Phonological Development in Children with Down Syndrome: An Analysis of Patterns and Intervention Strategies

Thesis submitted for the degree of Doctor of Philosophy

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January 2018

Declaration

I confirm that this is my own work and the use of all material from other sources had been properly and fully acknowledged.

Najwa Salim Yousif

I dedicate this thesis to my beloved

Eman Salim Yousif

for her unconditional love and limitless support.

There is no better friend than a sister and there is no sister better than you.

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Acknowledgements

This journey would not have been possible without the support of my supervisors, mentors, university staff members, the participating families and their lovely prosperous children, all beloved my family members and friends. My very special gratitude and sincere thanks go to my supervisors Dr Vesna Stojanovik, Prof. Jane Setter and DR Tom Loucas. I am deeply indebted to them for their inspiring guidance and valuable and beneficial comments in addition to their patience and readiness at all times to support me complete this research. My deepest gratitude and warmest thoughts are extended to my principal supervisor Dr Vesna Stojanovik for her excellent guidance, valuable support and beneficial comments, and above all for always being by my side encouraging and supporting me at all times to accomplish the PhD project all throughout the long research journey.

Grateful thanks are also dedicated to staff members at the University of Reading Arpita Bose and Holly Robson for monitoring and following up the progress my research project. I also extend big thanks to Alison Biddle for always being there to answer my queries and provide me with academic advice. Special thanks are gratefully dedicated to Graham Schafer who provided me with child databases essentially needed to accomplish my project. I also would like to gratefully thank Emma Marshall at the School of Psychology and Clinical Language Sciences Reception for facilitating the clinic room bookings and promptly answering my emails. I would also like to give special thanks to the library staff members at the University of reading for the assistance they offered me to get the necessary references and easily photocopy other required research materials. I also wish to express my sincere gratitude to the University of Reading for giving me the opportunity to gain educational knowledge and accomplish this modest research.

I would like to extend enormous thanks to all my friends and classmates for their encouragement, kindness and emotional support. Special thanks are sincerely presented to my parent, sisters and brothers for their unconditional love and support and all my dearest friends for their assistance and encouragement throughout this research journey.With a special mention to my dearest friends Sawsen Atiya, Anas and Osama Al Janabi, Nesreen Rekany Lamya Aldukair Susan Murdoch and colleagues George Pontikas, Louis Williams, Abhijeet Patra Isobel Chick, Evelyn Egger, Emily Seager, who fantastically supported me in many different ways and facilitated working and researching.

Last but not least, I gratefully acknowledge my profound indebtedness to the Ministry of Higher Education and Scientific Research and Iraqi Cultural Attaché for granting me this auspicious academic scholarship, thus giving me the opportunity to travel abroad, elaborate educational horizons and get a magnificent international perspective.

Abstract

Speech tends to be the most challenging developmental difficulty for children with Down syndrome (DS). Studies on the development of phonology in this special population are currently limited and based on the sound mastery model of typically developing (TD) children. The available studies on phonological development in English-speaking children with DS have been confined either to examining one type of speech data, have small speech samples with limited representativeness, have included fewer participants, or rarely compare children with DS to another group. Additionally, most of the available speech intervention programmes have focused either on developing daily living communication skills or articulation at the expense of phonology for highly unintelligible children with DS. Therefore, developing a research study which combines single word (SW) and connected speech (CS) production data helps identify the difficult areas in phonology that may affect speech development in DS within the age range tested in the present study. Enhancing the phonological abilities of children with DS by adopting phonology-based intervention models to treat phonology-based speech problems facilitates learning of new sounds and using these sounds in correct contexts. The present study fills this gap in the current knowledge. The thesis is divided into two parts: a cross-sectional group study and a multiple baseline single subject case study. The group study aims at explaining the development of phonological systems of children with DS by analysing both SW and CS samples to determine the differences between children with DS and TD children in terms of: consonants and vowels acquisition, effect of consonant position on production accuracy and type and frequency of occurrence of phonological processes. The case study aims at evaluating the effectiveness of a phonological pattern-based cycles approach in improving the speech production accuracy of a child with DS and, in return, increasing the child's speech intelligibility. In the group study, the comparison of the developmental trajectories of children with DS and TD children showed significant differences between the two groups in terms of onset and rate of development when producing single word/connected speech. There were also differences within DS group between SW and CS samples in that there were more sound errors/phonological processes in CS than in SW samples. By and large, it was found that children with DS develop their phonological systems in a similar way to TD children, but at a slower pace and also have a delayed onset of development of the tested phonological aspects. The findings of the case study revealed that a phonology-based intervention model, such as the cycles procedure, was effective in reducing the occurrence of the target phonological processes and increasing sound production accuracy and speech intelligibility.

Chapter 1: General Introduction

1.1 Down Syndrome Aetiology and Phenotype: An Overview

Down syndrome (DS) is considered as one of the most well-identified genetic syndromes which result in a wide variety of child developmental learning problems (Cantwell and Baker, 1987; Dodd, McCormack, & Woodyat, 1995; Wood, 1964). It affects nearly one in every 800 births and it is the most common neurodevelopmental disorder resulting in intellectual disability (Dodd and Crosbie, 2005; Ypsilanti, Grouios, Aleveriadou & Tspakin, 2005). Biologically, Down syndrome is caused by an additional copy of chromosome 21 which is often known as Trisomy 21 (Dodd and Crosbie, 2005; Joffe and Varlokosta, 2007; Korenberg, Chen, Schipper, Sun, Gonsky, Gerwehr, Carpenter, Daumer, Dignan, Disteche, Graham, Hudgins, McGillivray, Miyazaki, Ogasawara, Park, Peuschel, Sack, Say, Schuffenhauer, Soukup, & Yamanka, 1994). Individuals with DS from birth to age of 18;0 years have cardiac, gastrointestinal, immunological, respiratory, sensory and orthopaedic anomalies (Bittles et al., 2006). However, children with DS might share all or some of the observable features of DS population (Newton, 2015; Wood, 2005). The brain structure is characterised with a small cerebellum and brain stem resulting in atypical neural development and constraining their muscular tone (hypotonia) and affecting the learning process. The following sections explain the phenotypic characteristics of DS.

1.1.1 Cognitive Characteristics

DS is a condition which entirely stems from biological factors (Dodd and Crosbie, 2005). Newton (2005, p. 238) stated that “a variety of biological mechanisms, most of which are poorly understood, lead to neurodevelopmental impairment in trisomy 21. This may be a reflection of the underdevelopment of neural circuits or atypical neural signalling, or both.” According to Dodd and Crosbie (2005), DS forms approximately 30% of moderate to severe intellectually impaired population. The individuals with DS have intellectual traits similar to these of cognitively impaired populations matched for chronological age and IQ measures, yet with more complicated speech and language difficulties. Based on studies reviewed on the developmental attainment in DS, Cunningham (2006) reported that developmental quotients of approximately 80% were scored for infants with DS; however, these quotients scores declined to 60% for children with DS aged 5;0 years. The descending IQ scores, as children with DS grow older, indicated a developmental delay when compared to TD children. However, IQ scores tended to be approximately constant between the ages 5;0 and 20;0 years (Cunningham, 2006). Approximately 40% of individuals with DS have IQs ranges from 50 to 70 which revealed mild learning disability; while 35% of children with DS have IQs ranged from 30 to 70 which showed moderate learning disability. Nearly 25% of the samples scored less than 30% indicating severe to profound learning disability; yet, only 1% scored 70 (Cunningham, 2006; Levy and Eilam, 2013; McDuffie and Abbedutto, 2009). Couzens et al. (2012) conducted a longitudinal study of the relationship between cognitive development and interactive and environmental features in individuals with DS to analyse the course of their developmental patterns and identify their cognitive characteristics. The study findings stressed that earlier understanding of cognitive abilities of children with DS and targeting speech, language and other communication difficulties enhanced developing intellectual abilities in individuals with DS.

General cognitive abilities are affected in children with DS (Couzens et al., 2012; Levy and Eilam, 2013; McDuffie and Abbeduto, 2009; Newton, 2015; Sokol and Fey, 2013). They have limited thinking abilities including reasoning, concentration, remembering, and analysing concepts (Kumin, 2008; McDuffie and Abbedutto, 2009). The limited intellectual abilities of this special population seriously impact their communication skills in general and speech and language development in particular (Kumin, 2008; 2012; Newton, 2015). Additionally, children with DS have visual memory stronger and better than auditory memory. They are capable of storing out and easily retrieving visual information than processing auditory information. This can be attributed to the difficulty they have with phonological loop process linked to short term memory responsible for processing verbal information (Couzens et al., 2012; Kumin, 2008). The phonological loop process helps them retrieve sounds and rules for combining them into meaningful units in response to what has been previously spoken by surrounding individuals. However, children with DS tend to store either the first or the last part of an utterance (Cantwell and Baker, 1987; Chapman, 1995; Kumin, 2008; 2012; McDuffie and Abbedutto, 2009). On the other hand, children with DS are more capable of processing visual input than verbal input (Chapman, 1995; Fidler et al., 2007). For instance, a child with DS finds it easier to remember the steps to follow to play a DVD player than to follow verbal instruction (Fidler et al., 2007; Kumin, 2008; 2012; Levy and Eilam, 2013). The cognitive disabilities in children with DS affect understanding concepts, especially abstract concepts or ideas, as these concepts need to be expressed by using vocabulary items with which they may be unfamiliar (e.g. *government*, *democracy*, and so on) (Chapman, 1997; Kumin, 2008). However, these vocabulary items could be retrieved when linked to specific individuals, settings or events. Consequently, the ability to process visual information rather than auditory information could be considered as a relative strength in individuals with DS (Chapman and Hesketh; 2001; Kumin, 2008; 2012).

1.1.2 Hearing and Visual Characteristics

There are other characteristics related to DS profile; these include hearing loss and visual difficulties. Most children with DS have hearing problems which affect speech and language development (Kumin, 2008; 2012; Newton, 2015; Stoel-Gammon, 1980; 1997; Wilson, 1979). Hearing problems in DS population can be classified into three main types: conductive hearing loss, sensorineural hearing loss and mixed hearing loss (Chapman and Hesketh, 2001; Kumin, 2008, McNeil et al., 2015; Sacks and Wood, 2003). Children with DS may suffer from mild to moderate conductive hearing loss. It results from preventing the sound waves from being perceived by outer or middle ear due to existence of fluids, accumulated cerumen or infections (e.g. recurrent otitis media/Eustachian tube infections) which affect both the speech perception and production (Bowen, 2009; Kumin, 2008). Kumin (2008, p.25) reported that in 60% to 70% of children with DS recurrent conductive hearing difficulty resulted from accumulated fluid in the middle ear. However, the status of conductive hearing loss continuously changes depending upon the level of fluid in the ear. Fluctuating hearing loss means that a child with DS might not be able to perceive a given sound or sound structure in a similar way when these units are re-produced over different time intervals (Dodd, 1995; Kumin, 2008; McNeil et al., 2015). This definitely affects language and speech development, and speech sound acquisition (Bernthal et al., 2009; Desai, 1997; Perkins and Howard, 1995; Desai, 1997).

Nonetheless, the hearing loss might gradually disappear as the children with DS grow older, but many of them may continue to suffer from hearing loss caused by anatomical aetiologies (Shott, 2006; Shott et al., 2001). Conductive hearing loss may result from anatomical structure of the relatively narrow and less curved ear canals affecting the adequate draining of accumulated fluids (Kumin, 2008; 2012). Kumin (2008, p.26) mentioned that children with DS aged between 6;0 and 14;0 years have hearing problems caused by the malfunctioning of the Eustachian tube which, in return, accumulate fluid behind the ear drum and cannot be drained away. Kumin (2008) also reported that the problem of accumulated fluid in middle ear (glue ear) usually disappears by age of 8;0 years, but for some other children it may continue beyond age 8;0 years. McNeil et al. (2015) reported that ‘glue ear’ affected 35% of children with DS at birth and 93% of them at the age of 1;0 year. However, for older children with DS aged 5;0 years or older conductive hearing loss decreased to 68%.

The second type of hearing problems in DS population is called sensorineural loss (deafness). Sensorineural hearing loss tends to be a permanent hearing difficulty that may appear at birth or at older ages due to either the distortion of inner ear, the hearing nerve or both of them (Sacks and Wood, 2003). The severity of this type of hearing problems may limit the child’s perceptibility of certain sounds rather than other ones, as the child may be able to hear a given sound at certain frequencies rather than other ones (Kumin, 2012; McNeil at al., 2015). Therefore, children with DS who suffer from sensorineural hearing loss need Cochlear implantation or need to use hearing aids to intensify the sound frequencies. Some children with DS may have a mixture of both types of hearing losses (Kumin, 2008; 2012; McNeil et al., 2015).

As previously mentioned, children with DS are capable of remembering visual information more than auditory information. As a result, they can easily learn new utterances through seeing miscellaneous objects and pictures (Doyle et al., 2016; Woodhouse, 2013). Therefore, if children with DS have vision problems the learning process will be hindered. It was reported that 60% of DS population have vision difficulties (Charleton and Woodhouse, 2015). According to Kumin (2008, p.29), 50% of children with DS have visual problems; these included: strabismus in which one or two eyes are typically aligned either inward or outward, near-sightedness in which children have blurred near vision level, and astigmatism in which the child has blurred vision in all directions.

1.1.3 Oral-Motor Structure Characteristics

DS population have special physical characteristics with varying degrees of severity that could affect speech and language development. In as far as the oral motor structure in children with DS is concerned, the middle structure of the face is not fully developed in terms of muscles and structure (Kumin, 2008; Sokol and Fey, 2013). Children with DS have low muscle tone (hypotonia) (Newton, 2015; Rosenfeld-Johnson, 1997). That is, the muscles in the mouth (including lips, tongue and jaws) tend to be more relaxed so that they affect the mobility of articulators in the mouth and, in return, affect sound articulation. Children with DS may also show lip-tongue-jaw dissociation, i.e., they cannot move these three parts independently which causes them problems with coordination, accuracy and timing of movement. However, hypotonia may improve as the children grow older, but it may continue to affect speech production to certain degrees at later ages in life (Kumin, 2008; 2012; McDuffie and Abbedutto, 2009).

Structurally, children with DS do not have fully-developed midfacial bones (midfacial hypoplasia). Jaws tend to be smaller and narrower (with prognathous lower jaw) resulting in narrow oral and nasal cavities (Marder and Nunn, 2015). Another feature of oral motor structure of DS is open mouth posture which is sometimes accompanied by drooling. As a result, children with DS usually tend to breathe throughout the mouth and leave the mouth open with the tongue straight behind the lips (Marder and Nunn, 2015). Generally, children with DS have large-sized tongue that may cause them difficulty moving the tongue to form specific sounds, especially alveolar sounds (Kumin, 2008; 2012). They may also have high-narrow palate which may constrain the tongue mobility. In addition, the upper and lower teeth do not meet properly forming an open bite. Functionally, such oral-motor abnormalities affect voice quality and resonance; besides, they limit tongue mobility and shaping during speech production. Definitely, all these factors combined differently impact language and speech development, and phonology acquisition in particular in children with DS (Bernthal et al., 2009; Desai, 1997; Perkins and Howard, 1995).

1.2 Phonological Development in Children with DS

Generally, the phonological development in children with DS is interdependently correlated with speech sound acquisition and connected speech development at later stages in life. Since speech is considered as the most effective verbal way of expressing thoughts, needs, events, and so on, for children and adults, it tends to be the most cognitively and physiologically demanding communicative means, especially for individuals with mental retardation, such as children with DS (Kent, 1997; Kumin, 2012). Speech development requires learning and using different interlinked cognitive and articulatory strategies, such as coordination between brain systems and the speech articulators and using and moving the right muscles in precise timing to articulate and produce meaningful combinations of speech sounds (Buckley and Le Prevost, 2002; Kumin, 2012).

The area of typical speech sound acquisition, rather than delayed or disordered speech sound acquisition in a special population such as DS, has been widely studied to provide the essential data needed for research and for clinical assessment and intervention programme design purposes. Therefore, extensive normative data on phonological development have been obtained and analysed (e.g. Antony et al., 1971; Chirlian and Sharpley, 1982; Dodd et al., 2003; Kliminster and Laird, 1978; Prather et al., 1975; Robb and Bleile, 1994; Smit et al., 1990). It has also been emphasised that there is a need to develop research about phonological development in children with DS and how speech sound acquisition and production accuracy affect speech development in DS population (Buckley and Le Prevost, 2002; Iacono. 1998, Kumin, 1986; Kumin et al., 1994; Northern, 1988; Peuschel and Hopmann, 1993, Stoel-Gammon, 1980; Stoel-Gammon, 1997). Most of the previous research agreed that, in the light of information obtained from research on phonological development in children with DS, various individualised speech intervention programmes targeting speech could be designed for children with DS in order to improve sound production accuracy and increase speech intelligibility (Buckley and Le Prevost, 2002; Stoel-Gammon, 2001).

According to Swift and Robsin (1990), there were limited intervention programmes designed to target phonology-oriented speech difficulties for children with DS. In some other studies, it was argued that in spite of the significance of communication skills intervention programmes to develop the children's daily life, the need to enhance the children's phonological skills via developing phonology-based treatment models should be considered (Shriberg and Widder, 1990). Thus, individualised speech intervention programmes need to be planned and tailored to the needs of each individual child with DS. However, the decision-making process regarding the selection of a suitable intervention programme is not easy, as it needs substantial effort to understand each child's phonological system and needs. The continuous research in addition to clinical practice and the children's characteristics and needs are considered as the most informative factors that could support speech-language therapists (SLTs) during the decision-making process (Kamhi, 2006).

The present study aims at explaining the phonological systems of children with DS within a specific age range by analysing both SW and CS samples. It analyses the children's consonant and vowel sets, investigates the effect of consonant position in a word on the consonant production accuracy, and provides examples of the error pattern types. It clarifies the frequency and type of sound pattern errors produced by children with DS compared to TD children matched for nonverbal mental age (MA). In the light of the phonological analysis findings of children with DS, the present study examines the effectiveness of a phonological pattern-based approach in improving the speech production accuracy and, in return, increasing speech intelligibility in a participant with DS. Accordingly, the thesis will have two parts. Part one is a cross-sectional group study which focuses on assessing and analysing the phonological systems of children with DS compared to TD children and it consists of six chapters. Part two is a multiple baseline single-subject case study which examines the effectiveness of the cycles phonological remediation approach in addressing the phonological difficulties of child with DS and it consists of three chapters.

1.3 Structure of Study

1.3.1 Aims of Study

The aim of the first part of the study is to explore and explain the phonological systems of children with DS by analysing both SW and CS samples using a developmental trajectory approach. This will include: determining the sets of consonants and vowels, investigating the effect of consonant position in a word on consonant production accuracy, and providing a phonological analysis of the frequency and type of sound pattern errors in children with DS compared to TD children matched for non-verbal MA. The speech data to be elicited consists of two types of samples: SW and CS samples for this is considered as the most reliable database for a phonological rule analysis (Iacono, 1998; Shriberg and Kwiatkowski, 1980). The aim of the second part of the study is to examine the effectiveness of a phonological pattern-based approach in remediating the target phonological processes, improving the speech production accuracy and, in return, increasing speech intelligibility in a participant with DS (Dodd et al., 1994; Fidler and Hepburn, 2007).

1.3.2 Objectives of Study

A. In the first part of the study (group study), the developmental trajectory approach was adopted to create cross-sectional trajectories. This approach would assist in constructing a function linking children's performance and MA on specific experimental tasks and then evaluating whether this function for DS group would differ from that for TD group. The group study was set out to achieve the following objectives:

1. To determine the consonants and vowels of DS group compared to TD group when matched for non-verbal MA.
2. To explain the order of acquisition of the speech sounds in DS group compared to TD group when matched for non-verbal MA.
3. To analyse the speech sound development and sound pattern errors used in the speech of DS group compared to TD group when matched for non-verbal MA.
4. To explain the effect of consonant production accuracy and use of phonological processes on speech intelligibility in DS and TD groups.

B. The second part of the study (case study) was conducted to achieve the following objectives:
   1. To identify the two most frequently used phonological processes which a child with DS used in speech by using standardised and non-standardised speech assessment tools.
   2. To use a cycles-based intervention to help the participant reduce using the target phonological processes.
   3. To increase the participant's speech production accuracy.
   4. To increase the participant's speech intelligibility.
   5. To facilitate generalisation of the learned patterns to other untreated sounds to emerge unconsciously in the participant's spontaneous speech.

1.3.3 Research Questions and Hypotheses

The thesis has two parts: part I is a group study which analyses the phonological systems of children with DS. Part II comprises a single case study which addresses the effectiveness of the Cycles Phonological Remediation Approach in remediating the phonological processes of a school-age child with DS. The research questions are as follows:

Part I – Group Study

1. Is the development of sound production and use of phonological processes in children with DS delayed in SW sample, CS sample and in SW sample compared to CS sample?
2. Do children with DS demonstrate a slower rate of development of sound production and use of phonological processes in relation to their non-verbal MA in SW sample, CS sample and in SW sample compared to CS sample?
3. Is the development of speech intelligibility in children with DS delayed in CS sample?

4. Do children with DS demonstrate a slower rate of development of speech intelligibility in relation to their non-verbal MA in CS sample?

The study hypothesises:

1. Children with DS would progress at a delayed onset of development in terms of sound production and use of phonological processes in SW sample, CS sample and SW sample compared to CS sample.
2. Children with DS would demonstrate a slower rate of development of sounds production and use of phonological processes relative to their non-verbal MA in SW sample, CS sample and SW sample compared to CS sample.
3. Children with DS would progress at a delayed onset of development in terms of speech intelligibility in CS sample.
4. Children with DS would demonstrate a slower rate of development of speech intelligibility relative to their non-verbal MA in CS sample.

Part II – Case Study

The study aimed at addressing the following questions:

1. Does cycles-based intervention improve speech production accuracy of the target patterns and the related target sounds in a child with DS?
2. Can the newly-learned sound patterns be generalised to other untreated sounds and sound patterns due to the implementation of the cycles-based intervention?
3. Is the cycles approach effective in improving the speech of the participating child with DS?

The hypotheses are:

1. The production accuracy in relation to the target patterns and the related target sounds would improve.
2. The implementation of the cycles-based intervention would help the participant with DS generalise the newly-learned patterns to other untreated sounds and sound patterns.
3. The cycles approach would be effective in improving the speech of the participating child with DS.

Part I

Group Study

Chapter 2: Literature Review on Phonological Development in TD Children and Children with DS

2.1 Introduction

The present chapter presents a review of the available literature in the field of child speech sound acquisition. It specifically explains the main theoretical and experimental findings associated with the process of speech sound acquisition in children with DS compared to TD children. It also accounts for the phonological processes that characterise the speech of these two distinct populations and the extent to which mastery of speech sound production and the use of phonological processes impact children's speech intelligibility. The chapter also clarifies the utility of studying children's phonological development in terms of analysing a combination of SW and CS samples and it identifies the advantages of manipulating both types of speech samples.

2.2. Why Study Phonological Development in Children with DS Compared to TD Children?

Phonological development refers to the gradual phonemic development of the adult-like speech sound system in children (Bowen, 2011). It includes the sound acquisition process and the ability to use phonological rules to form meaningful phonological units (e.g. syllables, words, phrases, etc.). Phonological development has been widely studied in TD children. Despite the fact that other populations (e.g. children with DS) with developmental and learning difficulties are at high risk for phonological problems, there have been fewer studies on the development of phonology in these populations. The phonological problems in children with DS could either be delay- or disorder-based or a combination of phonological delay and disorder (Cleland, Wood, Hardcastle, Wishart, & Timmins, 2010). Phonological delay implies that children, diagnosed with speech problems, typically develop speech sounds and sound patterns in a similar way to that of younger TD children, but at a slower rate of development. For example, using fronting process of velar /k/ in *key* [ki:] and producing it as /t/ in [ti:]. Phonological disorder involves the inconsistent use of atypical phonological processes which could highly impact the children's speech intelligibility (Bowen, 2009; 2011; Cleland et al., 2010,). For instance, substituting velar stop /k/ in *look* [lʊk] with a far more back uvular consonant /χ/ in [lʊχ]. Therefore, developing research in this field is of paramount importance for it can help analyse the phonological development in children with DS, identify the phonological problems they have and clarify how these problems may affect speech sound development. It can also help provide recommendations for parents and practitioners about the most appropriate intervention programmes to plan or select from (Kumin et al., 1994; Rondal and Edwards, 1997; Stoel-Gammon, 1980).

The available studies on phonological development in English-speaking children with DS have been based either on one type of speech data, have small speech samples with limited representativeness, have included fewer participants, or were confined to one specific population rather than comparing two or more distinct populations. For instance, the available studies on speech sound acquisition in English-speaking children with DS have been based on the sound mastery model of TD children (Dodd, 1976; Dodd and Thompson, 2001; Smith and Stoel-Gammon, 1983; Stoel-Gammon, 1980). In these studies, different standardised tests of articulation to collect SW or CS samples were used. In as far as the phonological development in children with DS was concerned, it appeared to be more complicated to apply the same norms and testing strategies to children with DS who evidently have various sensory, perceptual, physical and intellectual problems that could occur separately or collectively and could affect sound acquisition and result in speech difficulties (Bleile, Schawrtz, 1984; Kumin et al., 1994; Pueschel and Hopmann, 1993; Stoel-Gammon, 1980). Consequently, a different model for production accuracy in DS population needed to be developed. The new model was based on analysing the speech sound production accuracy in both single word and connected speech samples (Iacono, 1998; Norbury and Bishop, 2003; Morrison and Shriberg, 1992). It was argued that connected speech samples provided a wider analytical perspective of tested children's speech, as children produced the collected utterances in natural context (Shriberg& Kwiatkowski, 1980; 1985).

The most commonly reported communication problems faced by individuals with DS were associated with speech development difficulties (Kumin, 2006; Sokol & Fey, 2013). Many studies revealed that speech sound problems in children with DS resulted from using sound and sound pattern errors more frequently than their TD peers with or without speech problems and/or matched for MA (Cleland et al., 2010; Kumin, 2006; Roberts et al., 2005; Roberts, Stoel-Gammon, &Barnes, 2008; Rupela & Manjula, 2007). Additionally, children with DS were found to be more inconsistent in terms of sound and sound pattern productions (Rondal, 1980; Rosin, Swift, Bless, & Vetter, 1988). It was argued that the speech problems in children with DS involve a three-level difficulty consisting of planning, articulation and phonology, which collectively decreased speech intelligibility (Bleile & Schawrtz, 1984; Buckley & Le Prevost, 2002). In addition, children with DS have shown individual differences in terms of speech difficulties they have, although their speech development has been often compared with the characteristic profile of DS (Kumin, 2012; Smith and Stoel-Gammon, 1983; Stoel-Gammon, 1997). The continuous research in addition to clinical practice, and children's characteristics and needs tended to be the most informative factors that could support SLTs during the decision-making process (Kamhi, 2006; Stoel-Gammon and Dunn, 1985). Thus, individualised speech intervention programmes need to be planned and tailored to the needs of each individual child with DS.

2.3 TD Children – Early Speech Development

TD children acquire speech during four main phases of speech development starting from birth and lasting to the age of 5;0 years or even older, when children become able to produce adult-like speech. Bleile (2004) and Stoel-Gammon and Dunn (1985) identified four phases of child speech development. However, the age of acquisition at which each phase started was varying. These phases are explained in the following sections.

2.3.1 Pre-linguistic Period - Phase I

The first phase starts from birth to 1;0 year. This phase establishes the foundations for speech. It is characterised by the production of reflexive sounds, cooing, babbling toward purposeful vocalisations. These vocalisations represent the foundation for speech development as children grow older. During the first phase, the physiological (the size of the vocal tract, and pharyngeal and oral cavities), respiratory (the maturation of lungs and respiration process for speech), and neurological (brain weight and structure, neurological maturation of nerve fibres responsible for articulatory movements of speech) systems contributing to speech production and perception are being developed (Bleile, 2007; Fitch and Giedd, 1999; Kent and Tilkens, 2007). Functionally, children during the first year of age continuously make various articulation gestures and movements of the lips, lower jaw and the tongue (Walsh and Smith, 2002). As children move towards the second year of age and older, the articulation movements become more accurate and coordinated and, at the same time, the movement rates increase and accelerate as an indication of the maturation of the constituents of oral motor structure (Robb et al., 1994; Walker and Archibald, 2006; Williams and Stackhouse, 2000). In as far as speech production is concerned, infants during the first two months of age begin producing non-speech vocalisations, such as crying, fussing, burps, hiccups, laughing, groaning, and semi-vowel productions. Infants expand speech-like production during 3-6 months of age, i.e., they become able to produce marginal babbling including few easily articulated consonants and vowels. At the age of 6 months and older infants begin to utter several duplicated CVCV syllables, such as [bæbæ], [mæmæ], and so on (Nathani et al., 2006; Oller et al., 1999; Vihman et al., 1985).

2.3.2 Precursors of First words - Phase II

The second phase lasts from 1;0 to 2;0 years. It witnesses the emergence of first words and gradual transference to speech. It is characterised by the emergence of first words, the phonological structure of which tends to be more simplified than the adult realisations. For example, fronting /k/ in *come* [kʌm] into /t/ in [tʌm], or assimilation of /j/ in *yellow* [jeləʊ] into /l/ in [leləʊ]. The pronunciation of the first 50 words (e.g. *'snow'* [snəʊ], *'nose'* [nəʊz]) shows the various phonetic and phonemic structures that TD children were able to produce (Grunwell, 1982;1987; Robb et al., 1994; Stoel-Gammon and Dunn, 1985). Phonetically, the first words may consist of consonants articulated at the front part of the mouth, such as /p,b,t,d,m,n/ embedded in word shapes, such as CV in '*no'* [nəʊ] , VC *up* [ʌp], and CVCV *bye-bye* [baɪbaɪ] syllable structures (Bernthal et al., 2009; Robb and Bleili, 1994; Vihman et al., 1985). It is obvious that children tend to produce open syllable structures in which final consonants are either deleted or followed by a vowel sound, as in *dog* [dɒg] is either pronounced as [dɒ] or [dɒgi:] (Bernthal et al., 2009; Donegan, 2002). Donegan (2002) also clarified vowel production during the first two years of age in TD children. Children at this age have developed the production of specific set of easily articulated vowel sounds, such as low, open unrounded vowels. The fact that TD children tend to be selective in the type and structure of the words they speak out can be associated with the sound type and sound structures they are able to produce (Ferguson, 1978). Canonical babbling and early speech attempts are interdependently related and share similar phonetic characteristics (Robb et al., 1994; Stoel-Gammon, 1985; Stoel-Gammon and Cooper, 1984; Vihman et al., 1985). The similarities include the production of consonant types (e.g. stops, nasals, and glides) and syllable structures (e.g. CV, CVCV). Additionally, these characteristics continue to appear in the children's first word productions (Fitch and Giedd, 1999; Stoel-Gammon and Cooper, 1984; Vihman et al., 1987).

A longitudinal study conducted by Vihman and Greenlee (1987) examined speech development in 10 TD children aged 9-17 months and again at 36 months. They found that there was great variability between participants in terms of sound substitutions (e.g., substituting /g/ in *'go'* [gəʊ] by /d/ in [dəʊ]) and cluster reductions (e.g., *'smile'* produced as [maɪl]). Based on the study results, two main learning styles were identified at the age of 1;0 year and continued to appear at the age of 3;0 years: 'systematic' and 'exploratory' learning. Learning to speak in children aged from 1;0 to 3;0 years was looked at as a series of fluctuations between these two styles of speech production (Vihman and Greenlee, 1987, p.519). The findings of a study conducted by Bates et al. (1995) have extended those found in Vihman and Greenlee's (1987). That is, older children were able to produce whole well-pronounced and intelligible words (word-oriented speech development). On the other hand, younger children showed greater variability in terms of pronunciation, suprasegmental features, and intelligibility (intonation-oriented speech development).

Grunwell (1981) reported that the consonants of young children, aged between 1;0 and 2;0 years, comprised of stops, fricatives, approximants, labials and the lateral consonant /1/, and continued to develop as more speech sounds were acquired as children grew older. A longitudinal study by Robb and Bleile (1994) investigated the consonants acquired in 7 TD children, aged between 8 and 25 months. The findings showed that the early acquired consonant types were stops, fricatives and nasal consonants articulated at the front part of the mouth, i.e., these were labial and alveolar consonants. They also reported that the number of consonants occurring in syllable initial position ranged between 4 and 16, while the number of consonants occurring in syllable final position ranged between 2 and 11.

2.3.3 Linguistic Period - Phase III

The third phase starts from the age of 2;0 to 5;0 years. The third phase evidence the maturation of the children's consonants and vowels. The consonants and vowels acquired become more developed in terms of the numbers and types of sounds as children grow older. That is, children become able to produce various speech sounds and sound structures embedded in longer grammatical structures (Bernthal et al., 2009; Bleile, 2004; Stoel-Gammon and Dunn, 1985). The vocabulary repertoire also increases to include more than 50 adult-like words. However, several phonological patterns could emerge throughout speech development (e,g., a child may replace /θ/ in *three* [θɹi:] by /f/ in [fɹi;], which is a quite typical occurring process at the age of 4;0 years (more details about the speech sound development in phase III are presented in sections 2.5.1, 2.5.2, 2.5.3 and 2.5.4).

2.3.4 Linguistic Period - Phase IV

The fourth phase starts from the age of 5;0 to 9;0 years. During the fourth phase, children fully master speech sounds and are capable of producing longer and more complicated utterances in terms of both phonological structure and grammatical structure which marks their literacy skills development necessary for academic achievement in school (Bernthal et al., 2009; Bleile, 2004; Stoel-Gammon and Dunn, 1985). In this phase, children's phonological systems become more developed in terms of phonotactics, prosodic features development, as well as speech sound production accuracy which are all important for developing reading and writing skills; i.e. phonological awareness skills (Bernthal et al., 2009; Stackhouse and Wells, 1993). Phonological awareness skills include the ability to thoughtfully manipulate and form various word structures to produce meaningfully distinctive oral and written utterances which are of paramount importance for leaning reading and spelling skills, such as rhyming, segmentation and blending of phonemes and phoneme clusters (Bernthal et al., 2009; Burt et al., 1999; Carroll et al., 2003; Stackhouse and Wells, 1997) (more details about the speech sound development in phase IV are presented in sections 2.5.1, 2.5.2, 2.5.3 and 2.5.4).

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2.4 Children with DS – Early Speech Development

Speech is considered as the most challenging difficulty which children with DS face during early life (Chapman et al., 1992; Dodd, 1975; 1976; 1995; Dodd and Leahy, 1989; Dodd and Thompson, 2001; Kumin, 2006). This could be attributed to the fact that speech requires producing voice and combining speech sounds within specific phonetic contexts to form meaningful units (e.g. syllables, words, phrases, sentences, and so on) for conveying their thoughts and needs (Dodd, 1995; Dodd and Thompson, 2001; Kumin, 2012). The difficulty of developing speech in children with DS could be linked to their limited neurological abilities in coordinating speech articulators to produce meaningful streams of speech (Buckley and Le Prevost, 2002; Dodd and Crosbie, 2005; Kumin, 2008; Kumin, 2012; Stoel-Gammon, 1997). For children with DS speaking tends to be the most neurologically and physiologically demanding communicative skill.

It has been claimed that children with DS follow the same course of speech development as TD children. They acquire speech sounds through the same phases characteristic of TD children, although the periods of these stages overlap. For instance, a new acquisition stage could be identified when new vocalisations were produced, and these new vocalisations were not noticed in a previous stage (Oller, 1980; Stark, 1980; Stoel-Gammon, 1997). Most of the descriptions of phonological development for children with DS were based on normative standards and on speech data collected at a single point of time-observation usually took place during the time when the phonology-based difficulties were diagnosed and failed to detect changes in phonological development over longer periods of time. For these reasons, limited information is available about the characteristics of the pre-linguistic or early linguistic phases of speech development for children with DS (Kumin et al., 1994; Stoel-Gammon, 1997; Stoel-Gammon and Dunn, 1985).

Kumin et al. (1994) conducted a longitudinal study to investigate the acquisition and emergence rather than the mastery of phonemes in recordings of CS samples for 60 children with DS aged between 9 months to 9;0 years. The study findings indicated that the emergence of speech sounds in DS children followed the same general order as in TD children in terms of the production of earlier emerging stop, nasal, and gliding consonants than later emerging fricatives and affricates. However, children with DS might not use sounds at typical ages. For instance, the researchers found that a TD child could acquire /b/ at the age of 3;0 years; while DS child might be able to acquire it at the age of 8;0 years. The findings also demonstrated noteworthy differences; for example, the labio-dental fricative /f/ appeared later than the post-alveolar fricative /ʃ/. Since the emergence of consonants occurred within a wider age range for children with DS, it was obviously inappropriate to associate these ages with the typical ages of consonant mastery. The beginnings and ends of phases of early speech development for children with DS are undefinable as is the case with TD children because the stages overlap. There is also a wider age gap between the two populations in terms of the ages of mastery of sounds during the linguistic period, in particular (Kumin et al., 1994; Stoel-Gammon, 1985; Stoel-Gammon, 1997).

