Title: Word production inconsistency of Singaporean-English speaking adolescents with Down’s Syndrome aged 13-18 years old

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ABSTRACT

**Background:** The nature of speech disorders in individuals with Down Syndrome (DS) remains controversial despite various explanations put forth in the literature to account for the observed speech profiles. A high level of word production inconsistency in children with DS has led researchers to query whether the inconsistency continues into adolescence, and if the inconsistency stems from inconsistent phonological speech disorder (IPD) or childhood apraxia of speech (CAS). Of the studies that have been published, most suggest that the speech profile of individuals with DS is delayed, while a few recent studies suggest a combination of delayed and disordered patterns. However, no studies have explored the nature of word production inconsistency in this population, and the relationship between word production inconsistency, receptive vocabulary and severity of speech disorder.

**Aims:** This pilot study investigated the extent of word production inconsistency in adolescents with DS and examined the correlations between word production inconsistency, measures of receptive vocabulary, severity of speech disorder and oro-motor skills in adolescents with DS.

**Methods and procedures:** The participants were 32 native speakers of Singaporean-English adolescents, comprising 16 participants with DS and 16 typically-developing (TD) participants. The participants completed a battery of standardised speech and language assessments, including The Diagnostic Evaluation of Articulation and Phonology (DEAP) assessment. Results from each test were correlated to determine relationships. Qualitative analyses were also carried out on all the data collected.
**Results:** In this study, 7 out of 16 participants with DS scored above 40% on word production inconsistency, a diagnostic criterion for IPD. In addition, all participants with DS performed poorly on the oro-motor assessment of the DEAP. The overall speech profile observed did not exactly correspond with the cluster symptoms observed in children with IPD or CAS.

**Conclusions and implications:** Word production inconsistency is a noticeable feature in the speech of individuals with DS. In addition, the speech profiles of individuals with DS consist of atypical and unusual errors alongside developmental errors. Significant correlations were found between the measures investigated, suggesting that speech disorder in DS is multi-factorial. The results from this study will help to improve differential diagnosis of speech disorders and individualized treatment plans in the population with DS.

**What this paper adds?**

What is already known on this subject?
Recent studies have found a high level of word production inconsistency in children with Down Syndrome (DS). However, there has been little research examining if the inconsistency continues into adolescence, and whether it from inconsistent phonological speech disorder (IPD) or childhood apraxia of speech (CAS).

What this study adds?
Word production inconsistency is a noticeable feature in the speech of individuals with DS and can continue into adolescence if untreated. The unique speech profile in individuals with DS appears to arise from breakdowns in phonological planning and motor speech program implementation. The importance of careful selection of appropriate assessment and effective intervention approaches is demonstrated.
INTRODUCTION

Down Syndrome (DS), a disorder resulting from the presence of an additional chromosome 21, is a common genetic anomaly encountered in the caseloads handled by speech pathologists. Although there is considerable variation in the degree of cognitive impairment amongst individuals with DS, there is general consensus that individuals with DS have language deficits particularly in language production and syntax, as well as speech deficits causing poor speech intelligibility (Ken & Vorperian, 2013; Roberts, Melkin & Price, 2007). Several studies have reported speech intelligibility as one of the main concerns in the communication of people with DS (Rondal & Edwards, 1997; Kumin, 1994; Kumin, 2006). In a study by Kumin (1994), data collected from 937 parent questionnaires revealed that over 58% of parents reported that their children with DS frequently had difficulty being understood. Even with an increased amount of research conducted in the last decade, the nature of speech disorder in individuals with DS remains controversial. While the debate continues as to whether speech is delayed (Stoel-Gammon, 1997; Van Borsel, 1996), or a combination of delayed and disordered (Dodd & Thompson, 2001; Roberts, Price & Melkin, 2007), there is growing interest with regards to the presence of word production inconsistency in individuals with DS. Dodd and Thompson (2001) first established an observation of high percentage of word production inconsistency in a group of children and adolescents with DS, and found that the group with DS scored similarly in terms of inconsistency, compared to a group of participants with phonological disorder, matched by percentage consonants correct (PCC). Similarly,
Timmins and colleagues (2007) found that individuals with DS present with high variability in production of fricatives, and errors were more noticeable when analysis was carried out by electropalatography compared to perceptual transcription. However, the few studies conducted have not thoroughly examined the characteristics of word production inconsistency in adolescents with DS, nor established possible relations between inconsistency, phonology and oromotor abilities. Understanding the relations between these measures help deduce the level of impairment in the speech processing chain. Clinically, knowledge about these areas enables clinicians to target relevant areas for both assessment and intervention, thereby achieving optimal results during therapy.

**Speech disorder in individuals with DS – Phonological delay versus disorder**

The speech characteristics of individuals with DS appear to be heterogeneous and dependent on numerous factors such as the severity of the genetic condition and implicated levels of intellectual and physical functioning such as sensory deficits, anatomical and physiological irregularities (Miller et al., 1999; Stoel-Gammon, 1997). Some researchers have found that the speech of children with DS reflected delayed phonological characteristics similar to typically-developing (TD) children, based on findings of high occurrence of typical phonological processes and phonological development that appears to parallel that in TD children (Stoel-Gammon, 1997; Van Borsel, 1996).
On the other hand, others have proposed that children with DS display errors suggesting a combination of delayed and disordered phonology (Dodd & Thompson, 2001; Roberts, Price & Melkin, 2007), based on observed atypical characteristics such as: greater than 10% mean frequency of occurrence of processes that affect final consonants, differing order of emergence of sounds (Kumin, Councill & Goodman, 1994), slow and poor acquisition of the feature [+nasal] which should be acquired by two years old, and high percentage of errors in the use of stop consonants in final position (Sommers, Patterson & Wildgen, 1988). A few recent studies examining articulatory and phonological patterns conducted on children and adolescents with DS have also suggested a pattern of both delayed and disordered speech amongst them (Cleland et al., 2010; Timmins et al., 2011; Wood, Wishart, Hardcastle, McCann & Timmins, 2008).

Wood and colleagues (2008) used electropalatography (EPG) to study the speech characteristics of two children with DS and found high percentage of errors in PCC and presence of distorted sounds, which are incompatible to typically delayed phonological development. Additionally, the findings of increased variability and inconsistency in the speech of individuals with DS provide further support of a disordered speech profile.

**Word production inconsistency in individuals with DS**
Word production inconsistency refers to speech that is characterised by a high proportion of differing repeated productions with multiple and unpredictable error types, including both segmental (phoneme) and structural errors (Holm et al., 2007). An example is a six year old child producing ‘umbrella’ as [ʌmbwɛlʌ, ʌmbwɛlʌ, ʌmbwɛlʌ] on three separate occasions in a similar linguistic context. However, consistency is independent of the accuracy of pronunciation, for example, if the child used [ʌmbwɛlʌ, ʌmbwɛlʌ, ʌmbwɛlʌ], he is considered consistent even though his productions of ‘umbrella’ were incorrect.

