for reading, though M04CP demonstrated similar
inspiratory durations across tasks. Both had higher LVI for extemporaneous speech, but M04CP
had similar LVI across tasks. Interestingly, the participants had LVI comparable to one another
for reading. Both M04CP and M43TD maintained approximately the same intensity across tasks,
but M04CP produced slightly greater intensity in extemporaneous speech.

M04CP had approximately the same length of utterance in each task, but M43D had
longer utterances in reading. M04CP had a faster rate in reading than in extemporaneous speech,
but M43TD had approximately the same rate in both tasks. It may be easier to use a faster rate in
reading when the content is planned. Perhaps M43TD was already using a comfortable rate and
did not need to modify. M04CP used higher %VC/syll in reading, but M43TD used higher
43

%VC/syll in extemporaneous speech. This difference may be attributed to stiffness/rigidity of the chest wall in M04CP.

**Pair 4: M08CP and M75TD**

**Figure 16:** Mean utterance length for M08CP and M75TD.

![Bar chart showing utterance length for M08CP and M75TD in reading and extemporaneous contexts.]

**Figure 17:** Mean speech rate for M08CP and M75TD.

![Bar chart showing speech rate for M08CP and M75TD in reading and extemporaneous contexts.]
**Figure 18:** Mean %VC/syllable for M08CP and M75TD.

![Graph showing mean %VC/syllable for M08CP and M75TD](image)

**Figure 19:** Mean inspiratory duration for M08CP and M75TD.

![Graph showing mean inspiratory duration for M08CP and M75TD](image)
Figure 20: Mean lung volume excursion for M08CP and M75TD.
Table 5: Pair 4 Data

<table>
<thead>
<tr>
<th>Participant</th>
<th>Utterance Length</th>
<th>Speech Rate</th>
<th>SPL</th>
<th>%VC/syll</th>
<th>%LVI-EEL</th>
<th>%LVT-EEL</th>
<th>%LVE</th>
<th>Inspiratory duration</th>
</tr>
</thead>
<tbody>
<tr>
<td>M08CP read</td>
<td>4.81(0.29)</td>
<td>2.21(0.06)</td>
<td>81.43(0.27)</td>
<td>3.53(0.36)</td>
<td>11.78(0.56)</td>
<td>-1.02(0.71)</td>
<td>12.81(0.74)</td>
<td>0.39(0.02)</td>
</tr>
<tr>
<td>M08CP ex</td>
<td>4.78(0.43)</td>
<td>2.24(0.10)</td>
<td>82.25(0.25)</td>
<td>2.72(0.32)</td>
<td>16.16(1.28)</td>
<td>2.49(1.48)</td>
<td>13.67(1.48)</td>
<td>0.50(0.03)</td>
</tr>
<tr>
<td>M75TD read</td>
<td>14.06(1.61)</td>
<td>4.98(0.16)</td>
<td>82.73(0.53)</td>
<td>0.58(0.05)</td>
<td>12.25(0.86)</td>
<td>4.54(0.99)</td>
<td>7.71(0.97)</td>
<td>0.58(0.08)</td>
</tr>
<tr>
<td>M75TD ex</td>
<td>12.52(1.64)</td>
<td>3.59(0.21)</td>
<td>82.00(0.35)</td>
<td>0.85(0.11)</td>
<td>12.76(0.79)</td>
<td>4.38(0.94)</td>
<td>8.38(1.02)</td>
<td>0.79(0.05)</td>
</tr>
</tbody>
</table>

Note: CP=cerebral palsy; TD=typically developing; read=reading task; ex=extemporaneous task
**M08CP: Reading vs. Extemporaneous Speech**

M08CP was a 13-year-old male with spastic, quadriplegic cerebral palsy and concomitant dysarthria. Additional demographic information is reported in Table 1. Data for speech and respiratory kinematic measures can be found in Table 5 and Figures 16-20.

M08CP produced approximately the same utterance length at approximately the same speaking rate across both tasks. Using a similar speaking rate might lead to similar utterance length if the main limiting factor is how many syllables he can produce per breath. Spasticity/chest wall stiffness may account for an inability to manage breaths efficiently. M08CP has dysarthria, so it is possible that he could not adjust his speaking rate for the dysarthria. He maintained approximately the same intensity across tasks, so variations in utterance breath management were not due to variations in intensity.

M08CP used higher %VC/syll for reading than for extemporaneous speech. This indicates tighter valving during extemporaneous speech than during reading. Interestingly, this is the same finding as M04CP but opposite from all other participants. M08CP had greater LVE for extemporaneous speech than for reading. He also began utterances at a higher LVI for extemporaneous speech than for reading. M08CP had longer inspiratory durations for extemporaneous speech than for reading. Taken together, these findings indicate that he was taking bigger breaths to prepare for extemporaneous speech than to prepare for reading. He needed additional time to plan the content of extemporaneous speech. Taking a bigger breath allowed him to take advantage of higher passive forces to drive expiration, which in turn forced more air out of the lungs.