The pre-linguistic stage of early speech development for children with DS starts from birth to 1;0 year during which children with DS produce reflexive vocalisations (e.g. crying, fussing, burping, cooing, going, raspberries, nasal resonance perceived as back vowels or short open syllables constituted of consonants produced at the back of the mouth and back vowels classified as non-adult like syllables) (Oller, 1980; Stoel-Gammon, 1997). Between 6 and 7 months, canonical syllables (e.g. CVCV syllables) as a simulation of adult-like syllables begin to emerge. These repeated syllables could be counted as short spoken utterances (e.g. [mæmæ], [dædæ]). Yet, consonants acquired tend to be limited during the first 7 months including several consonants articulated either at the front or back of the mouth (e.g. labial and alveolar consonants) (Oller, 1988; Stoel-Gammon, 1997). In line with the view that children with DS acquire speech sounds and most of their communication skills in the same way as TD children but at delayed pace, a study by Dodd (1972) indicated that during this early stage of speech development (first and second phases), children with DS were similar to their TD peers. The babbling pattern in 10 children with DS and 10 TD children aged 9 months to 1;1 year were compared. There were non-significant differences between the two groups in terms of the number, length, type of sounds in the spontaneous vocalisations they produced, despite the low scoring level of mental and motor assessments for infants with DS compared to their TD peers.

A longitudinal study by Smith and Oller (1981) supported the cross-sectional findings by Dodd (1972). Oller and Lynch (1992) and Steffens et al. (1992) also supported these findings when compared children with DS to TD children aged between 4 and 18 months. The number of canonical syllables (e.g. *dog* produced as [dɒ], [bæbæ]) was proportional to age and syllables consisting of only vowel sounds gradually decreased. However, TD children were able to produce more canonical syllables compared to children with DS within the age range tested. Stoel-Gammon (1981) reported that children with DS aged from 3;10 to 6;3 years extensively used inconsistent sound substitutions. For instance, a participating child with DS substituted /f/ in *fork* [fɔːk] by /s,v,f,k,ʃ/, and in *fish* [fɪʃ] by /h,s,w,m,f/.

Unlike these studies, Lynch et al. (1995) discovered several differences between children with DS and TD children during the early speech development stages. In a longitudinal study, Lynch et al. (1995) found that the age of acquisition of canonical babbling for infants with DS was two months later than TD infants. That is, TD children produced various canonical babbling approximately around age 7 months, while infants with DS produced babbling within the first 9 months. However, due to the oral motor anomalies and motor developmental delays for infants with DS, the productions of canonical babbling tended to be less consistent than in TD infants. This suggested that infants with DS followed a typical developmental pattern during the pre-linguistic period, but it lasted into the second year of life (Stoel-Gammon, 1981; Stoel-Gammon, 1997).

The second phase starts at the age of 1;0 to 2;0 years. During this phase, children with DS start to produce their meaningful first words representing more than one person or object at the same time. For instance, [dædæ] could refer to a parent and, at the same time, to another family member. This phase forms the basis for production of speech at later advanced stages, although these first words were no more than an approximation of adult realisations, for example *no* [nəʊ] *car* [kɑː] (Kumin, 2012). Smith et al (1989) and Smith and Stoel-Gammon (1996) assessed canonical syllable production including reduplicated syllables (e.g., [mæmæ]) and variegated syllables (e.g., [gæbɪdæ]) in TD children and children with DS aged between 6 months and 2;1 years. Both groups were found to be similar in the production of reduplicated and variegated canonical syllables within similar periods of acquisition.

If the pre-linguistic period of vocalisation for children with DS was similar to that of TD children, it would be concluded that this would also continue to later stages of speech development (e.g, first word production). However, this was not the case. Speech acquisition for children with DS was characterised by substantial delay, despite the similarity recognised during the canonical babbling period to typical development (Dodd, 2005; 1995; Stoel-Gammon, 1997). According to Kumin (2012), some children with DS begin to say their first one-word utterances between the ages of 2;0 and 3;0 years (e.g. *mine* [maɪn]); while some other children with DS may produce their first words or short phrases between the ages of 4;0 to 5;0 years (e.g. *eat* [iːt], *doggy out* [dɒgiː aʊt]). This definitely made it difficult to determine the exact average age of first word production for children with DS. In early school years by the age of 11;0 years, they become able to combine two words or more to formulate relatively short phrases and/or sentences (e.g. doggy bark [dɒgiː bɑːk]); yet with omitted suffixes and grammatical inflections (Kumin, 2012). They may produce inaccurate utterances with articulation errors, phonological errors, or both (e.g. sun [θʌn], yellow [leləʊ]) (Kumin, 2012; Stray-Gunderson, 1986).

During late years in elementary school and middle school, they have extensive vocabulary repertoire, however, they find it difficult to combine longer conversational streams of speech partly due to attention and concentration problems and partly due to speech production problems. That is, they have difficulty to combine sound and sound structures to be used in the correct context to communicate their thoughts and needs (Kumin, 2012). Children with DS did not develop all verbal communication components at the same pace. For instance, some children with DS were more capable of perceiving the sounds and sound structures of spoken messages, but they found it a verbally demanding and difficult task to formulate their own utterances so that they could express themselves (Dodd, 1995; Kumin, 2008; Kumin, 2012). The phonological development in children with DS as compared to TD children was explained in detail in sections 2.5.5, 2.5.6, 2.5.7 and 2.5.8.

2.5 A Comparison Between Speech Sound Acquisition in TD Children and Children with DS

Generally speaking, to analyse the phonological systems of children of special populations, such as children with DS, researchers and SLTs usually refer to tables of developmental norms to: (1) analyse the differences and the similarities between the phonological systems in typical and special populations; and (2) identify the sound and sound pattern errors which characterise the phonological systems in the target special population (Dodd et al., 2003; Stoel-Gammon and Dunn, 1985). The following sections present a detailed review of the previous studies on speech sound acquisition in TD children and children with DS.

2.5.1 Acquisition of Consonants in TD Children

Many studies of speech sound acquisition in TD children, who have English as their first language, have been published (Antony et al., 1971; Arlt & Goodban, 1976; Chirlian and Sharpley, 1982; Dodd et al., 2003; Kilminster & Laird, 1978; Paynter & Petty, 1974; Porter & Hodson, 2001; Prather et al., 1975; Smit et al., 1990; Templin, 1957). Age of acquisition of consonants in a number of English dialects spoken in USA, UK, Scotland and Australia have been investigated. Generally, TD children were found to be able to produce most of the consonantal types by the age of 4;0 years, and children continued to acquire the later emerging sounds at ages between 8;0 and 9;0 years. In these studies, the reported ages of acquisition of singleton consonants were limited to age ranges investigated. For instance, only the studies conducted by Chirlian and Sharpley (1982), Prather et al. (1975), and Paynter and Petty (1971) examined the acquisition in TD children at the age of 2;0 years and contributed to the available literature by adding information about speech sound acquisition at earlier ages (Bernthal et al., 2009). Thus, the studies cited reported variety of ages of speech sound acquisition.

In a comprehensive normative study, Dodd et al. (2003) investigated the phonological development in 684 British English-speaking children aged between 3;0 and 6;11 years. It was reported that children acquired a wide variety of consonants at the age of 3;0 years. The finding as such was discrepant with those of other studies in the same domain. This was attributed to the fact that Dodd et al. (2003) included all consonants that were produced with modelling as well as the ones produced spontaneously. On the contrary, the other studies were confined to spontaneous production of sounds (Bernthal et al., 2009). For example, the age of acquisition of fricative sounds /s,z/ was found to be variable more than other consonants across speech sound acquisition studies. For instance, Dodd et al., reported that /z/ was acquired by the age of 3;0 years, and this contradicted what was previously reported in a study conducted by Arlt and Goodban (1976). Arlt and Goodban (1976) found that /z/ was acquired by the age of 4;0 years, whereas the findings of other studies indicated that these sounds were acquired by the age of 5;0 years (Antony et al., 1971; Kilminster and Laird, 1978). Smit et al. (1990) discovered that the age of acquisition of /s,z/ was noticeably different in female and male participants. That is, female children were able to able to produce /s,z/ by the age of 5;0 years; while male participants were able to produce the same consonants by the age 6;0 years. Templin (1957) reported that these fricatives were fully acquired by the age of 7;0 years, whereas other studies revealed that these fricatives were learned by the age of 9;0 years (Chirlian and Sharpley, 1982). Bernthal at al. (2009) and Smit et al. (1990) argued that the variability among these studies in terms of the appropriate age of acquisition of fricatives /s,z/ stemmed from three restrictions: (1) some of the participating children's lack of the front incisor teeth, the existence of which is indispensable for /s,z/ articulation; (2) the disparity between child production and adult production of /s,z/; (3) the phonetic complexity of the assessment words.

In a study of phonological development in 64 children aged between 3;0 and 6;0 years and diagnosed with speech problems, Shriberg (1993) presented a new classification approach to speech sound acquisition. A 'profile of consonant mastery' was suggested, which is derived from the average percentage of correct consonants in spontaneously elicited connected speech samples. Based on study findings, Shriberg (1993) defined three phases of consonant sounds acquisition with 8 in each phase. These included: (1) early acquired consonants /m,b,j,n,w,d,p,h/; (2) middle acquired consonants /t,ŋ,k,g,f,v,ʧ,ʤ/; (3) late acquired consonants /ʃ,θ,s,z,ð,l,ɹ,ʒ/. These three phases were labelled as 'developmental sound classes' profile of consonant mastery. The profile of consonant mastery has been widely referred to in speech sound acquisition studies (Bleile, 2006). The reliability of these three phases was based on a comparison of the findings of Shriberg's (1993) cross-sectional study of children with speech problems with the findings of four other studies, including Hoffmann (1982), Prather et al. (1975), Sander (1972) and Smit et al. (1990) of typical phonological development. When compared to the findings of Sander's study (1972), Shriberg (1993) reported a set of differences between studies on TD speech data and the speech data of children diagnosed with speech delay. For instance, it was reported that 15 out of the 24 English consonants were identified and included within the hypothesised ages of acquisition of consonants. In this respect, Shriberg (1993) stated that "as a cross-sectional estimate of the rank-order of consonant mastery in speech delayed children, the reference consonant mastery profile agrees quite well with estimates of the developmental order of consonant acquisition" (Shriberg, 1993, p.122).

The percentage of consonants correct (PCC) produced by TD children could also be considered as a reliable indicator of speech sound acquisition. PCC can be defined as the number of correct consonants produced divided by the total number of the consonants produced and multiplied by 100. Watson and Scukanec (1997) analysed typical data and estimated PCC of 12 differently-aged American English-speaking children who participated in a longitudinal study. The researchers revealed that PCC was 69.2% and 86.2% for children aged 2;0 and 3;0 years, respectively. Consequently, it was concluded that PCC could increase as children's ages increase. This finding was supported by Dodd et al's. (2003) study of typical phonological development of British English speaking-children in which PCC for TD children aged 5;6 to 6;6 was 95.9%. In conclusion, most of TD children were found to be capable of producing intelligible speech by the age of 4;0 years, in spite of the fact that their phonological systems were not entirely developed (Coplan and Gleason, 1988; Stoel-Gammon, 1997).

2.5.2 Acquisition of Consonant Clusters in TD Children

Regarding the acquisition age of consonant clusters, four comprehensive studies have been conducted (Antony et al., 1971; Higgs, 1968; Smit et al., 1990; and Templin, 1975). Age of acquisition of consonant clusters in word-initial and word-final positions, but not in word-medial position was analysed. McLeod et al. (2001a; 2001b; 2002) presented a comprehensive review of the typical acquisition of consonant clusters. Consonant clusters were produced least correctly at the age of 2;0 years, and the correct production of a whole range of consonant clusters could be achieved by the age of 9;0 years. Therefore, TD children begin to acquire two-consonant clusters (e.g. *spot* [spɒt], *star* [stɑ:]) and gradually develop to produce three-consonant clusters (e.g., *spring* [spr], *street* [str]). Stop consonant clusters were found to be easier to acquire than fricative consonant clusters (e.g., *clean* [kli:n] was found to be easier to acquire than *flower* [flaʊə]). Templin (1957) and Anthony et al. (1971) investigated the typical acquisition of final consonant clusters and the effect of the morphological structure of words on the acquisition of final consonant clusters. For instance, /kt/, which could occur in two different morphophonemic contexts (e.g., '*act'* [ækt] and '*locked'* [lɒkt]) appeared to be acquired by the age of 8;0 years (Templin, 1957). Therefore, Templin (1957) concluded that morpheme-specific clusters tended to be acquired at older ages. They were acquired late during the acquisition process and this could be attributed to structural complexity.

The percentage of consonant clusters correct (PCCC) was also measured and considered as an index of speech sound acquisition process in TD children. It is calculated by dividing the number of correctly produced consonant clusters by the total number of consonant clusters and multiplied by 100. In a study conducted by Roulstone et al. (2002), PCCC was 22% for children aged 2;1 years. In CS samples of Australian English-speaking 2-year old children, PCCC was found to be 31.5% (McLeod et al., 2002). In their longitudinal study, McLeod et al. (2002) reported that PCCC for final consonant clusters was 48.9%, for initial fricative clusters was 38.5%, and for initial stop clusters was 24.3%. In a cross-sectional study, Waring et al. (2001) investigated the production of consonant clusters in SW samples of Australian English-speaking children. The results revealed that PCCC in children aged between 3;5 and 3;11 years was 86%, whereas the PCCC in children aged between 7;0 and 7;11 years was 98%; i.e., PCCC increased as children grew older.

2.5.3 Acquisition of Vowels in TD Children

In as far as the acquisition of vowel sounds is concerned, typical vowels acquisition has been less extensively investigated than consonants. It was argued that this could be attributed to the accentual and dialectal variations that might affect the number and variants of vowel sounds (Smit, 2007). For instance, the inclusion/exclusion of a specific vowel sound due to dialectal/ accentual variation affected the number of vowels in America English; therefore, it could either be 19 or 18. In British, Australian, New Zealand English varieties the vowels set includes 20 vowels (12 pure vowels and 8 diphthongs) characterised with dialectal differences. The pure vowels include /i:/ in *seat* [si:t], /e/ in *bed* [bed], /æ/ in *cat* [kæt], /ɑ:/ in *card* [kɑ:d], /ʌ/ in *cup* [kʌp], /ə/ in *about* [əbaʊt], /ɒ/ in *dog* [dɒg], /ɔ:/ in *door* [dɔ:], /ʊ/ in *foot* [fʊt], and

/u:/ in *goose* [gu:s]. The diphthong vowels comprise of /eɪ/ in *cake* [keɪk], /aɪ/ in *ice* [aɪs], /ɔɪ/ in *boy* [bɔɪ], /ɪə/ in *deer* [dɪə], /eə/ in *bear* [beə], /aʊ/ in *cow* [kaʊ], /əʊ/ in *bout* [bəʊt], and /ʊə/ in *poor* [pʊə] (Howard, 2007; Maclagan and Gillon, 2007; McLeod, 2007; Roach, 2009).

Two aspects associated with the acquisition of vowel sounds were presented; these included 'paradigmatic' and 'syntagmatic' acquisition (Donegan, 2002; McLeod at al., 2001a; Otomo and Stoel-Gammon, 1992). Paradigmatic acquisition of vowels implied practicing producing vowels in isolation (e.g., /æ/), or within one-syllable words (e.g., *cat* [kæt]) which usually characterised the sound production at very young ages. Accordingly, TD children at the age of 1;0 year were able to produce low unrounded vowel sounds (Donegan, 2002). The acquisition of unrounded vowels in 6 children aged between 1;10 and 2;6 years was investigated in a longitudinal study conducted by Otomo and Stoel-Gammon (1992). The findings indicated that /ɪ, ɛ/ vowels were acquired earlier, yet less accurate than /e, æ/ which were acquired later. Antony et al. (1971) mentioned that TD children fully developed vowels by the age of 3;0. Donegan (2002, p.12) stated that "vowels are acquired early, both in production and perception. There is a considerable variability in their production, but most studies suggest that vowel production is reasonably accurate by age 3;0 years, although some studies call this into question." This statement was supported by many studies (e.g., Dodd et al., 2003; Donegan, 2002; Selby et al., 2000; Vihman, 1992). It was concluded that the paradigmatic acquisition of vowel sounds could be achieved between the ages of 3;0 and 4;0 years.

Regarding the syntagmatic aspect of vowel acquisition, this aspect was defined as the children's ability to produce vowel sounds (one or a sequence of vowels) embedded in stressed/unstressed syllable structures within words. Children also learn to produce schwa vowel /ə/ in multi-syllable words (e.g., *banana* [bəˈnɑ:nə]) (James et al., 2001). It was found that the syntagmatic acquisition of vowels could be achieved between the ages 3;0 and 5;0 years (James et al., 2001). The development and stabilisation of the vowels could be extended at ages older than 3;0 years (Allen and Hawkins, 1980; Bernthal et al., 2009; James et al., 2001; Selby et al., 2000; Stoel-Gammon and Herrington, 1990). For instance, TD children acquired and produced vowels in stressed syllables by the age of 3;0 years (e.g., *eyes* [ˈaɪz]), but they become able to produce vowels in unstressed syllable between ages 4;0 and 5;0 years (e.g., *tomato* [təˈmɑ:əʊ]) (Allen and Hawkins,1980; Bernthal et al., 2009).

The percentage of the vowels correct (PVC) was also considered as an indication of the age of acquisition of vowel sounds. PVC could be defined as the number of the correct vowel sounds produced by a child divided by the total number of vowels produced and multiplied by 100 (Bernthal et al. 2009). Dodd et al. (2003) stressed that the accuracy of non-rhotic vowel production in British English-speaking children increased with age (e.g., *bird* [bɜ:d]). Thus, PVC for the youngest age group 3,0-3;11 years was 97.39%; while for older age group 4;0-5;5 years and 5;6-7;0 years was 98.93% and 99.19%, respectively. Similarly, James et al. (2001) also conducted a study on non-rhotic vowel sounds in Australian English-speaking children. It was found that the number of syllables within a given word affected the vowel production accuracy. As a result, vowels production in one-syllable words was more accurate than in multi-syllable words. The findings of Dodd's et al. (2003) and James's et al. (2001) studies agreed with the findings of Pollock and Berni's (2003) study in as far as the accuracy of production of non-rhotic vowel was concerned.

2.5.4 Phonological Processes in TD Children

Within the natural phonology approach to typical speech sound acquisition, the concept of a natural process was introduced (Stampe, 1973; Stoel-Gammon and Dunn, 1985). A natural phonological process could be defined as an intellectual processing that "merges a potential phonological opposition into that member of the opposition which least tries the restrictions of the human speech capacity" (Stampe, 1973, p.vii). Phonological processes have been considered as the underlying representations that have been systematically used in children's speech until they could be entirely suppressed. These representations have been found to be universal, i.e. they were applicable to children's speech production all over the world (Bernthal et al., 2009). For speech-language therapists, natural phonology represented the phonological process approach to assessment and treatment of phonological disorders in the 1970s and 1980s. It was introduced by Stampe (1973) and was considered as the most influential phonological model in speech-language therapy field. Its main objective was to teach children how to suppress innate phonological processes. Natural phonology greatly contributed to the understanding of child speech sound acquisition. It also embraced an attitude similar to that of generative phonology which implied that the child's underlying phonological representations simulated the adult representations. Natural phonology explained how children apply the phonological processes to speech production. For example, it was hypothesised that if children have an adult-like form of a given consonant cluster in their underlying phonological representation, children might reduce this consonant cluster because of the limitation to produce certain sound sequences. For example, /sp/ cluster in *spider* [spaɪdə] could be reduced into [paɪdə] (Grunwell, 1987; Ingram, 1976).

The phonological processes characterising the speech of TD children and ages at which these patterns could be eliminated have been widely studied (Grunwell, 1981; Ingram, 1976; Stampe, 1969). Despite the similarities among the available research findings, there have been noticeable differences in terms of two aspects: the frequency of occurrence of processes and age of suppression of these processes. Antony et al (1971) presented an analysis of the phonological processes occurring in words used by TD children. For instance, TD children aged 3;0 years frequently use initial cluster reduction (e.g., /st/ in *star* [stɑ:] reduced into [tɑ:]), but they could gradually suppress two-consonant cluster reduction by the age of 3;5 years and three-consonant cluster reduction (e.g., /spl/ in *splash* [splæʃ] reduced into [læʃ]) by the age of 4;5 years. Dyson and Paden (1983) assessed 40 two-year old children and examined the ages at which they began to reduce the production of five phonological processes to less than 10% of occurrence; these included: gliding (e.g., /l/ in *leg* [leg] produced as /j/ in [jeg]), cluster reduction (e.g., /kl/ in *clean* [kli:n] reduced into /k/ in [ki:n]), velar fronting (e.g., /g/ in *gate* [geɪt] replaced by /d/ in [deɪt]), stopping (e.g., /f/ in *fish* [fɪʃ] replaced by /t/ in [tɪʃ]), and final consonant deletion (e.g., /z/ in *nose* [nəʊz] deleted and produced as [nəʊ]). This was the ordering of processes investigated during initial assessment from the most to the least occurring processes in the children's speech. During the final assessment, it was found that children at the age of 2;7 years kept using the phonological processes in the same order from the most frequently to the least frequently occurring processes. Accordingly, gliding and cluster reduction remained the most frequently occurring processes. Nonetheless, final consonant deletion was nearly entirely suppressed, whereas fronting and stopping became extremely less frequent.

Haelsig and Madison (1986) examined 16 phonological processes that could appear in the speech of 50 TD children divided into three age groups: 3;0, 4;0, and 5;0 years. The results indicated that the occurrences of processes were inversely related to children's age. That is, the older the children the fewer phonological processes occurred in their speech. It was also found that the speech of children aged between 3;0 and 3;6 years evidenced the occurrences of 5 processes: cluster reduction (e.g., /sk/ in *school* [sku:l] reduced into [ku:l]), weak syllable deletion (e.g., deletion of the first unstressed syllable in *banana* [bənɑ;nə] and produced as [nɑːnə]), glottal replacement (e.g., /k/ in *book* [bʊk) replaced by a glottal stop in [bʊʔ]), labial assimilation (e.g., *rabbit* [ræbɪt] produced as [wæwɪt]), and gliding of liquids (e.g., /l/ in *leg* [leg] replaced by /w/ in [weg]). A finding as such indicated that these processes could appear even in the speech of children at ages younger than 3;0 years. It was also found that children aged between 4;6 and 5;0 years frequently used cluster reduction and weak syllable deletion. More importantly, the finding revealed that the extensive decrease in the occurrence of phonological processes was evidenced at ages between 3;0 and 4;0 years. The findings indicated that processes including velar assimilation (e.g., /d/ in *dig* [dɪg] assimilated into /g/ in [gɪg]), initial voicing (e.g., /f/ in *fan* [fæn] produced as /v/ in [væn]), gliding of fricatives (e.g., /s/ in *sun* [sʌn] replaced by /w/ in [wʌn]), affrication (e.g., /d/ in *doggie* [dɒgiː] replaced by /ʤ/ in [ʤɒgiː]) and denasalisation (e.g., /n/ in *no* [nəʊ] replaced by /d/ in [dəʊ]) were frequently used by children in the three age groups tested. Grunwell (1981; 1987) presented a list of the duration of occurrence and age of suppression of nine phonological processes. For instance, the process of final consonant deletion frequently appeared in the speech of TD children by the age of 2;9 years and was completely suppressed by the age of 3;3 years. Another example was cluster reduction which could be suppressed by the of 3;3 years.

Preisser et al. (1988) analysed the occurrences of eight phonological processes in the utterances of 60 TD children who were divided into three age groups. The first group included children aged between 1;6 and 1;9 years. The second group included children aged between 1;10 and 2;1 years. The third group included children aged between 2;2 and 2;5 years. The study findings indicated that the most frequently occurring phonological processes were cluster reduction (e.g., /bl/ in '*black'* [blæk] reduced to [bæk]) and sound pattern errors affecting liquids, such as gliding process (e.g., /l/ in *'leaf'* [liːf] reduced to [wiːf]). It was also found that the second age group scored percentages of occurrence of phonological processes lower than the first age group, especially syllable reduction and final consonant deletion. It was found that TD children frequently used cluster reduction and liquid deviation, such as gliding of liquids at ages between 1;6 and 2;5 years.

Roberts et al. (1990) revealed that the most frequently occurring processes were final consonant deletion, cluster reduction, fronting, stopping and gliding of liquids. It was discovered that the occurrences of phonological processes tended to decrease in the speech of children aged between 2;6 and 4;0 years. Smit (1993a; 1993b) explained that describing the typical sound and sound pattern errors produced by TD children during the sound acquisition process assisted in identifying the ages at which children master specific classes of sounds and the ages at which they supress the use of phonological processes. Smit (1993a; 1993b) recognised that children aged between 2;0 and 2;6 years were more likely to stop initial /s/ and replace it either with /t/ or /d/. On the other hand, children aged between 3;0 and 3;9 years frequently used final /s/ dentalisation, but rarely used final /s/ lateralisation. Children also tended to use derhotacised (labialised) /ɹ/ sound.

James et al. (1999), as cited in Bernthal et al. (2009, p.104), investigated the use of phonological processes in the speech of 240 TD children aged between 5;0 and 7;11 years. Based on the speech data elicited, four phonological process groupings called 'clusters of phonological process use' were identified. These clusters were presented from the rarely occurring clusters of processes to the frequently occurring ones. Accordingly, the first cluster included voicing (e.g., /f/ in *fan* [fæn] produced as /v/ in [væn]), initial stopping (e.g., /z/ in zoo [zu:] replaced by /d/ in [du:]), final consonant deletion (e.g., deleting /k/ in *bike* [baɪ]) and nasal assimilation (e.g., /f/ in *funny* [fʌni:] replaced by /m/ and produced as [mʌni:]); the second cluster comprised final stopping (e.g., /ʃ/ in *fish* [fɪʃ] replaced by /t/ in [fɪt]), velar assimilation (e.g., /t/ in *take* [teɪk] replaced by /k/ in [keɪk]) and velar fronting (e.g., /k/ in *come* [kʌm] replaced by /t/ in [tʌm]); the third cluster consisted of deaffrication (e.g., /ʧ/ in *watch* [wɒʧ] deaffricated into /ts/ in [wɒts]) and palatal fronting (e.g., /ʃ/ in shoe [ʃu:] fronted into /s/ in [su:]); the fourth cluster constituted of cluster reduction (e.g., /sm/ in *smoke* [sməʊk] reduced into /m/ in [məʊk]), cluster simplification (e.g., /bl/ in *black* [blæk] simplified into /bw/ in [bwæk]), fricative simplification (e.g., /θ/ in *three* [θri:] simplified into /f/ in [fri:]), liquid simplification (e.g., /l/ in *lake* [leɪk] simplified into [jeɪk]) and liquid deletion (e.g., deleting /l/ in *ball* [bɔ:]). In another study, James (2001) assessed the speech of 365 TD children aged between 2;0 and 7;11 years. The study results indicated that children reduced the use of phonological processes between the ages of 3;0 and 4;0 years, although the percentages of occurrences of processes were disparately decreased. For instance, the occurrence of gliding process was decreased by 50% between the ages of 2;0 and 3;0 years, yet for some TD children the same process could also be decreased between the ages of 4;0 and 5;0 years.

2.5.5 Acquisition of Consonants in Children with DS

When compared to typical development of speech, children with DS continue to produce unintelligible speech with various severity levels until ages older than 4;0 years (Kumin, 2006; Kumin et al., 1994; Pueschel and Hopmann, 1993). In their longitudinal study of speech development in children with DS compared to children with developmental disabilities, Sokol and Fey (2013) reported that, at the beginning of the study, DS children's production of consonants was similar to that of children without DS aetiologies. However, after 18 months, the same participants with DS were found to be considerably lagging behind children without DS on the same speech measures evaluated. This obviously evidenced developmental delay of the processes of acquisition and production of speech sounds. Kent and Vorperian, (2013), reported that atypical sound errors appeared earlier in infants with DS even during infant babbling. The speech patterns in children with DS were a combination of delayed (developmental) and disordered (non-developmental) phonological errors which were evident in their speech by the age of 3;0 years.

Van Bysterveldt et al., (2010) also reported that children with DS learn sounds through stages of sound acquisition similar to these in TD children, although phonological development and first word productions were considerably delayed. For instance, they can accurately produce stops, nasals and glides rather than fricatives, affricates and liquids (Bysterveldt et al., 2010). Yet, they evidenced sound acquisition delay in that their phonetic repertoire was found to be nearly 5;0 years below that of TD children. In a longitudinal study of the emergence of phonemes in 60 children with DS aged between 9 months and 9;0 years, Kumin et al., (1994) found that there was a wide age span in sound development in children with DS. The study findings indicated that the emergence of speech sounds in children with DS followed the same general order as in TD children; yet, children with DS might not use sounds at the same typical ages as their TD peers. For instance, it was found that a TD child could acquire /b/ at the age of 3;0 years; while a child with DS could acquire the same sound at the age of 8;0 years; i.e., 5;0 years behind typical acquisition of the same consonant (Kumin et al., 1994).

The same viewpoint was supported by other researchers (e.g., Dodd and Leahy, 1989; Rosenburg and Abbeduto, 1993; Stoel-Gammon, 1997). It was found that children with DS were able to correctly produce stops, nasals and glides; while they were not able to correctly articulate fricatives, affricates and liquids (Bleile and Schawrtz, 1984; Smith, 1984; Stoel-Gammon, 1980; Stoel-Gammon, 1983). Stoel-Gamon (1980) experimentally investigated spontaneous speech of 4 children with DS aged between 3:10 and 6:3 years. The study provided information on the phonological systems of the participants by analysing spontaneous connected speech samples. Stoel-Gammon (1980) identified the consonants of each child and examined the accuracy of production of phonemes. The study findings revealed that children were able to produce most of the target phonemes, although they could do so only in specific word positions. For instance, they produced stops and nasals initially, medially and finally, but they could not produce velar nasal /ŋ/ in any position. They were also capable of producing some fricatives, affricates, liquids and glides but not all of phonemes belonging to these consonantal types. They produced these consonants in certain positions rather than in other ones. For instance, the participants could not produce fricatives /θ, ð/ in word-initial, word-medial and word-final positions. It was also found that children with DS experienced difficulty in producing fricatives and affricates more than nasals and stops.

Bleile (1982) studied the organisation of phonemes in a 4-year child with DS. The child had a constrained forward-backward consonant ordering that in CVC words the initial consonant should either be identical to the final consonant (e.g. *'cup'* [kʌp] produced as [bɜ:p]) or articulated at the front part of the mouth (e.g. *'cheek'* [ʧi:k] produced as [di:k]). The study revealed that the consonant ordering accounted for the consonant substitutions the child produced. This led to conclude that the child with DS had actively imposed specific structure on sound production. In order to yield a more coherent picture of the phonology acquisition process in children with DS, Bleile and Schwartz (1984) investigated the phonology acquisition in 3 children with DS aged 3;4, 3;6 and 4;6, respectively. The development of the phonological systems of the three children was assessed in naturalistic settings, such as free play with toys, and live transcriptions were made. The analysis was based on three perspectives: (1) contrastive production of consonants (2) the children's consonant acquisition (3) the phonological processes the children used. First, the analysis of the contrastive use of consonants implied comparing repeated production trials of single words. For example, the analysis of the multiple productions of word-initial /k/ showed that there was a fluctuation between the production of aspirated [k^h] and unaspirated [k]. The same was also true for the multiple productions of /g/ sound occurring in word initial position. Second, for the consonant acquisition, the results showed the children scored higher PCCs for consonants occurring in word-initial position more than consonants occurring in word-final position. For example, for one of the participants, PCC of initial /m/ was 75%; while it was only 20% for final /m/ (Bleile and Schwartz, 1984). Third, the analysis of phonological processes occurring in conversational speech showed that final consonant deletion (e.g., deleting /g/ in *dog* [dɒ]), initial consonant cluster reduction (e.g., reducing /fl/ into /f/ in *flower* [faʊə]) and stopping (e.g., /s/ replaced by /d/ in [dəʊp]) were the most frequently occurring processes in the speech of the three participants. It was inferred that participants with DS developed basic sound contrasts which could help them express their needs in limited contexts. The sounds they were able to produce correctly represented their limited phoneme repertoire. Finally, children with DS appeared to be identical to TD children at younger ages in terms of consonant acquisition (Bleile and Schawrtz, 1984).

Based on the analysis of SW samples, Roberts et al., (2005) found that boys with DS, aged between 4;0 and 13;0 years, scored PCC lower than these in fragile X and younger TD children when the three groups matched for MA. Similar findings were reported in a study conducted by Barnes et al. (2009) when they tested CS samples of children with DS, aged between 4;0 and 16;0 years. Smith and Stoel-Gammon, (1983) compared the phonological development of 4 TD children, aged between 1;6 and 3;0 years, and 5 children with DS, aged between 3;0 and 6;0 years, throughout a longitudinal observation of the development of singleton stops and stops occurring in consonant clusters. Both groups showed similarity in developing stops, however, children with DS were considerably delayed when compared to their TD peers. Although research findings were limited to stops development, the results showed no major qualitative production differences between both groups. However, there were quantitative differences related to the age of acquisition. Children with DS showed nearly a one- to two- year delayed production at age of 3;0 years. As a result, the production of stop consonants was delayed for children with DS more than for their TD children. Stoel-Gammon (2001) reported that children with DS were found to be similar to TD children in terms of the correct production of stops, nasals, and gliding consonants, although the acquisition process tended to be delayed for children with DS. However, children with DS often made more errors when producing fricatives, affricates and liquids. These results were supported by previous studies conducted by Beleile and Schawrtz (1984), Smith (1984), and Stoel-Gammon (1980; 1981; 1983).

2.5.6 Acquisition of Consonant Clusters in Children with DS

As children with DS begin transitioning into the first word production phase, the speech development difficulties began to appear (Stoel-Gammon, 1997; Stray-Gunderson, 1986). Thus, sound and sound pattern errors are characteristic of the speech of preschool and school aged children with DS, especially consonant and consonant cluster errors (Martin et al., 2009). The acquisition of consonants and consonant clusters tended to be more delayed for children with DS compared to younger TD children with similar mental abilities levels. Children with DS continue to use cluster reduction longer than their TD peers. (Dodd, 1976; Dodd and Thompson, 2001; Iacono, 1998; Roberts et. al., 2005; Stoel-Gammon, 1997).

Based on the assessment results of SW and CS samples of children with DS (Barnes et al., 2009; Iacono, 1998; 2009; Roberts et al., 2005), it was found that the most frequently occurring errors were cluster reduction (e.g., /skw/ in *square* reduced to [weə]), or cluster simplification in which one of the cluster constituents replaced by a glide /w/ (e.g., /kl/ in *clean* simplified to [kwi:n]). Children with DS used these errors more than their TD peers when the two groups were matched for MA. Children with DS who have phonological problems usually have difficulty producing consonant clusters (Chin & Dinnsen, 1991; Hodson & Paden, 1981; McLeod et al., 1997; Powell & Elbert, 1984; Stoel-Gammon, 1987). The difficulty of producing correct consonant clusters in correct contexts tends to continue even at older ages in children with DS (Hodson & Paden, 1981; Wyllie-Smith et al., 2006). Therefore, cluster reduction process lasted for longer time to be reduced, and finally eliminated.

Wyllie-Smith et al. (2006) conducted a study to compare consonant cluster reduction in two groups. The first group included 40 children diagnosed with phonological difficulties, aged 3;6 and 5;8 years. The second group comprised of 16 TD children aged 2;0 and 2;11 years. The study findings revealed 29 of participants with phonological difficulties used cluster reduction by 30.3%; while younger TD participants used the same process by 37.1%. This indicated that performance of children with phonological problems approximated the performance of their younger TD counterparts. Hodson and Paden (1981) compared the cluster productions in 60 children with unintelligible speech, aged 3;0 and 8;0 years, and 60 TD children, aged 4;0 years. The study findings showed that cluster reduction occurred very rarely in the speech sample of all of TD participants. On the contrary, cluster reduction frequently occurred in the speech samples of participants with phonological problems, aged between 4;0 and 5;0 years. Therefore, it was recommended that in children with phonological difficulties consonant cluster production needed to be targeted in order to instruct children that clusters were essentially constituted of two sounds to be produced together (Hodson, Scherz, & Strattman, 2002).

2.5.7 Vowel Acquisition in Children with DS

Children with DS were able to produce back vowel sounds correctly between the ages 9 months and 1;1 year (Dodd, 1972; Oller and Eilers, 1988). In their longitudinal study, Smith and Oller (1980) indicated that the children with DS aged 8 months and 4 days produced vowel qualities similar to those produced by their TD peers at the age of 8 months. Children with DS made fewer errors with vowels (Kumin, 2012; Stoel-Gammon, 1997; Van Bysterveldt et al., 2010; Stoel-Gammon, 1980). For instance, Stoel-Gammon (1980) phonologically analysed spontaneous speech samples of four children with DS aged between 3;10 and 6;3 years. It was found that the participants did not have difficulties with the production of vowel sounds.