In young TD children, a certain amount of variability is normal, and can be accounted for by a number of contextual factors including phonetic context, pragmatic context and cognitive linguistic influences (Holm, Farrier & Dodd, 2007). Such developmental variability often continues beyond the acquisition of the first 50 words and indicates a transitional period where adult realization of words is still developing (McLeod & Hewett, 2008). However, when variability is at a high level, it may be indicative of speech impairment.

Amongst the studies investigating the speech of individuals with DS, a few studies have observed word production inconsistency and variability of speech production in this population. Dodd and Thompson (2001) first reported an observation of high level of word production inconsistency in a group of children and young adolescents with DS (mean age 10 years, 6 months). They analysed the speech error patterns of
children with DS and compared them to those of typically developing children with IPD. The study matched participants with DS and IPD by number of PCC, and found that the two groups both scored high levels of inconsistency. All 15 children with DS exhibited high levels of inconsistency (67%) similar to the group of typically developing children with IPD (62%). These scores were significantly higher compared to TD children without speech difficulties who attained a mean inconsistency score of less than 10% (Burt et al., 1999), and also children with delayed phonological disorders who attained a mean inconsistency score of less than 20% (Dodd, 1995).

In the same study (Dodd & Thompson, 2001), comparisons of error pattern profiles between the two groups found that the group with DS made significantly less phoneme changes within words on repeated productions, fewer substitutions for any one phoneme and fewer consonant additions/deletions. These findings led Dodd and Thompson (2001) to hypothesise that the underlying deficits between the children with DS and the children with IPD are different. Two explanations were proposed for the inconsistency observed in the former: one is that they establish incomplete phonological representations of words at the lexical level due to the high occurrence of hearing loss and phonological working memory deficits; the other is that the learning environment of most children with DS accepts their inconsistency, because parents seek the meaning of their children’s inconsistent speech through contextual cues.

In a research conducted by Wood and colleagues (2009) using EPG to assess and treat speech intelligibility problems in two participants with DS (aged 11 years; 6 months and 14 years, 11months), it was found that the participants presented with
high number of inconsistent errors especially with words consisting fricatives and affricates /s, z, ʃ, tʃ, dʒ, ʒ/. Similarly, Timmins and colleagues (2007) used EPG to analysis fricative production of six young people with DS (aged 10 to 18 years) and observed high variability in the articulation of fricatives in these participants.

In view of these past findings, it appears that there is some evidence for the presence of high levels of inconsistency in children and young adolescents with DS. However, previous papers have not explored in depth the nature of whole word inconsistency and the relations between inconsistency, phonological and oromotor performance. This paper hopes to address these and explain the levels of impairment in the speech processing chain, particularly in a group of adolescents with DS.

Inconsistent phonological disorder (IPD) versus childhood apraxia of speech (CAS)

It is believed that inconsistency may stem from either a phonological or motor-planning problem (Dodd, 1995). Inconsistent phonological disorder (IPD) is a phonological planning disorder with inconsistency as its main symptom. The diagnostic label of IPD originated from Dodd's classification system of phonological disorders which subcategorises speech disorders into four types: articulation disorder, delayed phonological acquisition, consistent phonological disorder and IPD (Dodd, 1995).

Children diagnosed as having IPD exhibit high levels of inconsistency but have no difficulties with oro-motor skills (Dodd, 1995). The criterion for diagnosis of IPD was established to be an inconsistency score of 40% or higher as a large-scale study done
by Holm and colleagues (2007) revealed this cut-off was almost 2.5 standard deviations (SD) above the mean inconsistency score of 12.96% obtained in the most variable age-group (3;00 – 3;05 years). Dodd and McCormack (1995) proposed that the underlying cause of IPD is impairment at the phonological planning level, which implies difficulties planning the sequence of phonemes making a word, thus causing inaccurate mental phonological representations of words to be established in the lexicon. This results in children with IPD having phonemic programmes with articulatory parameters that are broader than usual and consequently inconsistency in word production (Dodd & McCormack, 1995).

CAS, on the other hand, is a controversial diagnostic label used to describe a disorder of motor planning, with a cluster of clinical symptoms including: inconsistencies in word productions, greater difficulty with increased utterance length, preserved automatic phrases, greater difficulty in imitation than in spontaneous speech, difficulty combining and sequencing phonemes, vowel production errors, oro-motor difficulties e.g. struggling or groping on speech and non-speech tasks and problems with prosody (Forrest, 2003; Shriberg, Aram & Kwiatkowski, 1997). The Cascade model (refer to figure 1) explains that CAS results from three levels of breakdown in the speech processing chain: phonological plan, phonetic program assembly and motor speech program implementation (Ozanne, 1995). Basically, the model suggests that deficits from each level can impact on other levels, and in CAS impairments in the 3 levels
produce a resultant cumulative effect that leads to the wide spectrum of clinical symptoms observed.

Figure 1: The Cascade model (Adapted from Ozanne, 1995)

Of the aforementioned symptoms, inconsistent errors and increased difficulties with increased word length are symptoms common to both individuals with CAS and IPD. Furthermore, children with CAS and IPD may present with similar speech profiles, e.g. poor performance in assessment of articulation and phonology. Thus, failure to accurately distinguish one from the other is likely. Nonetheless, several symptoms exhibited by children with IPD distinguish them from children with CAS, for example, in IPD, oro-motor difficulties are no greater than children with other speech disabilities whereas oro-motor difficulties are key deficits in CAS; imitation is better than
spontaneous production in IPD while the reverse is true for CAS; fluency, prosody and voice difficulties are not reported in IPD but reported in CAS (Dodd, 1995; Bradford & Dodd, 1996).

With regard to children with DS, it has not been clearly established whether the inconsistency demonstrated stems from CAS, IPD or other phonological deficits. Several recent studies suggested that the diagnosis of CAS is commonly overlooked in individuals with DS (Kumin & Adams, 2001; Kumin, 2006). In these studies, a large proportion of the assessed children with DS exhibited characteristics of CAS, for example, greater difficulty with increased utterance length, preserved automatic phrases, greater difficulty in imitation than in spontaneous speech, oro-motor difficulties e.g. struggling or groping on speech and non-speech tasks and problems with prosody on formal assessments and parental questionnaires. This is in contrast to the findings of similarities between characteristics exhibited by children with DS and children with IPD (Dodd & Thompson, 2001). Dodd and Thompson (2001) noted that children with DS made fewer errors in imitation than in spontaneous production of the same words, and this behaviour is incompatible with the diagnosis of CAS. Nevertheless, it is still firmly established that these children are prone to inconsistent production (Dodd & Thompson, 2001; Stoel-Gammon, 1997; Timmins et al., 2011; Wood et al., 2008), but whether this inconsistency continues into adolescence is not well-established. Furthermore, the nature and reason for this inconsistency remains unclear, hence this paper aims to address these concerns.
Languages in Singapore

In Singapore, most of the population is bilingual with four official languages spoken: English, Mandarin, Malay and Tamil (Gn, Brebner & McCormack, 2014). The second language usually depends on ethnicity, with approximately 75% of the population being English-Mandarin bilingual (Gn et al., 2014).