**M75TD: Reading vs. Extemporaneous Speech**
M75TD was a 13-year-old typically developing male. Data for speech and respiratory kinematic measures can be found in Table 5 and Figures 16-20.

M75TD produced longer utterances in reading than in extemporaneous speech. He used a faster rate of speech during reading than during extemporaneous speech. Once again, the faster rate in reading likely accounts for less planning time involved in a reading task than in extemporaneous speech. Using a faster rate in reading allowed for longer utterances during this task. M75TD maintained approximately the same intensity across tasks, suggesting that utterance length is a produce of speech rate rather than adjusting breath patterns to change intensity.

M75TD used higher %VC/syll in extemporaneous speech than in reading, though the values were approximately the same. He showed less efficient valving for extemporaneous speech, but it is likely that this child has good control of valving for both tasks. M75RD had greater LVE, longer inspiratory duration, and higher LVI for extemporaneous speech than for reading. Taking longer and larger breaths suggests planning for speech content to be produced during the extemporaneous task. Beginning at a high LVI increases passive recoil forces and drives expiration during speech, leading to greater LVE and reducing the amount of work required to produce speech. While LVI was higher for extemporaneous speech, it was comparable to LVI for reading. M75TD may not have needed much additional planning for extemporaneous speech, or he may have taken extra planning time during the reading task.

Comparison of M08CP to M75TD

M08CP and M75TD demonstrated features that were both similar and different. Both had greater LVE for extemporaneous speech than for reading. Interestingly, this is the same finding as the female participants, who were also 13-year-olds, but opposite from the other male participants, who were 11-year-olds. Both M08CP and M75TD had longer inspiratory durations
for extemporaneous speech than for reading. Both had a higher LVI for extemporaneous speech than for reading, but M75TD had approximately the same LVI across tasks. Both participants used approximately the same intensity across tasks, so differences in utterance length do not reflect changes in breath management for intensity.

M08CP had approximately the same utterance length across tasks, but M75TD had longer utterances in reading than in monologue. This is likely an effect of speaking rate. M08CP had approximately the same speaking rate across tasks, but M75TD had a faster rate in reading than in extemporaneous speech. Reading was likely faster because cognitive resources did not need to be used to generate the content. It is possible that M08CP was unable to adjust his speaking rate due to dysarthria. M08CP used higher %VC/syll in reading than in extemporaneous speech, but M75D used higher %VC/syll in extemporaneous speech than in reading. Of note, M08CP and M04CP were the only participants who used higher %VC/syll during reading, while M75TD and the remaining participants used higher %VC/syll in extemporaneous speech.

**Conclusion**

This study sought to investigate how speech task impacted speech breathing in children with CP vs. TD children. Several themes emerged from the data and are discussed below.

Overall, both groups tended to have longer utterances during reading than during extemporaneous speech. This happened for two out of four children with CP and three out of four TD children. These results support the findings of Mitchell et al. (1996), who found that healthy adult women produced longer utterances during an outlined discussion task than in extemporaneous speech. For two of the four pairs, the child with CP produced shorter utterance lengths than the TD child. The children with CP in these two pairs were the children with CP
who also had speech motor impairment. Speech motor impairment also results in shorter utterance lengths in individuals with PD as compared to health controls (Bunton, 2005; Huber & Darling, 2011).

The majority of children used a faster speech rate in reading than in extemporaneous speech based on a measure of syllables per second. This occurred for two out of four children with CP and three out of four TD children. No participant used a faster rate in extemporaneous speech than in reading. Mitchell et al. (1996) had similar results regarding speech rate in that participants produced slower speech rates in extemporaneous speech than in an outlined discussion task. Huber and Darling (2011) also found that individuals with PD and healthy controls used a slower rate in extemporaneous speech than in reading. For two of the four pairs, the child with CP used a slower speaking rate than the TD child. The children with CP in these two pairs were the children with CP who also had speech motor impairment. In one pair, the child with CP had a slower rate of speech than the TD child in extemporaneous speech only. In the final pair, the child with CP and the TD child used approximately the same speech rates. Bunton (2005) found that individuals with PD produced slower speech rates than healthy controls.

Intensity was approximately the same across tasks. For three of the four pairs, the child with CP had about the same intensity as the TD child. For one of the four pairs, the child with CP produced a lower intensity than the TD child. Huber and Darling (2011) found that while individuals with PD produced lower intensities than controls during reading, there was no difference in intensity for extemporaneous speech.

The majority of children used a higher %VC/syll in extemporaneous speech than in reading. This occurred for two of the four children with CP and all of the four TD children. Only
the two males with CP used a higher %VC/syll in reading than in extemporaneous speech. Mitchell et al. (1996) found that adult women used higher %VC/syll in extemporaneous speech than in reading. Similarly, Huber and Darling (2011) found that adults with PD and healthy controls had higher %VC/syll for extemporaneous speech than in reading. For two of the four pairs, the child with CP had greater %VC/syll for both tasks than the TD child. The children with CP in these two pairs were the children with CP who also had speech motor impairment. Individuals with PD had higher %VC/syll than healthy controls (Huber & Darling, 2011).