Van Bysterveldt (2009) investigated literacy development in 77 school age children with DS, aged between 5;0 and 14;0 years. The results showed that mean PVC was 92.8%. In another study conducted by Van Bysterveldt et al. (2010) to evaluate the effectiveness of an integrated intervention approach simultaneously targeting speech, letter knowledge and phonological awareness skills in 10 preschool age children with DS, aged between 4;4 and 5;5, it was found that mean PVC was 91.3%. In several studies on speech development in children with DS (e.g., Bunton et al., 2007; Stoel-Gammon and Dunn, 1985; Van Borsel, 1996; Van Bysterveldt et al. 2010), it was observed that occurrences of vowel production errors were less frequent than consonant production errors. However, Stoel-Gammon and Dunn (1985) argued that vowel production received less research attention than consonant production, and this might account for the explanation that vowel production seemed to be less difficult than consonant production for children with disordered phonology. The vowel production errors might impact speech development; therefore, vowel errors needed to be further investigated and described (Grunwell, 1981; Ingram, 1976). Hargrove (1982) conducted a case study of a child diagnosed with phonological disorder. The analysis of the speech data collected evidenced the frequent occurrence of vowel production errors, but these errors were rarely mentioned in the available literature. Consequently, the study findings stressed the need to further examine vowel errors in speech of children with speech problems. This would practically help understand the reason for rarity of studies on vowel production problems and whether these problems could be attributed to actual low occurrence of the types of vowel errors or the limited research attention they received. On the other hand, Bunton et al. (2007)

reported that vowel errors could be linked to the tongue mobility and shaping in the mouth. These vowel errors implied either replacing high with low vowels (e.g., replacing /iː/ in feet [fiːt] by /ɪ/ in [fɪt]) or front with back vowels (e.g., replacing /e/ in *pet* [pet] by /ɑː/ in [pɑːt]). To sum up, children with DS acquire vowel sounds in a way similar to typical development. Compared to difficulties of consonant production, the production of vowel sounds tended to be less problematic for children with DS, although they make vowel production errors more than TD children.

2.5.8 Phonological processes in Children with DS

The analysis of CS samples of 4 children with DS, aged between 3;10 and 6;3 years, revealed that children with DS extensively used phonological processes similar to ones reported in the speech of their TD peers. Yet, cluster reduction was the most frequently occurring process (e.g., /fr/ in *frog* reduced to [fɔːg] /sl/ in *sleepy* reduced to [siːbiː]) (Stoel-Gammon, 1980). Bleile and Schwartz (1984) also investigated the phonological processes in CS samples of 3 children with DS, aged 3;4, 3;6 and 4;6 years, respectively. The results revealed that cluster reduction, final consonant deletion and stopping were the most frequently occurring phonological processes for the three participants. On the other hand, processes such as assimilation and weak syllable deletion were the least occurring processes. The results also indicated that participants with DS had developed basic sound contrasts which could help them express their needs in limited contexts. The children with DS appeared to be identical to TD children at younger ages in terms of the number and types of phonological processes they used. Kumin et al. (1998) supported this finding and explained that the speech characteristics of children with DS were not unique to the children of this special population. Instead, they had speech characteristics similar to these of younger TD children. The speech of children with DS contained a variety of speech difficulties and inconsistent speech sound errors.

According to Dodd (1976) and Dodd et al. (1994), the speech of children with DS was characterised by using typical and atypical sound error patterns which usually occurred inconsistently in their speech. So and Dodd (1994) examined the phonological abilities of 28 Cantonese-speaking children. The first group included 14 children with DS, aged between 4;0 and 9;1 years and MA ranged from 2;6 to 8;8 years. The second group comprised of 14 intellectually impaired children without DS, aged between 4;1 and 9;8 years and MA ranged from 2;6 to 5;9 years. The study findings indicated that the phoneme repertoires of the two groups were non-significantly different in terms of consonant and vowel production, articulation errors they made (e.g., producing bilabial fricative /f/ and lisps), however, they were significantly different in the number and types of phonological processes they used in their speech. When comparing the speech sample of children with DS to that of intellectually impaired children, children with DS made a greater number of inconsistent (non-developmental) sound and sound pattern errors including frication (e.g., /pʰɪŋ/ produced as [hɪŋ]), aspiration (e.g., /fa/ produced as [pʰa]), gliding (e.g., /nɐw/ produced as [jɐw]), addition (e.g., /ap/ produced as [nap]), backing (e.g., /si/ produced as [hi]), initial consonant deletion (e.g., /tin/ produced as [in]) (So and Dodd, 1994, p.511). However, the speech sample of children with DS also evidenced the extensive occurrence of consistent developmental sound and sound pattern errors. In addition, children with DS were better in imitation than in spontaneous production. Although Cantonese and English have different phonological structures, children with DS use similar sound pattern errors when acquiring these languages. So and Dodd (1994) argued that the study findings supported the hypothesis that the phonological errors characteristic of the speech of children with DS could be correlated to their impaired phonological planning, i.e. a cognitive linguistic deficit.

In a cross-sectional study conducted by Roberts et al. (2005), the SW samples of 32 boys with DS, aged between 4;0 and 13;0 years, were compared to the SW samples of 50 boys with Fragile X ,aged between 3;0 to 14;0 years, 33 TD boys, aged 2;0 and 6;0 years. The three groups were matched for non-verbal MA. In as far as boys with DS were concerned, they made similar sound substitutions and omissions. For example, 16% of boys with DS used less common processes such as cluster simplifications (e.g., /kr/ in *crane* simplified to [kweɪn]) and lateralisation of sibilants. The results also showed that boys with DS used more structural simplifications than the other two groups. Thus, more than 16 boys with DS frequently used cluster reduction; while approximately 5 (13% of the participants with DS) boys with DS used final consonant deletion. These findings were consistent with the ones obtained in previous research (e.g., Bleile and Schwartz, 1984; Dodd, 1976; Smith and Stoel-Gammon, 1983; Stoel-Gammon, 1980) in terms of the speech development in children with DS. The boys with DS showed delayed speech development in terms of sound errors, especially later developing sounds (e.g., fricatives affricates and liquids) rather early developing sounds (e.g., stops, nasals and glides). The results also revealed that the most frequently occurring processes were consonant cluster reduction and final consonant deletion (final nasals and liquids). However, liquid simplifications (e.g., /l/ in *log* replaced by /w/ in [wɒg]) occurred in the speech of few participants with DS.

Similar findings were also realised in a cross-sectional study conducted by Barnes et al. (2009). The connected speech samples of 34 boys with DS aged between 4;0 and 16;0 years, 32 boys with fragile X syndrome only, aged between 3;0 and 14;0 years, 31 boys with fragile X syndrome with autism spectrum disorder, aged between 5;0 and 15;0 years, and 45 TD boys of similar non-verbal MA were compared. The results showed that boys with DS used phonological processes similar to the ones used by their MA-matched TD counterparts. However, boys with DS used more processes than their TD pees because they tended to either delete or substitute consonants, or delete a syllable (e.g., /tə/ in tomato deleted [mɑ:təʊ]). Thus, boys with DS used late developing consonant stopping (e.g., /ʧ/ in *watch* produced as /t/ in [wɒt]), liquid simplification (e.g., /l/ in *leaf* produced as /w/ in [wi:f]), and cluster simplification (e.g., /spl/ in *splash* produced as /spw/ in [spwæʃ]). The study findings revealed a delayed phonological development in boys with DS when compared to their MA matched TD peers. Additionally, the study findings indicated the sound and sound pattern errors made by participants with DS significantly impacted their phonology development and minimised their speech intelligibility. Martin et al. (2009) and Roberts et al. (2007) stressed that speech development problems and speech intelligibility in children with DS could be attributed to deficits in phonology. It was also reported that preschool and school aged children with DS have phonological errors similar to those of younger TD children, but the errors are inconsistent particularly due to the characteristics of DS. Children with DS tend to use these errors for a longer time than their TD peers do.

Smith and Stoel-Gammon (1983) conducted a phonological study to investigate the phonological development of 5 children with DS, aged between 3;0 and 6;0 years, and 4 TD children, aged between 1;6 and 3;0 years. The similarities and differences in terms of type and percentage of occurrence of phonological processes were identified. Both groups evidenced the use of similar phonological processes, although participants with DS were considerably delayed compared to the TD group in suppressing these processes. Children with DS showed nearly a one- to two-year delayed production at age of 3;0 years. The study findings showed that TD children, aged between 1;6 to 2;0 years, were using the target phonological processes (including final stop devoicing (e.g., /t/ in *teddy* produced as /d/ in [dedi:), initial cluster reduction (e.g., /sk/ in school reduced to /k/ in [ku:l]), initial stop deaspiration (e.g., /p/ in *parrot* produced as [bærət]), and final stop deletion (e.g., deleting /t/ in *boat* [bəʊ]) by 63% as compared to 61% of children with DS at ages 3;0 and 4;0 years.

MacKay and Hodson (1982) studied the systematic sound pattern errors in 20 cognitively impaired children, aged between 6;4 and 15;0 years. Ten of the participants were attending classes for children with learning disability and 10 were attending classes for trainable cognitively impaired children. Six of the trainable cognitively impaired children were diagnosed with DS. The analysis of SW samples for all participants showed that liquid deviations and cluster reduction were the most recurrently used processes. The participants' speech samples also evidenced initial and final consonant devoicing. On the other hand, processes such as initial consonant deletion, deviations of glides and nasals, velar deviations, and stopping were less frequently occurring in the participants' speech. It was reported that the highest percentage of speech defects was identified in the speech of participants classified as trainable cognitively impaired children including children with DS. The phonological errors in children with DS were also analysed by Dodd and Thompson (2001). The sound pattern errors of two groups (15 children with DS and 15 intellectually average children) with mean age of 10;5 years, matched for percentages of incorrect consonant production, were experimentally investigated and compared. The results revealed that children in both groups were nearly similar in the number of inconsistent sound errors during repeated picture naming task of 25 words. However, the children in both groups were different in the type of sound pattern errors they produced. The phonological errors included sound substitutions (e.g., /f/ in fish replaced by /p/ in [pɪʃ]), consonant addition and consonant deletion.

The phonological errors in children with DS were found to be a combination of developmental errors and atypical errors. However, whether their speech was delayed or disordered has been a controversial topic. Most of the previously mentioned studies suggested a delay, yet few studies investigated the relationship between cognitive or language skills and intelligibility. Cleland et al. (2010) conducted a study to determine whether expressive phonological difficulties in children and adolescents with DS could be associated with language and cognitive levels. The study also aimed at identifying the types of phonological errors (developmental or non-developmental) occurring in the speech of children and adolescents with DS. Therefore, the speech of 15 participants with DS, aged between 9;0 and 18;0 years was evaluated. In as far as the phonological errors were concerned, the results indicated that most of the participants' sound pattern errors were developmental in nature, but all of them exhibited at least one atypical or non-developmental articulation-based speech error.

Cleland et al. (2010) found that individuals with DS had sound errors characterised by atypical, and often unusual, errors in combination with many developmental errors. Since the results revealed that there was non-significant correlation between speech and cognition or language measures, a finding as such suggested that the phonological difficulties in individuals with DS could not only be linked to cognitive delay.

Cleland et al. (2010) reported that SW samples of children with DS evidenced the occurrence of 29 processes. These included labiodental /ɹ/, backing of /ɹ/, gliding, velar fronting, post-alveolar fronting, stopping, context-sensitive voicing, devoicing, glottal replacement, affrication, deaffrication, backing, spirantisation, palatalization, debuccalisation, nasalisation, dentalisation, lateralisation, phoneme-specific nasal emission, lateral release, feature synthesis, weak syllable deletion, consonant harmony, cluster reduction, final consonant deletion, initial consonant deletion, metathesis, ingressive, ejective and other processes. Additionally, 23 of these processes occurred at least 3 times in at least one participant's speech. Participants with DS used 11 processes out of 29 similar to the ones occurring in the speech of TD children. The speech of participants with DS was characterised by the use of approximately 65 unknown phonological processes which could be classified as unusual or atypical processes. Structural processes such as consonant deletions (e.g., *mouse* produced as [maʊ]) and the non-developmental initial consonant deletion (e.g., *five* produced as [aɪv]) frequently occurred in participants' SW samples. The speech of highly unintelligible participants was characterised by the production of words void of any consonants, i.e., they produced only the vowels in CVC words (e.g., *sheep* produced as [iː]). Cleland et al (2010) explained that the development of whole word production evidenced the occurrence of structural simplifications prior to the occurrence of systematic simplifications such as sound substitutions. This suggested a developmental delay of speech in children with DS.

Corsley and Dowling (1989) examined the relationships between three factors including sentence length, chronological age, and IQ and five phonological processes comprised of stopping, velar fronting, velar deletion, stridency deletion, and substituting a strident consonant with a non-strident consonant in 22 children with DS, aged between 6;6 and 12;7 years. The results revealed significant inverse relationships between the sentence length factor and four phonological processes including velar fronting, velar deletion, stopping, and strident consonant deletion. The study findings indicated that sentence length could be used as the primary predictor of cluster reduction and liquid simplification in speech production of children with DS. Crosley and Dowling (1989) also indicated that children with DS used phonological patterns similar to those used by TD children, although they did that at a slower rate, expressing delay rather than disorder. Since speech in TD children with phonological problems manifested a correlation between utterance syntactic structure and its phonological structure, children with DS were found to perform in a similar way to TD children (Menyuk, 1969; Panagos, Quine & Klich, 1979; Paul & Shriberg, 1982; Shriner, Holloway & Daniloff, 1969). That is, children with DS used fewer processes in longer sentences, especially velar fronting, velar deletion, stopping and strident consonant deletion (Corsely and Dowling, 1989).

The study findings showed significant relationship between chronological age and two processes: velar deletion and strident consonant deletion. Therefore, age factor was found to be a significant predictor of final consonant deletion in children with DS. Accordingly, velar deletion and strident consonant deletion processes decreased as children with DS grew older. A finding as such suggested that children with DS could develop and improve their phonological abilities in a similar way to that of TD children. However, there was a non-significant relationship between chronological age and velar fronting, stopping and strident substitution (Corsley and Dowling, 1989). The results also revealed that there was a significant association between IQ and only one process, i.e., velar deletion. Since it was difficult to determine the reason behind the ambiguous association between IQ and examined processes, IQ was considered to be a non-practical indicator of the phonological processes of velar fronting, stopping, strident consonant deletion and strident substitution (Corsely and Dowling, 1989).

2.6 Speech Intelligibility in TD Children and Children with DS

Generally, intelligibility can be defined as the "degree to which others can understand a person's speech" (Hodson, 2010, p.199). Gordon-Brannan (1994) considered intelligibility as the most functional index of spoken language proficiency. Speech intelligibility could be affected by articulation and phonology problems. In this respect, Vihman (1998) reported that children aged 3;0 years tended to use more complex utterances so that their speech became more difficult to be perceived by the surrounding individuals. In many studies (e.g., Coplan and Gleason, 1988; Gordon-Brannan, 1993; 1994; and Roulstone et al., 2002; Vihman, 1998; Weiss, 1982), speech intelligibility of TD children was investigated. The findings indicated that children's speech intelligibility (number of understandable words) increased as children grew older.

The understandability of children's speech could be affected by the children's relationship with different types of listeners with whom they spoke. For instance, in the comprehensive study conducted by Roulstone et al. (2002), the speech intelligibility of 1,127 children aged 2;1 years was examined. The results revealed 12.75% of parents considered their children's speech as intelligible; while 2.1% of parents considered their children's speech as unintelligible (Roulstone et al., 2002, p.264). On the contrary, in other studies investigating speech intelligibility of children aged 2;0 years it was found that children were intelligible to 50% of strangers, and when children were 3;0 years of age their speech was intelligible to 75% of strangers (Coplan and Gleason, 1988; Vihman, 1998). Therefore, children who were found to be unintelligible at the age of 3;0 years or older needed immediate speech intervention (Bernthal and Bankson, 1998). Flipsen (1995) emphasised that understandability of children's speech could be affected by their relationship with the surrounding individuals depending on whether they were immediate family members or strangers. In another investigation of speech intelligibility, Flipsen (2006) assessed speech intelligibility in 320 TD children aged between 3;1 and 8;0 years. The study findings indicated that speech intelligibility was proportional with age, i.e. the older the children grew, the more intelligible their speech became. Intelligibility index could be defined as "the percentage of words in the entire sample that the transcriber could reliably understand" (Flipsen, 2006, p.306).

For children with DS, speech intelligibility is considered as a major communication problem. Typical and atypical phonological deficiencies in children with DS negatively affected their speech intelligibility (Shriberg and Widder, 1990; Stoel-Gammon, 1997). Parents of children with DS have been considerably concerned that their children could not be understood by other individuals who are not immediate family members, such as friends, acquaintances as well as teachers (Kumin, 2006; 2012). In a questionnaire-oriented study conducted by Kumin (2006), opinions of 937 parent of children with DS were collected and analysed. The study findings revealed that approximately 60% of parents (whose children's ages ranged between 1;0 and 21;0 years with mean age of 8;16 years) considered their children's speech as unintelligible. In addition, the parents reported that they were continuously faced with the difficulty of understanding what their children said. On the other hand, 37% of participating parents reported that they were sometimes unable to understand their children's utterances. According to the responses of 80% of participating parents, most of the speech intelligibility problems resulted from articulation difficulties. In another questionnaire-oriented study, Pueschel and Hopmann (1993) revealed that 71% to 94% of parents of children with DS aged between 4;0 and 21;0 years attributed their children' intelligibility problems to articulation and the inability to produce phonemes in the correct context (phonological problems).

Speech intelligibility is critical for the development of children with DS not only because it limits their communication abilities, but also it may result in behavioural problems if they could not be understood by other individuals (Kumin, 2012; Stoel-Gammon, 2001). According to Stoel-Gammon (1997; 2001) and Roberts et al. (2007), producing intelligible speech tended to be the main lifelong interaction barrier for children with DS when compared to TD children who tended to be approximately fully intelligible by the age 4;0 years. Children with DS at younger ages produced unintelligible utterances. At later ages, for most children with DS one- or two-word utterances could be easily understood, however, longer utterances in connected speech (e.g. a conversation about a day at school) turned out to be more challenging to be produced and more difficult to be perceived (Bray and Woolnough, 1988; Martin et al., 2009). Bray and Woolnough (1988) investigated the speech intelligibility in 11 children with DS aged between 12;0 and 16;0 years. It was found that speech intelligibility decreased as the syntactic complexity of spoken utterances increased and that speech intelligibility and understandability levels tended to be variable. The children's speech intelligibility and the extent to which listeners could understand what was said also depended on the type of the conversational topic and the closeness of the relationship with the listener (Kumin, 2006; 2008; 2012).

Roberts et al. (2007) argued that the causes of speech intelligibility problems in children with DS seemed to be of varied origins, such as frequent use of phonological processes, changing or reducing word shapes/structures (e.g., blindfold [blaɪndfəʊld] produced as [bɑːfɔ;]), childhood apraxia of speech (CAS) or dysarthria. Therefore, the identification of speech intelligibility difficulties and their causes could practically assist professionals in designing appropriate intervention programmes to target these problems and improve speech intelligibility (Kumin, 2008; 2012). However, limited literature was available on speech intelligibility problems in children with DS before mid-1990s (Kumin, 2012; Roberts et al., 2007). The main factors affecting speech intelligibility are: (1) anatomical and physiological factors; (2) neurological malfunctioning factor; (3) articulation and phonology factors. Children with DS could have one or a combination, but not all of these factors affecting the intelligibility of their speech (Ertmer, 2011; Kent and Verporian, 2013; Kumin, 2012).

The various anatomical (structure) and physiological (function) characteristics in children with DS tend to affect speech intelligibility to different extents. The structures of specific body parts, especially the parts responsible for speech production, and the functioning of these parts could reduce speech intelligibility (McDuffie and Abbeduto, 2009). The structure distortions include: jaw structure, palate structure, teeth distortion, tongue size and shape. The jaw structure could be small and narrow which could limit the tongue mobility during the speech sound articulation. The palate, which forms the roof of the mouth, sometimes appears to be either narrower or higher than the typical structure and results in nasalised speech sound productions (Newton, 2015; Sokol and Fey, 2013). Teething in children with DS could be slower than in TD children, or it comes out with missing or crowded teeth which negatively impacts the production of specific speech sounds for which teeth form part of their articulation process (e.g., dental /θ,ð/ or alveolar /s,z/). The teeth could also be characterised by malocclusion so that the upper teeth could overbite the lower teeth. This would extend the tongue out of the mouth and would result in producing incorrect sound (Desai, 1997; Marder and Nunn, 2015; Rosenfeld-Johnson, 1997). For instance, instead of producing /s/ the tongue would be protruded and /θ/ sound would be articulated. Finally, the relatively abnormal tongue shape and size in children with DS could affect its mobility during the articulation of a great deal of consonants and vowels. The relatively large tongue size in a small and narrow mouth structure limit tongue movements necessary for the production of speech sounds, such as /t,d,s,n,l/.

Physiologically, the malfunctioning of body parts responsible for speech production could also impact speech intelligibility. These include hypotonia of the facial muscles and recurrent otitis media with effusion causing hearing problems (Kumin, 2012; 2008). Hypotonia is low tone in the muscles of the mouth, palate and pharynx which result in speech sound distortions as these lax muscles prevent the articulators from being in the appropriate posture necessary for the production of a given sound or a sound sequence. Since typical hearing level is of paramount importance for perceiving and learning speech sounds, children with DS need to recurrently listen to sounds and sound sequences to internalise them. However, for children with DS learning sounds through hearing could be hindered due to recurrent otitis media with fluid in one or both ears. This usually causes hearing fluctuation that the children sometimes hear the sounds clearly but could not do so at some other times. Therefore, children with DS sometimes need to use hearing aids (Kumin, 2008; 2012; Kent and Vorperian, 2013).

The second factor affecting speech intelligibility is associated with the neurological functioning (Cunningham, 2006; Kumin, 2012). The nervous system is responsible for coordinating the movements and functioning of different body parts (e.g. organs of speech) and muscles. Therefore, problems of malfunctioning of the neurological system could negatively affect accurate speech production. The neurological malfunctioning comprises of oral motor, motor planning and auditory perception difficulties (Kumin, 2006; 2008; Sokol and Fey, 2013). The motor planning difficulty relates to the inability to coordinate the articulator movements with the sounds to be produced and causes speech sound sequencing problems (Kumin, 2008; 2012; Newton, 2013). Finally, auditory information processing has been found to be more challenging than visual information processing for children with DS. They tend to perceive or retrieve what they see more than what they hear. This causes them problems of segmenting and discriminating speech sounds during speaking and, in return impacts learning speech sounds (Fidler et al., 2009; Jarrold and Baddley, 2002; Pueschel et al., 1987).

The third and most important factor affecting speech intelligibility is articulation- and phonology-based difficulties. The speech of most children with DS has been characterised with the occurrence of articulation and phonological errors. Articulation problems were considered to be more difficult than phonological errors. This could be attributed to the fact that articulation was entirely associated with anatomical and physiological factors that might stem from either oral-motor structure abnormalities or oral-motor malfunctioning or both kind of difficulties. The available research on articulation disorders in children with DS has revealed that 95% of children with DS have articulation difficulties (Bray, 2007; Dodd and Thompson, 2001; Stoel-Gammon, 2001). For children with DS, the articulation of consonants tended to be more challenging than the articulation of vowels (Stoel-Gammon, 1980; Rosin et al., 1988).

On the other hand, phonological errors were essentially associated with the production of incorrect sounds and sound patterns in incorrect contexts. Yet, these errors could be overcome through early speech intervention. TD children used phonological processes at certain ages, but they became able to supress them all at early ages. On the contrary, children with DS tended to use phonological processes longer even at older ages (Kumin, 2012; Smith and Stoel-Gammon, 1983). Phonologically, the extensive use of phonological processes highly impacted speech intelligibility in children with DS. That is, reducing consonant clusters, deleting consonants, vowels or whole syllables, or substituting sounds would result in decreasing speech intelligibility (Roberts et al., 2005). The phonological errors used by children with DS simultaneously included developmental and atypical errors which tended to occur inconsistently in children's speech (Cleland et al., 2010; Kumin, 2008). The longer and more complex the structure of the utterance was, the more processes would be expected to occur and the less intelligible the utterance would become (Kumin and Adam, 2000; Kumin, 2002; Stoel-Gammon, 1980; Stoel-Gammon; 2001). This explains why CS samples in children with DS included an increasing number of phonological processes more than the ones identified in SW samples (Sommers et al., 1988).

2.7 Speech Sample Representativeness

The representativeness of speech assessment materials and the accuracy of the assessment results have been the main concerns of SLTs and researchers. The assessment of phonological systems of children with speech sound disorders and unintelligible speech, as in children with DS was based either on single word production by using picture naming tasks or connected speech production by manipulating playing-oriented interactive activities (Dodd et al., 2002; Hodson, 1980; Hodson, 2004; Shriberg and Kwiatkowski, 1980). Hodson (1980) stressed that speech samples based on single word production were considered as a stable and predictable representation of the children's speech production, especially for children diagnosed with highly unintelligible speech. This viewpoint was supported by Paden and Moss (1985). The responses of 8 children, aged between 4;11 and 10;7 years and diagnosed with phonological problems, were evaluated. Three types of phonological assessments were compared. The first two assessments assisted in eliciting SW samples, the third one assisted in eliciting CS samples. Two problems were identified in CS samples. Five participants were excluded due to high speech unintelligibility of their CS samples that the samples could not be glossed and analysed. The excluded participants were not able to produce spontaneous continuous utterances, instead they produced one-word utterances. Therefore, this observation supported the viewpoint that administering single word production assessment could practically assist in evaluating the phonological abilities of highly unintelligible children. However, Shriberg and Kwiatkowski (1980) supported the use of CS samples rather than SW samples for phonology assessment purposes. It was argued that CS samples would require children to produce longer utterances in naturalistic contexts; therefore, these samples would reflect the children's actual speaking skills and, at the same time, demonstrate the number and type of sound and sound pattern errors they frequently used in their connected speech.

Campbell and Shriberg (1982) and Paul and Shriberg (1982) argued for the inclusion of CS samples in the assessment of phonological system development. It was found that production of phonological units (sounds and sound patterns) could be affected by syntactic and pragmatic variables. Campbell and Shriberg (1982) investigated the association of the pragmatic factor (e.g., conversation topic or making comments on a given topic) with phonological errors. The results indicated that children diagnosed with speech delay used more phonological processes when conversing about the test topics rather than when making shorter comments about these topics. Paul and Shriberg (1982) conducted a study to examine the way syntax affected the production of phonological units in 30 children diagnosed with speech delay problems. The study findings revealed an interdependent association between the syntactic structure of utterances and the number of phonological errors used. Thus, the more complex the syntactic structure of a given utterance was, the more phonological processes it contained. The findings of these two studies supported what was reported in a phonology-based study conducted in late 1970s. For instance, Panagos et al. (1979) found that CS sample could be considered as a reliable indicator of the phonological errors, as CS samples required children to produce longer utterances. Consequently, the longer and syntactically more complicated the utterances were, the more errors occurred in the children's speech.

Comparing the phonological errors occurring in SW and CS samples, it was discovered that children used sound and sound pattern errors in CS samples more frequently than in SW samples (Andrew and Fey, 1986; Klein, 1984; Morrison and Shriberg, 1992). Klein (1984) found that specific sound pattern errors (e.g., cluster reduction, final consonant deletion and weak syllable deletion) were more frequently occurring phonological errors in CS samples than in SW samples. Morrison and Shriberg (1992) supported these findings and evidenced these differences between and within groups of children assessed. Similarly, Andrew and Fey (1986) reported these differences in terms of specific types and number of phonological errors in SW and CS samples. Yet, it was found that the level of severity was relatively the same in both types of speech samples. In order to fully understand the phonological development of children with DS, the present study was based on analysing both types of sampling conditions: single word samples and spontaneous connected speech samples. That is, it explained the frequency and type of phonological errors produced by children with DS as a group and analysed the same aspects as produced by each individual child. The speech data elicited could assist in providing a wider range of understanding the phonological development in children with DS compared to their TD peers when matched for non-verbal MA.

Chapter 3: Methodology for Group Study

3.1 Ethics, Recruitment, Consent and Demographics

The Research Ethics Committee at University of Reading approved the present study which focused on analysing the phonological development in children with DS as compared to the phonological development in TD children. The TD group was mainly recruited through the Child Development Group Database at University of Reading which included the contact details of the families of TD children. The participating families were contacted either by email, ordinary mail correspondence, or telephone. They were informed about the study and provided with detailed study information sheets, posters and consent forms (see appendix A). They were asked to contact the researcher if they were willing to take part in the study. For recruiting the participants of DS group, the study was advertised through the DS Association in the UK, the DS local charities and the support groups for mothers of children with DS in Reading and London. Furthermore, the study was advertised throughout the Department of Clinical Language Sciences and Speech and Language Therapy Clinic at the University of Reading, and several mainstream primary schools in Reading and Leatherhead. Officially, cover letters to the parents and the schools' head teachers (see appendix A) were sent to invite the families of the children in both groups to participate in the experiment.

After reviewing the study information and poster advertisement, the families of children in both groups contacted the researcher expressing their willingness to participate. The volunteering families signed the provided consent forms to give permission to the researcher to administer the assessment of the participants' speech and general intellectual abilities on previously arranged days and times. The volunteering families were informed that participation was on a voluntary basis, and that they could withdraw from the study at their discretion. The families were also asked to read the information sheet thoroughly prior to the start of the experiment. They were also encouraged to ask questions about the study so that they were satisfied with the answers and explanations they received. During the assessment sessions, each child in both groups was repeatedly asked whether he/she was willing to continue responding to the assessment items. Each child was also offered several short breaks to motivate them and ensure their readiness to respond to the rest of the assessment activities. At the end of each assessment session, the child was rewarded with a story book, two play dough tubs, a little toy and five pounds.

3.2 Participants

For the present study, two groups of children were recruited. The first group included 17 monolingual British English-speaking children with DS (5 girls and 12 boys) aged between 5;5 and 12;0 (year; month) years, i.e. 65 to 144 months, with the mean age of 9;0 years and mean age of 109 months (with the average MA 23 months behind CA) (see table 3.1). This age range was chosen due to the substantially delayed emergence of the first meaningful utterances of children with DS. Due to the difficulty of collecting adequately reliable speech data from children with DS at ages younger than 5;0 years, the age range tested started from 5;0 years. The 17 participants with DS met the following selection criteria: (1) they were monolingual, British-English-speaking children; (2) they were diagnosed with DS (trisomy 21); (3) they had relatively normal vision and hearing levels; (4) they had no serious oral-motor structure malfunctioning/distortion; and (5) they had no serious medical/surgical conditions, such as congenital heart defects, gastrointestinal tract abnormalities, thyroid dysfunction, seizures, and so on (Iacono, 1998; Van Bysterveldt et al., 2010). Although they were not using hearing aids, 8 participants with DS had mild hearing difficulty. In addition, 5 participants with DS were wearing glasses as they have vision problems. All the 17 DS participants had received speech and language therapy in addition to other communication skills training which was either conducted at schools or privately. The second group comprised of 20 TD children (12 girls and 8 boys) aged between 3;0 and 6;3 years, or 36 to 75 months with the mean age of 4;7 years, the mean age of 57.45 months and *SD*=12.64 (with an average MA of 32 months above CA) (see table 3.1). The participants in TD group were recruited based on the following criteria: (1) they were monolingual, British English-speaking children; (2) they were not diagnosed with any cognitive disorder or learning disability; (3) they had normal vision and hearing levels.

The participants in TD and DS groups were matched for MA because the profile of the speech and language development of children with DS may be related to their non-verbal MA (Buckly and Le Prevost, 2002). With regards to the participants' non-verbal MA, the non-verbal MAs for the DS group ranged between 50 and 124 months with a mean of 86.06 months and *SD*=22.63. For the TD group, the non-verbal MAs ranged between ranged between 50 and 147 months with a mean of 89.65 months and *SD*=26.01 (see table 3.1). Running a between-participant t-test, the results showed that the two groups were non-significantly different in terms of the mean MA [$t= 0.44$, $p=0.66$]. The mean difference was found to be 3.59, and the effect size was considerably small 0.14 (see table 3.2). However, the two groups were significantly different in terms of the mean CA [t=7.98, p<0.001]. The mean difference was found to be 51.60 months, and the effect size was large, (d=2.70) (see table 3.2).

Table 3.1 Descriptive analysis of CA, MA and MLU for TD and DS groups

Variables	Groups	Mean	*SD*	*SE*	Median	Range	Minimum	Maximum	95% CI for Mean	
									Lower Bound	Upper Bound
CA in months	TD	57.45	12.64	2.82	59	39	36	75	51.53	63.37
	DS	109.06	25.49	6.18	121	79	65	144	95.95	122.17
MA in months	TD	89	26.01	5.81	85.50	97	50	147	77.47	101.83
	DS	86	22.63	5.48	91.00	74	50	124	74.42	97.69
MLU	TD	5.03	0.78	0.17	5	3	4	7	4.66	5.40
	DS	2.23	0.56	0.13	2.26	2	1	4	1.99	2.52

Note: CA-Child's chronological age in months. MA-Child's nonverbal mental age in months. MLU-Mean length of utterance in morphemes. TD-Typically developing children, and DS-Children with Down syndrome. CI-Confidence limits around the mean.

Table 3.2 T-test results for participants characteristics

Accuracy Measures	Groups	Mean	*SD*	*t*-value	*p*-value	*SE*	*df*	Mean Difference	95% CI of Difference	
									Lower Bound	Upper Bound
CA in months	TD	57.45	12.64	7.98	0.001	6.46	35	51.60	38.48	64.73
	DS	109.06	25.49							
MA in months	TD	89	26.01	0.44	0.66	8.09	35	3.59	12.83	20.01
	DS	86	22.63							

Note: CA-Child's chronological age in months. MA-Child's nonverbal mental age in months. TD-Typically developing children, and DS-Children with Down syndrome. CI-Confidence limits around the mean difference.

The measurement of the mean length of utterance (MLU) was calculated in morphemes for TD and DS groups. Fifty intelligible utterances were selected out of the CS sample for each participant in the two groups. Since there was no systematic difference between the participants' spontaneous and facilitated responses, both types of production were scored in the same way, i.e. they were counted as correct productions (Dodd et al., 2003; Smith and Stoel-Gammon,1983). The morphemes in each utterance were counted and added to the morphemes of the rest of the utterances to calculate the total number of morphemes. The MLU was calculated by dividing the total number of morphemes by the number of the selected 50 utterances.

Descriptive statistics showed that mean MLU for DS group was shorter than that for TD group. The means, *SD*s, ranges, minimum and maximum values were summarised (see table 3.1). One-way between-participants ANCOVA was carried out to examine the effect of group factor as the independent variable (IV) on the MLU as the dependent variable (DV) when non-verbal MA was held constant (covariate). The results showed that there was a significant difference between TD and DS groups in terms of MLU [$F(1,33)=47.551$, $p=0.004$, $\eta^2=0.590$]. This indicated that DS group performed at a delayed onset. The effect size was very large ($\eta^2=0.590$). However, there was a non-significant group*MA interaction [$F(1,33)=0.069$, $p=0.795$, $\eta^2=0.002$] (see table 3.3). This indicated that DS group developed at a typical rate similar to that of their MA-matched TD group. Linear regression was also conducted. For the TD group, the results showed that MA was a significant predictor of TD group performance in terms of MLU [$R^2=0.441$, $F(1,19)=14.205$, $p=0.001$]. The intercept was 4.3023 and the gradient was 0.0201 (see figure 3.1). The confidence intervals around TD trajectory were narrow, indicating that there was 95% confidence that the population slope was between 3.774 and 4.830. Similarly, in DS group MA was found to be a reliable predictor of MLU development [$R^2=0.285$, $F(1,16)=6.015$, $p=0.027$]. The intercept was 1.5939 and the gradient was 0.0178 (see figure 3.1). The confidence limits around the DS trajectory were between 0.941 and 2.247. When developmental trajectories were plotted by non-verbal MA, TD and DS trajectories were parallel and positively-trended. This indicated that TD and DS participants continued to develop MLU which was correlated to their cognitive abilities.

Table 3.3 ANCOVA results for MLU in CS Samples for TD and DS groups

Source	*df*	Mean Square	*F*	*p*-value	*Effect Size* η^2
Group	(1,33)	18.821	47.551	0.001	0.590
MA	(1,33)	7.192	18.170	0.001	0.355
Group * MA	(1,33)	0.027	0.069	0.795	0.002

Note: MLU-Mean length of utterance in morphemes. TD-Typically developing children. DS-Children with Down syndrome. MA-Nonverbal mental age measured in months from youngest age in TD group.

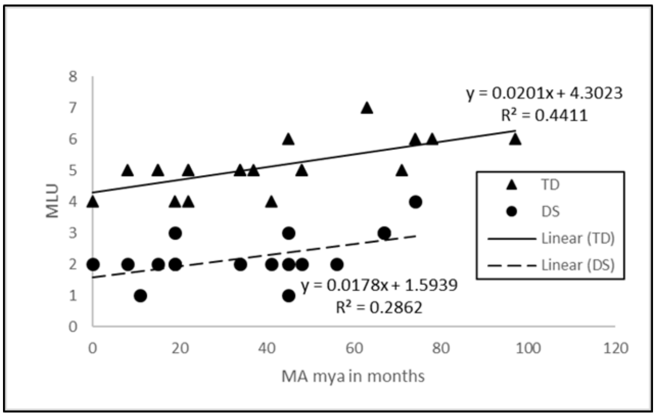


Figure 3.1. MLU measured in CS samples for TD and DS groups. The figure illustrates the developmental trajectories of mean length of utterance in morphemes (MLU) in connected speech (CS) samples. The trajectory for TD group is represented with a solid line, and for DS group is represented with a dotted line. MA represents non-verbal mental age measured from youngest age in months in TD group.