As this study was conducted in Singapore, all participants were speakers of standard Singaporean-English (SSgE) and the dialect pronunciation features which can affect the results were taken into account in data analysis. SSgE is a form of Standard English similar to other forms of Standard English spoken around the world (Deterding, 2007) and studies investigating the pronunciation of speakers of SSgE found several salient features pertaining to SSgE speakers’ production of consonants and vowels that were different from speakers of Standard British English (SBE) and Australian English (Brown, Deterding & Low, 2000; Deterding, 2007). Refer to Gn et al. (2014) and to Appendix B for the dialectal differences in SSgE.

Assessment and therapy implications for population with DS

Establishing the presence and extent of inconsistency in adolescents with DS is crucial as this knowledge influences clinical methodology and efficacy in speech pathology intervention. Clinical efficacy studies have found that inconsistency in children can be effectively treated by a specific therapy known as Core Vocabulary Therapy. This is different from traditional phonological therapy and therapy for CAS
Thus, a greater understanding of word production consistency in these individuals will assist in the formulation of treatment plans that can increase clinical efficacy.

The present study aims to establish the extent and characteristics of word production inconsistency in adolescents with DS. Furthermore, this study attempted to determine whether inconsistency is related to measures of receptive vocabulary, severity of speech disorder and oro-motor skills in results obtained from adolescents with DS. The study also examined the word production of TD adolescent speakers of SSGe, as the information served as a benchmark for expected word pronunciation and level of inconsistency in this dialect and age-group. Based on the research previously conducted on the inconsistency in children with DS, it was hypothesised that the adolescents with DS in this study would exhibit higher levels of inconsistency compared to TD subjects.

**METHODS**

**Participants**

Thirty-four participants aged 13-18 years were recruited, comprising 18 participants with DS and 16 TD participants. All participants were English-Mandarin bilingual and native speakers of SSGe. Parent and school consent were obtained for all participants, and verbal assent to participate from all participants.
Participants with Down Syndrome. The 18 subjects with DS were drawn from several schools for individuals with intellectual disabilities. Although the intention was to recruit participants aged 13 to 18 years of age, the 18 participants who signed up had a narrow age range; ranging from 16 years 3 months to 17 years 9 months (Mean = 17 years 4 months, standard deviation (SD) = 0.4 years). Nine were female and nine were male. They fulfilled the criteria of (1) a diagnosis of DS with no known current major medical conditions (e.g. neurological injury, cancers), or additional developmental disabilities (e.g. cerebral palsy) (2) having pure-tone average of 25dB bilaterally (3) ability to follow two step commands containing up to two information carrying units and name pictures showing everyday objects (4) not receiving speech-language intervention in the past year and (5) aged between 13-18 years (i.e. adolescence). Records of past speech therapy intervention were not available for use. These criteria excluded two participants from the study as testing was incomplete due to their short attention span and poor understanding of instructions.

Typically-developing Participants. The 16 TD participants, nine females and seven males who ranged in age from 14 years 2 months to 18 years 10 months (Mean age = 16 years 4 months (SD) = 2.1), were enrolled in main-stream schools. They fulfilled the criteria of (1) no existing medical conditions (2) pure-tone average of 25dB bilaterally (3) typical development based on academic progress and (4) aged between 13-18 years (i.e. adolescence). The purpose of this group was not for statistical
comparison, but to provide a reference for typical speech patterns expected in SSgE-speaking adolescents.

Procedure

Each participant went through a hearing screening test followed by receptive vocabulary and speech assessments. All tests were audio-recorded using an Olympus (Model WS-210S) digital voice recorder and video recordings were made for one of the subtests (oro-motor subtest) using a Sony digital video recorder. Testing was undertaken by the first author in a one hour session.

Hearing. A screening otoscopic examination was conducted followed by a pure-tone audiometric assessment. The condition of the ear canal was observed and any abnormalities were recorded. The Interacoustic AD226 diagnostic audiometer was used to test for participants’ responses to pure tones at 25dB for four frequencies (500Hz, 1 kHz, 2KHz, and 4KHz). Participants were included in the study only if they passed the screening 25dB bilaterally for all frequencies.

Receptive vocabulary. Although this study was not designed to include a comparison group for the group with DS, the normative data of Australian and UK children aged 6;6–6;11 years from DEAP were also compared to the receptive vocabulary scores elicited from the Bilingual Language Assessment Battery, BLAB (Lee, Sze & Rickard Liow, 2013) to provide some descriptive information on the participants’ language
level. The BLAB had been developed for use with the multilingual population in Singapore although it should be noted that there are very few standardised assessment tools adapted or designed for use this population. An early version of the BLAB was used to evaluate comprehension of simple noun and verb vocabulary in English, with participants asked to point to the picture of the word spoken by the examiner.

*Diagnostic Evaluation of Articulation and Phonology (Dodd et al., 2002).* The Diagnostic Evaluation of Articulation and Phonology (DEAP) is an assessment consisting of several subtests used for the differential diagnosis of speech disorders. In this study, the phonology, word inconsistency and oromotor subtests were administered. Although the use of single words test items may pose restrictions on the understanding of the participants’ functional carrier system, it was a concern if the participants with DS will be able to perform if the test items were more complex. Only three subtests were used as this study aims to analyse the word production inconsistency present in the participants' speech as literature has suggested inconsistency may stem from a phonological or motor-planning difficulty. The participants’ responses for the phonology and inconsistency subtests were transcribed with reference to the audio-recording using broad phonetic transcription symbols from the International Phonetic Alphabet, with diacritics when necessary. Cueing and scoring were done according to the manual.
**Phonology assessment:**

The Phonology Assessment examines participants’ ability to use sounds in context. The percentage consonants correct (PCC), percentage vowels correct (PVC) and percentage phonemes correct (PPC) were calculated in accordance with the assessment manual instructions. Culturally appropriate variations were excluded in these values. Consistent speech error patterns (five or more examples of error pattern) were identified and classified as typical or atypical phonological processes with reference to data from another study investigating typical development of speech in 4-5 year-old speakers of SSgE (Gn et al., 2014).

**Inconsistency assessment:**

The Inconsistency Assessment was administered to establish consistency of word production. In this subtest, the participants named 25 pictures on three occasions, each separated by an activity of approximately 5-10 minutes. Only inconsistent productions were counted i.e. a score of 1 is given if any of the three productions varied. The scores were then tallied and converted to a percentage score.

In addition, the extent of inconsistency for each participant with DS was investigated by using a phoneme substitution grid (as shown in figure 2). This study also employed methods used in the Dodd & Thompson study (2001), namely the computation of phoneme change, calculated by adding the number of shaded squares not on the diagonal; and maximum number of substitutions per phoneme (the maximum number
of different speech sounds which were substituted for any one phoneme). These methods were chosen to provide comprehensive analyses of substitution patterns, as opposed to only exploring the percentage of inconsistency, which can be misleading because both a single change and multiple changes for a stimulus item yield the same score.

*Figure 2. DEAP Phoneme substitution grid adapted from the DEAP test form (Dodd et al., 2002)*
Oro-motor Assessment: The oromotor subtest consists of three components (Diadochokinetic (DDK) task, isolated and sequenced movements tasks) which evaluate the structure and function of a subject’s speech mechanism. The precision, force, accuracy and rate of each movement were observed and a maximum score of three was given for each movement.