The majority of children began speaking at a higher LVI for extemporaneous speech than for reading. This occurred for all four participants with CP and two of the four TD participants. Huber and Darling (2011) found LVI to be higher in extemporaneous speech than reading for individuals with PD and for healthy controls. For one of the four pairs, the child with CP began speaking at a lower LVI than the TD child for both tasks. For one of the four pairs, the child with CP began speaking at a higher LVI than the TD child for both tasks. For one of the four pairs, the child with CP began speaking at a lower LVI than the TD child for extemporaneous speech only. For one of the four pairs, the child with CP began speaking at a higher LVI than the TD child for extemporaneous speech only. LVI was quite variable. Similarly, Bunton (2005) found that individuals with PD had increased variability in LVI compared to healthy controls.

The majority of children ended speech at a higher LVT in extemporaneous speech than in reading. This was true for all four children with CP and two of the four TD children. This is to be expected as LVT is a function of LVI. LVT was also higher in extemporaneous speech than in reading for individuals with PD (Huber & Darling, 2011). For three of the four pairs, the child with CP ended speech at a lower LVT than the TD child in both tasks. For the remaining pair, the child with CP ended speech at a higher LVT than the TD child in both tasks. The opposite
trend is true for individuals with PD, who demonstrate higher LVT than healthy controls (Huber & Darling, 2011).

The majority of children had greater LVE in extemporaneous speech than in reading. This happened for three children with CP and two TD children. No participant showed the same LVE across tasks. For three out of the four pairs, the child with CP had greater LVE than the TD child in both tasks. Similarly, individuals with PD had larger LVEs than healthy controls (Huber & Darling, 2011).

All children had longer inspiratory durations for the extemporaneous task than for the reading task. In two of the four pairs, the child with CP had longer inspiratory durations than the TD child for both tasks. Notably, these two pairs included female participants. In one pair, the child with CP had longer inspiratory durations than the TD child in reading only. In the final pair, the child with CP had shorter inspiratory durations than the TD child for both tasks. Huber and Darling (2011) found that individuals with PD had longer inspiratory durations in extemporaneous speech than controls but found no difference between groups for reading. Also, the PD group was found to have longer inspiratory durations in extemporaneous speech, but the control group showed no significant differences across tasks.

**Limitations and Future Research**

For the present study, the children in the CP group all had spastic type CP. This is the most commonly occurring type, but it is not the only type. Future studies should include athetoid (dyskinetic) and ataxic subtypes to determine if speech breathing is affected differently across the subtypes.

In general, there is a lack of literature reporting on children with CP. As stated previously, CP is the most common cause of severe motor disability in children. Future research
should include this population because many people live with CP and could benefit from new research findings.

An interesting finding from the present study was that the 11-year-old males had greater LVE in reading than in extemporaneous speech. This was the opposite trend from the older children. It may be worth investigating age effects on speech breathing. Additionally, the female children with CP had longer inspiratory durations than the TD children, but the male children with CP did not. It would be interesting to examine possible effects of sex on speech breathing in children with CP.

The present study only examined two different types of speech tasks, reading and extemporaneous speech via monologue. In the future, it might be interesting to examine how speech breathing changes in tasks such as story retelling or peer-to-peer or adult caregiver-to-child conversation. This would allow a wider range of children with participate given that not all children with CP are able to read due to cognitive-linguistic deficits. A wider range of speech task would also be more representative of the types of speech production demands children are required to do in daily life.

Intellectual disability is fairly common in children with CP. If the child has cognitive-linguistic deficits, speech breathing may also be affected, especially during tasks with higher cognitive-linguistic loads, such as extemporaneous speech. Future research should investigate further into the impact of cognitive-linguistic deficits on speech breathing.

**Summary of Conclusions**

**Speech Task Matters**

While individual variation exists across speech tasks, it is clear that speaking task affects how the individual uses the respiratory system to support speech production. Planning time
increases with extemporaneous speech, as evidenced by all children having increased inspiratory duration in this task. Intensity was relatively unchanged across tasks, so any change in lung volume was not related to intensity. The coupling of the phonatory and respiratory subsystems is less tightly regulated in extemporaneous speech than in reading, as evidenced by greater %VC/syll in extemporaneous speech than in reading. These results support prior research suggesting that the respiratory system interacts with the cognitive-linguistic system. It will be important for clinicians to assess children with CP across various speech tasks not only to maintain ecological validity but also to determine behaviors across task.

**Children with CP Are Different from TD Children**

Children with CP demonstrate different speech breathing patterns from TD children, particularly if children with CP have concomitant speech motor impairment. Children with CP demonstrate higher variability for LVI as compared to TD children, likely due to incoordination of respiratory muscles. Children with CP who also have speech motor impairment produce shorter utterances, use slower speaking rates, and have higher %VC/syll than TD children. Clinicians should keep this in mind as they plan treatment for children with CP and comorbid speech motor impairment.
References