To ascertain the general characteristics of the participants in the two groups tested, demographic data were collected (Connelly, 2013). A demographic information sheet (see appendix B) was either sent to the parents/caregivers via email to be completed, or the parents were asked to fill in these sheets during the assessment sessions. The information sheet consisted of three (yes/no) questions which enquired about the participants' vision and hearing problems, language/s of communication other than English used at home or school, and whether they received speech therapy services. Table 3.4 summarises the participants' demographic information. The questions centred on the following: whether the participating children had any hearing or vision problems, whether they spoke languages other than English at home and school, and whether they had received speech therapy services within the last 12 months prior to their participation in the study or around the time of administering the assessment sessions. The demographic data collected were statistically tested using Fisher's exact test to see the differences and similarities between the various characteristics of DS and

TD participants. The Fisher's exact test results indicated that there was a significant difference between DS and TD groups in terms of gender (*p*=0.002). For the hearing or vision problems and the speech therapy service the Fisher's test results revealed that there were statistically significant differences between the two groups (*p*=0.001). The same was also true for reception of the speech therapy service; i.e., there were considerably significant differences between the two groups (*p*=0.001).

Table 3.4 Demographic data for TD and DS participants

Demographic Variables	**Levels**	**Frequency Counts**		**Percentage of Valid Cases**	
		TD Participants	DS participants	TD Participants	DS Participants
Gender	Female	12	5	60%	29%
	Male	8	12	40%	71%
Hearing Problems	Yes	0	8	0%	47%
	No	20	9	100%	53%
Vision Problems	Yes	0	5	0%	29%
	No	20	12	100%	71%
Other Languages	Yes	0	0	0%	0%
	No	20	17	100%	100%
Receiving Speech and Language Therapy Service	Yes	4	17	20%	100%
	No	16	0	80%	0%

Note: TD-Typically developing children. DS-Children with Down syndrome.

3.3 Method: Group Study

The first part of the thesis is a group study which analyses the phonological systems of children with DS as compared to TD children. The sections that follow explain the methodology adopted to collect data and conduct speech data analyses in addition to explaining the characteristics of the participants in both groups.

3.4 Data Collection and Materials

The performance of the participants in the DS and TD groups were evaluated using a combination of standardised and non-standardised assessment battery. The assessment sessions were administered in different locations. Since all the TD participants were from Reading, they were all assessed in the Speech and Language Therapy Clinic at the University of Reading. However, the assessment sessions for the participants with DS were administered either in the Speech and Language Therapy Clinic at the University of Reading or in the participants' own houses/schools. This was due to the fact that most of the DS participants were not from Reading, or were based in Reading, but did not reside near the University of Reading campus. In all the locations (clinic, house, or school), the assessment sessions took place in a quiet room free from background noise and distractions. The assessment sessions were administered by the researcher who followed the testing instructions which were fully explained in the manual of every single assessment tool to avoid invalidation of the test results. For the assessment items that required producing given sentences, the researcher also practised producing theses sentences in a clear, understandable native-like English.

3.4.1 Assessment of Non-verbal Mental Ability and Language Comprehension

The participants' general intellectual abilities and comprehension of grammar were evaluated by employing the standardised assessments of the Coloured Progressive Matrices (CPM) (Raven, et al., 2008), and the Test for Reception of Grammar (TROG-2) (Bishop, 2003). All the assessment elements will be explained in the following sections.

3.4.1.1 The Coloured Progressive Matrices (CPM): Procedure and Scoring

The Raven's Educational Coloured Progressive Matrices (CPM) is a standardised test that assesses the general ability in children aged between 4;0 and 11;0 years (Raven, et al., 2008). The Coloured Progressive Matrices can be run in 15 minutes and administered collectively or separately based on the goal of the assessment. This version of the test has been updated to include new normative data collected from a group of children who demographically represent normal children in the UK aged between 4;0 and 11;0 years. It also includes raw score conversion tables which enable researchers to convert the tested participants' raw scores into standard scores, percentile ranks, age equivalents and confidence intervals.

Since the purpose of the present assessment was the evaluation of the child's cognitive ability, only the CPM test was administered. It was used to measure the participant's general intellectual ability. It required the participant to think and make sense of complex sets of visual patterns and shapes. The CPM test consisted of 36 diagrammatic puzzles divided into three 12-item subtests: A, A_B and B in which the items in each subtest were arranged in a hierarchical order. To ensure the validity and reliability of the CPM test and the results obtained, the participants' cognitive abilities were tested under a test-related standard set of conditions including the test administration and scoring procedures which were thoroughly explained in the test manual. However, adherence to the test administration procedures did not affect running the test in an enjoyable context in addition to a friendly tone of instructions that pleasantly encouraged the participant to respond to the test items. In the current study, all the 12 items for each subtest were examined. The test was easily scored by using the acetated scoring form which was placed over the record form. One point was scored for each correct answer. The total raw score for each set was calculated and placed in the appropriate box on the record form. The descriptive analysis and t-test results of Raven's CPM scores for TD and DS groups were summarised (see tables 3.5 and 3.6).

3.4.1.2 The Test for Reception of Grammar (TROG-2): Procedure and Scoring

The Test for Reception of Grammar (TROG-2) is a standardised assessment used to evaluate the language receptive skills of individuals aged from 4;0 and 16;0 years. It assesses the participants' ability to understand English grammatical contrasts formulated by adding various inflections, using function words, and using different word orders. The assessment helps to evaluate the performance of children with cognitive and learning disabilities compared to their TD peers. Additionally, TROG-2 helps to identify the grammatical difficulties of children with learning disabilities compared to TD children of the same age. The test's practicality and usefulness have been proven in evaluating grammar comprehension in special populations, such as individuals with specific language impairments (SLI), hearing loss, physical disabilities affecting speech production, learning disabilities and acquired aphasia.

The assessment materials used during the testing sessions were the stimulus book and the scoring form. Every page in the stimulus book displayed four pictures, one of which represented the target sentence uttered by the researcher. The participants were asked to recognise the target picture representing the sentence spoken by the researcher. The test comprised 80 sentences distributed over 20 blocks, i.e., four sentences in each block. Participants were asked to respond correctly to all of the items in a given block in order to pass that block. Since each block targeted a particular grammatical structure, passing or failing to pass a block qualitatively helped identify the grammatical contrasts the participants could not realise. The test sentences included easily recognisable content words, i.e., simple nouns, verbs and adjectives. In addition, the assessment blocks were arranged in a gradually increasing difficulty, i.e., it started with the least difficult grammatical structures ascending to the most difficult ones.

In both groups, each child was assessed individually for 20 minutes. The participant, the participant's parent, and the researcher were seated at a table where the stimulus book was clearly displayed so that each participant could see all the four pictures in every page of the stimulus book. The first page of the stimulus book contained practice pictures to familiarise the participant with the upcoming task. Afterwards, the researcher began to produce in a clear, near native English the actual test sentences in each block. The researcher read each sentence clearly and slowly and gave stress to the words shown in bold on the record form. The participant was required to listen carefully to the uttered sentence and point to the correctly matching picture in the stimulus book. The participant was not given a prompt or a hint of the correct answer but was offered general encouragement in addition to offering at least three repetitions of each item after nearly five seconds. When the participants' responses agreed with the key numbers for the correct answers of a given block, that block was scored as passed (P), otherwise it was scored as failed (F). The test was discontinued if the participant failed to respond to five consecutive blocks. The descriptive analysis and t-test results of TROG-2 scores for TD and DS groups were summarised (see tables 3.5 and 3.6).

Table 3.5 Descriptive analysis of Raven's and TROG-2 for TD and DS groups

Variables	Groups	Mean	*SD*	*SE*	Median	Range	Minimum	Maximum	95% CI for Mean	
									Lower Bound	Upper Bound
Raven's CPM Raw Score	TD	20.65	7.00	1.56	19.50	26.00	10.00	36.00	17.37	23.92
	DS	19.64	6.11	1.48	21.00	20.00	10.00	30.00	16.50	22.79
TROG-2 Raw Score	TD	14.40	4.63	1.03	15.00	15	5	20	12.23	16.57
	DS	10.18	5.06	1.22	10.00	19	1	20	7.55	12.78

Note: Raven's CPM-Coloured progressive matrices (Raven, et al., 2008). TROG-2-Test for reception of grammar (Bishop, 2003), TD-Typically developing children and DS-Children with Down syndrome. CI-Confidence limits around the mean.

Table 3.6 T-test results for Raven's and TROG-2 for TD and DS groups

Variables	Groups	Mean	*SD*	*t*-value	*p*-value	*SE*	*df*	Mean Difference	95% CI of Mean Difference	
									Lower Bound	Upper Bound
Raven's raw score	TD	20.65	7.00	0.46	0.64	2.18	35	1.00	3.42	5.43
	DS	19.64	6.11							
TROG-2 raw score	TD	14.40	4.63	2.64	0.01	1.59	35	4.22	0.98	7.46
	DS	10.18	5.06							

Note: Raven's CPM-Coloured progressive matrices (Raven, et al., 2008). TROG-2-Test for reception of grammar (Bishop, 2003), TD-Typically developing children and DS-Children with Down syndrome. CI-Confidence limits around the mean difference.

3.4.2 Speech Assessment

The participants' speech was assessed by administering both standardized and non-standardised tests. Two speech samples were collected: SW and CS samples. The speech assessment tools included; the standardised assessment Diagnostic Evaluation of Articulation and Phonology (DEAP) (Dodd et al., 2002); and the non-standardised assessment Clinical Linguistics Educational Assessments and Resources (CLEAR) (Keeling and Keeling, 2006). In addition, interactive activities including storytelling and playing with toys were carried out to collect CS samples for TD and DS groups. The speech assessments are explained as follows:

3.4.2.1 Diagnostic Evaluation of Articulation and Phonology(DEAP)-Assessment of Phonology: Procedure and Scoring

The single word sample was collected via running a Diagnostic Evaluation of Articulation and Phonology (DEAP) (Dood et.al, 2002). DEAP comprises of four subtests: a diagnostic screening, articulation assessment, phonology assessment, and inconsistency assessment. In the present study, only the DEAP-phonology and DEAP-inconsistency tests were administered. The phonological assessment evaluated the child's phonological ability to use sounds in context and consisted of two components: (1) picture naming task, which entailed naming 50 picture words covering all consonants in syllable-initial and syllable-final positions, in addition to all vowels and diphthongs (except /ʊə/ as in cure). (2) picture description in which the child was shown three pictures containing 14 items selected from the picture naming task. The DEAP manual provided all the instructions needed to administer the test items. The materials used were DEAP stimulus book and a colour-coded record form. The stimulus book contained 50 age-appropriate coloured pictures that the child was required to name once. The researcher practised administering the test prior to the beginning of the assessment sessions to ensure the validity of the test standardisation. The test took place in a quiet room where the child, the child's parent and the researcher were seated at a table facing each other. The stimulus book was set up on a built-in easel on the table in front of the child so that the pictures were clearly visible to the researcher and the participant.

In order to encourage the child to respond, the researcher started the task by asking a simple question "What is this?" for the single word production. For the connected speech sentences, the researcher asked the child "What's happening in this picture, or What's funny about this picture?" These two questions were used to motivate the child to give a brief description of the given picture. To elicit the test items, the participant was provided with prompting and modelling whenever needed. For instance, semantic cues were used to elicit the target word, such as "a spider lives in a …" to help the child say "web". If the child failed to understand the semantic cue given, the researcher could model the production of target word. Thus, when the child faced a difficulty of producing a particular item, the researcher modelled the item so that the participant could easily imitate it. The imitated items were indicated on the record form and the session was audio recorded for transcription.

3.4.2.2 Clinical Linguistics Educational Assessments and Resources (CLEAR): Procedure and Scoring

In order to obtain a large SW sample and establish an accurate phonological analysis of the participant's speech, DEAP- phonology assessment was combined with the non-standardised Clinical Linguistics Educational Assessments and Resources (CLEAR) (Keeling and Keeling, 2006) assessment. CLEAR assessment required the child to name 82 pictures representing consonants occurring in word-initial, -medial, and –final positions and occurring within different sound combinations so that a wide range of consonant clusters was also elicited. Since the participants were more attracted to computer-based materials, the test pictures were adapted and computerised, i.e. they were transformed into PowerPoint slides on a password-secured computer used by the researcher. For this purpose, a Lenovo laptop was used. The computer was placed on the table in front of the participant. To get the child engaged in the picture naming activity, he/she was encouraged to change the pictures by himself/herself by pressing the Page Down and Page Up buttons on the computer. All the DEAP-Assessment of Phonology and CLEAR assessment sessions were recorded by employing a high quality digital voice recording device (H4next Handy Recorder with a SanDisk memory of 16GB) placed approximately 2-3 feet from the child. The same procedure for administering DEAP-phonology assessment was also adopted when running and scoring the record form for CLEAR assessment.

The qualitative measures (including numbers of consonants and vowels and types of frequency of occurrence of processes) and quantitative measures including Percentage of Consonants Correct (PCC), Percentage of Vowels Correct (PVC), Percentage of Phonemes Correct (PPC), and Percentage of Consonant Clusters Correct (PCCC) were calculated. The PCC of singleton consonants occurring in the syllable initial word initial (SIWI), syllable initial word medial (SIWM), syllable final word medial (SFWM), and syllable final word final (SFWF); and PCCC of consonant clusters occurring in SIWI, SIWM, SFWM, and SFWF measures were derived from DEAP-Assessment of Phonology and CLEAR assessments. The scoring procedure introduced by Dodd et al. (2002) in DEAP was adopted to analyse the participants' sound production in both DEAP-Assessment of Phonology and CLEAR collectively and is described as follows:

1. **Calculating PCC and PCCC**: First, PCC of all consonant, whether produced as singleton or in clusters was calculated as follows: The number of consonants (singletons and in clusters) in words not elicited was counted and labelled as (a). The total number of consonants elicited was labelled as (b) and calculated by using the formula b=318-a. The number of consonants in error was counted and labelled as (c). The total number of correct consonants was labelled (d) and calculated by using the formula d=b-c. The PCC was calculated by using the formula PCC=d/b*100. The PCC of singleton consonants in four word positions and PCCC of consonant clusters in four word positions were calculated by using the same formula developed by Dodd et al. (2002).

2. **Calculating PVC**: The number of vowels in words that was not elicited was counted and labelled as (a). The total number of vowels elicited was labelled (b) and calculated by using the formula b=171-a. The number of vowels in error was counted and labelled as (c). The total number of correct vowels was labelled as (d) and calculated by using the formula d=b-c. The PVC was calculated by using the formula PVC=d/b*100.

3. **Calculating PPC**: The total number of phonemes elicited was labelled (y) and calculated by adding the total number of consonants elicited PCCb and the total number of the vowels elicited PVCb. The total number of correct phonemes was labelled (z) and calculated by adding the total number of correct consonants PCCd and the total number of correct vowels PVCd. The PPC was calculated by using the formula PPC=z/y*100.

4. **Analysing Error Patterns**: Each error was ticked on the record form. The errors which were not listed were mentioned in the last column on the record form. If participants made the same error twice, the appropriate box on the record form was also ticked twice. Errors occurring five times or more (except weak syllable deletions) were regarded as error patterns. When participants used weak syllable deletions more than once then it was regarded as an error pattern. The criteria of five or more occurrences of an error pattern and two for weak syllable deletion accounts for the developmental fluctuation, besides, the test standardised data was calculated based on these criteria.

3.4.2.3 Diagnostic Evaluation of Articulation and Phonology (DEAP)-Word Inconsistency: Procedure and Scoring

DEAP-word inconsistency assessment evaluated the participant's ability to produce three realisations of the same test item consistently. That is, it helped identify if the child was consistent in producing the same items over three production trials. The test involved naming each of 25 pictures three times. The three picture naming trials were separated by another activity (e.g. comprehension or cognitive ability assessments which did not require verbal response). The inconsistency test compared the performance of the participant with DS to that of TD children of the same age. According to the norm standards of DEAP-word inconsistency test, TD children are expected to be consistent when they produce the 25 items over three trials. On the contrary, children with phonological development delay (as in the case of children with DS) are supposed to be more inconsistent and this can be considered as an indicator of delayed or atypical speech development. A child with disordered phonology could be more consistent in producing some error patterns rather than others. The criterion assigned for the diagnosis of inconsistent phonological disorder is that if the percentage of the items produced inconsistently was$\geq$40%, the child's production could be considered as inconsistent. This would also indicate that the child makes multiple error forms of the same word. In other words, the child had changed the phonological structure of the words produced (e.g., the sound types and the number of syllables). On the contrary, if the child's score was <40%, then he/she would be considered consistent.

With regards to test administration, DEAP manual contained all the instructions needed to run the test items. The materials used were DEAP stimulus book and colour-coded record form. The stimulus book contained 25 age-appropriate coloured pictures that the child was required to name three times. The researcher practised administering the test prior to commencement of the assessment sessions to ensure the validity of the test's standardisation. The test took place in a quiet room where the child, the child's parent and the researcher were seated facing each other. The stimulus book was set up on a built-in easel on the table in front of the child so that the pictures were clearly visible to the researcher and the participant. At the beginning of the test, the researcher attempted to establish a good rapport with the participant to encourage him/her to respond to the test items. The participant was provided with prompting and modelling whenever needed to elicit the test items. For instance, if the child was not able to produce a given item, the researcher modelled the item so that the participant could easily imitate it. Imitated items were indicated on the record form. The assessment sessions were audio recorded for later transcription. The participant's responses were transcribed, and the production of each item was compared over the three production trials. For each item, if the three productions were the same, it was scored 0, otherwise it was scored 1. For calculating the inconsistency score, the number of the items that were scored 1 was divided by the number of the items which were produced three times, and then multiplied by 100.

3.4.2.4 Assessment of CS Sample: Procedure and Scoring

The connected speech production can be considered as a reliable measure of speech sound production accuracy, since the production of connected speech tends to be affected by other language demands and tended to be more representative of a child's production skills in a naturalistic context (Shriberg and Kwiatkowski, 1980). Consequently, a spontaneous CS sample was also included and analysed. The assessment of CS sample consisted of the speech data collected in naturalistic friendly settings where the child was encouraged to get involved in a variety of interactive activities. These activities included free conversation with her/him about things she/he was interested in within child-parent/child-researcher interactions, playing with different toys, or telling a story. In addition, facilitative procedures were used to encourage conversation during play. These procedures included providing opportunities for child-initiations, commenting on the child's activities, providing open-ended questions and some closed questions when clarification of a child utterance was needed. For CS samples, the 90-70-225 sampling rule put forward by Morrison and Shriberg (1992) was adopted. This sampling rule implied comparing continuous speech samples containing either 90-word types, 70 utterances, or a total of 225 words, and choosing whichever criterion would be met first during the transcription process.

In the present study, in order to collect adequately sufficient CS samples, the connected speech data was based on the analysis of the first 70 utterances. All the word productions in addition to semi word productions were counted and transcribed; yet, only meaningful productions (words which could be glossed) were included in the phonological analysis. The analysis of CS sample comprised of: (1) PCC; (2) PVC; (3) PPC; (4) the type, frequency and percentage of occurrence of phonological processes (Iacono, 1998). Comparing SW and CS samples would be necessary to determine the extent to which speech production deficiencies could affect speech, language and communication performance. Furthermore, it was important to compare the types and frequency of occurrence of sound pattern errors in both samples to explain how these errors affected speech intelligibility (Iacono, 1998).

3.4.2.5 Assessment of Speech Intelligibility

The speech intelligibility of the participant in TD and DS groups was subjectively rated by their parents. The parents were provided with a speech intelligibility rating scale called the Intelligibility in Context Scale (ICS) (McLeod et al., 2012). The ICS is used to rate the clarity of the speech of preschool or school age children with disordered speech. Although the ICS assessment is based on subjective viewpoints, it was a functionally useful assessment tool that can be used in research on speech and language development and in clinical settings. Essentially, it can be used to give a general overview of the child's speech intelligibility. The ICS rating form includes seven questions the answers to which are based on a five-point scale. The seven questions are about the degree to which the child's speech can be understood by the surrounding individuals and the members of the immediate family. The ICS can be used alongside measures of speech severity, such as PCC of SW/CS samples to provide additional information about a child's speech intelligibility. Additionally, the ICS assessment results can be used to help plan speech and language intervention programmes and assist in evaluating improvements due to treatment application.

In the present study, the ICS assessment was carried out to assess the speech intelligibility of participants in DS and TD groups. The parents were provided with the ICS forms either prior to the assessment sessions via email or during the assessment sessions. The questions could be answered in approximately 5 minutes. Before answering the questions, the researcher briefly explained the test requirements to the parents so that they could answer the seven questions and rate their child's speech. The parents were requested to think in an unbiased way about their child's speech intelligibility (or their ability to express themselves and their needs clearly when speaking to various people) during a month prior to the assessment sessions. The parents were required to circle the appropriate rating score on a five-point scale including: 1= never, 2= rarely, 3= sometimes, 4= usually, 5= always. With regards to scoring ICS test, for each participant, all of the ratings circled by their parent were summed up and the total score was divided by seven to create an average score of ICS. The researcher ensured that all seven questions were answered by the parents. In case the parents did not complete an item (e.g., parents may not complete item 6, if their child did not attend school/preschool), then the average score could be calculated out of the number of completed items. The analysis of the ICS scores indicated a child's level of functional intelligibility, ranging from a score of 1.00 (low intelligibility) to a score of 5.00 (high intelligibility). For instance, if a child achieved an average score of 3.5, this score would reveal that the child was 'usually' to sometimes 'understood'.

Speech intelligibility was also assessed by analysing the spontaneous speech samples collected by administering interactive activities. Thus, spontaneous speech samples for DS and TD participants were collected by using two activities: story reading and playing with toys. The samples also included the utterances obtained from parent-child/researcher-child interactions. The participants were found to interact more comfortably with their parents and were more motivated to produce spontaneous speech as much as they could. The parents were instructed to encourage their children to create their own stories by describing the pictures in a selected picture story book (Frog, Where Are You and Spot's Birthday). Additionally, children were allocated time to play with toys (Mr Potato Head, a popping-up pirate, and a turtle with popping-up shapes). The participants were encouraged to play with these toys to give them time to relax and, at the same time, elicit additional spontaneous utterances while they were playing in a natural setting. The participants' speech intelligibility was assessed by using their first 50 spontaneous utterances which totalling approximately 100 words with 'yes' and 'no' words excluded from the sample. Each participant's spontaneous speech was edited to a length of two-minute excerpt recordings by using the digital sound file editing software Cool Record Edit Pro version 9.0.5. The software helped exclude the researcher's/parents' speech but retained the child's spoken utterances. All the editing of the sound files was carried out manually. The speech samples of children, including DS group who produced fewer than 100 words in the original recordings, were also included in the analysis. In fact, producing fewer spontaneous utterances could be a sign of speech difficulties and an indication of an unwillingness to speak.

For the speech intelligibility procedure, the materials of TD and DS groups were collectively divided into four sets. Thus, each set contained nine participants (5 TDs and 4 DSs), except for the fourth speech set which included 10 children (5 TDs and 5 DSs). Additionally, 20 adult native British English-speaking listeners were recruited (male and female undergraduates and postgraduates at the University of Reading) and divided into four groups (5 listeners in each group). Each group was responsible for transcribing the speech samples/sets of 9 children. The listeners were divided in this way to avoid listeners' burden as the transcription of all of the speech samples by each listener would have been a time and effort consuming task. The CS samples were presented randomly, making the listeners unaware whether a particular participant belonged to TD group or DS group. These speech files were numbered as (1,2,3…, and so on). The transcription of a whole speech set lasted for nearly an hour. Before starting to listen to the speech samples, the researcher explained the procedure to the listeners and remained with them to answer queries related to the speech samples and the assessment procedure.

The intelligibility assessment procedure required listeners of each of the nine children sets to listen to each utterance of a given participant in a set twice before assessing the next utterance. The sound files were played to the listeners using the Windows Media Player software aided with headphones attached to a password-secured DELL laptop (Intel(R) Core(TM) i3-5005u, CPU 2.00 GHz, RAM 8.00 GB, System (64-bit, x64-based processor). The listeners were allowed to adjust the sound volume at their discretion. The listeners were also instructed to transcribe orthographically the words they understood including onomatopoetic words and excluding filler words (e.g., eh, um), repetitious words or syllables. They were also required to orthographically transcribe the unintelligible words, i.e., the words they did not understand. The listeners were also instructed not to guess the words they listened to. The intelligibility score for each participant was calculated by dividing the number of intelligible words by the total number of the words produced (intelligible and unintelligible words) in the sample multiplied by 100 (Lagerberg et al., 2014).

3.5 Data Analysis

The analysis of SW and CS samples was conducted for the participants as a group and as individuals, therefore, individual differences were also reported. For example, the consonant production accuracy and the phonological processes occurring in the speech of some participants were described and analysed. What follows comprises of the qualitative and quantitative measures derived from the speech assessment of SW and CS samples:

3.5.1 Qualitative Measures of SW and CS Samples

To address the research questions and find the similarities and differences between DS and TD groups, the following qualitative measures were included in the phonological development analysis:

3.5.1.1. Analysis of Consonants and Vowels

The analysis of consonants and vowels is a descriptive measure of the child's ability to produce consonants in word-initial, -medial and -final positions in addition to vowels. For the purpose of analysing the consonant and vowel sets of each participant in both groups, all the phonemes (consonants and vowels) occurring in target words of SW and CS samples were included, regardless of being produced spontaneously or imitatively. The inclusion of the consonants produced by each participant in the two types of speech samples was based on two-time occurrence criterion, i.e., the phones occurring at least twice in two different words were included (Core, 2012). The analysis of consonants and vowels assisted in identifying the range of sounds the children could produce. The consonants table developed by Grunwell (1985) was used for explaining the classification and distribution of singleton consonant and consonant clusters produced by participants in TD and DS groups. The consonants were classified in terms of the place and manner of articulation. The table also outlined the various distributions of consonant and consonant cluster occurrences in different word positions.

3.5.1.2. Analysis of Phonological Processes

The phonological processes can be defined as simplified realisations of the adult sound production including sound substitutions and omissions. The type and frequency of occurrence of phonological processes that the participants in both groups tended to use frequently in SW and CS samples were analysed according to the criteria explained in DEAP-Assessment of Phonology (Dodd et al., 2002). The criteria implied that the errors occurring five or more times (except weak syllable deletion) were regarded as sound pattern errors. When the child used weak syllable deletion twice or more, then it was also regarded as a pattern error. The five-time occurrence criterion of a pattern error and two-time occurrence criterion of weak syllable deletion were adopted to account for the fluctuating phonological development in TD and DS groups. Additionally, the test standardised data was calculated based on these criteria. The differences between the pattern errors produced by the participants and the adult production of the same sound structures were analysed. The processes were looked upon either as age-appropriate, delayed or unusual. First, the age-appropriate processes included sound pattern errors used by at least 10% in the normative data reported (Dodd et al., 2002). Second, the delayed pattern errors comprised of sound pattern errors not used by 10% of children within the same age range in the normative sample (Dodd et al., 2002). Finally, the unusual pattern errors included the sound pattern errors not used by more than 10% of children in any age in the normative data (Dodd et al., 2002).

3.5.2 The Quantitative Measures of SW and CS Samples

The quantitative measures of the phoneme production accuracy and occurrence of the phonological processes were analysed in terms of the percentages of correct sound production, percentage of occurrence of phonological processes and the percentage of intelligible words TD and DS groups produced. The details are as follows:

3.5.2.1 PCC and PCCC Measures

PCC can be defined as the percentage of correct consonant productions divided by the total number of all consonants produced multiplied by 100. PCCC can be defined as the percentage of correct consonant cluster productions divided by the total number of all consonant clusters produced multiplied by 100. In SW sample, PCC of all consonants produced as singletons or in cluster was calculated by using the formula developed by Dodd et al. (2002). The PCC was calculated collectively for both DEAP-Assessment of Phonology and CLEAR. As a result, the total number of consonants in these two assessments was 318 (see table 3.7). Similarly, PCC of singleton consonants occurring in SIWI, SIWM, SFWM, and SFWF; and PCCC of consonant clusters occurring in SIWI, SIWM, SFWM, and SFWF measures were derived from DEAP-phonology and CLEAR assessments and estimated in accordance with the same formula developed by Dodd et al. (2002) (see table 3.8). The calculations of PCC of all consonants, PCC of singleton consonants in four word-positions, and PCCC of consonant clusters in four word-positions in DEAP and CLEAR assessments were explained in detail (see section 3.4.2.2, p.62). The same procedure was followed for calculating PCC of all consonants in CS sample.

3.5.2.2 PVC Measure

PVC can be defined as the percentage of the correct vowel productions divided by the total number of all vowels produced multiplied by 100. Thus, PVC was calculated by using the formula developed by Dodd et al. (2002). The PVC was calculated collectively for both DEAP-Assessment of Phonology and CLEAR. As a result, the total number of vowels in these two assessments was 171 (see table 3.7). The calculation of PVC of vowels was explained in detail (see section 3.4.2.2, p.62). The same procedure was followed for calculating PCC of all consonants in CS sample.

3.5.2.3 PPC Measure

PPC can be defined as the percentage of the correct phoneme (consonants and vowels) productions divided by the total number of all phonemes produced multiplied by 100. The formula developed by Dodd et al. (2002) was used to estimate PPC. The PPC was calculated collectively for both DEAP-Assessment of Phonology and CLEAR. As a result, the total number of phonemes in these two assessments was 489 (see table 3.7). The calculations of PPC of all consonants and vowels was explained in detail (see section 3.4.2.2, p.62). The same procedure was followed for calculating PPC of all consonants in CS sample.

Table 3.7 Number of consonants, vowels and phonemes in DEAP-phonology and CLEAR assessments

Categories	DEAP-Phonology	CLEAR	DEAP&CLEAR
Consonants	141	177	318
Vowels	78	93	171
Phonemes	219	270	489

Table 3.8 Number of initial, medial, and final singleton consonants and consonants in clusters in DEAP-phonology and CLEAR assessments

Position of Singleton Consonants	Total	Position of Consonant Clusters	Total
SIWI	63	SIWI	38
SIWM	37	SIWM	3
SFWM	21	SFWM	2
SFWF	73	SFWF	8
Total	194	Total	51

Note: SIWI-Syllable initial word initial position. SIWM-Syllable initial word medial position. SFWM-Syllable final word medial position. SFWF-Syllable final word final position.

3.5.2.3 Percentage of Occurrence of Phonological Processes

In SW and CS samples, the percentages of occurrence of the 13 phonological processes determined in DEAP-Assessment of Phonology were calculated. These included the following processes as ordered in DEAP-Assessment of Phonology record form: (1) gliding, (2) deaffrication, (3) cluster reduction (CR), (4) fronting, (5) weak syllable deletion (WSD), (6) stopping, (7) voicing, (8) assimilation, (9) initial consonant deletion (ICD), (10) medial consonant deletion (MCD), (11) final consonant deletion (FCD), (12) backing, and (13) other processes. For each participant, the percentage of occurrence of a particular phonological process was calculated by dividing the number of occurrences of that process by the total number of occurrences of all phonological processes in a child’s speech multiplied by 100 (Hodson, 2010).

3.5.2.4 Inconsistency Rating

The inconsistency score was calculated by dividing the number of items that were scored 1 by the number of items which were produced three times, and then multiplied by 100. The developmentally age-appropriate errors were excluded from the calculation of the inconsistency score. DEAP-Assessment of Word-Inconsistency was explained in detail (see section 3.4.2.3, p.63).

3.6 Reliability

The SW and CS samples were manually transcribed by using the broad phonemic transcription. The broad phonemic transcription is a phonemic transcription that does not entail the use of the phonetic diacritics to dictate fine phonetic details. It was used to minimise the extent of the inter-rater transcription disagreement. This type of transcription was used partly to ensure agreement of the transcription of the speech assessment data from DEAP-Assessment of Phonology, CLEAR, DEAP-Assessment of Word Inconsistency, and CS samples, and partly to avoid the phonological biases that could be perceived by non-native inter-raters. For the transcription reliability, two native British, English-speaking students who are specialised in speech therapy (a graduate student and a postgraduate student from the Department of Clinical Language Sciences, University of Reading) rated 20% of SW data and 20% of CS data for DS and TD groups. The two students who rated data transcriptions and the researcher attempted to work out the transcription differences to reach a consensus by re-listening to the controversial items.

For SW sample, the reliability of agreement between the transcriptions of the independent inter-raters was determined by calculating Cohen's Kappa coefficient by using the cross tabs in the SPSS software. Cohen's Kappa coefficient is considered as a strict indicator of reliability to explain chance agreement (Rowe, 2012). The results showed that Cohen's Kappa Coefficient was highly significant [k=0.920, p=0.001]. This indicated that there was a strongly reliable agreement between the two inter-raters. The percentage of the transcription agreement between the transcriptions of the two inter-raters was 96.4%. For the CS sample, the results demonstrated that Cohen's Kappa Coefficient was highly significant [k=0.903, p=0.001]. This showed that there was a strongly reliable agreement between the two inter-raters. The percentage of the transcription agreement between the transcriptions of the two inter-raters was 95.3%.

3.7 Research Design

In the present study, to provide a clear and precise analysis of the phonological development in children with DS compared to TD children, a cross-sectional design was adopted. A cross-sectional design allowed measuring the development of the phonological systems of participants of different ages and variable speech abilities at a single point in time (Alexander et al., 2015; Dukes and Bjorklund, 2009; Levin, 2006; Stoel-Gammon and Dunn, 1985). The design helped reveal the sounds participants could/could not produce in addition to the type and frequency of occurrence of phonological processes.

One of the advantages of the cross-sectional design is that it facilitates the estimation of speech sound production accuracy and prevalence of phonological processes in the speech of a given population (typical population or special population, such as children with DS) at specific ages of acquisition. However, the cross-sectional design cannot infer the cause of the speech production difficulty but could only illustrate the relationship between production accuracy and mental age as assessed in the present study. Nonetheless, the findings of a cross-sectional study could be substantially informative for further advanced studies (e.g., longitudinal studies of speech sound development in children with DS). Another advantage of a cross-sectional design is that speech assessments for the same participants can be reduplicated or repeated at different points in time to detect changes in the prevalence of difficulties related to the production of speech sounds and sound patterns so that any changes in trends over time could be recognised (Levin, 2006; Sedgewick, 2014).

A descriptive cross-sectional design also helps assess and compare representative samples of individuals with DS who have been diagnosed with various speech sound difficulties to TD children. Analytically, the design as such would help to comparatively analyse the differences and similarities of DS and TD populations in terms of speech sound production and the occurrence of phonological processes. The cross-sectional design would also be beneficial for establishing an experimental indication of the development of speech sounds and how such development could affect the speech intelligibility of participants with DS in a short period of time at a variable range of the ages tested. The cross-sectional design would also help identify the similarities and differences in the performance of children with DS and TD children matched for non-verbal MA by creating developmental trajectories accounting for the onset and rate of development in these groups. The design as such could provide insights into the difficulties DS participants faced at different ages.

The limited number of participants with DS in previous studies on phonological development raised the problem of generalising the findings to the whole special population. In the present study, to reduce the probability of errors in the phonological analyses outcome, the number of participants was calculated according to a significance level ≤ 0.05 (confidence level of 95%) which represents the likelihood that the expected prevalence of sound and sound pattern errors would be within the margin error specified (Martinez-Mesa et al., 2014). For this purpose, the two groups comprised of participants representing the age range tested in a balanced way regardless of gender differences. For TD children, speech data of 20 participants in TD group was evaluated at ages ranging from 3;0 to 6;3 years. This age range highlights the beginning of the linguistic stage in which TD children start to produce adult-like meaningful utterances (Lenneberg, 1967; Smith and Stoel-Gammon, 1983). The chronological age-based distribution of participants in TD group was summarised (see table 3.9). For children with DS, speech data of 17 participants in DS group was evaluated at ages ranging from 5;5 to 12;0 years because children with DS usually start producing meaningful utterances with a delayed onset (Dodd and Thompson, 2001; Kumin, 2008; Lenneberg, 1967; Smith and Stoel-Gammon, 1983; Stoel-Gammon, 1997). The chronological age-based distribution of participants in DS group was summarised (see table 3.9). The assessment sessions for two participants in DS group, aged between 5;10 and 7;2 years, were not included due to inadequate SW and CS sample productions. Therefore, their speech samples were excluded from the analysis. The children in both groups were matched for non-verbal MA rather than CA because the ages of children in TD group did not cover the whole age range for children in DS group.

Table 3.9 CA in TD and DS groups

TD Group	CA	DS Group	CA
TD1	5;4	DS1	6;9
TD2	6;1	DS2	10;11
TD3	3;9	DS3	10;4
TD4	4;10	DS4	8;8
TD5	6;2	DS5	10;7
TD6	6;0	DS6	11;1
TD7	3;0	DS7	11;2
TD8	5;0	DS8	12;0
TD9	4;3	DS9	10;1
TD10	6;3	DS10	5;5
TD11	3;9	DS11	6;0
TD12	5;5	DS12	7;1
TD13	3;0	DS13	6;6
TD14	4;0	DS14	10;11
TD15	6;0	DS15	8;1
TD16	4;0	DS16	8;2
TD17	4;2	DS17	10;9
TD18	5;9		
TD19	4;11		
TD20	4;11		

Note: CA-Child's chronological age in years, TD-Typically developing children. DS-Children with Down syndrome.

In order to investigate the phonological development of children with DS and the way their phonological ability to produce sounds in the correct contexts would affect their speech intelligibility, a developmental trajectory approach within a cross-sectional design was adopted. The data collection was carried out at a single point of measurement for both DS and TD groups, and a series of cross-sectional developmental trajectories were created. The underpinning concept of the developmental trajectory approach (DTA) is that the phenotype of any developmental disorder (e.g., DS) does not entirely emerge at birth. Instead, it gradually develops, sometimes in transformative ways, with age (Thomas et al., 2009). The purpose behind using the developmental trajectories was to interpret the developmental difficulties associated with a given developmental disorder. The developmental trajectories assisted in accounting for change of performance with CA/non-verbal or verbal MA and discouraged rigid interpretations of developmental difficulties. Developmental trajectory approach has been an increasingly used approach to investigating the behavioural deficits in individuals with developmental difficulties (e.g., children with DS). It has been based on creating a function that associates performance with age on a specific task, and then comparing it with function differences in control group and disorder group (Carney et al., 2013; Thomas et al., 2009).