Reliability of transcription and scoring

Inter-judge and intra-judge reliability measures were obtained on approximately 20% of the data (six out of 32 participants) of all subtests of the DEAP. Intra- and inter-judge transcription reliability was obtained using point-to-point agreement. Mean transcription intra-judge reliability for the author was 95.7% for the phonology subtest,
94.0% for the inconsistency subtest and 100% for the oromotor subtest. The third author randomly selected and independently transcribed six samples to obtain inter-rater reliability measures. Inter-judge reliabilities were 92.2% for the phonology subtest, 99.3% for the inconsistency subtest and 98.0% for the oromotor subtest. Dialectal familiarity may account for these differences as the first author is a native speaker of SSgE whereas the third author was not.

RESULTS

The results obtained from the participants with DS were compared to that of the TD group, the normative data for Australian and UK English from the DEAP manual, and data from the study by Dodd and Thompson (2001). Appendix A presents the descriptive statistics for the three subtests obtained from the participants with DS, the TD participants, and normative data of Australian and UK children aged 6;6–6;11 years from the DEAP (2002) manual, which was the oldest group for which comparative scores were available.

Although this study was not designed to include a comparison group for the group with DS, the normative data of Australian and UK children aged 6;6–6;11 years from DEAP provides a useful developmental comparison to the receptive vocabulary scores elicited from the BLAB. Table 1 presents the BLAB score obtained by the two groups of participants in this study.
As shown in Table 1, the participants with DS scored evidently lower in the BLAB assessment compared to TD participants and the standard deviation was greater for the participants with DS in comparison with the TD participants.

**Phonology assessment**

On comparison, the results obtained by the adolescents with DS most closely matched Australian and UK children scoring at the 1st percentile rank (PVC= 0-97%, PCC= 0-90%, PPC= 0-92%). Analyses of sounds in error revealed that the consonant sounds /r, k, s, ð, v/ and the vowel sounds /e, ə, aɪ/ were the most frequently misarticulated. The occurrence of errors was influenced by the phonological structure of the test words; specifically, the adolescents with DS made more errors with syllable-final consonants than with syllable-initial consonants, and more errors with consonants in clusters than with singleton consonants.

A wide variety of speech errors were identified and these errors were classified under four groups: typical phonological processes (PP), atypical phonological processes,
errors of an articulatory nature, and idiosyncratic errors (Clark et al., 2007). The six most frequently occurring typical PPs amongst adolescents with DS (in descending order of frequency) were: (1) CR; (2) fronting (palatal and velar); (3) gliding; (4) FCD; (5) stopping and (6) devoicing. Figure 3 presents the distribution of error types used by the adolescents with DS.

Other than the aforementioned typical processes, atypical processes such as ICD, backing, phoneme insertion, vowel distortions, glottal stop substitution and insertion were also identified amongst all participants with DS, even though only 25% of the participants used them more than 5 times. Glottal stop insertion and substitution was the most frequently occurring atypical process. In this process, an unusual pattern of substitution was frequently used, where the stop portion of the affricate was replaced by a glottal stop, such as, /ʧ/ -> [ʔʃ], /ʤ/ -> [ʔʃ]. While 25% of the participants
consistently used such substitutions, others used this only once or twice. Vowel distortions were the second most commonly occurring atypical process, with errors ranging from inappropriate elongation of a vowel to substitution of target vowel with another vowel, inappropriate reduction of a diphthong to a monophthong e.g. /bɔɪ/ -> [bo], /naɪf/ -> [naf] and producing a reduced vowel as a full vowel e.g. /ʤərɑf/ -> [ʤurɑf].

A total of four different types of articulatory errors were identified and these were: nasalisation, strong nasal emission, dentalisation and labialisation. Dentalisation on /s/ was commonly observed amongst 55.6% of the participants (10 out of 18) e.g. /swɪŋ/ > [swɪŋ]. Analyses also revealed high occurrence of nasalisation of stop consonants, and strong nasal emission when producing nasal consonants, final stops and affricates in test items such as ‘train’, ‘swing’, ‘duck’, ‘orange’ and ‘watch’. Examples include /treɪn/ -> [reɪn], and /ɔrɪndʒ/ -> [ɔrɪndʒ]. 25% of the participants presented with this substitution pattern, but none evidenced a voice quality that could explain this substitution pattern. Nasalisation of stop consonants was not confined to a specific word position, and was observed when a nasal consonant was present in the word. On the other hand, the strong nasal emissions appears to be a transitional nasal coupling at the end of the basic articulation as it was only observed in word final positions.
There was also a high occurrence of speech changes that could not be described in terms of general patterns, for example, substituting /b/ with [w], /j/ with [n], /ð/ with [l]). Thirty one of these usual or idiosyncratic errors were identified (labeled ‘Other’ as shown in figure 3).

**Inconsistency assessment**

Participants with DS scoring a high percentage of inconsistency tended to have greater phoneme change and maximum number of substitutions. Table 2 presents the descriptive statistics of the inconsistency performance measures for participants with DS, TD participants and children with DS in the Dodd and Thompson (2001) study. In this subtest, the study by Dodd and Thompson (2001) was used as a comparative study to understand how inconsistency changes with age in the population with DS.

*Table 2. Means, standard deviations and range on inconsistency performance measures for (1) Participants with DS, (2) TD participants and (3) Children with DS in the Dodd and Thompson (2001) study.*

<table>
<thead>
<tr>
<th>Group</th>
<th>Percentage word production inconsistency (%)</th>
<th>Phoneme change</th>
<th>Maximum number of substitutions per phoneme</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>SD</td>
<td>Range</td>
</tr>
<tr>
<td>Participants with DS</td>
<td>32.8</td>
<td>17.7</td>
<td>0-60</td>
</tr>
<tr>
<td>TD participants</td>
<td>0.5</td>
<td>1.4</td>
<td>0-4</td>
</tr>
</tbody>
</table>
Children with DS from Dodd & Thompson study (2001)

|               | 67.4 | 12.3 | 40-92 | 16.1 | 9.0 | -  | 6.3 | 3.2 | -      |

**Percentage of inconsistency:** Out of the 16 adolescents with DS, seven (44%) obtained an inconsistency score equal to or above 40%. This contrasts with the comparative study, whereby all 15 children with DS scored equal to or above 40% for inconsistency. The mean inconsistency score for this study’s adolescents with DS was 32.8% while their younger counterparts from the comparative study scored 67.4%.

**Phoneme change:** Despite the lower percentage of inconsistency scored by the adolescents with DS in this study, their mean phoneme change was similar to that of children with DS from the comparative study. It was observed that fricatives, affricates, glides, and alveolar stops were the most frequently substituted.

**Maximum substitution:** The maximum number of substitutions per phoneme for participants in this study (2.8) was evidently lower than the participants in the comparative study (6.3), suggesting a more stable phoneme representation.

**Stimulus items with high percentage of inconsistency:** Figure 4, shows the distribution of inconsistent errors for the participants with DS. As can be seen, there were more participants with inconsistent errors on test items with syllable length of three or more e.g. slippery slide, helicopter and vacuum cleaner. However, it was also observed that
single syllable test item with later-developing phoneme sounds e.g. shark, bridge were also more likely to yield inconsistent errors.

Substitution pattern: Four of the participants with DS (25%) showed a tendency to replace velar sounds with labial sounds e.g. [p] for /k/, [m] for /ŋ/. It was noted that the participants with higher percentage of inconsistency tended to have more varied substitution patterns, whereby a greater range of phonemes were used to replace the target phoneme. In particular, a participant with DS who scored 60% on inconsistency, and produced 23 phoneme changes, was more likely to substitute target phonemes with other phonemes that share fewer articulatory features e.g. coronal fricatives /θ/ and /s/ being substituted with velar stop [k]. Similar traits were also observed for four other participants with DS who scored more than 40% on percentage inconsistency.

Oro-motor assessment
Similar to the other two subtests, it was observed that the mean scores from participants with DS most closely match TD 6;6-6;11 year-old Australian and UK children who performed on the 1st percentile rank (DDK= 0-5, Isolated movement= 1-10, Sequenced movement=0-12). This indicates that the adolescents with DS have poor oro-motor and oro-motor planning skills. Table 3 represents the means scores for the oromotor subtest for the 3 groups compared.

Table 3: Mean scores for oromotor subtest for (1) subjects with DS, (2) TD subjects and (3) Australian and UK children aged 6;6 – 6;11 years

<table>
<thead>
<tr>
<th>Subtest</th>
<th>Participants with DS</th>
<th>Mean DDK score (out of 9)</th>
<th>Mean score for isolated movements (out of 12)</th>
<th>Mean score for sequenced movements (out of 18)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>5.8</td>
<td>9.1</td>
<td>12.9</td>
</tr>
<tr>
<td></td>
<td>TD participants</td>
<td>8.9</td>
<td>12</td>
<td>17.9</td>
</tr>
<tr>
<td></td>
<td>Australian &amp; UK children aged 6;6 – 6;11 years</td>
<td>8-9</td>
<td>12</td>
<td>18</td>
</tr>
</tbody>
</table>

In the DDK task, participants were judged on three components including correct sound sequencing, intelligibility and fluency. Some difficulties observed amongst the participants with DS in this task were poor coordination and sequencing of syllables, unclear pronunciation of /pətəkə/ and apparent pauses between the renditions of /pətəkə/. In the isolated movement task, frequent problems noted included difficulties with tongue elevation and tongue lateralisisation. For the sequenced movements task, slow and incomplete actions on the ‘kiss and cough task’ were commonly observed.
amongst several participants. Furthermore, evidence of groping was observed in two participants, for example, struggling for tongue position and groping for sequencing of /pətəka/.

**Correlations between the different measures**

A bivariate correlational analysis using Spearman Rank Order Correlation was performed to determine whether the measure of percentage inconsistency has any correlation to measures of (a) receptive vocabulary i.e. BLAB score, (b) severity of phonological errors i.e. PPC score, and (c) oro-motor performance i.e. DDK, isolated movement and sequenced movements scores. A correlational approach was chosen to analyse the relationship between the six variables, giving an indication of how one variable may predict another. Table 4 presents the results.

**Table 4. Spearman Rank Order Correlations**

<table>
<thead>
<tr>
<th>Scale</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Percentage of inconsistency</td>
<td>-</td>
<td>-0.522*</td>
<td>-0.624**</td>
<td>-0.444</td>
<td>-0.270</td>
<td>-0.154</td>
</tr>
<tr>
<td>2. Receptive language score</td>
<td>-0.522*</td>
<td>-</td>
<td>0.828**</td>
<td>0.163</td>
<td>0.047</td>
<td>0.138</td>
</tr>
<tr>
<td>3. PPC</td>
<td>-0.624**</td>
<td>0.828**</td>
<td>-</td>
<td>0.451</td>
<td>0.186</td>
<td>0.146</td>
</tr>
<tr>
<td>4. DDK score</td>
<td>-0.444</td>
<td>0.163</td>
<td>0.451</td>
<td>-</td>
<td>0.664**</td>
<td>0.580*</td>
</tr>
</tbody>
</table>
A significant negative correlation was found between receptive vocabulary and the percentage of inconsistency \((r=-0.522, n=16, p<0.005)\), indicating that the higher the receptive vocabulary score the lower the percentage of word production inconsistency. Similarly, a significant negative correlation exists between the percentage of inconsistency and PPC \((r= -0.624, n=16, p< 0.001)\), implying that the higher the level of inconsistency the lower the percentage of phonemes produced correctly.

A significant positive correlation was observed between receptive vocabulary and PPC \((r= -0.828, n=16, p<0.001)\), i.e. the higher the receptive vocabulary score the higher the PPC score. Significant positive correlations were also observed between DDK scores, isolated movement scores \((r=0.664, n=16, p<0.001)\), and sequenced movement scores \((r=0.580, n=16, p<0.005)\), indicating that the higher the DDK score the higher the scores for isolated and sequenced movement tasks.
In contrast to the existing literature, significant correlations were observed between receptive vocabulary and the speech measures (i.e. PPC and percentage of inconsistency). A Kendall’s rank order partial correlation was performed to explore the relationship between measures of inconsistency, severity of phonological errors, and oro-motor skills, while controlling for variations in receptive vocabulary. Generally, controlling for the receptive vocabulary score did not change the significance of the previous bivariate correlations except for the correlations between DDK and the speech measures, which became significant. The correlation between DDK and percentage was $r=0.426$, $n=16$, $p<0.05$, and the correlation between DDK and PPC was $r=0.571$, $n=16$, $p<0.05$.

**DISCUSSION**

In this study, the adolescents with DS presented with multiple error types including errors that cannot be described with typical phonological processes. Results of this study revealed that word production inconsistency is a noticeable feature in the speech of adolescents with DS, as 44% of the participants with DS presented with a high percentage of inconsistency. Furthermore, poor oro-motor functioning was observed amongst all these participants. These observed features form a unique profile that does not correspond exactly with the cluster symptoms observed in children with IPD or CAS. Statistical analyses established significant correlations between percentage of inconsistency and measures of receptive vocabulary, severity of phonological errors and oro-motor skills.
**Phonological acquisition in adolescents with DS – Delay or disorder**

Results from this study suggest that the speech errors of adolescents with DS reflect a combination of delayed and disordered phonology. Speech errors observed included typical phonological processes, atypical phonological processes, articulatory errors and idiosyncratic errors. The contention that adolescents with DS display error patterns resembling those of delayed phonological acquisition is not entirely unfounded. Data from this study support the existing literature’s claim that FCD, CR, gliding, stopping, fronting and vocalisation are the typical PPs most frequently observed in adolescents with DS. Furthermore, the greater incidence of typical processes implies there is an element of delay in these adolescents with DS.