In the present study, the developmental trajectories for children with DS were created and compared to trajectories for TD children matched for non-verbal MA. The difference between the trending lines representing the developmental trajectories of the two groups was evaluated. The comparison was based on two values representing the developmental trajectory for each group; these values included: (1) the intercept of the trending line which stands for the level at which sound and sound pattern productions begin; (2) the gradient of the trending line which stands for the rate at which the sound and sound productions get maximised or minimised. Developmental trajectories were created to evaluate the performance in SW and CS conditions for children with DS compared to TD peers matched for non-verbal MA. Three types of comparisons were established: (1) SW production in DS group compared to TD group, (2) CS production in DS group compared to TD group, and (3) the SW production compared to the CS in DS and TD groups. The three types of comparisons included analyses of developmental trajectories for the following measures:

1. **The SW production in DS group compared TD group:**
    1. Two developmental trajectories were created to illustrate the number of consonants included in the phonetic repertoires in DS group compared to TD group when matched on non-verbal MA.
    2. Three separate developmental trajectories were created to depict the performance on the measures of PPC, PCC (for all consonant, whether produced as singletons or in clusters), and PVC in SW samples for DS group compared to TD group when the two groups were matched for non-verbal MA.
    3. Four trajectories were created to depict PCC of singleton consonants in four word positions (SIWI, SIWM, SFWM, and SFWF) in SW for DS group compared to TD group when the two groups were matched for non-verbal MA.
    4. Four trajectories were created to depict PCCC of consonant clusters in four word positions (SIWI, SIWM, SFWM, and SFWF) in SW for DS group compared to TD group when the two groups were matched for non-verbal MA.

5. A developmental trajectory was created to depict the total occurrences of phonological processes in SW for DS group compared to TD group when the two groups were matched for non-verbal MA.
6. Thirteen developmental trajectories were created to illustrate the percentages of occurrence of the thirteen phonological processes included in the phonological analysis of SW samples for DS group compared to TD group when the two groups were matched for non-verbal MA.

2. The CS production in DS group compared to TD group:

1. Three developmental trajectories were created to depict the performance on the measures of PPC, PCC (for all consonants, whether produced on singletons or in clusters), and PVC in CS samples for DS group compared to TD group when the two groups were matched for non-verbal MA.
2. A developmental trajectory was created to depict the total occurrences of phonological processes in CS samples for DS group compared to TD group when the two groups were matched for non-verbal MA.
3. Thirteen developmental trajectories were created to illustrate the percentages of occurrence of the thirteen phonological processes included in the phonological analysis of CS samples for DS group compared to TD group when the two groups were matched for non-verbal MA.
4. A developmental trajectory was created to illustrate the percentage of speech intelligibility in CS samples for DS group compared to TD group when the two groups were matched for non-verbal MA.

3. SW production compared to CS production in DS and TD groups:

1. Three developmental trajectories were created to depict the performance on the measures of PPC, PCC (for all consonant, whether produced on singletons or in clusters), and PVC in SW samples compared to CS samples for DS group.
2. Three developmental trajectories were created to depict the performance on the measures of PPC, PCC (for all consonant whether produced in singleton or in clusters), and PVC in SW samples compared to CS samples for TD group.
3. A developmental trajectory was created to depict the total occurrences of phonological processes in SW samples compared to CS samples for DS group.
4. A developmental trajectory was created to depict the total occurrences of phonological processes in SW samples compared to CS samples for TD group.

5. Thirteen developmental trajectories were created to illustrate percentages of occurrence of the thirteen phonological processes included in the phonological analysis of SW samples compared to CS samples for DS group.
6. Thirteen developmental trajectories were created to illustrate percentages of occurrence of the thirteen phonological processes included in the phonological analysis of SW samples compared to CS samples for TD group.

3.8 Statistical Analysis

The differences in the performance of participants in the DS and TD groups were identified and a series of statistical tests were carried out using the software SPSS version 20. Excluding non-verbal MA, between-participants t-test was run to examine the differences between TD and DS groups (group factor was set as IV) in terms of Raven's CPM, TROG-2 and ICS scores as dependent variables (DVs). The between-participants t-test was also run to investigate the mean difference between the two groups in terms of percentages of occurrence of the 13 phonological processes listed in DEAP-assessment of phonology (DVs) in SW and CS samples (see appendix C). The repeated measures t-test were run to examine mean differences in TD and DS groups in terms of percentages of occurrence of the 13 phonological processes listed in DEAP-assessment of phonology in SW sample compared to CS sample (see appendix C).

Between-participants one-way ANCOVA was carried out to examine differences between TD and DS groups means when including non-verbal MA as a covariate. ANCOVA helped evaluate the effect of group factor as IV on number of consonants acquired, PCC, PVC, PPC, PCC of singleton consonants in SIWI, SIWM, SFWM and SFWF, PCCC of consonant clusters in SIWI, SIWM, SFWM and SFWF, number of occurrences of processes, percentage of word inconsistency, percentages of occurrence of phonological processes in SW sample and CS sample as DVs. The ANCOVA test also helped identify the type of onset and rate of development in the two groups when match for MA. To evaluate the effect of group factor as IV on PCC, PVC, PPC, number of occurrences of phonological processes, and percentages of occurrence of phonological processes as DVs in SW sample compared to CS sample within each group, repeated measures ANCOVA was carried out, including non-verbal MA as a covariate.

Linear regression was also conducted to examine the developmental trajectories for each group. The software EXCEL 2016 was used to create the graphical representations of developmental trajectories. Before including MA as a covariate in the ANCOVA analysis, MA in months was rescaled. Since the range of chronological ages for participants with DS exceeded that of TD participants, the two groups were matched for non-verbal MA. To ensure comparing the between-participants trajectories for DS and TD groups at a similar starting age point (at "zero" age), the MAs in months for children in both groups were rescaled. Since MAs for TD children fell within the range of MAs for children with DS, the ages were rescaled and measured in months from the youngest non-verbal MA in TD group which is 50 months, therefore, rescaled as MA =MA-50.

Chapter 4: Results I - Group Study

4.1 Introduction

After completing the data transcription, the qualitative measures were analysed. The quantitative measures were also calculated, and the statistical tests results were reported. The tables were designed in such a way that the descriptive analyses and test statistics were summarised. The developmental trajectories of performances for DS group compared to TD group were created and analysed to determine types of onset and rate of development. The results explaining performance in SW samples for DS group compared to TD group are presented in detail in the following sections.

4.2 SW Samples: Qualitative Measures

4.2.1 Qualitative Measures: Consonants and Vowels in SW Samples for DS Group Compared to TD Group

The abilities of children in DS and TD groups to produce consonants in word-initial, -medial and -final positions and vowels were analysed. The inclusion of consonants produced by each participant in SW sample was based on the criterion of occurrence at least twice in two different words. The consonants were classified in terms of place and manner of articulation. All of the British English consonantal classes were consistently represented, i.e., each consonant occurred either in one word, two different words (for consonants with two-time occurrence possibility) or three different words (for consonants with three-time occurrence possibility) in the word-initial, word-medial and word-final positions. Thus, a consonant occurring in one word position scored 1 and in two word positions scored 2, respectively; while a consonant occurring in three word-positions scored 3. The consonant representation scores were calculated across the target items of DEAP - Assessment of Phonology and CLEAR. The calculations were made by dividing the total number of actual occurrences of each consonant by the total number of possible occurrences of consonants in British English (Iacono, 1998; Roach, 2009). The consonants across the target items occurred 62 out of 67 with a percentage of occurrence 93%. All consonant classes were well-represented throughout the SW sample and there were no missing consonants. However, the percentage of consonant representation was <100% because some consonants scored below their possible occurrences. For instance, both /w/ and /ʒ/ scored 1 as they occurred in only one word position for each sound in SW sample. Similarly, /θ/ and /ð/ scored 2 out of 3 as they occurred in two word-positions rather than three.

The results of the range of consonants in TD group were summarised (see table 4.1). The consonants of TD children aged between 3;0 to 3;9 years included plosives except /k,g/, two fricative consonants /z,h/, and no affricate consonants. The phonetic inventory of TD children aged between 4;0 to 4;11 years included all the five consonant types. However, it lacked one plosive /k/ and three fricatives /θ,ð,ʒ/. The phonetic repertoires of TD children aged between 5;0 to 5;9 and 6;0 to 6;3 years, respectively included all consonant classes. Regarding vowel sounds, all TD participants had no difficulties with the production of vowels. Two TD participants aged 3;0 and 3;9 years, respectively, deleted unstressed short syllables containing the short vowels /ɪ,ə/ in some phonetic contexts (e.g. *banana* /nɑːnə/).

Table 4.1 Consonants in SW samples for TD group

Chronological Age	Number of Participants	Present Consonants	Absent Consonant
3;0-3;9	4	Plosive /p,b,t,d/ Fricative /z,h/ Nasal /m,n,ŋ/ Approximant /l,ɹ,w,j/	Plosive /k,g/ Fricative /f,v,θ,ð,s,ʃ,ʒ Affricate /ʧ,ʤ/
4;0-4;11	7	Plosive /p,b,t,d,g/ Fricative /f,v,s,z,ʃ,ʒ,h/ Affricate /ʧ,ʤ/ Nasal /m,n,ŋ/ Approximant /l,ɹ,w,j/	Plosive /k/ Fricative /θ,ð,ʒ
5;0-5;9	4	Plosive /p,b,t,d,k,g/ Fricative /f,v,θ,ð,s,z,ʃ,ʒ,h/ Affricate /ʧ,ʤ/ Nasal /m,n,ŋ/ Approximant /l,ɹ,w,j/	
6;0-6;3	5	Plosive /p,b,t,d,k,g/ Fricative /f,v,θ,ð,s,z,ʃ,ʒ,h/ Affricate /ʧ,ʤ/ Nasal /m,n,ŋ/ Approximant /l,ɹ,w,j/	

The results of the range of consonants in DS group were summarised (see table 4.2). The range of consonants produced by participants with DS and the missing consonants in the children's consonant repertoires were illustrated. Regarding vowel sounds, most of the participants with DS had no difficulties with the production of vowels six participants with DS made a number of vowel errors, especially with the vowel sound /ə/ (e.g., tomato [mɑːtəʊ]). The participant DS1, aged 6;6 years, the participant deleted short close-mid front vowel /e/ and open-mid central vowels /ə,ʌ/ and substituted the diphthong /aɪ/ with a shorter vowel /æ/ (e.g., *slide* [læd]). The participant DS2, aged 10;11 years, the child omitted the long front close vowel /iː/ and short vowels /e,ə/, and replaced the diphthong /əʊ/ by the long back vowel /ɔː/, The participant DS6, aged 11;1 years, deleted only the short central vowel /ə/. The participant DS10, aged 5;5 years, substituted the front long vowel /iː/ with a short close-mid vowel /e/ and deleted the short vowels /e,ə/. The participant DS14, aged 10;11 years, substituted a diphthong or a long vowel by a shorter vowel sound, such as /aɪ/ by /æ/ and /iː/ by /ɪ/, and deleted the short vowels /e,ə,ʌ/. Finally, the participant DS16, aged 8;2 years, the participant deleted vowels /iː,ɑː,ə/ and replaced /aɪ/ by /æ/.

Table 4.2 Consonants in SW samples for DS group

Chronological Age	Number of Participants	Present Consonants Types	Absent Consonant Types
5;5	1	Plosive /p,b,t,d,k,g/ Fricative /f,v,s,h/ Nasal /m,n/ Approximant /l,w,j/	Fricative /θ,ð,z,ʃ,ʒ/ Affricate /ʧ,ʤ/ Nasal /ŋ/ Approximant /ɹ/
6;0-6;9	3	Plosive /p,b,t,d,k,g/ Fricative /f,v,s,z,ʃ,ʒ/ Nasal m,n/ Approximant /l,w,j/	Fricative /θ,ð,h/ Affricate /ʧ,ʤ/ Nasal /ŋ/ Approximant /ɹ/
7;1	1	Plosive /p,b,t,d,k,g/ Fricative /f,v,s,z,ʃ,ʒ,h/ Nasal /m,n,ŋ/ Approximant /l,r,w,j/	Fricative /θ,ð,ʃ,ʒ/ Affricate /ʧ,ʤ/ Approximant /ɹ/
8;1-8;8	3	Plosive /p,b,t,g/ Fricative /f,s,z,ʃ,h/ Nasal /m,n/ Approximant /l,w,j/	Plosive /d, k,g/ Fricative /v,θ,ð,ʒ/ Affricate /ʧ,ʤ/ Nasal /ŋ/ Approximant /ɹ/
10;1-10;11	6	Plosive /p,b,t,d/ Fricative /v,ʃ,h/ Nasal /m,n/ Approximant /l,w,j/	Plosive /k,g/ Fricative /f,θ,ð,s,z,ʒ/ Affricate /ʧ,ʤ/ Nasal /ŋ/ Approximant /ɹ/
11;1-11;2	2	Plosive /p,b,t/ Fricative /f,vʃ,ʒ,h/ Nasal /m,n,ŋ/ Approximant /l,ɹ,w,j/	Plosive /k, g/ Fricative /θ,ð,s,z/ Affricate /ʧ,ʤ/
12;0	1	Plosive /p,b,t,d,k,g/ Fricative /f,vs,z,ʃ,ʒ,h/ Nasal /m,n,ŋ/ Approximant /l,ɹ,w,j/	Fricative /θ,ð/ Affricate /ʧ,ʤ/

4.2.2 Qualitative Measures: Phonological Processes in SW Samples for DS and TD Groups

The type of phonological processes that the participants in both groups tended to use frequently in SW speech samples were analysed according to the criteria the in DEAP-Assessment of Phonology (Dodd et al., 2002). The results for the TD group showed that the phonological processes which frequently occurred for five or more times appeared in the SW speech samples of only five participants in the TD group (see table 4.3). The rest of participants in the TD group either did not use any processes or used processes that were less frequent than five times. All participants in the DS group used phonological processes that occurred five times or more except DS17, aged 10;9 years, who used 9 processes in total, neither of which met the five-occurrence criterion (see table 4.4).

Table 4.3 Frequency of occurrence of phonological processes in SW Samples for TD group

Participants	CA in year;month	Deaffrication	CR	Fronting	WSD	Stopping	Voicing	Assimilation	ICD	MCD	FCD	Backing	Other Processes
TD7	3;0		6	27	2								
TD13	3;0		6										
TD3	3;9	5	18	14	3	20			5			6	11
TD14	4;0		11	5									
TD12			6										
Total		5	47	46	5	20			5			6	11

Note: TD-Typically developing children. CA-Chronological age. SW-Single word speech sample. CR-Cluster reduction process. WSD-Weak syllable deletion. ICD-Initial consonant deletion. MCD-Medial consonant deletion. FCD-Final consonant deletion.

Table 4.4 Frequency of occurrence of phonological processes in SW samples for DS group

Participants	CA in year;month	Gliding	Deaffrication	CR	Fronting	WSD	Stopping	Voicing	Assimilation	ICD	MCD	FCD	Backing	Other Processes
DS10	5;5			11		2	12	6	9		6	16	8	
DS11	6;0			17	7		14						5	6
DS13	6;6			8	5			7						
DS1	6;9			40	15	2			9	9				
DS12	7;1	10	5	6										
DS15	8;1	10		20	16		10				6			
DS16	8;2			14	12						7			
DS4	8;8			14	5			20	5			12		
DS9	10;1		9		7									
DS3	10;4				55									
DS5	10;7			10	7	3					5			
DS2	10;11			18	14		15					6		
DS14	10;11			18	9			5			5			5
DS6	11;1			6	5									
DS7	11;2		9	11	5		8	19			5			
DS8	12;0			12	5									
Total		20	23	205	157	7	59	57	23		34	16	13	11

Note: DS-Children with Down syndrome. CA-Chronological age. SW-Single word speech sample. CR-Cluster reduction. WSD-Weak syllable deletion. ICD-Initial consonant deletion. MCD-Medial consonant deletion. FCD-Final consonant deletion.

4.3 SW Samples: Quantitative Measures

Before including MA as a covariate in the ANCOVA analysis, between-participants t-test was also conducted to investigate the mean difference between the two groups. The group factor was set as IV and the percentages of occurrence of 13 phonological processes were set as DVs in SW sample (see appendix C). To investigate the difference between DS and TD groups, ANCOVA test was carried out. The non-verbal MA was set as the covariate. Linear regression was also run in order to analyse the developmental trajectories for each group in relation to non-verbal MA. The group factor was set as IV. In SW sample, DVs included the number of consonants acquired, PCC (for all singleton consonants and consonants in clusters), PVC, PPC, PCC of singleton consonants in SIWI, SIWM, SFWM and SFWF, PCCC of consonant clusters in SIWI, SIWM, SFWM and SFWF, number of occurrences of phonological processes, and percentages of occurrence of phonological processes.

4.3.1 *Accuracy Measures: Number of Consonants in SW Samples for DS Group Compared to TD Group*

In SW samples of the TD and DS groups, the number of consonants acquired in TD and DS groups were calculated. The descriptive analysis for the measure mentioned above was summarised (see table 4.5).

Table 4.5 Descriptive analysis of number of consonants in TD and DS groups

Variables	Groups	Mean	*SD*	*SE*	Median	Range	Minimum	Maximum	95% CI for Mean	
									Lower Bound	Upper Bound
Number of Consonants	TD	22.70	1.78	0.39	23	7	17	24	21.87	23.53
	DS	19.29	1.82	0.44	19	6	16	22	18.35	20.23

Note: TD-Typically developing children. DS-Children with Down syndrome. CI-Confidence limits around the mean.

The results of ANCOVA test showed that the two groups were significantly different [$F(1,33)=4.544, p=0.041, \eta^2=0.121$]. DS group developed consonants with a delayed onset. The effect size was medium ($\eta^2=0.121$). However, there was a non-significant group*MA interaction [$F(1,33)=1.260$, $p=0.270$, $\eta^2=0.037$]. This indicated that children with DS developed consonants at a typical rate similar to that of TD children but at a delayed onset. There was a marginal relationship between group factor and MA, as indicated by a partial eta squared value of 0.03. Linear regression was run in order to investigate the developmental trajectories in relation to the number of consonants acquired by DS group and TD groups. For the TD group, the results showed that MA was a reliable predictor of development in terms of the number of consonants acquired [$R^2=0.251$, $F(1,19)=6.036$, $p=0.024$]. The intercept was 21.34 and the gradient was 0.034 (see figure 4.1). The confidence intervals around the TD trajectory were narrow, indicating that there was 95% confidence that the population slope was between 19.960 and 22.720. For DS group, the results revealed that MA was a non-significant predictor of development of the number of consonants acquired [$R^2=0.007$, $F(1,16)=0.111$, $p=0.744$]. The intercept was 19.045 and the gradient was 0.0069 (see figure 4.1). The results indicated that there was 95% confidence that the population intercept was between 17.174 and 20.915. When developmental trajectories were plotted by non-verbal MA, the data indicated that the number of consonants in children with DS was lower than that in their MA-matched TD counterparts. Yet DS group developed number of consonants acquired at a typical rate as the two trajectories were parallel and positively trended, but at a delayed onset. However, the trajectory for DS group also illustrated that MA was not significantly effective in terms of the development of the number of consonants acquired when compared to their MA-matched TD peers (see figure 4.1).

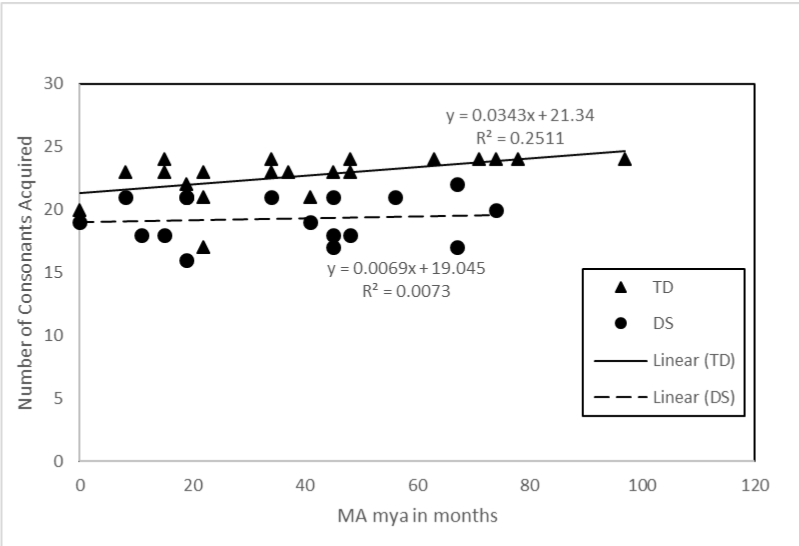


Figure 4.1. Number of consonants acquired in SW samples for TD and DS groups. The figure illustrates the developmental trajectory for the number of consonant acquired in single word (SW) samples. The trajectory for typically developing (TD) group is represented with a solid line, and for children with Down syndrome (DS) group is represented with a dotted line. MA mya represents rescaled nonverbal mental age measured form youngest age in months in the TD group.

4.3.2 *Accuracy Measures: PCC, PVC and PPC in SW Samples for DS Group Compared to TD Group*

Based on the results for SW samples, the following quantitative measures were included in the phonological analysis, and the statistical similarities and differences between the DS and TD group are reported. The results of the descriptive analysis of PCC, PVC and PPC were summarised (see table 4.6).

Table 4.6 Descriptive analysis of PCC, PVC and PPC measures in SW samples for TD and DS groups

Characteristics	**Groups**	**Mean**	***SD***	***SE***	**Median**	**Range**	**Minimum**	**Maximum**	**95% CI for Mean**	
									Lower Bound	Upper Bound
PCC	TD	95.90%	7.07	1.58	98%	30%	70%	100%	92.59%	99.21%
	DS	80.35%	7.40	1.79	83%	25%	64%	89%	76.54%	84.16%
PVC	TD	99.50%	0.88	0.19	100%	3%	97%	100%	99.08%	99.92%
	DS	97.18%	1.74	0.42	97%	5%	95%	100%	96.28%	98.07%
PPC	TD	97.25%	4.65	1.04	99%	20%	80%	100%	95.07%	99.43%
	DS	85.24%	5.69	1.38	88%	20%	70%	90%	82.31%	88.16%

Note: PPC-Percentage phonemes correct. PCC-Percentage consonants correct. PVC-Percentage vowels correct. TD-Typically developing children. DS-children with Down syndrome. SD-Standard deviation. SE-Standard error. CI-Confidence intervals around the mean.

1. PCC

The results of ANCOVA test showed that there was an overall effect of group factor in terms of PCC [$F(1,33)=10.972$, $p=0.002$, $\eta^2=0.250$]. This indicated that the two groups were significantly different, suggesting a delayed onset of development for DS group. The effect size ($\eta^2=0.250$). The results also showed that there was non-significant group*MA interaction [$F(1,33)=0.851$, $p=0.363$, $\eta^2=0.025$] suggesting DS group developed at a typical rate. The effect was small ($\eta^2=0.025$) (see table 4.7). The results of linear regression were reported. For TD group, MA was not a reliable predictor of development in terms of PCC [$R^2=0.162$, $F(1,19)=3.479$, $p=(0.079)$]. The intercept was 91.334% and the gradient was 0.1088 (see figure 4.2a The confidence intervals around TD trajectory were between 85.564% and 97.105%. Similarly, MA was a marginal predictor of development of PCC in DS group [$R^2=0.005$, *F*(1,16)=0.071, *p*=0.794]. The intercept for DS group was 77.32% and the gradient was 0.0205 (see Figure 4.2a). There was 95% confidence that the population intercept was between 70.397% and 84.242%. As the plotted data suggested, the two trajectories were parallel. The rate of development was approximately normal by plotting DS group trajectory in terms of MA. However, DS group developed PCC at a delayed onset. Thus, PCC in DS group developed in line with the rate of general development in TD group but suffered a delay in onset.

2. PVC

Regarding PVC measure, the results showed that the two groups were significantly different [$F(1,33)=14.189$, $p=0.001$, $\eta^2=0.301$]. The results showed that DS group shows a delayed onset. The effect size was large ($\eta^2=0.301$). However, there was non-significant group*MA interaction [$F(1,33)=1.188$, $p=0.284$, $\eta^2=0.035$], suggesting the two groups produced PVC at a typical rate of development (see table 4.7). The results of linear regression for TD group showed that MA was not a reliable predictor of development in terms of PVC [$R^2=0.132$, $F(1,19)=2.735$, $p=0.116$]. The intercept was 99.008% and the gradient was 0.0124 (see figure 4.2b). The confidence intervals around TD trajectory were between 98.267% and 99.750%. Examining the developmental trajectory of DS group, MA was also a non-significant predictor of development of PVC [$R^2=0.173$, $F(1,16)=3.129$, $p=0.097$]. The intercept for DS group was 96.024% and the gradient was 0.0139 (see figure 4.2b). There was 95% confidence that the population intercept was between 94.399% and 97.650%. As plotted data illustrated, the performance of DS group in relation to PVC manifested a typical rate of development but the trajectory onset was delayed. DS and TD trajectories were very closely parallel, suggesting that DS group correctly produced most of vowel sounds, therefore DS performance approached TD group performance in terms of PVC.

3.PPC

The two groups were also found significantly different in terms of PPC as indicated the results of ANCOVA test indicted [$F(1,33)=11.113$, $p=0.002$, $\eta^2=0.252$]. This suggested that DS group produced PPC at a delayed onset. The effect size was large ($\eta^2=0.252$). The results also manifested that there was a non-significant group*MA interaction [$F(1,33)=0.189$, $p=0.666$, $\eta^2=0.006$]. That is, DS group developed at a typical rate similar to that of TD group (see table 4.7). The analysis of linear regression for TD group indicated that MA was unreliable predictor of PPC production development [R^2=0.152, F(1,19)=3.227, p=0.089]. The intercept was 94.442% and the gradient was 0.0696 (see figure 4.2c). The confidence intervals around TD trajectory were between 90.614% and 98.271%. The results for DS group showed that MA was of marginal significance in predicting the development of PPC scores [R^2=0.023, F(1,16)=0.355, p=0.560]. The intercept for DS group was 83.855% and the gradient was 0.2283 (see figure 4.2c). There was 95% confidence that the population intercept was between 78.075% and 89.634%. As the plotted data suggested, DS group developed at a typical rate, but they started development at a delayed onset. This can be easily recognised by the parallel trajectories representing PPC scores in the two groups. The trajectories were positively trended and that PPC were found to be higher for children at older ages.

Table 4.7 ANCOVA results for PCC, PVC, and PPC measures in SW samples for TD and DS groups

Measures	Variables	*df*	Mean Square	*F*	*p*-value	Effect Size η^2
PCC	Group	(1,33)	503.933	10.972	0.002	.250
	MAmya	(1,33)	83.724	1.823	0.186	.052
	Group*MAmya	(1,33)	39.067	0.851	0.363	.025
PVC	Group	(1,33)	22.842	14.189	0.001	0.301
	MAmya	(1,33)	9.846	6.116	0.019	0.156
	Group*MAmya	(1,33)	1.912	1.188	0.284	0.035
PPC	Group	(1,33)	287.602	11.113	0.002	0.252
	MAmya	(1,33)	58.212	2.249	0.143	0.064
	Group*MAmya	(1,33)	4.894	0.189	0.666	0.006

Note: PPC-Percentage phonemes correct. PCC-Percentage consonants correct. PVC-Percentage vowels correct. TD-Typically developing children. DS-Children with Down syndrome. SD-Standard deviation. SE-Standard error. CI-Confidence intervals around the mean. MAmya-Nonverbal mental age measured in months form youngest age in TD group.

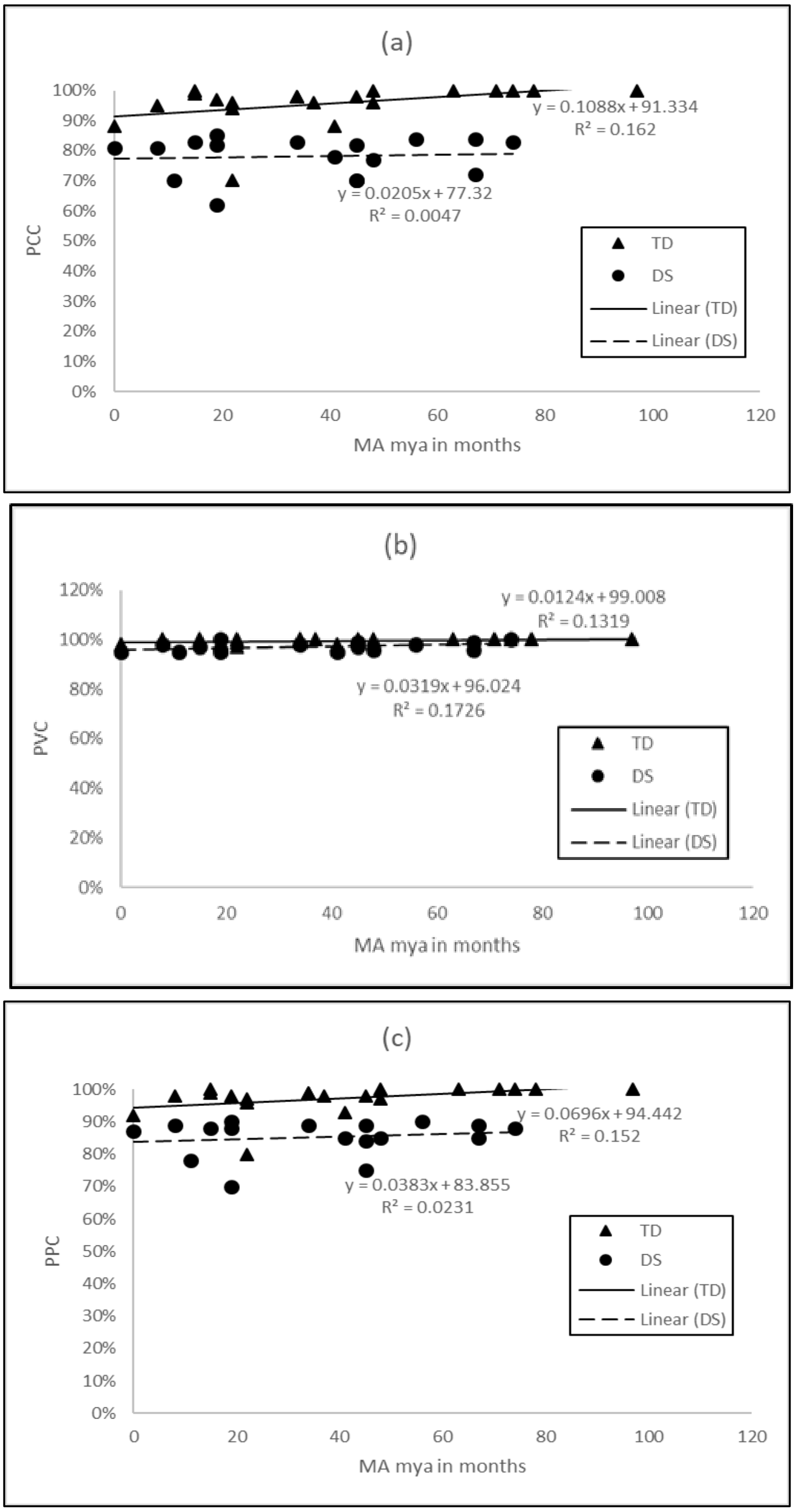


Figure 4.2(a-c). PCC, PVC, and PPC measures in SW samples for TD and DS groups. The figures a, b, and c illustrate the developmental trajectories for percentage consonants correct(PCC), percentage vowels correct (PVC), and PPC-percentage phonemes correct (PPC) in single word (SW) samples. The trajectory TD group is represented with a solid line and for DS group is represented with a dotted line. MAmya represents rescaled nonverbal mental age measured from youngest age in months in the TD group.

4.3.3 Accuracy Measures: Singleton Consonants Distribution in SW Samples

To investigate the extent to which word position could affect the consonant production accuracy, various phonetic distributions of singleton consonants were analysed and considered as important in identifying the range of the consonants produced by the participants in both groups. The distribution and PCC of singleton consonants was assessed in four different syllable/word positions as outlined by Grunwell (1985): SIWI, SIWM, SFWM, and SFWF. The descriptive analysis of the results was summarised (see tables 4.8).

Table 4.8 Descriptive analysis of PCC of single consonants occurring in different word positions in SW samples for TD and DS groups

Measures	Groups	Mean	*SD*	*SE*	Median	Range	Minimum	Maximum	95% CI for Mean	
									Lower Bound	Upper Bound
SIWI	TD	96.75%	4.85	1.08	98%	21%	79%	100%	94.48%	99.02%
	DS	82.65%	8.77	2.12	86.30%	30%	60%	90%	78.14%	87.16%
SIWM	TD	96.15%	7.77	1.73	100%	26%	74%	100%	92.51%	99.79%
	DS	83.88%	4.02	0.97	85%	14%	75%	89%	81.81%	85.95%
SFWM	TD	98.20%	2.64	0.59	99%	10%	90%	100%	96.96%	99.44%
	DS	70%	15.53	3.76	71%	53%	35%	88%	62.01%	77.99%
SFWF	TD	96.85%	6.58	1.47	99%	29%	71%	100%	93.77%	99.93%
	DS	83.47%	8.13	1.97	87%	31%	58%	89%	79.29%	87.65%

Note: SIWI-Syllable initial word initial position. SIWM-Syllable initial word medial position. SFWM-Syllable final word medial position. SFWF-Syllable final word final position. TD-Typically developing children. DS-Children with Down syndrome. SD-Standard deviation. SE-Standard error. CI-Confidence intervals around the mean. MAmya-Nonverbal mental age measured in months form youngest age in TD group.

The results of ANCOVA test in terms of PCC of singleton consonants in SIWI revealed that the two groups were significantly different [$F(1,33)=9.214$, $p=0.005$, $\eta^2=0.218$]. This suggested that DS group started producing correct consonants in SIWI with a delayed onset. The effect size was large ($\eta^2=0.218$). Yet, there was a non-significant group*MA interaction [$F(1,33)=0.117$, $p=0.735$, $\eta^2=0.004$]. Thus, DS group developed at a typical rate (see table 4.9). Running linear regression, the results showed that MA was a significant predictor of development in terms of PCC in SIWI for TD group [$R^2=0.199$, $F(1,19)=4.253$, $p=0.054$]. The intercept was 93.42% and the gradient was 0.0815 (see figure 4.3a). The confidence intervals around TD trajectory were between 89.514% and 97.326%. However, MA was an unreliable predictor of development [$R^2=0.017$, $F(1,16)=0.254$, $p=0.622$]. The intercept for DS group was 80.594% and the gradient was 0.0488 (see figure 4.3a). There was 95% confidence that the population intercept was between 71.889% and 89.299%. As plotted data suggested, no atypicality was observed. That is, DS and TD trajectories were parallel and positively trended, therefore, PCC of singleton consonants for participants with DS was in line with the development of their MA-matched TD peers. Yet, DS trajectory started at a delayed onset when compared to TD trajectory.

The PCC of singleton consonants in SIWM was also investigated by conducting a one-way between-groups ANCOVA. The results revealed that DS and TD groups were significantly different [$F(1,33)=6.512$, $p=0.016$, $\eta^2=0.165$], suggesting that DS group developed at a delayed onset in terms of PCC of singleton consonants in SIWM. The effect size was medium ($\eta^2=0.165$). However, there was a non-significant group*MA interaction [$F(1,33)=0.291$, $p=0.140$, $\eta^2=0.065$]. Thus, DS group produced singleton consonants in SIWM at a typical rate (see table 4.9). The results of linear regression for TD group indicated that MA was a statistically unreliable predictor of development of PCC of singleton consonants in SIWM [$R^2=0.172$, F(1,19)=3.751, p=0.069]. The intercept was 91.475% and the gradient was 0.1179. See Figure 4.3b. The confidence intervals around TD trajectory were between 85.456% and 97.495%. Similarly, MA was also found to be of marginal significance in predicting the development of DS group in terms of PCC of singleton consonants [$R^2=0.000$, $F(1,16)=0.006$, $p=0.940$]. The intercept for DS group was 82.464% and the gradient was 0.0031 (see figure 4.3b). There was 95% confidence that the population intercept was between 78.855% and 86.074%. Examining the developmental trajectories of the two groups, they were parallel. TD trajectory was positively trended, i.e., children performance improved as MA increased. On the contrary, DS trajectory was approximately neutrally trended, i.e., it suggested that the performance of DS group was static and not changing even at older MAs

The ANCOVA results of PCC of singleton consonants in SFWM showed that there was an overall effect of group factor [F(1,33)=18.201, p<0.05(0.001), η^2=0.355], suggesting that DS group produced PCC of singleton consonants in SFWM at an onset later than their MA-matched TD controls. There was also a large effect size (η^2=0.355). However, there was a non-significant group*MA interaction [F(1,33)=0.008, p=0.930, η^2=0.000], indicating that DS group produced singleton consonants in SFWM at a typical rate (see table 4.9). For TD group, linear regression results showed that MA was a statistically significant predictor of development in terms of PCC of singleton consonants in SFWM [R^2=0.197, F(1,19)=4.405, p=0.050]. The intercept was 96.058% and the gradient was 0.0477 (see figure 4.3c). The confidence intervals around TD trajectory were between 93.809% and 98.306%. However, MA was non-significant predictor of development in DS group in terms of PCC of single consonants in SFWM [R^2=0.008, F(1,16)=0.125, p=0.729]. The intercept for DS group was 67.505% and the gradient was 0.061 (see figure 4.3c). There was 95% confidence that the population intercept was between 51.950% and 83.059%. As plotted data suggested, the trajectories of the two groups were parallel and positively trended. DS group developed at a typical rate, but the produced singleton consonants in SFWM at a delayed onset.