However, given that all of the adolescents with DS presented with atypical errors, it indicates that their speech disorder is not merely a delay. The observation of frequently occurring atypical errors such as glottal stop substitution, vowel distortions, dentalisation, backing and strong nasal emission were similarly reported in other studies (Cleland et al., 2010; Sommers et al., 1988; Stoel-Gammon, 1997), providing evidence for disorder rather than delay in DS. An interesting observation was that more than half the glottal stop insertions and substitutions were used on affricates, for example, /ʧ/ -> [ʔʃ], /ʤ/ -> [ʔʃ]; which suggests lack of stability in the acquisition of affricates. Our results are in congruent to the findings made by Wood and colleagues (2009) as their study also reported disordered and high variability of the production of
affricates. The high occurrence of FCD in this group with DS as well as in other studies is unusual, as FCD is a PP that should be eliminated by the age of 2;5, further supporting the notion of speech disorder rather than delay in DS. However, we cannot rule out the possibility that the dialectal features of SgE partially contributing to this observation of high FCD as FCD was identified as a typical process for speakers of SgE in the study by Gn at al. (2014).

Approximately half of the adolescents with DS in this study had difficulties with stop consonants and affricates, frequently using a strong nasal emission or nasalising these consonants. While Sommers and co-researchers (1988) attributed nasalisation to an organic factor of nasal quality in voice, the participants in this study did not present with consistent nasality in their speech. Similar to our findings, Cleland and colleagues (2010) also reported observation of nasal emission in their subjects with DS. Interestingly, they found that the nasal emissions were confined to certain phonemes like sibilants and this led them to conclude that the nasal emission cannot be due to an organic cause. Integrating our findings with those of Cleland et al’s, it appears that in the participants’ effort to place the articulators for the pronunciation of these consonants, turbulence in airflow was produced in the nasal passages to compensate for the inadequate velopharyngeal closure. Whether such a gesture resulted from speech-motor involvement or processing limitations cannot be confidently determined in this study.
On the whole, it is plausible that the observed articulatory errors and atypical processes resulted from attempts to compensate for their reduced oro-motor skills due to the anatomical and neurophysiological differences present.

**Characteristics of inconsistency**

Findings from this study indicated that adolescents with DS have a higher tendency to produce words with greater inconsistency as compared to TD adolescents and even TD children of ages 6;6-6;11. Several interesting observations were observed when comparing the results of this study to that of the comparative study by Dodd and Thompson (2001). Whilst the participants in Dodd and Thompson’s study were younger than the participants in this study, aged 6 years to 15 years;10 months (mean=10 years; 6months), the adolescents with DS in this study yielded a lower percentage of inconsistency than their younger counterparts in the comparative study. However, both groups made an almost identical number of phoneme changes. These results support the hypothesis of incomplete phonological representation at the lexical level as it appears that the phonological representation of some words in the lexicon of children with DS becomes more accurate and stable as they grow older, leading to greater consistency, and hence the lower percentage of inconsistency in the adolescents with DS compared to children with DS. However, for certain words where complete phonological representation cannot be established even with age, the number of phoneme substitutions remained constant. An example is phoneme specific glottal stop substitution (i.e. /ʧ/ -> [ʔʃ], /ʤ/ -> [ʔʃ]). Nevertheless, it cannot be assumed
that the incomplete phonological representations persist from childhood to adulthood.

Fewer substitutions per phoneme made by the DS adolescents in this study compared to the children with DS in the comparative study seem to suggest that the lexicon of phonological representations can mature and become more stable.

Dialect pronunciation differences between SSgE and Australian and British Standard English could also account for the difference in level of inconsistency observed in adolescents with DS as compared to the comparative study. The phonology of vowels and word final consonants in SSgE is simpler than that for Australian and British Standard English. In SSgE lax and tense vowels are not differentiated and final stops are often realised as a glottal stop with voicing contrasts also neutralised. This reduction in the range of contrastive sounds in the dialect may have partly contributed to the observation of lower level of inconsistency in the adolescents with DS from this study, as compared to children with DS from the comparative study. In addition, the greater variability in cognitive and speech abilities within the population with DS could also explain the differences in results obtained between this study’s sample and that of the comparative study.

The effects of anatomical differences and motor deficits have been suggested as a factor contributing to the speech variability noted in children with DS. The results of this study provide evidence for this view as the high frequency of occurrence of articulatory errors, for example dentalisation of alveolars and palato-alveolars,
suggests the impact of forward tongue posture on the speech of individuals with DS. Furthermore, the poor oro-motor skills and oro-motor planning performance on the DEAP assessment substantiates the notion that oro-motor deficits have an impact on their speech.

**Oro-motor skills and oro-motor planning skills in adolescents with DS**

The results revealed that the adolescents with DS experience persisting oro-motor and oro-motor planning difficulties. Difficulties in sequencing of articulatory movements for polysyllabic words and poor range of tongue motion observed in these participants were also reported in other studies which studied adolescents and adults with DS (Cleland et al., 2010; Hamilton, 1993; Rosin, Swift, Bless & Vetter, 1988).

Similar to our findings, Cleland and colleagues (2010) found that their subjects with DS presented with oromotor function deficits such as difficulty combining and sequencing phonemes in DDK tasks, leading them to conclude that a diagnosis of CAS is possible in some of these subjects with DS. In another study, Rosin and colleagues (1988) found that the subjects with DS had difficulties with sequencing information in domains including oro-motor functioning, speech function, language comprehension and production. Significantly more errors were observed as sequential processing demands increased, leading to the suggestion that subjects with DS experienced difficulties with general sequential processing, which influences their entire communication profile. Findings of this study support this notion to some
degree, as one participant with DS had difficulties with DDK and sequenced movements’ tasks despite having a score of 0% for inconsistency and a score of 98% for PPC. This suggests that their difficulty in sequencing oro-motor movements may be related to a general deficit in motor abilities, because if it was a speech-specific deficit, one would expect the speech measures for this participant to be adversely affected as well.

Whilst speech motor abilities are not measured by oro-motor tasks, considering the oro-motor planning difficulties observed amongst the participants with DS, it is logical to associate their speech difficulties with CAS. In this study, characteristics of CAS were observed in two participants with DS, namely trial and error groping, poor volitional oral movements, high percentage of inconsistency, nasal emission, and increased difficulty with increasing performance load. However, although imitation skills were not explicitly investigated, it was observed that most participants, including the two who exhibited signs of CAS, had a more accurate production when asked to imitate the stimulus word as compared to spontaneous elicitation. Similarly, other studies have observed a trend of better production in imitation compared to spontaneous production in individuals with DS (Stoel-Gammon, 1997). These results differ from the argument for CAS in individuals with DS as one of the six main diagnostic criteria for CAS is poorer imitation compared to spontaneous production (Forrest, 2003; Ozanne, 1995). Future studies will need to further investigate imitation skills in individuals with DS to obtain more conclusive results.
**Nature of speech disorder and the level of breakdown**

The atypical phonological processes and high level of inconsistency observed in the adolescents with DS suggest that their speech difficulties reflect a disordered nature. The results revealed a high level of inconsistency in 44% of the participants, suggesting that inconsistency is a noticeable feature in the speech of adolescents with DS. This observation, coupled with the better pronunciation in imitation than in spontaneous elicitation of test items, leads one to associate their difficulties with IPD rather than CAS. However, the argument for IPD is incongruent with the observation of oro-motor skills and oro-motor planning difficulties. In consideration of the whole speech profile exhibited by the group of adolescents with DS, their speech disorder can neither be classified as IPD nor CAS. Although the speech profile of individuals with DS cannot be classified with the Dodd’s Differential Diagnosis System, the levels of deficit leading to the observed speech profile in these adolescents can be explained using the Cascade model (Ozanne, 1995) as shown in figure 1 and Stackhouse and Wells’ psycholinguistic framework (1997).

Using the Cascade model (Ozanne, 1995), the main levels of breakdown in the speech-processing chain appear to be phonological planning and motor speech program implementation, while phonetic program assembly and motor speech program implementation appear relatively intact. The participants with DS seem to have a key deficit at the level of phonological planning as the high level of
inconsistency and increased errors with increased performance load (i.e. increased inconsistency with increasing syllable length) indicates the presence of underspecified or incorrect phonological templates. Similarly, the findings of another study (Pettinato & Verhoeven, 2008) also suggest that adolescents with DS seem to have an underlying difficulty with phonological representations. In the study by Pettinato and Verhoeven (2008) analyzing the production and perception of word stress in children and adolescents with DS, they found a close match in errors between word perception and production tasks, suggesting an underlying problem with phonological representations. The Stackhouse and Wells Psycholinguistics Framework (1997) which proposes that sound error patterns may not be a result of a specific breakdown but arise from any points in the speech processing chain, provides further support for the above hypothesis. This is because the presence of structural abnormalities e.g. middle ear anomalies, may lead to a breakdown in peripheral auditory processing, which in turn causes errors in phonological representations.

On the other hand, it appears that the majority of adolescents with DS do not have a deficit at the level of phonetic programme assembly as only two participants presented with behaviours that suggest a deficit at this level, for example groping behaviours and difficulty producing sounds in isolation. In this study, all these adolescents presented with characteristics representative of deficit at the motor speech program implementation level. These characteristics include poor performance in DDK task,
phonetic errors reflecting uncoordinated fine motor skills, for example, voicing errors, changes in resonance characteristics, or phonetic variability of production.

The execution of speech motor program appears to be intact in this study’s participants as none of the participants recruited had experienced neurological events that can cause dysarthric speech. However, we cannot rule out deficits at this level for the general population with DS as they have anatomical and physiological differences that could affect the execution of motor programs, and cases of dysarthria have been reported in individuals with DS (Miller et al., 1999).

Collectively, the main levels of breakdown in the speech-processing chain of the participants with DS appear to be phonological planning and motor speech program implementation. As deficits from one level can have feedback effects on other levels, it could be that the unique profile of speech characteristics observed in the adolescents with DS resulted from an interaction and cumulative effect of these two levels of breakdown.

**Correlations between measures of word production inconsistency, receptive vocabulary, phonological severity and oro-motor skills**

Statistical analysis using bivariate Spearman rank order correlations found significant correlations between (1) percentage of inconsistency and receptive vocabulary; (2)
Conflicting results have been reported regarding the relationships between receptive vocabulary, cognition and measures of phonological severity. In contrast to our findings of a strong correlation between receptive vocabulary score and PPC score, the study by Cleland and colleagues (2010) reported a lack of correlation between these two measures in a group of children and adolescents with DS. Cleland and colleagues (2010) found no significant correlation between PCC and most language measures, except on CELF receptive language which did approach significance. In the same study, it was also found that PCC did not correlate with full scale intelligence quotient (IQ) on the Wechsler Preschool and Primary Scale of Intelligence, although a weak correlation existed between PCC and verbal IQ. These results led them to the conclusion that speech disorder is independent of language ability and cognitive delay is not a key contributing factor to the severity of speech disorder observed in the population with DS. Although this interpretation is logical, the weak correlation found between PCC and verbal IQ in their study should not be ignored and the significant correlations found between receptive vocabulary, percentage of inconsistency and PPC in our study needs to be considered.

Similar to the significant correlation observed between percentage of inconsistency and PPC score in this study, Tyler and Lewis (2005) observed a strong negative
correlation between PPC and errors consistency index (ECI), a measure of word variability, in a group of TD children with speech and language disorders. Unlike the percentage of inconsistency used in this study, ECI is calculated by summing the total number of different substitutions that the child makes, in each word position, for each of the 23 consonant phonemes. Interestingly, Tyler and Lewis (2005) concluded that ECI and other measures of word variability should be viewed as having the same construct as measures of phonological severity because increased variability appears to be a feature of simply increased severity of speech disorder. Although our study verified the presence of a strong correlation between percentage of inconsistency and PPC score, the assumption that measures of word variability are of the same construct as measures of phonological severity cannot be supported. This is because if the assumption was true, subjects with high inconsistency scores would have very low PPC scores. However, in our findings, all the DS adolescents who had inconsistency scores greater than 40% had PPC scores that were higher than a participant who was relatively consistent (16% inconsistency) yet yielded the lowest PPC score (70.2%). Thus, the equating of inconsistency to merely a feature of severe phonological disorder is questionable.

Before controlling for variations in receptive vocabulary, there was no significant correlation between oro-motor performance (i.e. DDK scores) with inconsistency or severity of phonological errors (i.e. PPC). The lack of significant correlations between these two sets of variables suggests that the speech disorders in the adolescents with
DS closely match those of individuals with IPD. However, when variation in receptive vocabulary was controlled in a Kendall correlation analysis, the correlations between DDK and the speech variables became significant. One explanation is that controlling for receptive vocabulary score limits the variation in cognitive or receptive language abilities amongst the participants with DS (Glenn & Cunningham, 2005). In controlling for this variation, the significant relationship between speech and oro-motor skills became evident. The findings of a significant correlation between measures of oro-motor function and PPC in the study conducted by Cleland and colleagues (2010) provide supporting evidence for this explanation. These results support the hypothesis that reduced oro-motor functioning has an impact on the nature and severity of speech disorder in adolescents with DS, and that individuals with poorer oromotor skills produced less intelligible speech with more errors.

Clearly, our research results need to be replicated in order to be considered robust. Nevertheless, the present findings offer a first indication that word production inconsistency exists in adolescents with DS and the significant correlations between the measures investigated suggest that the speech disorder of individuals with DS consist of a complex interweave of phonological and motor-speech delay and deviance.

**Clinical Implications**
The results of this study have important ramifications for service delivery as they assist speech and language therapists in selecting appropriate assessment and treatment procedures. Firstly, the highly varied and disordered nature of speech difficulties observed in the adolescents with DS implies that individually tailored interventions are necessary, as conventional therapy methods are less likely to be successfully implemented. Secondly, the results inform clinicians to be aware of the high occurrence of inconsistency in these individuals, as variable performances in a once-off assessment may not be truly indicative of their actual speech profile and such results can either under-estimate or over-estimate their speech abilities. Thus ongoing assessment needs to be performed and assessment should include examining the extent and pattern of inconsistency.