The ANCOVA results of PCC of singleton consonants in SFWF manifested that there was an overall effect of group factor [F(1,33)=8.909, p=0.005, η^2=0.213]. This indicated that DS group produced singleton consonants in SFWF at an onset later than that for TD group. The effect size was large (η^2=0.213). However, there was a non-significant group*MA mya interaction [F(1,33)=1.250, p=0.272, η^2=0.036]. Therefore, DS group develop singleton consonant production at a typical rate similar to that for TD group when matched for MA (see table 4.9). For TD group, the results of linear regression revealed that MA was unreliable predictor of development in terms of PCC of single consonants in SFWF [R^2=0.138, F(1,19)=2.888, p=0.106]. The intercept was 92.963% and the gradient was 0.0942 (see figure 4.3d). The confidence intervals around TD trajectory were between 87.479% and 98.447%. For DS group, was also a non-significant predictor of development in relation to PCC of single consonants in SFWF [R^2=0.001, F(1,16)=0.020, p=0.888]. The intercept for DS group was 80.523% and the gradient was 0.0112 (see figure 4.3d). There was 95% confidence that the population intercept was between 73.453% and 87.592%. When TD and DS trajectories were plotted by MA, the performance of DS group was in line with that of TD groups in terms of

PCC of singleton consonants in SFWF. DS groups produced singleton consonants in SFWF at a delayed onset but developed consonant production in this position at a typical rate of TD group. The two trajectories were parallel and positively trended

Table 4.9 ANCOVA results for PCC of single consonant occurring in different word positions in SW samples for TD and DS groups

Measures	Variables	*df*	Mean Square	*F*	*p*-value	Effect Size η^2
SIWI	Group	(1,33)	422.041	9.214	0.005	0.218
	MA mya	(1,33)	84.892	1.853	0.183	0.053
	Group*MA mya	(1,33)	5.352	0.117	0.735	0.004
SIWM	Group	(1,33)	208.319	6.512	0.016	0.165
	MA mya	(1,33)	65.972	2.062	0.160	0.059
	Group*MA mya	(1,33)	73.275	2.291	0.140	0.065
SFWM	Group	(1,33)	2091.825	18.201	0.001	0.355
	MA mya	(1,33)	59.217	0.515	0.478	0.015
	Group*MA mya	(1,33)	0.889	0.008	0.930	0.000
SFWF	Group	(1,33)	397.063	8.909	0.005	0.213
	MA mya	(1,33)	34.487	0.774	0.385	0.023
	Group*MA mya	(1,33)	55.697	1.250	0.272	0.036

Note: SIWI-Syllable initial word initial position. SIWM-Syllable initial word medial position. SFWM-Syllable final word medial position. SFWF-Syllable final word final position. TD-Typically developing children. DS-Children with Down syndrome. MA mya-Nonverbal mental age measured in months form youngest age in TD group.

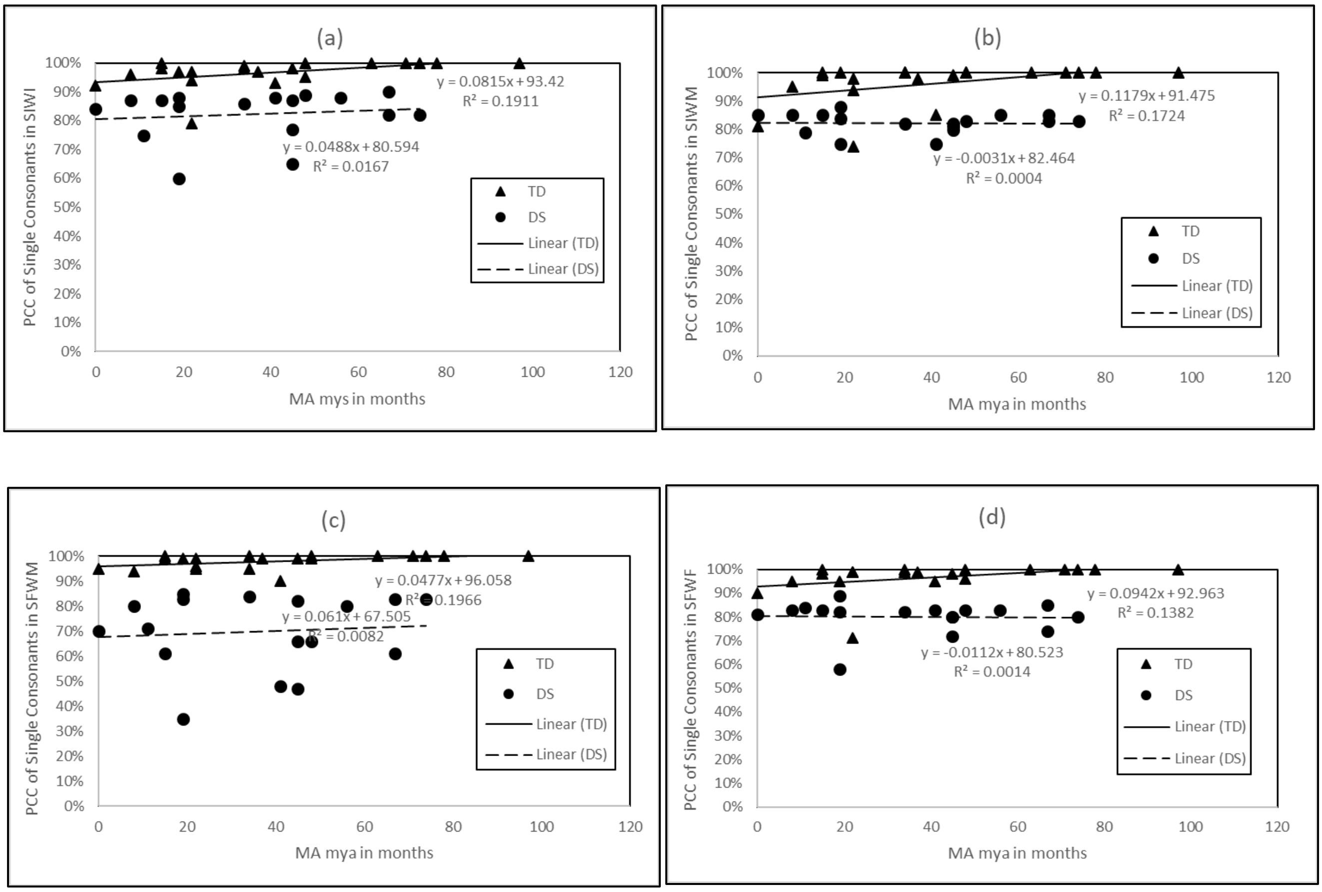


Figure 4.3(a-d). PCC of single consonants occurring in different word positions in SW samples for TD and DS groups. The figures a,b,c, and d illustrate the developmental trajectories for percentage of consonants correct (PCC) in four different word positions in single word samples (SW). The trajectory for TD group is represented with a solid line and for DS group is represented with a dotted line. SIWI is syllable initial word initial position. SIWM is syllable initial word medial position. SFWM is syllable final word medial position. SFWF is syllable final word final position. MA mya represents rescaled nonverbal mental age measured form youngest age in months in the TD group.

4.3.4 Accuracy Measures: Consonant Clusters Distribution in SW Samples

The PCCC of consonant clusters in SIWI, SIWM, SFWM, and SFWF was estimated. The results of descriptive analysis were reported (see table 4.10).

Table 4.10 Descriptive analysis of PCCC in different word positions in SW samples for TD and DS groups

Variables	Groups	Mean	*SD*	*SE*	Median	Range	Minimum	Maximum	95% CI for Mean	
									Lower Bound	Upper Bound
SIWI	TD	93.90%	11.46	2.56	98%	39%	61%	100%	88.54%	99.26%
	DS	61.94%	21.78	5.28	68%	75%	15%	90%	50.74%	73.14%
SIWM	TD	97.30%	7.10	1.58	99%	32%	68%	100%	93.98%	99.62%
	DS	58.47%	26.55	6.44	66%	90%	0%	90%	44.82%	72.13%
SFWM	TD	95.35%	11.45	2.56	99%	50%	50%	100%	89.99%	99.71%
	DS	33.59%	31.09	7.54	50%	89%	0%	89%	17.60%	49.57%
SFWF	TD	96.85%	7.45	1.66	99%	34%	66%	100%	93.36%	99.34%
	DS	49.35%	21.07	5.11	50%	75%	12%	87%	38.52%	60.90%

Note: SIWI-Syllable initial word initial position. SIWM-Syllable initial word medial position. SFWM-Syllable final word medial position. SFWF-Syllable final word final position. TD-Typically children. DS-Children with Down syndrome. SD-Standard deviation. SE-Standard error. CI-Confidence intervals around the mean. MA mya-Nonverbal mental age measured in months form youngest age in TD group.

Running between participants ANCOVA test, the results revealed a statistically significant difference between TD and DS groups in relation to PCCC of consonant clusters in SIWI [$F(1,33)=8.301$, $p=0.007$, $\eta^2=0.201$], suggesting that DS group developed with a delayed onset. The effect size was large ($\eta^2=0.201$). On the other hand, there was a non-significant group*MA interaction [$F(1,33)=0.012$, $p=914$, $\eta^2=0.000$], indicating that DS group developed at a typical rate (see table 4.11). For TD group, the results of linear regression indicated that MA was a significant predictor of development in terms of PCCC of consonant cluster sin SIWI [$R^2=0.190$, $F(1,19)=4.235$, $p=0.054$]. The intercept was 86.277% and the gradient was 0.1923 (see figure 4.4a). The confidence intervals around TD trajectory were between 77.038% and 95.515%. However, MA was not a reliable predictor of development for DS group [$R^2=0.030$, $F(1,16)=0.462$, p=o.507]. The intercept for DS group was 55.944% and the gradient was 0.1663 (see figure 4.4a). There was 95% confidence that the population intercept was between 33.919% and 77.968%. The trajectories for TD and DS groups were parallel and positively trended. The higher were MAs, the higher were PCCC scores for the two groups. Despite the typical rate of development in DS group, the correct production of consonant clusters in SIWI started at a delayed onset.

The ANCOVA results PCCC in SIWM demonstrated the overall effect of group factor [$F(1,33)=15.106$, $p<0.001$, $\eta^2=0.314$]. The effect size was large ($\eta^2=0.314$). This suggested that DS group developed at a delayed onset. However, there was a non-significant group*MA interaction [$F(1,33)=0.530$, $p=0.472$, $\eta^2=0.016$]. This means DS group developed at a typical rate (see table 4.11). The results of linear regression revealed that MA was unreliable predictor of development for TD group in terms of PCCC in SIWM [$R^2=0.061$, $F(1,19)=1.161$, $p=0.295$]. The intercept was 94.636% and the gradient was 0.0672 (see figure 4.4b). The confidence intervals around TD trajectory were between 88.469% and 99.802%. Similarly, for DS group MA was found to be a nonsignificant predictor of development in relation to PCCC in SIWM [$R^2=0.049$, $F(1,16)=0.776$, $p=0.392$]. The intercept for DS group was 49.083% and the gradient was 0.2603 (see figure 4.4b). There was 95% confidence that the population intercept was between 22.496% and 75.669%. Examining the trajectories of the two group, TD and DS trajectories were parallel and positively trended. DS group started a very delayed onset, but it demonstrated an improvement in the production of consonant clusters for DS participants at older ages. However, the data distribution around DS trajectory revealed that 4 participants with DS showed the lowest PCCC scores. This suggested that it was substantially hard for those four participants to produce consonant clusters correctly in SIWM.

Regarding PCCC in SFWM, the results of ANCOVA test revealed that there was a statistically significant difference between TD and DS groups [$F(1,33)=18.201$, $p<0.001$, $\eta^2=0.355$]. This indicated that participants with DS developed at a delayed onset. The effect size was very large ($\eta^2=0.355$). The results also revealed a non-significant group*MA mya interaction [$F(1,33)=0.008$, $p=0.930$, $\eta^2=0.000$]. Thus, participants with DS developed at a typical rate (see table 4.11). The results of linear regression showed that MA was not a significant predictor of development for TD group in terms of PCCC in SFWM [$R^2=0.177$, $F(1,19)=3.870$, $p=0.065$]. The intercepts and gradients for TD and DS trajectories. For TD group, the intercept was 88.007% and the gradient was 0.1852 (see figure 4.4c). The confidence intervals around TD trajectory were between 78.698% and 97.316%. For DS group, MA significantly predicted development in terms of PCCC in SFWM [$R^2=0.305$, F(1,16)=6.583, p=0.022]. The intercept for DS group was 6.2308% and the gradient was 0.7587 (see figure 4.4c). There was 95% confidence that the population intercept was between 20.378% and 32.840%. As data plotted by MA suggested, the trajectories of the TD and DS groups were not parallel. TD and DS trajectories were positively trended. DS trajectory started at a highly delayed onset than that for TD trajectory. When compared to TD group, DS group showed greater variability in terms of the production of consonant clusters in SFWM. DS trajectory revealed that 7 participants scored 0%; yet, DS production accuracy increased for the remaining participants as MAs increased.

The ANCOVA results of PCCC in SFWF showed that there was an overall effect of group factor [$F(1,33)=8.909$, $p=0.005$, $\eta^2=0.213$]. This indicated that DS group developed at a delayed onset in as far as PCCC in SFWF was concerned. The effect size was large ($\eta^2=0.213$). The results also revealed that there was a non-significant group*MA interaction [$F(1,33)=1.250$, $p=0.272$), $\eta^2=0.036$]. This revealed that DS group developed at a rate similar to that of TD children when matched for MA (see table 4.11). For TD group, the results of linear regression demonstrated that MA was a non-significant predictor of development in terms of PCCC in SFWF [$R^2=0.075$, $F(1,19)=1.458$, $p=0.243$]. The intercept was 93.739% and the gradient was 0.0785 (see figure 4.4d). The confidence intervals around TD trajectory were between 87.313% and 99.164%. Similarly, MA was not a reliable predictor of performance for DS group in terms of PCCC in SFWF [$R^2=0.192$, $F(1,16)=3.556$, $p=0.079$]. The intercept for DS group was 34.654% and the gradient was 0.4076 (see figure 4.4d). There was 95% confidence that the population intercept was between 15.202% and 54.105%. TD and DS trajectories were parallel and positively trended; yet, PCCC scores for participants with DS were lower than these for TD participants. Additionally, DS trajectory started at a significantly delayed onset of development in relation to PCCC in SFWF.

Table 4.11 ANCOVA test results for PCCC in different word positions in SW samples for TD and DS groups

Measures	Variables	*df*	Mean Square	*F*	*p*-value	Effect Size η^2
SIWI	Group	(1,33)	422.041	9.214	0.005	0.218
	MA mya	(1,33)	84.892	1.853	0.183	0.053
	Group*MA mya	(1,33)	5.352	0.117	0.735	0.004
SIWM	Group	(1,33)	208.319	6.512	0.016	0.165
	MA mya	(1,33)	65.972	2.062	0.160	0.059
	Group*MA mya	(1,33)	73.275	2.291	0.140	0.065
SFWM	Group	(1,33)	2091.825	18.201	0.001	0.355
	MA mya	(1,33)	59.217	0.515	0.478	0.015
	Group*MA mya	(1,33)	0.889	0.008	0.930	0.000
SFWF	Group	(1,33)	397.063	8.909	0.005	0.213
	MA mya	(1,33)	34.487	0.774	0.385	0.023
	Group*MA mya	(1,33)	55.697	1.250	0.272	0.036

Note: SIWI-Syllable initial word initial position. SIWM-Syllable initial word medial position. SFWM-Syllable final word medial position. SFWF-Syllable final word final position. TD-Typically developing children. DS-Children with Down syndrome. MA mya-Nonverbal mental age measured in months form youngest age TD group.

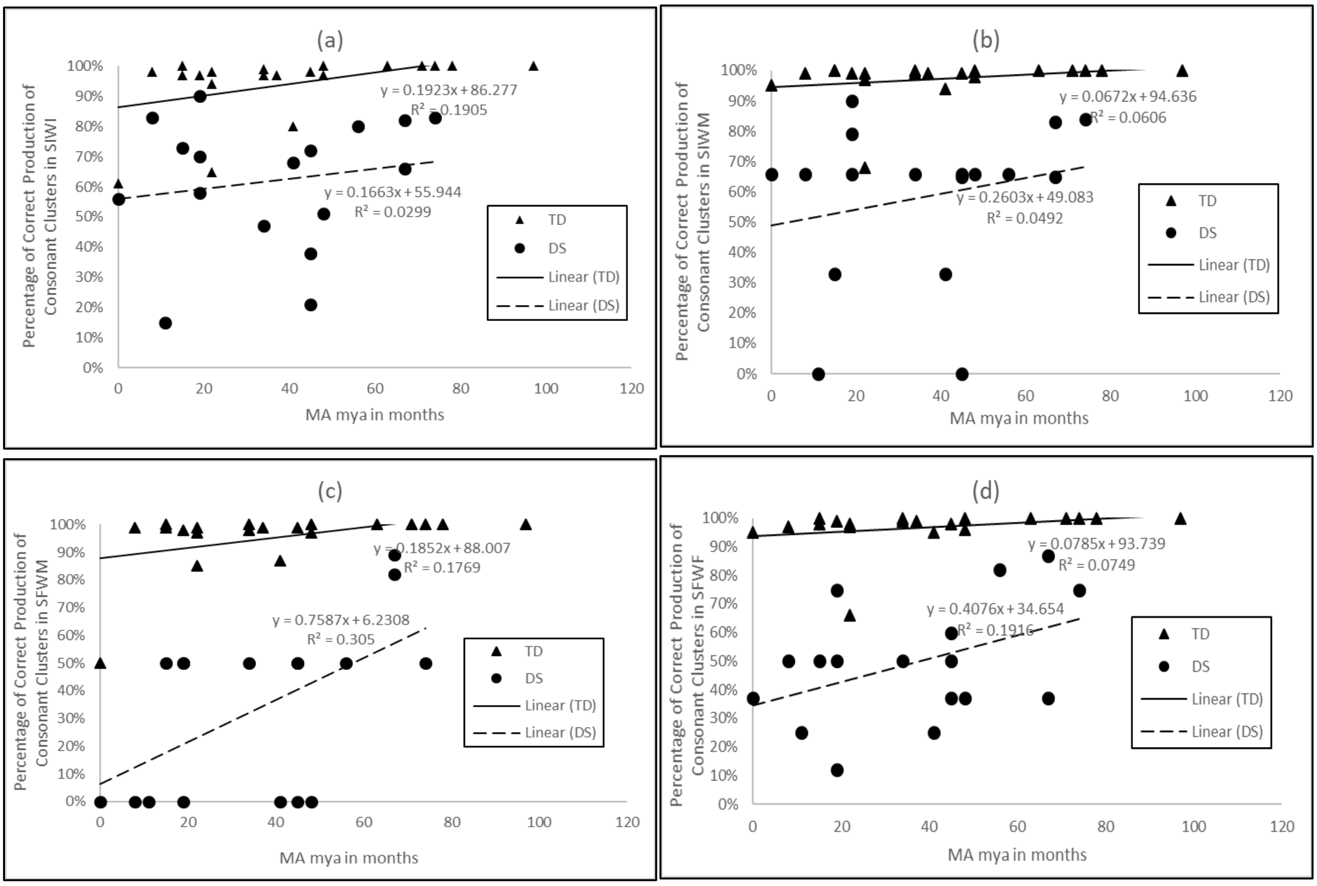


Figure 4.4(a-d). Percentage of correct production of consonant clusters occurring in different word positions in SW samples for TD and DS groups. The figures a,b,c, and d illustrate the developmental trajectories of percentage of correct consonant clusters (PCCC) in four different word positions in single word (SW) samples. The trajectory for TD group is represented with a solid line, and for DS group trajectory is represented with a dotted line. SIWI is syllable initial word initial position. SIWM is syllable initial word medial position. SFWM is syllable final word medial position. SFWF is syllable final word final position. MA mya represents rescaled nonverbal mental age measured form youngest age in months in the TD group.

4.3.5 Accuracy Measures: Phonological Processes in SW Samples for DS Group Compared to TD Group

The number of occurrences of phonological processes and differences between the two groups were illustrated (see table 4.12). The DS group used significantly more phonological processes than TD group in SW sample.

Table 4.12 Descriptive analysis of number of occurrences of phonological processes in SW samples for TD and DS groups

Groups	Mean	*SD*	*SE*	Median	Range	Minimum	Maximum	95% CI for Mean	
								Lower Bound	Upper Bound
TD	11.30	20.89	4.87	5	90	0	90	1.52	21.07
DS	52.58	33.94	8.23	53	109	9	118	35.13	70.04

Note: TD-Typically developing children. DS-Children with Down syndrome. SD-Standard deviation. SE-Standard error. CI-Confidence limits around the mean

Running ANCOVA test, the results revealed that DS and TD groups were significantly different in terms of the number of occurrences of processes in SW sample [$F(1,33)=5.980$, $p=0.041$, $\eta^2=0.153$]. This indicated that DS group started to reduce phonological processes at a delayed onset. The effect size was large ($\eta^2=0.153$). The results also showed that there was a non-significant group*MA interaction [$F(1,33)=0.11$, $p=0.916$, $\eta^2=0.000$]. Therefore, participants with DS tended to reduce using phonological processes in their speech at a rate of development similar to that of TD children when matched for MA. When the two groups were analysed separately, the results of linear regression revealed that MA was not a reliable predictor of performance on this task for TD [$R^2=0.141$, $F(1,19)=2.959$, $p=0.103$] and for DS group [$R^2=0.052$, $F(1,16)=0.827$, $p=0.378$]. For TD group, the intercept was 23.267 and the gradient was 0.3018 (see figure 4.5). The confidence intervals around TD trajectory were between 5.919 and 40.615. The intercept for DS group was 64.951 and the gradient was 0.3428 (see figure 4.5). The confidence limits around the DS trajectory were between 31.02 and 98.87. The plotted data suggested that TD and DS trajectories were parallel and negatively trended. The analysis of the trajectories of the two groups showed that DS used more processes than TD group. DS group started reducing the number of occurrences of processes at a very delayed onset, although they continue to minimise the number of occurrences of processes at a typical rate similar to that of their MA-matched TD controls.

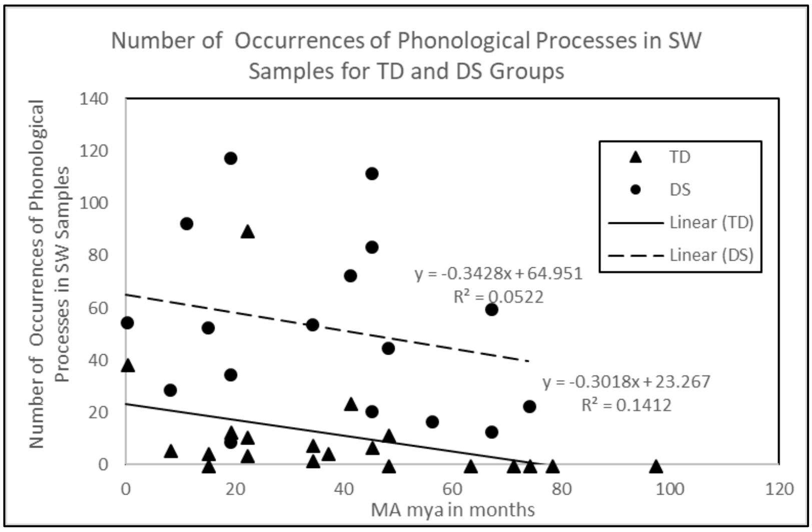


Figure 4.5 Number of phonological processes in SW samples for TD and DS groups. The figure illustrates the developmental trajectories for the occurrences of phonological processes in single word speech (SW) samples. The trajectory for TD group is represented with a solid line, and for DS is represented with a dotted line. MA mya represents rescaled nonverbal mental age measured form youngest age in months in the TD group.

The percentages of occurrences of the thirteen phonological processes evaluated in the phonology assessment were calculated. These processes included: gliding, deaffrication, cluster reduction, fronting, weak syllable deletion, stopping, voicing, assimilation, initial consonant deletion, medial consonant deletion, final consonant deletion, backing, and other types of phonological processes that might appear in the children's speech within the age ranges tested in TD and DS groups. For the TD group, the most frequently occurring processes were cluster reduction and fronting. However, other processes were less frequent with percentages of occurrence <1% (see table 4.13 for more details). For the DS group, the most frequently occurring processes were cluster reduction, fronting, stopping, voicing, assimilation, medial consonant deletion and deaffrication. Less frequent processes included initial consonant deletion, weak syllable deletion, gliding, final consonant deletion, and backing (see table 4.13 for more details).

Table 4.13 Descriptive analysis of percentages of occurrence of phonological processes in SW samples for TD and DS groups

Processes	Groups	Mean	*SD*	*SE*	Median	Range	Minimum	Maximum	95% CI for Mean	
									Lower Bound	Upper Bound
Gliding	TD	0.30%	0.97	0.21	0%	4%	0%	4%	0.16%	0.76%
	DS	4.76%	7.79	1.09	2%	30%	0%	30%	0.30%	8.38%
Deaffrication	TD	0.30%	1.12	0.25	0%	5%	0%	5%	0.23%	0.83%
	DS	5.76%	9.92	2.40	2%	39%	0%	39%	0.66%	10.87%
CR	TD	2.35%	4.85	1.08	0%	19%	0%	19%	0.08%	4.62%
	DS	25.59%	16.40	3.97	25%	65%	2%	67%	17.15%	34.02%
Fronting	TD	3.05%	5.96	1.33	1%	25%	0%	25%	0.26%	5.84%
	DS	18.59%	10.35	2.51	17%	35%	3%	38%	13.26%	23.91%
WSD	TD	0.35%	0.18	0.18	0%	3%	0%	3%	0.03%	0.73%
	DS	1.76%	2.41	0.58	2%	8%	0%	8%	0.52%	3%
Stopping	TD	0.90%	3.79	0.84	0%	17%	0%	17%	0.88%	2.68%
	DS	7.29%	7.06	1.71	6%	29%	0%	29%	3.66%	10.93%
Voicing	TD	0.55%	0.78	0.19	0%	2%	0%	2%	0.13%	0.97%
	DS	9.12%	7.60	1.84	8%	24%	0%	24%	5.21%	13.03%
Assimilation	TD	0.70%	0.73	0.16	1%	3%	0%	3%	0.36%	1.04%
	DS	4.76%	4.07	0.98	4%	11%	0%	11%	2.67%	6.86%
ICD	TD	1.00%	1.21	0.27	0%	3%	0%	3%	0.43%	1.57%
	DS	3.82%	3.26	0.79	2%	9%	1%	10%	2.15%	5.50%
MCD	TD	0.25%	0.63	0.14	0%	2%	0%	2%	0.05%	0.55%
	DS	6.18%	5.18	1.25	6%	14%	0%	14%	3.51%	8.84%
FCD	TD	0.85%	1.46	0.32	0%	5%	0%	5%	0.17%	1.53%
	DS	4.29%	5.03	1.22	3%	20%	1%	21%	1.71%	6.88%
Backing	TD	0.80%	2.89	0.64	0%	13%	0%	13%	0.55%	2.15%
	DS	3.65%	4.15	1.00	3%	13%	0%	13%	1.51%	5.78%
Other Processes	TD	0.65%	2.90	0.65	0%	13%	0%	13%	0.71%	2.01%
	DS	1.41%	3.28	0.79	0%	11%	0%	11%	0.27%	3.10%

Note: TD-Typically developing children. DS-Children with Down syndrome. CI-Confidence limits around the mean. CR-Cluster reduction. WSD-Weak syllable deletion. ICD-Initial consonant deletion. MCD-Medial consonant deletion. FCD-Final consonant deletion.

Developmental trajectories were constructed for each of the 13 processes as follows:

1. **Gliding**

The results of ANCOVA showed that there was a non-significant difference between DS and TD groups in terms of percentage of occurrence of gliding [$F(1,33)=0.152$, $p=0.699$, $\eta^2=0.005$]. This suggested that there was no delay in onset in DS group. However, there was a statistically significant group*MA interaction [$F(1,33)= 5.097$, $p=0.031$, $\eta^2=0.134$]. The DS group supressed gliding process at a rate slower than that for TD group. The effect size was medium ($\eta^2=0.134$) (see table 4.14). When the two groups were analysed separately, the results of linear regression demonstrated that MA was a non-significant predictor of the production of gliding for TD group [$R^2=0.004$, $F(1,19)=0.069$, $p=0.796$] and for DS group [$R^2=0.201$, $F(1,16)=3.768$, $p=0.077$]. For TD group, the intercept was 0.3922% and the gradient was 0.0023 (see figure 4.6a). The confidence intervals around TD trajectory were between 0.483% and 1.267%. The intercept for DS group was 0.8025% and the gradient was 0.1544 (see figure 4.6a). There was 95% confidence that the population intercept was between 6.355% and 7.960%. Examining the trajectories for TD and DS groups, the were not parallel. TD trajectory demonstrated that gliding processes rarely occurred in the speech of TD participants. TD trajectory was neutrally trended. On the contrary, approximately higher percentages of occurrence of gliding were observed in SW sample of participants with DS. DS trajectory was positively trended. This suggested that gliding process was not reduced/supressed with the MA range tested for DS group.

2. **Deaffrication**

The results of ANCOVA test showed that there was a non-significant difference between TD and DS groups in terms of percentage of occurrence of deaffrication [$F(1,33)=0.103$, $p=0.751$, $\eta^2=0.003$]. This indicated that there was no delay in onset in DS group. However, there was a statistically significant group*MA interaction [$F(1,33)= 4.288$, $p=0.046$, $\eta^2=0.115$]. DS group continued to use deaffrication at a rate slower than that for TD group (see table 4.14). The results of linear regression showed that MA was not a reliable predictor of performance of TD group [$R^2=0.024$, $F(1,19)=0.448$, $p=0.512$] and DS group [$R^2=0.167$, $F(1,16)=3.017$, $p=0.103$]. For TD group, the intercept was 0.568% and the gradient was 0.0068 (see figure 4.6b). The confidence intervals around TD trajectory were between

0.431%) and 1.567%. The intercept for DS group was 0.7045% and the gradient was 0.1794 (see figure 4.6b). There was 95% confidence that the population intercept was between 8.589% and 9.998%. TD and DS trajectories had approximately similar onset and they were not parallel. TD trajectory was negatively trended. However, DS trajectory was positively trended, suggesting that DS group were not able to suppress deaffrication process and continued to use this process at older MAs (within MA range tested) when compared to their MA-matched controls.

3. Consonant Cluster Reduction

Between-participants ANCOVA test was carried out. The results revealed that TD and DS groups were significantly different in relation to percentage of occurrence of cluster reduction (CR) [$F(1,33)=10.755$, $p=0.002$, $\eta^2=0.246$]. This indicated that DS group used this process at a delayed onset. The effect size was large ($\eta^2=0.246$). However, there was a statistically non-significant group*MA interaction [$F(1,33)= 0.41$, $p=0.841$, $\eta^2=0.001$]. The two groups continued to suppress CR at a typical rate (see table 4.14). Linear regression was conducted. The results demonstrated that MA was not a statistically significant predictor of performance for TD group [$R^2=0.119$, $F(1,19)=2.439$, $p=0.136$] and for DS group [$R^2=0.018$, $F(1,16)=0.282$, $p=0.603$] in terms of percentage of occurrence of CR. For TD group, the intercept was 4.908% and the gradient was 0.0645 (see figure 4.6c). The confidence intervals around TD trajectory were between 0.823% and 8.993%. The intercept for DS group was 29.137% and the gradient was 0.0984 (see figure 4.6c). There was 95% confidence that the population intercept was between 12.451% and 45.823%. Examining TD and DS trajectories, they were negatively trended, indicating that both groups continued to reduce the occurrence of CR. However, DS trajectory started to minimise the occurrence of CR at a significantly delayed onset, although DS group continued to reduce the occurrence of CR at a typical rate.

4. Fronting

The results of ANCOVA test of percentage of occurrence of fronting indicated that there was a significant effect of group factor [$F(1,33)=2.974$, $p=0.094$, $\eta^2=0.083$]. Therefore, there was no delay in onset in DS group. The effect size was small ($\eta^2=0.083$). Similarly, there was a statistically non-significant group*MA interaction [$F(1,33)= 2.332$, $p=0.136$, $\eta^2=0.066$]. This indicated that DS group continued to use fronting at a typical rate (see table 4.14). When the trajectories of the two groups were analysed separately, the linear regression revealed that MA was a significant predictor of percentage of occurrence of fronting for TD group [$R^2=0.232$, $F(1,19)=5.424$, $p=0.032$]. Yet, MA was not a reliable predictor of performance for DS group on this task [$R^2=0.021$, $F(1,16)=0.318$, $p=0.581$]. For TD group, the intercept was 7.4214% and the gradient was 0.1102 (see figure 4.6d). The confidence intervals around TD trajectory were between 2.741% and 12.102%. The intercept for DS group was 16.21% and the gradient was 0.0659 (see figure 4.6d). There was 95% confidence that the population intercept was between 5.698% and 26.731%. As the plotted data suggested, TD and DS trajectories were not parallel. Instead, these were trended in different directions. TD trajectory was positively trended, suggesting that TD participants continued to supress fronting process. On the other hand, DS trajectory was positively trended, indicating that DS participants continued to use fronting longer when compared to their MA-matched counterparts.

5. Weak Syllable Deletion

The ANCOVA results of percentage of occurrence of weak syllable deletion (WSD) in the SW samples for TD and DS groups showed that there was a non-significant difference between the two groups [$F(1,33)=0.546$, $p=0.465$, $\eta^2=0.016$]. This indicated that there was no delay in onset in DS group. The effect size was marginal ($\eta^2=0.016$). Similarly, there was a statistically non-significant group*MA mya interaction [$F(1,33)= 2.332$, $p=0.136$, $\eta^2=0.066$]. The DS group produced WSD at a typical rate (see table 4.14). When the two groups were analysed separately, the results of linear regression demonstrated that MA was not a reliable predictor of performance in terms of percentage of occurrence of WSD for TD group [$R^2=0.129$, $F(1,19)=2.677$, $p=0.119$] and for DS group [$R^2=0.002$, $F(1,19)=0.023$, $p=0.881$]. For TD group, the intercept was 0.79.57% and the gradient was 0.0112 (see figure 4.6d). The confidence intervals around TD trajectory were between 0.116% and 1.575. The intercept for DS group was 1.6141% and the gradient was 0.0042 (see figure 4.6d). There was 95%

confidence that the population intercept was between 0.860% and 4.088%. Examining the trajectories of the two groups, these were not parallel. TD trajectory was negatively trended, indicating that TD participants started to minimise the occurrence of WSD process. On the contrary, DS trajectory was positively trended, suggesting that DS participants were not able to reduce the occurrence of WSD process.

6. Stopping

Regarding the percentage of occurrence of stopping in SW samples for TD and DS groups, ANCOVA results showed that showed that there was a non-significant difference between the two groups [$F(1,33)=1.822$, $p=0.186$, $\eta^2=0.052$]. This indicated that there was no delay in onset in DS. Similarly, there was also a statistically non-significant group*MA mya interaction [$F(1,33)= 0.279$, $p=0.601$, $\eta^2=0.008$]. DS group continued to use stopping at a typical rate (see Table 4.14). The results of linear regression MA was not a reliable predictor for TD group [$R^2=0.025$, $F(1,19)=0.468$, $p=0.503$] and DS group [$R^2=0.004$, $F(1,16)=0.056$, $p=0.815$] in terms of percentage of stopping. For TD group, the intercept was 1.8211% and the gradient was 0.0232 (see figure 4.6f). The confidence intervals around TD trajectory were between 1.536% and 5.179%. The intercept for DS group was 6.6046% and the gradient was 0.0191 (see figure 4.6f). There was 95% confidence that the population intercept was between 0.639% and 13.848%. The two trajectories were different. TD trajectory was negative trended, suggesting that TD participants proceeded to reduce the occurrence of stopping. Yet, DS trajectory was positively trended, indicating that continued to use stopping frequently.