Determining the level of inconsistency is important, as effective treatment for inconsistency is different from traditional phonological contrast therapy. Studies revealed that the variability of a child’s pre-treatment substitution pattern has a critical impact on his phonological learning, and reducing inconsistency should be the initial target before working on specific phonological targets (Forrest, Elbert & Dinnsen, 2000; Crosbie et al., 2005; McIntosh & Dodd, 2008). In particular, a therapy known as Core Vocabulary Therapy has demonstrated effectiveness in reducing inconsistency in children. Core vocabulary intervention targets the ability to construct phonological plans for output, and consequently remediates inconsistency of word production, even across languages (Crosbie et al., 2005). Furthermore, research has recorded
significant improvements in the accuracy of production and lower mean proportion of disordered errors amongst children with DS whose parents were trained to implement core vocabulary therapy (Dodd et al., 1994). In view of these results, it is likely that bilingual adolescents with DS may respond well to Core Vocabulary Intervention.

The high frequency of oro-motor and oro-motor planning difficulties observed amongst this study’s participants with DS cautions clinicians to be aware of these difficulties and appropriately assess and treat these difficulties. Henceforth, a holistic approach to assessment and treatment is essential to remediate the multi-faceted speech disorder in the population with DS.

Limitations of this study and implications for future research

Several limitations need to be considered. The findings are constrained by the number of participants available within the time of the study. Although the number of subjects fulfils the statistical requirements, the statistical power is somewhat limited due to the small sample size. Furthermore, as individuals with DS exhibit a heterogeneous profile of speech, language and cognitive abilities, our results cannot represent the general population of individuals with DS.

Eligibility criteria for the study included adolescents to be aged between 13-18 years. A limitation of the participant matching was that different age ranges were recruited for the participants with DS and the TD participants. Future studies may like to consider matching participant samples more closely.
Although all the adolescents with DS were recruited from special schools dedicated for individuals with mild to moderate intellectual impairment, there was no quantifiable information regarding each individual's mental age and intelligence quotient. Hence, direct comparison between these individuals and a cognitive-aged matched group was not included in this study. Implementing a research design to control for mental age and non-verbal IQ could be desirable, as it would enable investigation of the relationship between intellectual abilities and the measures of speech and language performances.

The use of a single word test designed for children developing their language skills with adolescents who have already developed theirs may have imposed restrictions on the ability to determine the form of their functional carrier system. Furthermore, the omission of the Diagnostic Screen and Articulation subtests of the DEAP limited the ability to analyse any possible oral, motor and neurological factors that could have contributed to the inconsistencies in the participants’ speech.

The use of an early version of the receptive vocabulary test, the BLAB (Lee, Sze & Rickard-Liow, 2013), where standardisation had not been completed, also restricted the scope and level of confidence in the interpretation of results relating to this test. Future studies should consider adopting a communication profile analysis examining cognitive abilities, speech-and-language skills, word production consistency, oro-
motor skills, imitation skills and spontaneous speech through standardized methods. In particular, as the standard deviation for performance on the BLAB was much greater for the participants with DS in comparison with the TD participants, influence of the lexicon on consistency may warrant further exploration. This would allow better understanding of the nature of speech disorders in individuals with DS.

Lastly, future longitudinal research should be considered to investigate the intricacies of the relationships between the measures of inconsistency, receptive vocabulary, phonological severity, and oro-motor skills in the population with DS.

**Conclusion**

In summary, the results of the present study revealed that the adolescents with DS exhibited speech disorders characterised by atypical errors alongside developmental errors, a high level of word production inconsistency and difficulties with oro-motor and oro-motor planning skills. The cause of the speech disorder in DS remains unclear as the overall speech profile does not correspond with the cluster of symptoms for IPD or CAS.

Significant statistical correlations obtained from assessing the relationships between receptive vocabulary, severity of phonological errors, inconsistency and oro-motor skills suggest that the disorder in DS is multi-factorial. On exploring the levels of breakdown using the speech-processing chain, the underlying deficits in most of the
adolescents with DS appear to be incomplete phonological representations of the
words at the lexical level and difficulties with the implementation of motor speech
program. On the other hand, four (25%) of the participants seem to have difficulties at
an additional level, the assembly of phonetic program; a feature which may warrant a
diagnosis of CAS.

From a clinical perspective, it seems clear that assessment and intervention for
speech disorder in individuals with DS requires specific attention. The results
emphasise the need for clinicians to adopt a holistic approach in the differential
diagnosis and treatment of speech disorders in individuals with DS. It is imperative to
assess their speech on an individual basis, including a critical analysis of all
components instead of only assessing their general phonology. A thorough
assessment will allow one to have a holistic view of the individual’s speech difficulties,
hetence allowing targeted and effective intervention.

References

Bradford, B., & Dodd, B. (1996). Do all speech-disordered children have motor

Research on pronunciations. Singapore: The Singapore Association for Applied
Linguistics.


### Appendix B

Table of differences between Standard British English and Standard Singaporean English

<table>
<thead>
<tr>
<th>Standard British English</th>
<th>Standard Singaporean English</th>
</tr>
</thead>
<tbody>
<tr>
<td>/θ/ /ð/</td>
<td>Substitution of dental fricatives with /d/, /t/ and /l/ e.g. [tif] for /teeth/</td>
</tr>
<tr>
<td>Voiced and voiceless consonants</td>
<td>Less obvious distinction between voiced and voiceless consonants</td>
</tr>
<tr>
<td>distinctively enunciated</td>
<td></td>
</tr>
<tr>
<td>Final consonant /t/ and /k/</td>
<td>Substituted with /ʔ/ e.g. [bæʔ] for /back/ and [puʔ] for /put/</td>
</tr>
<tr>
<td>Final consonant clusters</td>
<td>Simplification of final consonant clusters by deleting the final consonants in these clusters e.g. [balʔ] for /bulk/</td>
</tr>
<tr>
<td>Postvocalic /ɹ/</td>
<td>Omitted</td>
</tr>
<tr>
<td>Dark /l/</td>
<td>Deletion or substitution of dark /l/ e.g. wheel produced as /wiɹ/</td>
</tr>
<tr>
<td>Short and long vowels distinctively enunciated</td>
<td>No distinction between short and long vowels e.g. ‘beat’-‘bit’ and ‘pool’-‘pull’ pronounced as homophones</td>
</tr>
<tr>
<td>/e, æ/</td>
<td>Substituted with /ɛ/</td>
</tr>
<tr>
<td>Diphthong vowels</td>
<td>Pronounced as monophthong vowels</td>
</tr>
</tbody>
</table>
Appendix C

Table of words commonly misarticulated in the phonology subtest with unclassified speech changes

<table>
<thead>
<tr>
<th>Words in the phonology subtest that were misarticulated with unclassified speech changes</th>
<th>Examples of the unclassified speech changes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Umbrella</td>
<td>[umweʔa], umweŋa</td>
</tr>
<tr>
<td>rabbit</td>
<td>[abiʔ]</td>
</tr>
<tr>
<td>bread</td>
<td>[bweʔŋ]</td>
</tr>
<tr>
<td>Yellow</td>
<td>[ŋeʔoʊ]</td>
</tr>
<tr>
<td>This</td>
<td>[lɪs ʊ]</td>
</tr>
<tr>
<td>Feather</td>
<td>[eːdʰŋ]</td>
</tr>
<tr>
<td>Swing</td>
<td>[sʰiŋʔ]</td>
</tr>
</tbody>
</table>