7. Voicing

The ANCOVA results revealed that there was a significant effect difference between DS and TD group in terms of percentage of occurrence of voicing [$F(1,33)=5.936$, $p=0.020$, $\eta^2=0.152$]. DS group reduced the occurrence of voicing at a delayed onset. The effect size was medium ($\eta^2=0.152$). However, the results revealed a statistically non-significant group*MA mya interaction [$F(1,33)= 0.022$, $p=0.883$, $\eta^2=0.001$]. The DS group proceeded to reduce the occurrence of voicing at a typical rate (see table 4.14). The results of linear regression indicated that MA was a reliable predictor on this task for TD group [$R^2=0.236$, $F(1,19)=5.571$, $p=0.030$], but was not reliable for DS group on the same task [$R^2=0.000$, $F(1,19)=0.004$, $p=0.951$]. For

TD group, the intercept was 1.2073% and the gradient was 0.0166 (see figure 4.6g). The confidence intervals around TD trajectory were between 0.513% and 1.902%. The intercept for DS group was 9.3118% and the gradient was 0.0054 (see figure 4.6g). As the plotted data suggested, TD and DS trajectories were parallel and negatively trended. DS group proceeded to reduce the occurrence of voicing at atypical rate, although they started to minimise the occurrence of this process at a delayed onset,

8. Assimilation

Regarding the percentage of occurrence of assimilation, the results also showed that there was a significant effect of group factor [$F(1,33)=11.590$, $p=0.002$, $\eta^2=0.260$]. This indicated that DS group produced assimilation at a delayed onset. However, there was also a statistically non-significant group*MA mya interaction [$F(1,33)= 1.591$, $p=0.216$, $\eta^2=0.046$]' suggesting that DS group continued to reduce the occurrence of assimilation at a typical rate (see table 4.14). The results of linear regression manifested that MA was a reliable predictor of performance on this task for TD group [$R^2=0.205$, $F(1,19)=4.651$, $p=0.045$], but not for DS group [$R^2=0.115$, $F(1,16)=1.958$, $p=0.182$]. For TD group, the intercept was 1.206% and the gradient was 0.0128 (see figure 4.6h). The confidence intervals around TD trajectory were between 0.621% and 1.791%. The intercept for DS group was 6.9681% and the gradient was 0.0611 (see figure 4.6h). The confidence intervals around DS trajectory were between 3.038% and 10.898%. Examining the trajectories of the two groups, DS and TD trajectories were parallel and negative trended. This suggested that the two groups continued to reduce the occurrence of assimilation. However, DS group started to minimise the occurrence of assimilation at an onset later than that for their MA-matched controls.

9. Initial consonant deletion

The results of initial consonant deletion (ICD) showed that there was a non-significant difference between TD and DS groups [$F(1,33)=2.484$, $p=.0.125$, $\eta^2=0.070$]. This indicated that there was no delay in onset in DS group. The effect size was small ($\eta^2=0.070$). Similarly, there was a statistically non-significant group*MA interaction [$F(1,33)=1.097$, $p=0.758$, $\eta^2=0.003$]. DS group continued to reduce the occurrence of ICD at a typical rate (see table 4.14). The results of linear regression revealed that MA was a reliable predictor of performance on this task for TD group [R^2=0.274, F(1,19)=6.788, p=0.018], but not for DS group [R^2=0.009, F(1,16)=0.140, p=0.713]. For TD group, the intercept was 1.9682% and the gradient was 0.0244 (see figure 4.6i). The confidence intervals around TD trajectory were between 1.041% and 2.895%. The intercept for DS group was 4.3244% and the gradient was 0.0139 (see figure 4.6i). The confidence around DS trajectory were between 0.989% and 7.660%. Detecting the trajectories of the two groups, TD and DS trajectories were parallel and negatively-trended. This suggested that DS participants continued to reduce the occurrence of ICD process at a typical rate and with no delay in onset when compared to MA-matched TD participants.

10. Medial Consonant Deletion

The ANCOVA results revealed that there was a significant difference between TD and DS groups in relation to percentage of occurrence of medial consonant deletion (MCD) [F(1,33)=19.141, p=0.001, η^2=0.367]. This indicated that DS group produced MCD at a delayed onset. However, there was a statistically non-significant group*MA interaction [F(1,33)= 3.455, p=0.072, η^2=0.095], suggesting the two groups continued to suppress MCD at a typical rate (see table 4.14). When the two groups were analysed separately, the results of linear regression showed that MA was a non-significant predictor of performance on this task for TD group [R^2=0.176, F(1,19)=3.832, p=0.066] and for DS group [R^2=0.179, F(1,16)=3.276., p=0.090]. For TD group, the intercept was 0.6578% and the gradient was 0.0103 (see figure 4.6j). The confidence intervals around TD trajectory were between 0.138% and 1.177%. The intercept for DS group was 9.7119% and the gradient was 0.0979 (see figure 4.6j). The confidence intervals around DS trajectory were between 4.851% and 14.500%. As plotted data suggested, DS and TD trajectories were parallel and negatively-trended. Despite the higher percentages of occurrence of MCD in DS group compared to TD group, DS participants continued to suppress this process.

11. Final Consonant Deletion

Regarding percentage of occurrence of final consonant deletion in SW samples for TD and DS groups, the results showed that there was a non-significant difference between the two groups [F(1,33)=3.468, p=0.071, η^2=0.095]. This indicated that there was no delay in onset in DS group. There was also a statistically non-significant group*MA interaction [F(1,33)=

0.187, p=0.668, η^2=0.006]. The two groups proceeded to minimise the occurrence of FCD at a typical rate when matched for mental age (see table 4.14). The results of linear regression revealed that MA was a reliable predictor of performance on this task for TD group [R^2=0.256, F(1,19)=6.180, p=0.023], but not for DS group [R^2=0.051, F(1,16)=0.800, p=0.385]. For TD group, the intercept was 1.9757% and the gradient was 0.0284 (see figure 4.6k). The confidence intervals around TD trajectory were between 0.846% and 3.105%. The intercept for DS group was 6.0995% and the gradient was 0.0501 (see figure 4.6k). The confidence limits around the DS trajectory were between 1.064% and 11.135%. TD and DS trajectories were parallel and negatively trended. This suggested that the two groups proceeded to minimise the occurrence of FCD process.

12. Backing

TD and DS groups demonstrated a non-significant difference in terms of percentage of occurrence of backing process in SW samples for TD and DS groups [F(1,33)=2.071, p=0.160, η^2=0.059]. This indicated that there was no delay in the onset in DS group. There was also a statistically non-significant group*MA mya interaction [F(1,33)= 0.057, p=0.812, η^2=0.002], suggesting that the two groups continued to suppress backing at a typical rate (see table 4.14). The results of linear regression showed that MA was not a reliable predictor of performance on this task for TD group [R^2=0.038, F(1,19)=0.703, p=0.413] and for DS group [R^2=0.034, F(1,16)=0.522, p=0.481]. For TD group, the intercept was 1.6554% and the gradient was 0.0216 (see figure 4.6l). The confidence intervals around TD trajectory were between 0.889% and 4.199%. The intercept for DS group was 4.8599% and the gradient was 0.0336 (see figure 4.6l). The confidence limits around DS trajectory were between 0.669% and 9.051%. Examining the trajectories for the two groups, TD and DS trajectories were parallel and negatively trended. This suggested that DS and TD groups proceeded to suppress backing process regardless their intellectual abilities.

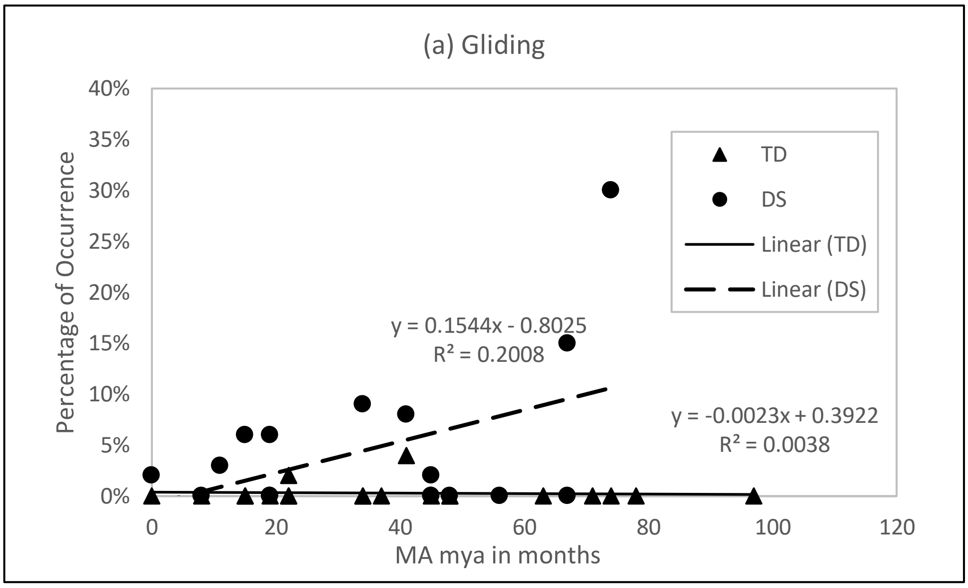
13. Other processes

Finally, the ANCOVA results of percentage of occurrence other processes in SW for TD and DS groups manifested that the two groups were non-significantly different [$F(1,33)=0.071$, $p=0.791$, $\eta^2=0.002$]. This indicated that there was no delay in the onset in DS group. Similarly, the results revealed a nonsignificant non-significant group*MA interaction [$F(1,33)= 0.581$, $p=0.451$, $\eta^2=0.017$], suggesting that DS participants continued to use other processes at a typical rate. (see table 4.14). The results of linear regression demonstrated that MA was not a reliable predictor of performance on this task for TD group [$R^2=0.026$, $F(1,19)=0.471$, $p=0.501$] and for DS group [$R^2=0.012$, $F(1,16)$, 0.186, $p=0.672$]. For TD group, the intercept was 1.3575% and the gradient was 0.0178 (see figure 4.6m). The confidence intervals around TD trajectory were between 1.213% and 3.928%. The intercept for DS group was 0.8328% and the gradient was 0.0161 (see figure 4.6m). The confidence limits around the DS trajectory were between 2.514% and 4.179%. As plotted data suggested, TD and DS trajectories were not parallel, and they were trended in different directions. TD trajectory was negatively trended, indicating that TD participants proceeded to suppress other processes occurring in their SW samples. On the contrary, DS trajectory was positively trended, suggesting that DS participants continued to use other processes in their SW samples regardless the level of their intellectual abilities.

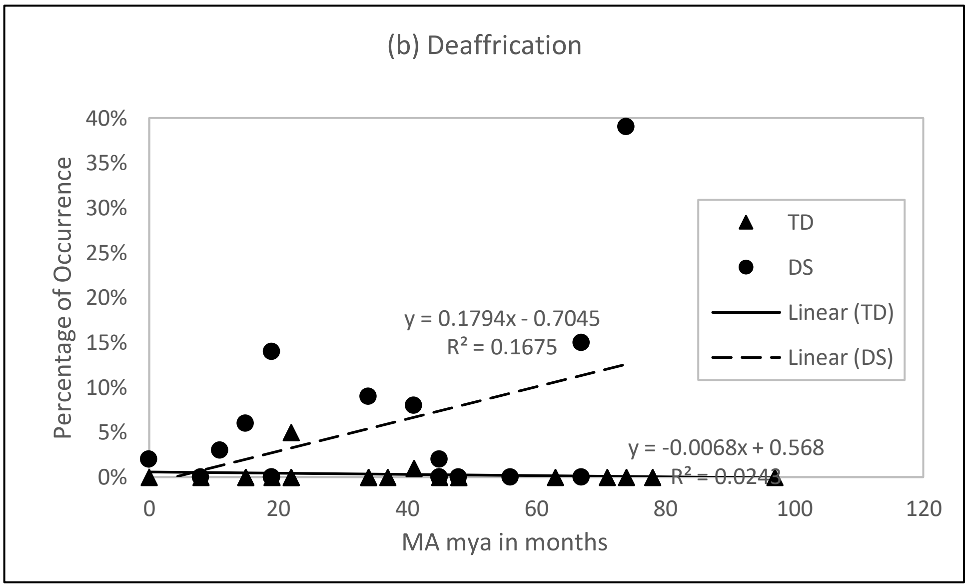
Table 4.14 ANCOVA results for percentages of occurrence phonological processes in SW samples for TD and DS groups

Phonological Processes	Variables	*df*	Mean Square	*F*	*p*-value	Effect Size η^2
Gliding	Group	(1,33)	3.662	0.152	0.699	0.005
	MA mya	(1,33)	115.740	4.799	0.036	0.127
	Group*MA mya	(1,33)	122.927	5.097	0.031	0.134
Deaffrication	Group	(1,33)	4.154	0.103	0.751	0.003
	MA mya	(1,33)	149.192	3.688	0.063	0.101
	Group*MA mya	(1,33)	173.466	4.288	0.046	0.115
Cluster Reduction	Group	(1,33)	1506.254	10.755	0.002	0.246
	MA mya	(1,33)	132.881	0.949	0.337	0.028
	Group*MA mya	(1,33)	5.756	0.041	0.841	0.001
Fronting	Group	(1,33)	198.193	2.974	0.094	0.083
	MA mya	(1,33)	9.825	0.147	0.703	0.004
	Group*MA mya	(1,33)	155.381	2.332	0.136	0.066
Weak Syllable Deletion	Group	(1,33)	1.718	0.546	0.465	0.016
	MA mya	(1,33)	0.250	0.079	0.780	0.002
	Group*MA mya	(1,33)	1.190	0.378	0.543	0.011
Stopping	Group	(1,33)	58.710	1.822	0.186	0.052
	MA mya	(1,33)	0.084	0.003	0.959	0.000
	Group*MA mya	(1,33)	8.978	0.279	0.601	0.008
Voicing	Group	(1,33)	168.526	5.936	0.020	0.152
	MA mya	(1,33)	2.414	0.085	0.772	0.003
	Group*MA mya	(1,33)	0.627	0.022	0.883	0.001
Assimilation	Group	(1,33)	85.188	11.590	0.002	0.260
	MA mya	(1,33)	27.311	3.716	0.063	0.101
	Group*MA mya	(1,33)	11.698	1.591	0.216	0.046
Initial Consonant Deletion	Group	(1,33)	14.243	2.484	0.125	0.070
	MA mya	(1,33)	7.345	1.281	0.266	0.037
	Group*MA mya	(1,33)	0.555	0.097	0.758	0.003
Medial Consonant Deletion	Group	(1,33)	208.637	19.141	0.001	0.367
	MA mya	(1,33)	57.644	5.288	0.028	0.138
	Group*MA mya	(1,33)	37.664	3.455	0.072	0.095
Final Consonant Deletion	Group	(1,33)	43.633	3.468	0.071	0.095
	MA mya	(1,33)	30.809	2.449	0.127	0.069
	Group*MA mya	(1,33)	2.352	0.187	0.668	0.006
Backing	Group	(1,33)	26.348	2.071	0.160	0.059
	MA mya	(1,33)	15.256	1.199	0.281	0.035
	Group*MA mya	(1,33)	0.728	0.057	0.812	0.002
Other Processes	Group	(1,33)	0.707	0.071	0.791	0.002
	MA mya	(1,33)	0.016	0.002	0.968	0.000
	Group*MA mya	(1,33)	5.752	0.581	0.451	0.017

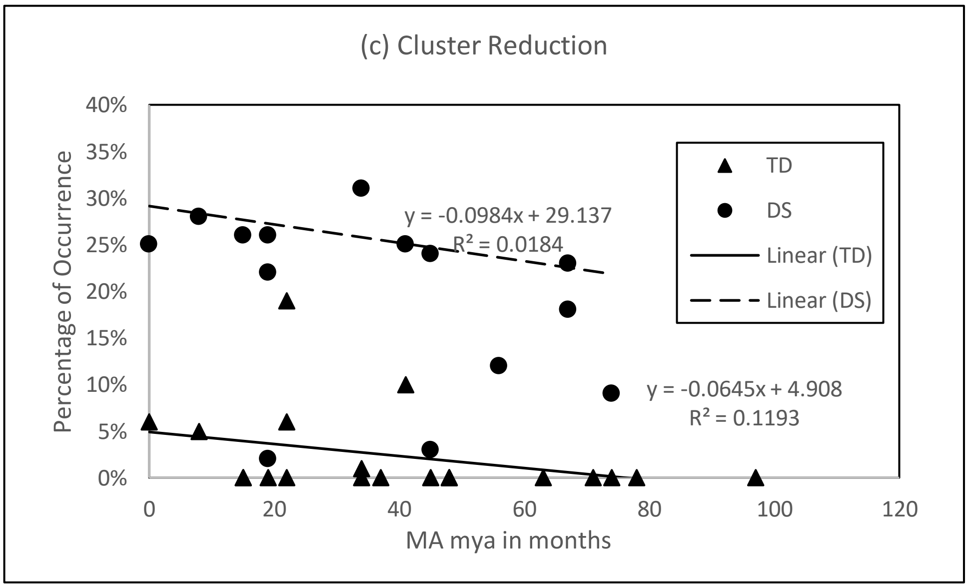
Note: MA mya-Nonverbal mental age measured from youngest age in TD group.



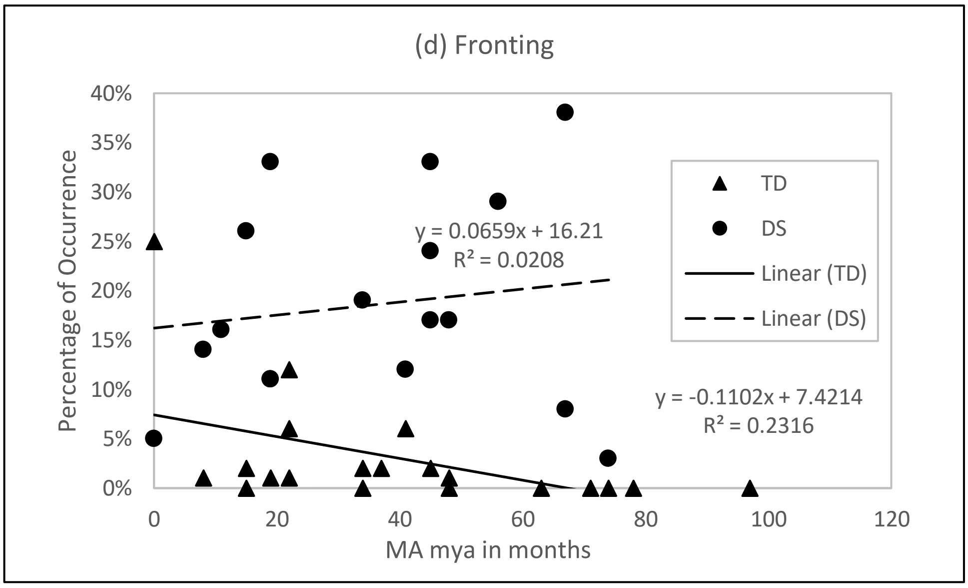
(a) Gliding
40%
35%
30%
25%
20%
15%
10%
5%
0%
Percentage of Occurrence
TD
DS
Linear (TD)
Linear (DS)
y = 0.1544x - 0.8025
R² = 0.2008
y = -0.0023x + 0.3922
R² = 0.0038
0
20
40
60
80
100
120
MA mya in months

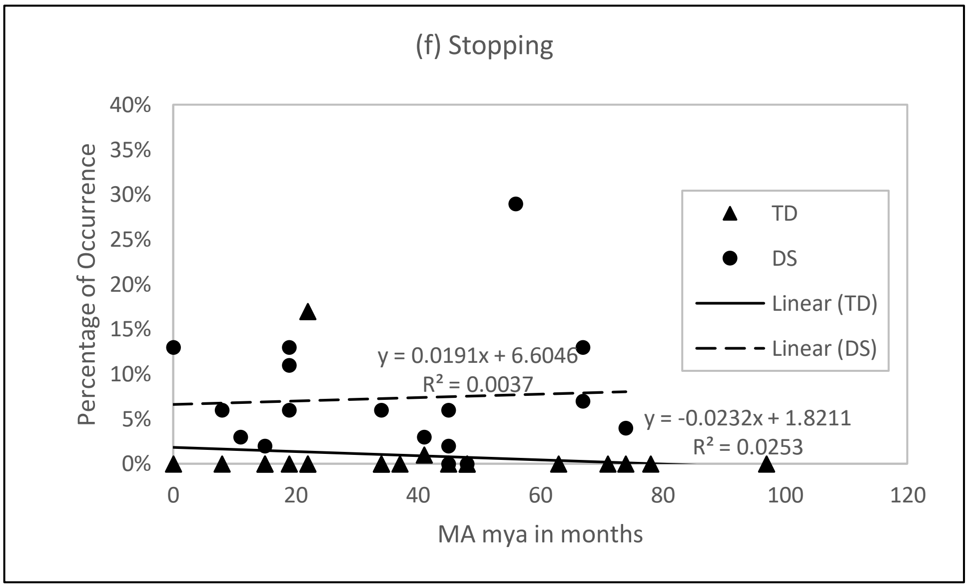


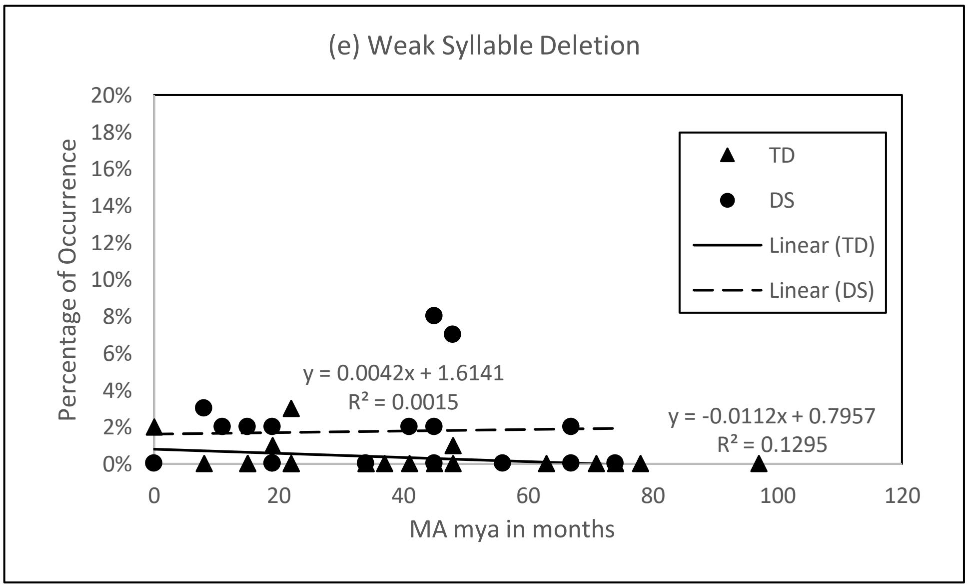
(b) Deaffrication
40%
35%
30%
25%
20%
15%
10%
5%
0%
Percentage of Occurrence
TD
DS
Linear (TD)
Linear (DS)
y = 0.1794x - 0.7045
R² = 0.1675
y = -0.0068x + 0.568
R² = 0.0248
0
20
40
60
80
100
120
MA mya in months

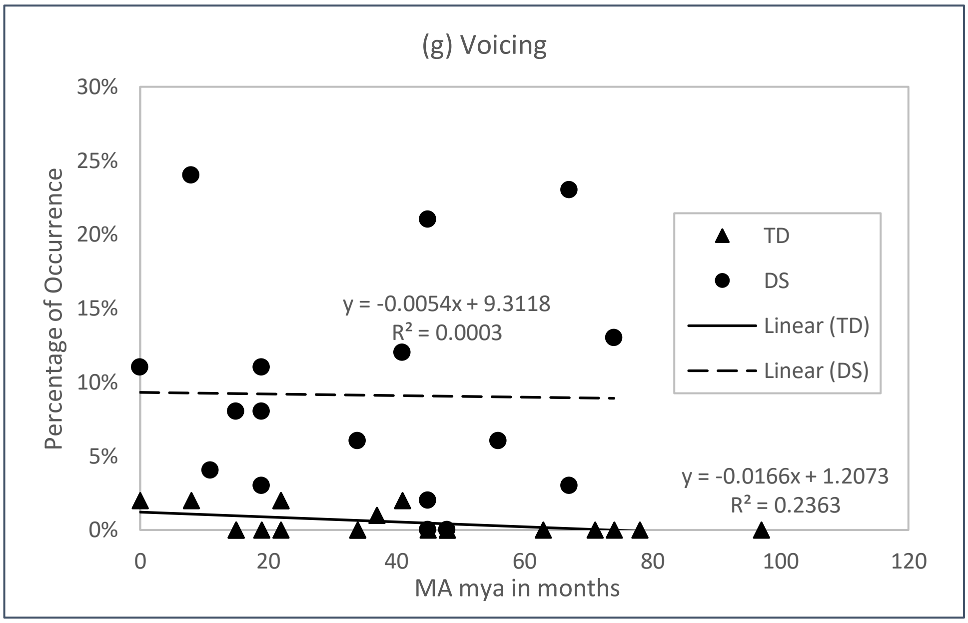


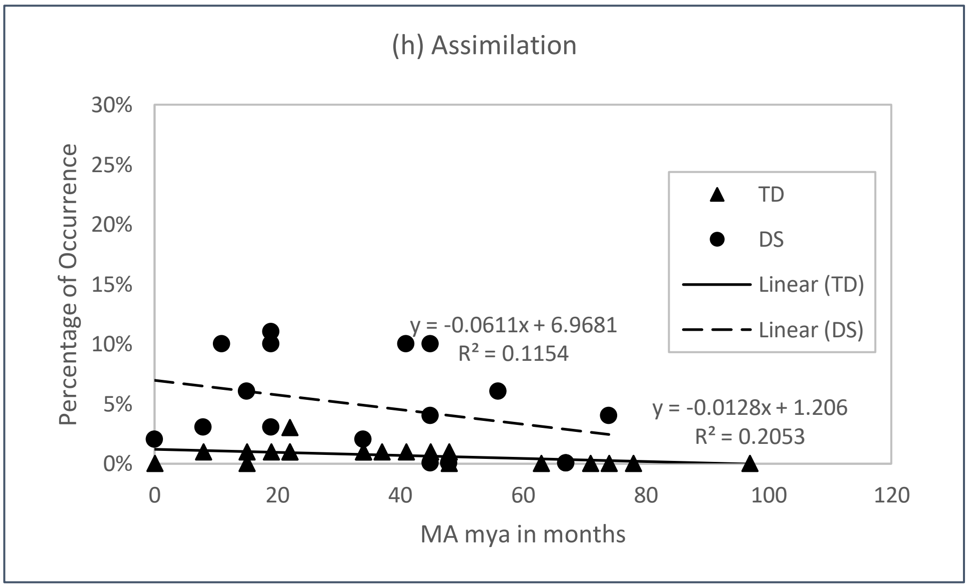
(c) Cluster Reduction
40%
35%
30%
25%
20%
15%
10%
5%
0%
Percentage of Occurrence
TD
DS
Linear (TD)
Linear (DS)
y = -0.0984x + 29.137
R² = 0.0184
y = -0.0645x + 4.908
R² = 0.1193
0
20
40
60
80
100
120
MA mya in months

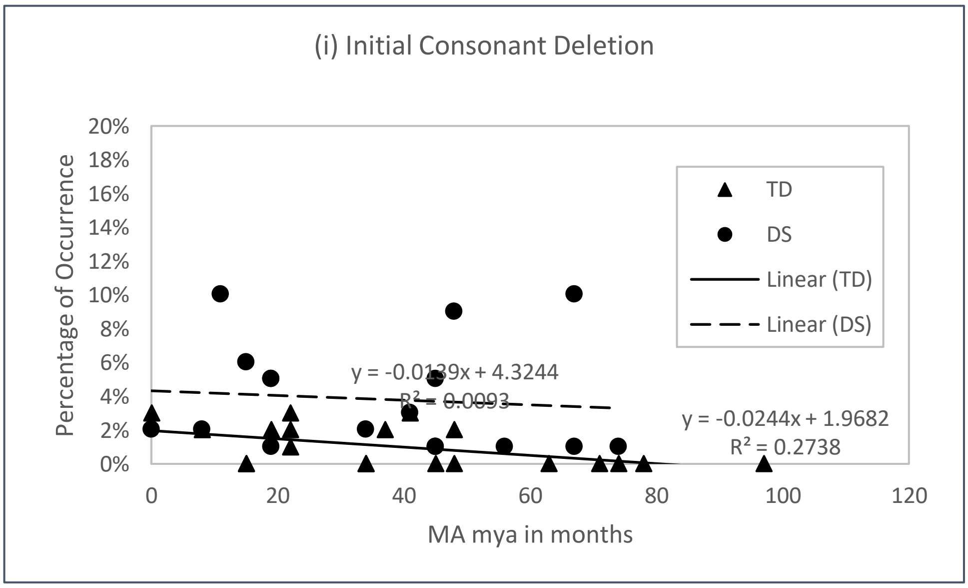

(d) Fronting
Percentage of Occurrence
MA mya in months
TD
DS
Linear (TD)
Linear (DS)
y = 0.0659x + 16.21
R² = 0.0208
y = -0.1102x + 7.4214
R² = 0.2316

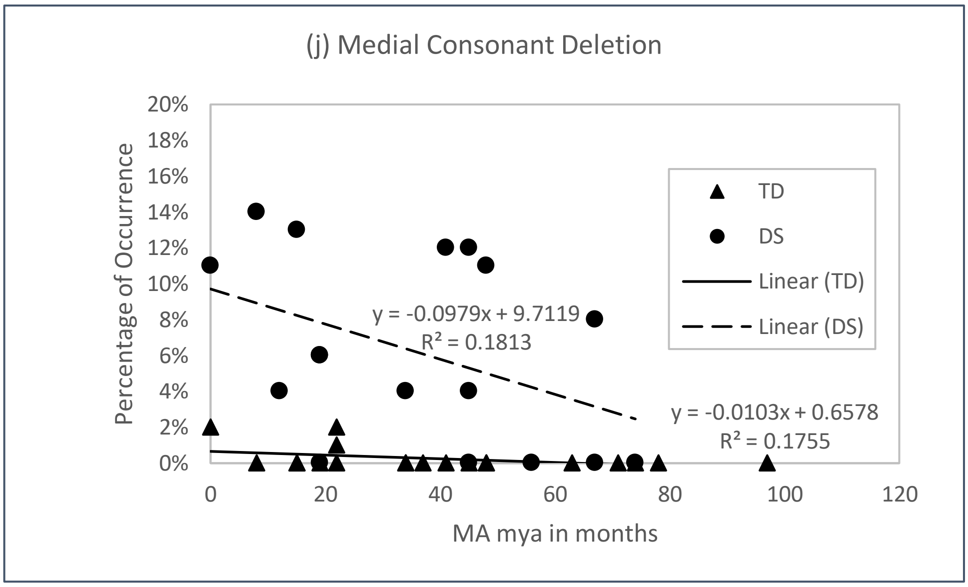

(f) Stopping
Percentage of Occurrence
MA mya in months
TD
DS
Linear (TD)
Linear (DS)
y = 0.0191x + 6.6046
R² = 0.0037
y = -0.0232x + 1.8211
R² = 0.0253

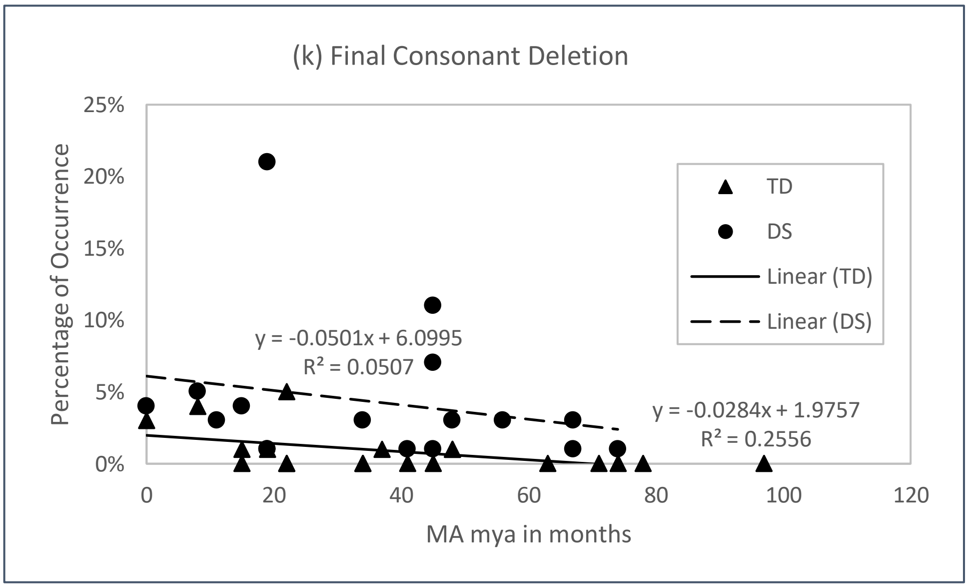

(e) Weak Syllable Deletion
Percentage of Occurrence
MA mya in months
TD
DS
Linear (TD)
Linear (DS)
y = 0.0042x + 1.6141
R² = 0.0015
y = -0.0112x + 0.7957
R² = 0.1295

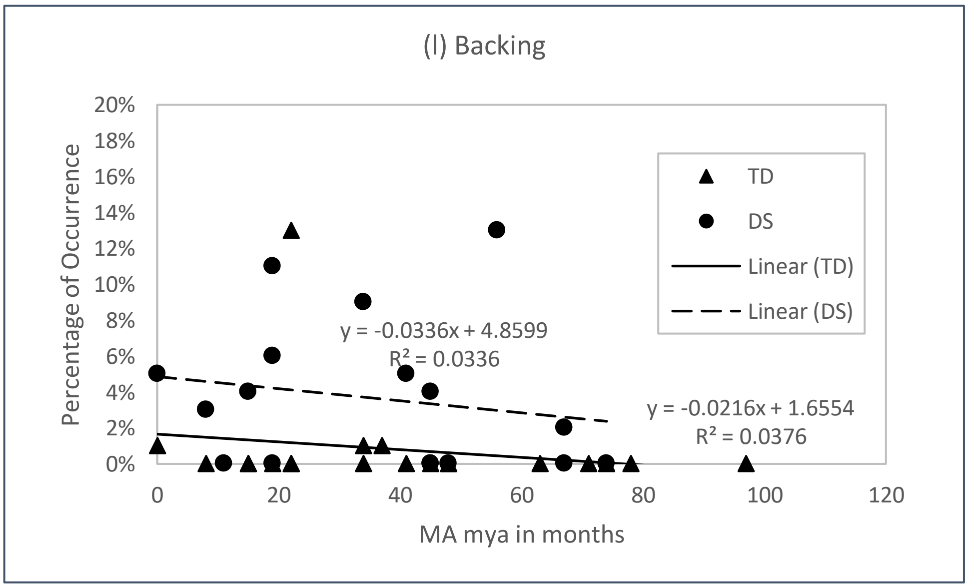

(g) Voicing
Percentage of Occurrence
MA mya in months
TD
DS
Linear (TD)
Linear (DS)
y = -0.0054x + 9.3118
R² = 0.0003
y = -0.0166x + 1.2073
R² = 0.2363
30%
25%
20%
15%
10%
5%
0%
0
20
40
60
80
100
120


(h) Assimilation
Percentage of Occurrence
MA mya in months
TD
DS
Linear (TD)
Linear (DS)
y = -0.0611x + 6.9681
R² = 0.1154
y = -0.0128x + 1.206
R² = 0.2053
30%
25%
20%
15%
10%
5%
0%
0
20
40
60
80
100
120


(i) Initial Consonant Deletion
Percentage of Occurrence
MA mya in months
TD
DS
Linear (TD)
Linear (DS)
y = -0.0244x + 1.9682
R² = 0.2738
20%
18%
16%
14%
12%
10%
8%
6%
4%
2%
0%
0
20
40
60
80
100
120


(j) Medial Consonant Deletion
Percentage of Occurrence
20%
18%
16%
14%
12%
10%
8%
6%
4%
2%
0%
0
20
40
60
80
100
120
MA mya in months
TD
DS
Linear (TD)
Linear (DS)
y = -0.0979x + 9.7119
R² = 0.1813
y = -0.0103x + 0.6578
R² = 0.1755


(k) Final Consonant Deletion
Percentage of Occurrence
25%
20%
15%
10%
5%
0%
0
20
40
60
80
100
120
MA mya in months
TD
DS
Linear (TD)
Linear (DS)
y = -0.0501x + 6.0995
R² = 0.0507
y = -0.0284x + 1.9757
R² = 0.2556


(l) Backing
Percentage of Occurrence
20%
18%
16%
14%
12%
10%
8%
6%
4%
2%
0%
0
20
40
60
80
100
120
MA mya in months
TD
DS
Linear (TD)
Linear (DS)
y = -0.0336x + 4.8599
R² = 0.0336
y = -0.0216x + 1.6554
R² = 0.0376

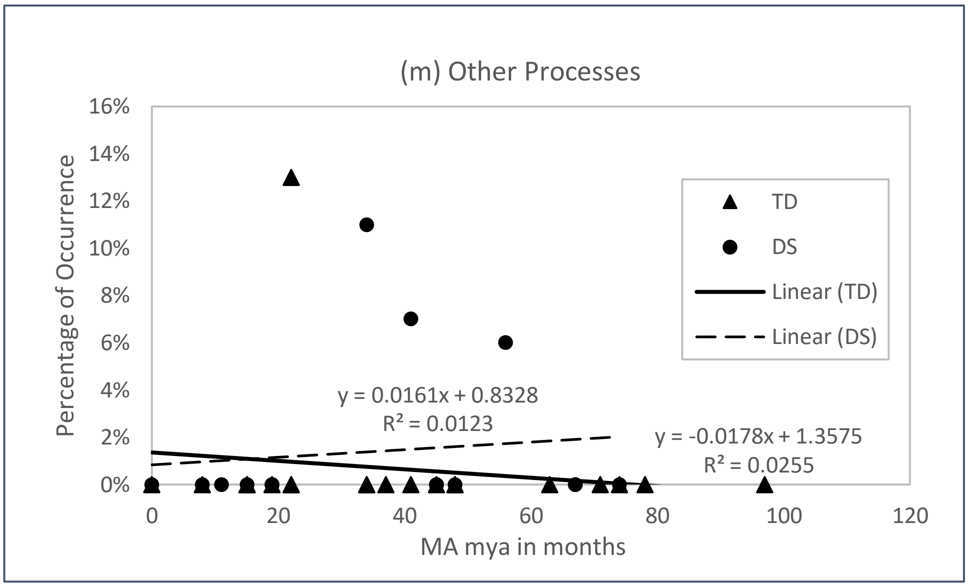


Figure 4.6(a-m). The percentages of occurrence of phonological processes in SW samples for TD and DS groups. The figures illustrate the developmental trajectories for percentage of occurrence of phonological processes in single word (SW) samples. The trajectory for TD group is represented with a solid line, and for DS groups is represented with a dotted line. MA mya represents rescaled nonverbal mental age measured form youngest age in months in the TD group.

4.3.6 Word Inconsistency in SW Samples for DS and TD Groups

DEAP-word inconsistency assessment evaluated the participant's ability to produce three realisations of the same test item consistently. It helped identify how consistent were the children in DS group in producing the same items over three production trials compared to children in TD group. The criterion assigned for the diagnosis of inconsistent phonological disorder implied that if the percentage of the items produced inconsistently was ≥40%, the child's production would be considered as inconsistent. On the contrary, if the child's score was <40%, then he/she would be considered consistent. The results for the TD group showed that they were all consistent as the mean inconsistency score was below 40%; i.e., with mean 1.80% and (*SD*=2.26). The TD group inconsistency scored ranged between 0% to 8% (see table 4.15). On the other hand, the mean inconsistency score for the DS group was 26.94% with (*SD*=3.44) which was higher than that for the TD group but was still below 40%. The inconsistency score for the DS group ranged between 7% to 50% (see table 4.15). It is evident that for some participants with DS the inconsistency score was ≥ 40%. Those included participants DS4, DS5, DS14, and DS15 aged 8;8, 10;7, 10;11; and 8;1 years, respectively.

Table 4.15 Descriptive analysis of word inconsistency in SW samples for TD and DS groups

Variables	**Groups**	**Mean**	***SD***	***SE***	**Median**	**Range**	**Minimum**	**Maximum**	**95% CI for Mean**	
									Lower Bound	**Upper Bound**
Word Inconsistency	TD	1.80%	2.26%	0.50%	1%	8%	0%	8%	0.74%	2.86%
	DS	26.94%	14.21%	3.44%	24%	43%	7%	50%	19.63%	34.25%

Note: TD-Typically developing children. DS-Children with Down syndrome. SD-Standard deviation. SE-Standard error. CI-Confidence limits around the mean.

One-way between-participants ANCOVA test was conducted. The results revealed statistically significant difference between TD and DS groups in terms of word inconsistency assessment [$F(1,33)=29.514$, $p=0.001$, $\eta^2=0.472$]. This indicated that DS group exhibited a delayed onset in the word inconsistency assessment. The effect size was large ($\eta^2=0.472$). However, there was a non-significant group*MA mya interaction [$F(1,33)=1.260$, $p=0.270$, $\eta^2=0.037$], suggesting that DS group performed at a typical rate when compared to their MA-matched TD counterparts. The results of linear regression showed that MA was a reliable predictor of performance on this task for TD group [$R^2=0.241$, F(1,19)=5.704, p=0.028], but was not reliable for DS group [$R^2=0.132$, F(1,16)=2.284, p=0.152]. For TD group, the intercept was 3.491% and the gradient was 0.0426 (see figure 4.7). The confidence intervals around TD trajectory were between 1.725% and 5.257%. The intercept for DS group was 35.174% and the gradient was 0.2283 (see figure 4.7). The confidence limits around the DS trajectory were between 21.579% and 48.768%. As the plotted data suggested, TD and DS developmental trajectories were parallel and negatively trended. However, DS group started to produce consistent words at an delayed onset when compared to TD group.

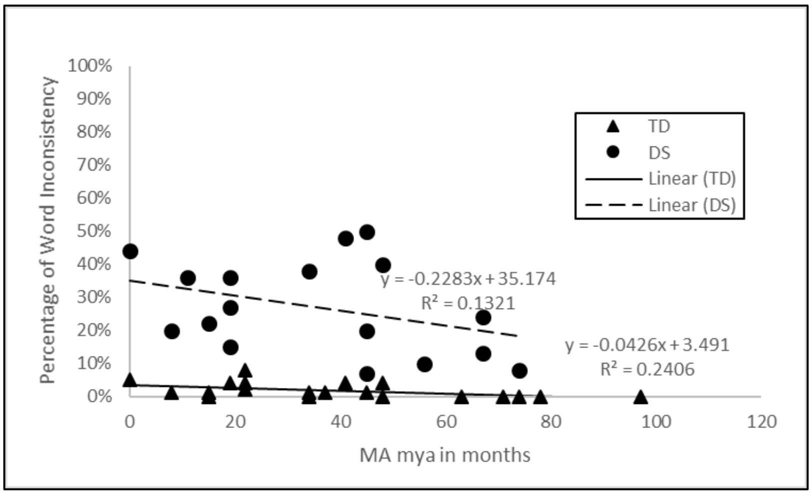


Figure 4.7. The percentage of word inconsistency in SW samples for TD and DS groups. The figures illustrate the developmental trajectories of percentage of word inconsistency in single word (SW) samples. The trajectory for TD group is represented with a solid line, and for DS group is represented with a dotted line. MA mya represents rescaled nonverbal mental age measured form youngest age in months in the TD group.

4.3.7 Summary of SW Sample for DS and TD Groups

To sum up, based on the ANCOVA results, the number of consonants acquired in children with DS were less than in TD children. There were significant differences between the two groups in terms of number of consonants acquired, PCC, PVC, PPC, PCC of single consonants and PCCC of consonant clusters in SIWI, SIWM, SFWM and SFWF positions. This indicated that the performance of children with DS developed at a delayed onset. However, the interaction between group factor and non-verbal MA was statistically non-significant, suggesting that DS group developed at a rate similar to that of their MA-matched TD controls. When the developmental trajectories of the two groups were analysed separately, the results of linear regression showed that MA was not a reliable predictor of performance in terms of number of consonants acquired in DS group compared to TD group. MA was also found to be a marginal predictor of performance in terms of PCC, PVC and PPC in both groups. The non-verbal MA was also found to be a non-significant predictor of performance in relation to PCC of singleton consonants in SIWM and SFWF for both groups. Yet, MA was not a reliable predictor of performance in terms of PCC in SIWI and SFWM for DS group when compared to TD group. Additionally, the results of linear regression revealed that MA was not a significant predictor of performance in terms of PCCC in SIWM and SFWF for both groups. It was also a non-significant predictor of performance in relation to PCCC in SIWI for DS group when compared to TD group. However, MA was a reliable predictor of performance in terms of PCCC in SFWM for DS group when compared to TD group.

Children with DS tended to use more phonological processes than TD children. The results of ANCOVA of percentages of occurrence of gliding, deaffrication, fronting, WSD, stopping, ICD, FCD, backing and other processes revealed non-significant differences between DS group compared to TD group. Therefore, there was no delay in the onset in DS groups in terms of percentages of occurrence of these processes. However, DS group showed slower rate of development than TD group in terms of percentages of occurrence of gliding and deaffrication. Non-significant differences were found between the two groups in terms of CR, voicing, assimilation and MCD indicated a delayed onset of development for DS group compared to TD group when matched for MA. These processes also developed at a rate similar to TD development. When the trajectories of the two groups were analysed separately, the results of linear regression revealed that MA was a non-significant predictor of development of performance in terms of percentages of occurrence of gliding, deaffrication, CR, WSD, stopping, MCD, backing and other processes for both groups. Yet, MA was a reliable predictor of performance in terms of percentages of occurrence of fronting, voicing, assimilation ICD and FCD for DS group when compared to TD group.

Chapter 5: Results II - Group Study

5.1 Introduction

After completing the data transcription, the qualitative measures were analysed. The quantitative measures were also calculated, and the statistical tests results were reported. The tables were designed in such a way that the descriptive analyses and test statistics were summarised. The developmental trajectories of performances for DS group compared to TD group were created and analysed to determine types of onset and rate of development. The results explaining performance in CS samples for DS group compared to TD group are presented in detail in the following sections.

5.2 CS Samples: Qualitative Measures

5.2.1 Qualitative Measures: Phonological Processes in CS Samples for DS and TD Groups

The type of phonological processes that the participants in TD and DS groups tended to use frequently in CS samples were analysed according to the same criteria explained by Dodd et al. (2002) as for SW samples (see chapter 4, section 4.2.2). The results for TD group showed that phonological processes used in CS samples which frequently occurred for five or more times appeared in CS speech of only five participants in the TD group: TD3, TD7, TD12, TD13 and TD14 (see table 5.1). The remaining TD participants either did not use any processes or used processes that were less frequent than five times. These less frequent processes did not meet the five-occurrence criterion and therefore were not considered as error patterns. Regarding the participants with DS, all the participants in the DS group used phonological processes that occurred five times or more, except DS17 who used 13 processes in total. The CS sample assessment revealed that the speech of DS17 aged 10;9 years evidenced the use of cluster reduction 5 times which met five-occurrence criterion; while the other processes were less frequent (see table 5.2).

Table 5.1 Frequency of occurrence of phonological processes in CS samples for TD group

Participants	CA in year;month	Gliding	Deaffrication	CR	Fronting	WSD	Stopping	Voicing	Assimilation	ICD	MCD	FCD	Backing	Other Processes
TD7	3;0			9	31	2								
TD13	3;0			8						5		5		
TD3	3;9		3	23	15	3	20			8			18	18
TD14	4;0	6		15	11									
TD12	5;5			8						5		5		
Total		6	3	63	57	5	20			18		10	9	18

Note: TD-Typically developing children. CA-Chronological age. CR-Cluster reduction. WSD-Weak syllable deletion. ICD-Initial consonant deletion. MCD-Medial consonant deletion. FCD-Final consonant deletion.

Table 5.2 Frequency of occurrence of phonological processes in CS samples for DS group

Participants	CA in year;month	Gliding	Deaffrication	CR	Fronting	WSD	Stopping	Voicing	Assimilation	ICD	MCD	FCD	Backing	Other Processes
DS10	5;5	5		24	14	2	12	10	13		8	27	12	
DS11	6;0			14	10	2	14	6					17	
DS13	6;6			14	11		9		7		7			
DS1	6;9	6		43	25	3	7	6	20	20	11	6		
DS12	7;1			10	8		9	10					12	
DS15	8;1	13		20	16		10					9		
DS16	8;2		6	20	15	3							18	
DS4	8;8			27	15	2	6				13	17		
DS9	10;1				15			6	6				5	
DS3	10;4			10	17								7	
DS5	10;7			23	16		8	6				7		
DS17	10;9			5										
DS2	10;11			25	30	2	20					9	5	
DS14	10;11			25	21		9	9				5	6	
DS6	11;1			6	10							5		
DS7	11;2			17	7		10			5	7	22	15	
DS8	12;0			16		2	17		15					
Total		24	6	299	230	16	131	53	61	25	46	107	88	

Note: DS-Children with Down syndrome. CA-Chronological age. CR-Cluster reduction. WSD-Weak syllable deletion. ICD-Initial consonant deletion. MCD-Medial consonant deletion. FCD-Final consonant deletion

5.3 CS Samples: Quantitative Measures

Before including MA as a covariate in the ANCOVA analysis, between-participants t-test was also conducted to investigate the mean difference between the two groups. The group factor was set as IV and the percentages of occurrence of 13 phonological processes were set as DVs in CS sample (see appendix C). To investigate the difference between DS and TD groups, ANCOVA test was carried out. The non-verbal MA was set as the covariate. Linear regression was also run in order to analyse the developmental trajectories for each group in relation to non-verbal MA. The group factor was set as IV. In CS sample, DVs included PCC, PVC, PPC, number of occurrences of phonological processes, percentages of occurrence of phonological processes and percentage of speech intelligibility.

5.3.1 Accuracy Measures: PCC, PVC and PPC in CS Samples for DS and TD Groups

The PCC, PVC and PPC measures were estimated and analysed based on the assessment results of CS samples for DS and TD groups. The results of descriptive analysis were summarised (see table 5.3).

Table 5.3 Descriptive analysis of PCC, PVC and PPC measures in CS samples for TD and DS groups

Measures	Groups	Mean	*SD*	*SE*	Median	Range	Minimum	Maximum	95% CI for Mean	
									Lower Bound	Upper Bound
PCC	TD	91.50%	8.67	1.94	95%	33%	66%	99%	87.44%	95.56%
	DS	73.24%	6.35	1.54	75%	25%	60%	85%	69.97%	76.50%
PVC	TD	99.15%	1.42	0.31	100%	5%	95%	100%	98.48%	99.82%
	DS	96.41%	1.37	0.33	96%	4%	95%	99%	95.71%	97.12%
PPC	TD	93.05%	6.83	1.52	96%	24%	75%	99%	89.85%	96.25%
	DS	78.06%	5.95	1.44	80%	23%	64%	87%	75.00%	81.12%

Note: PPC-Percentage phonemes correct. PCC-Percentage consonants correct. PVC-Percentage vowels correct. TD-Typically developing children. DS-children with Down syndrome. SD-Standard deviation. SE-Standard error. CI-Confidence intervals around the mean.

1. PCC

The results of ANCOVA showed that there was a significant difference between TD and DS groups in terms of PCC in CS sample [$F(1,33)=6.921$, $p=0.013$, $\eta^2=0.173$]. This indicated that DS group developed at a delayed onset. The effect size was medium ($\eta^2=0.173$). However, there was a non-significant group*MA mya interaction [$F(1,33)=2.322$, $p=0.137$, $\eta^2=0.066$]. This indicated that both groups developed at a typical rate (see table 5.4). The results of linear regression revealed that MA was a reliable predictor of PCC for TD group [$R^2=0.216$, $F(1,19)=4.971$, $p=0.039$], but MA was a non-significant predictor of PCC for DS group [$R^2=0.000$, $F(1,16)=0.001$, $p=0.973$]. For TD group, the intercept was 85.347% and the gradient was 0.1552 (see figure 5.1a). The confidence intervals around TD trajectory were between 78.464% and 92.229%. The intercept for DS group was 73.324% and the gradient was 0.0025 (see figure 5.1a). The confidence limits around DS trajectory were between 66.796% and 79.853%. Examining the trajectories of the two groups, DS and TD trajectory were different. TD trajectory was positively trended, indicating that PCC continued to improve. However, DS trajectory was negatively trended, suggesting that PCC tended to retract regardless of DS participants' intellectual abilities.

2. PVC

Regarding ANCOVA results of PVC in CS sample, TD and DS group were significantly different [$F(1,33)=9.539$, $p=0.004$, $\eta^2=0.224$]. This indicated that DS group produced PVC at a delayed onset. The effect size was large ($\eta^2=0.224$). However, there was a non-significant group*MA mya interaction [$F(1,33)=0.022$, $p=0.883$, $\eta^2=0.001$]. There was no delay in the onset in DS group (see table 5.4). Linear regression was carried out. The results indicated that MA was a non-significant predictor of PVC for TD group [$R^2=0.188$, $F(1,19)=4.160$, $p=0.056$] and for DS group [$R^2=0.119$, $F(1,16)=2.032$, $p=0.175$]. For TD group, the intercept was 98.209% and the gradient was 0.0237 (see figure 5.1b). The confidence intervals around TD trajectory were between 97.059% and 99.359%. The intercept for DS group was 95.657% and the gradient was 0.0209 (see figure 5.1b). The confidence limits around DS trajectory were between 94.335% and 96.979%. As plotted data suggested, TD and DS trajectories were parallel and positively trended. Compared to TD group, DS group continued to produce PVC scores at a delayed onset, yet at a rate of production similar to that of their MA-matched TD counterparts.

3. PPC

Regrading PPC measure in CS sample for TD and DS groups, the ANCOVA results revealed a statistically significant difference between the two groups [$F(1,33)=8.101$, $p=0.008$, $\eta^2=0.197$]. This indicated that Ds group developed at a delayed onset. The effect size was medium ($\eta^2=0.197$). However, group*MA mya interaction was non-significant [$F(1,33)=1.216$, $p=0.278$, $\eta^2=0.036$], suggesting that the rate of development of PPC was the same in both groups (see table 5.4). Linear regression was run. The results showed that MA was a reliable predictor of PPC for TD group [$R^2=0.199$, $F(1,19)=4.246$, $p=0.054$]. However, MA was a non-significant predictor of PPC [$R^2=0.004$, $F(1,16)=0.067$, $p=0.799$]. For TD group, the intercept was 88.501% and the gradient was 0.1147 (see figure 5.1c). The confidence intervals around TD trajectory were between 82.995% and 94.007%. The intercept for DS group was 77.425% and the gradient was 0.0176 (see figure 5.1c). The confidence limits around DS trajectory were between 71.328% and 83.523%. As plotted data suggested, TD and DS trajectories were parallel and positively trended.

Table 5.4 ANCOVA results for PCC, PVC, and PPC measures in CS samples for TD and DS Groups

Measures	Variables	*df*	Mean Square	*F*	*p*-value	Effect Size η^2
PCC	Group	(1,33)	370.851	6.921	0.013	0.173
	MA mya	(1,33)	116.735	2.178	0.149	0.062
	Group*MA mya	(1,33)	124.407	2.322	0.137	0.066
PVC	Group	(1,33)	16.718	9.539	0.004	0.224
	MA mya	(1,33)	9.984	5.696	0.023	0.147
	Group*MA mya	(1,33)	0.039	0.022	0.883	0.001
PPC	Group	(1,33)	314.716	8.101	0.008	0.197
	MA mya	(1,33)	87.608	2.255	0.143	0.064
	Group*MA mya	(1,33)	47.260	1.216	0.278	0.036

Note: PPC-Percentage phonemes correct. PCC-Percentage consonants correct. PVC-Percentage vowels correct. TD-Typically children. DS-Children with Down syndrome. MA mya-Nonverbal mental age measured in months form youngest age in TD group.

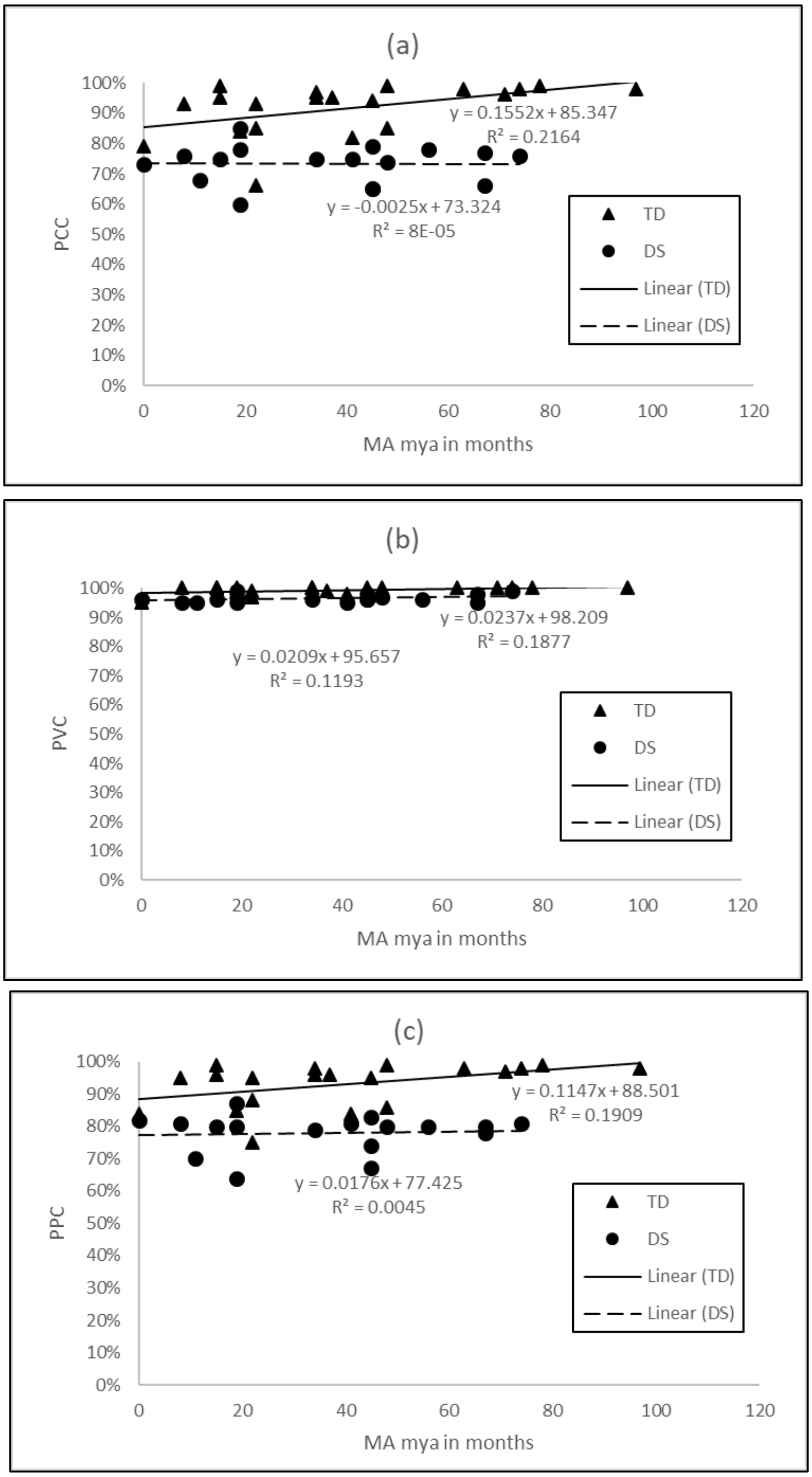


Figure 5.1(a-c). PCC, PVC, and PPC measures in CS samples for TD and DS groups. The figures a, b, and c illustrate the developmental trajectories for percentage consonant correct (PCC), percentage vowel correct (PVC), and percentage phoneme correct (PPC) in connected speech (CS) samples. The trajectory for TD group is represented with a solid line, and for DS group is represented with a dotted line. MA mya represents rescaled nonverbal mental age measured form youngest age in months in TD group.

5.3.2 Accuracy Measures: Phonological Processes in CS Samples for DS and TD Groups

The descriptive analysis of the number of occurrences of phonological processes in CS samples for DS group compared to TD group was summarised (see table 5.5).

Table 5.5 Descriptive analysis of number of occurrences of phonological processes in CS samples for TD and DS groups

Accuracy Measure	Groups	Mean	*SD*	*SE*	Median	Range	Minimum	Maximum	95% CI for Mean	
									Lower Bound	Upper Bound
Number of Occurrences of Processes	TD	14.70	22.96	5.31	8	95	0	95	3.95	25.45
	DS	63.59	33.54	8.13	61	110	13	123	46.34	80.83

Note: TD-Typically developing children. DS-Children with Down syndrome. SD-Standard deviation. SE-Standard error. CI-Confidence intervals around the mean.

The ANCOVA results revealed a significant difference between TD and DS groups in terms of number of occurrences of processes in CS samples [$F(1,33)=4.888$, $p=0.034$, $\eta^2=0.129$]. This indicated that DS group reduced the occurrence of processes at a delayed onset. The effect size was medium ($\eta^2=0.129$). However, there was a non-significant group*MA mya interaction [$F(1,33)=0.367$, $p=0.549$, $\eta^2=0.011$], suggesting that the two groups proceeded to minimise the occurrence of processes at a typical rate. The results of linear regression showed that MA was a non-significant predictor of performance on this task for TD group [$R^2=0.170$, $F(1,19)=3.682$, $p=0.071$], and for DS group [$R^2=0.007$, $F(1,16)=0.103$, $p=0.752$]. For TD group, the intercept was 29.122 and the gradient was 0.3637 (see figure 5.2). The confidence intervals around TD trajectory were between 10.379 and 47.866. The intercept for DS group was 33.691 and the gradient was 0.1226 (see figure 5.2). The confidence limits around the DS trajectory were between 33.691 and 102.326. Examining the trajectories of the two groups, TD and DS trajectories were parallel and negatively trended. This suggested that the participants in both groups continued to suppress processes regardless the level of their intellectual abilities. Nonetheless DS group started to suppress processes at an onset later than TD group.

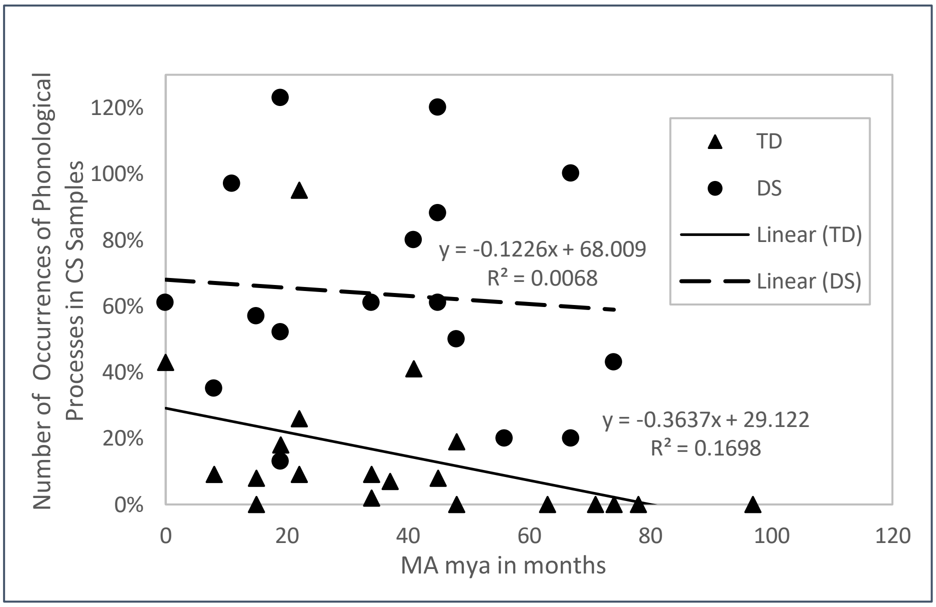


Figure 5.2 Number of occurrences of phonological processes in CS samples for TD and DS groups. The figure illustrates the developmental trajectories for the occurrences of phonological processes in connected speech (CS) samples. The trajectory for TD group is represented with a solid line, and for DS group is represented with a dotted line. MA mya represents rescaled nonverbal mental age measured form youngest age in months in the TD group.

The percentages of occurrences of processes in CS samples were estimated and analysed. For TD group, the most frequently occurring processes were cluster reduction, fronting, initial consonant deletion, backing and stopping. Less frequent processes which appeared in TD participants' speech with percentages of occurrence <1% included deaffrication, weak syllable deletion, voicing, medial and final consonant deletion, assimilation, gliding, other processes (see table 5.6). For DS group, the most frequently occurring processes comprised of cluster reduction, deaffrication, fronting, stopping, voicing, assimilation, medial consonant deletion, backing and final consonant deletion. The less frequent processes included five processes which appeared in DS participants' speech with percentages of occurrences <6%; these included: other processes, initial consonant deletion, WSD, and gliding (see table 5.6).

Table 5.6 Descriptive analysis for percentages of occurrence of phonological processes in CS samples for TD and DS groups

Phonological Processes	Groups	Mean	*SD*	*SE*	Median	Range	Minimum	Maximum	95% CI for Mean	
									Lower Bound	Upper Bound
Gliding	TD	0.95%	1.66	0.37	0%	6%	0%	6%	0.17%	1.73%
	DS	5.59%	3.85	0.93	5%	12%	0%	12%	3.60%	7.57%
Deaffrication	TD	0.50%	1.27	0.28	0%	5%	0%	5%	0.10%	1.10%
	DS	7.35%	9.74	2.36	4%	39%	0%	39%	2.35%	12.36%
CR	TD	4.15%	6.02	1.34	2.50%	23%	0%	23%	1.33%	6.97%
	DS	36%	14.82	4.32	35%	54%	13%	67%	26.83%	40.45%
Fronting	TD	3.95%	7.44	1.66	1.50%	31%	0%	31%	0.47%	7.43%
	DS	21.71%	8.06	1.95	20%	35%	5%	40%	17.56%	22.93%
WSD	TD	0.50%	1.05	0.23	0%	3%	0%	3%	0.01%	0.99%
	DS	3.29%	3.98	0.95	2%	12%	0%	12%	1.25%	5.34%
Stopping	TD	1.15%	4.48	1	0%	20%	0%	20%	0.95%	3.25%
	DS	15.29%	10.16	2.46	13%	35%	0%	35%	10.07	20.52%
Voicing	TD	0.85%	1.59	0.35	0%	6%	0%	6%	0.10%	1.60%
	DS	11%	7.10	1.72	10%	25%	0%	25%	7.35%	14.65%
Assimilation	TD	0.85%	1.18	0.26	0%	4%	0%	4%	0.30%	1.40%
	DS	9.76%	7.98	1.93	8%	30%	0%	30%	5.66	13.87%
ICD	TD	1.50%	1.96	0.43	0%	5%	0%	5%	0.58%	2.42%
	DS	5.76%	5.72	1.38	6%	20%	0%	20%	2.82%	8.71%
MCD	TD	0.35%	0.67	0.15	0%	2%	0%	2%	0.04%	0.66%
	DS	8.71%	6.43	1.56	9%	20%	0%	20%	5.40%	12.01%
FCD	TD	0.95%	1.76	0.39	0%	5%	0%	5%	0.13%	1.71%
	DS	6.71%	7.20	1.74	6%	22%	0%	22%	3%	10.41%
Backing	TD	1.10%	4.03	0.90	0%	18%	0%	18%	0.79%	2.99%
	DS	8.65%	7.35	1.78%	9%	28%	0%	28%	4.86%	12.43%
Other	TD	0.90%	4.02	0.90	0%	18%	0%	18%	0.98%	2.78%
	DS	2.24%	4.23	1.02	0%	15%	0%	15%	0.06%	4.41%

Note: TD-Typically developing children. DS-Children with Down syndrome. CI-Confidence limits around the mean. CR-Cluster reduction, WSD-Weak syllable deletion, ICD-Initial consonant deletion, MCD-Medial consonant deletion, and FCD-Final consonant deletion.

Developmental trajectories were constructed for each of the 13 processes as follows:

1. **Gliding**

The results of ANCOVA test revealed a significant difference between TD and DS group in terms of percentage of occurrence of gliding in CS samples [$F(1,33)=9.193$, $p=0.005$, $\eta^2=0.218$]. This indicated that DS group developed at a delayed onset. The effect size was large ($\eta^2=0.218$). However, there was a statistically non-significant group*MA mya interaction [$F(1,33)= 0.368$, $p=0.548$, $\eta^2=0.011$]. The two groups continued to suppress gliding at a typical rate when matched for MA (see table 5.7). The results of linear regression showed that MA was not a reliable predictor of performance on this task for TD group [R2=0.038, F(1,19)=0.716, p=0.409] and for DS group [R2=0.048, F(1,16)=0.759, p=0.397]. For TD group, the intercept was 1.4475% and the gradient was 0.0125 (see figure 5.3a). The confidence intervals around TD trajectory were between 0.019% and 2.914%. The intercept for DS group was 6.9373% and the gradient was 0.0374 (see figure 5.3a). The confidence limits around DS trajectory were that the population were between 3.073% and 10.801%. The analysis of developmental trajectories illustrated that TD and DS trajectories were parallel and negatively trended. This suggested that DS participants continued to suppress gliding process at a typical rate, yet at an onset later than that for TD participants regardless the level of their cognitive abilities.

2. **Deaffrication**

The ANCOVA results showed that there was a non-significant difference between TD and DS groups in terms of percentage of occurrence of deaffrication in CS sample [$F(1,33)=0.703$, $p=0.408$, $\eta^2=0.021$]. This indicated that there was no delay in the onset in DS group. The effect size was very small ($\eta^2=0.021$). However, there was statistically non-significant group*MA interaction [$F(1,33)= 0.910$, $p=0.347$, $\eta^2=0.027$], suggesting that DS group continued to use deaffrication at a typical rate (see table 5.7). Linear regression was carried out. The results demonstrated that MA was a nonsignificant predictor of performance in terms of percentage of occurrence of deaffrication in CS sample for TD group [$R^2=0.082$, $F(1,19)=1.602$, $p=0.222$] and for DS group [$R^2=0.032$, $F(1,16)=0.494$, $p=0.493$]. For TD group, the intercept was 1.0566% and the gradient was 0.0817 (see figure 5.3b). The confidence intervals around TD trajectory were between 0.40% and 2.153%. The intercept for DS group was 4.5824 % and the gradient was 0.0768 (see figure 5.3b). The confidence limits around DS trajectory were between 5.256% and 14,421%. As the plotted data suggested, TD and DS trajectories were not parallel. TD trajectory was negatively trended, suggesting that TD participants proceeded to suppress deaffrication process. On the contrary, DS trajectory was positively trended, indicating that DS participants continued to use deaffrication.

3. Cluster Reduction

Regarding the percentage of occurrence of cluster reduction (CR) in CS sample for TD and DS groups, the results revealed that there was a significant difference between the two groups [$F(1,33)=19.950$, $p=0.001$, $\eta^2=0.377$]. This indicated that Ds group continued to produce CR at a delayed onset. The effect size was highly large. However, there was a statistically non-significant group*MA mya interaction [$F(1,33)= 0.357$, $p=0.554$, $\eta^2=0.011$]. The two groups continued to suppress CR process at a typical rate (see table 5.7). The results of linear regression manifested that MA was marginal predictor of performance on this task for TD group [$R^2=0.177$, $F(1,19)=3.872$, $p=0.065$] and for DS group [$R^2=0.067$, $F(1,16)=1.084$, $p=0.314$]. For TD group, the intercept was 8.0105% and the gradient was 0.0974 (see figure 5.3c). The confidence intervals around TD trajectory were between 3.118% and 12.903%. The intercept for DS group was 43.375% and the gradient was 0.2045 (see figure 5.3c). The confidence limits around DS trajectory were between 25.702% and 61.047%. TD and DS trajectories were parallel and negatively trended. This indicated that TD group as well as DS group continued to suppress CR. Yet, DS participants started to suppress CR process at an onset later than TD participants.

4. Fronting

The ANCOVA results revealed a significant difference between TD and DS groups in terms of percentage of occurrence of fronting in the CS samples [$F(1,33)=6.996$, $p=0.012$, $\eta^2=0.175$], suggesting that there was a delay in the onset in DS group. The effect size was medium ($\eta^2=0.175$). However, there was a statistically non-significant group*MA mya interaction [$F(1,33)=1.653$, $p=0.207$, $\eta^2=0.048$]. This indicated that DS and TD groups continued to suppress fronting at a typical rate (see table 5.7). The results of linear regression showed that MA was a significant predictor of performance on this task for TD group

[R^2=0.232, F(1,19)=5.446, p=0.031]. Yet, MA was found to be a non-significant predictor of performance on this task for DS group [R^2=0.067, F(1,16)=1.084, p=0.884]. For TD group, the intercept was 9.4182% and the gradient was 0.1379 (see figure 5.3d). The confidence intervals around TD trajectory were between 3.575% and 15.262%. The intercept for DS group was 21.775% and the gradient was 0.0019 (see figure 5.3d). The confidence intervals around DS trajectory were between 13.500% and 30.050%. TD and DS trajectories were parallel and negatively-trended. This indicated that the participants in the two groups proceeded to suppress the occurrence of fronting in CS sample.

5. Weak Syllable Deletion

The ANCOVA results showed that there was a non-significant difference between TD and DS groups in terms of percentage of occurrence of weak syllable deletion (WSD) [F(1,33)=2.328, p=0.137, η^2=0.066]. This indicated that there was no delay in the onset in DS group. Similarly, there was a statistically non-significant group*MA mya interaction [F(1,33)=0.000, p=0.990, η^2=0.000]. The two groups continued to suppress WSD at a typical rate when matched for MA (see table 5.7). Linear regression was run. The results demonstrated that MA was a marginal predictor of performance on this task for TD group [R^2=0.082, F(1,19)=1.601, p=0.222] and for DS group [R^2=0.004, F(1,16)=0.059, p=0.811]. For TD group, the intercept was 0.9579% and the gradient was 0.0115 (see figure 5.3e). The confidence intervals around TD trajectory were between 0.055% and 1.860%. The intercept for DS group was 3.6914% and the gradient was 0.011 (see figure 5.3e). The confidence limits around DS trajectory were between 0.387% and 7.770%. As plotted data suggested, TD and DS trajectories were parallel and negatively trended. This suggested that the two groups continued to suppress WSD process regardless the level of their intellectual abilities.

6. Stopping

Based on ANCOVA results, TD and DS groups were significantly different in relation to percentage of occurrence of stopping [F(1,33)=7.392, p=0.010, η^2=0.183]. This indicated that DS group developed at a delayed onset. The effect size was medium (η^2=0.183). However, there was a statistically non-significant group*MA mya interaction [F(1,33)= 0.036, p=0.852, η^2=0.001]. The two groups continued to eliminate stopping at a typical rate (see table 5.7).

Linear regression was conducted. The results revealed that MA was not a reliable predictor of performance on this task for TD group [R^2=0.025, F(1,19)=0.457, p=0.508] and for DS group [R^2=0.000, F(1,16)=0.003, p=0.958]. For TD group, the intercept was 2.226% and the gradient was 0.027 (see figure 5.3f). The confidence intervals around TD trajectory were between 1.744% and 6.196%. The intercept for DS group was 15.52% and the gradient was 0.0063 (see figure 5.3f). The confidence intervals around DS trajectory were between 5.091% and 25.949%. TD and DS trajectories were parallel and negatively trended, suggesting that participants in both groups proceeded to minimise the occurrence of stopping in CS sample. Yet, DS participants started to reduce the occurrence of stopping at a delayed onset.

7. Voicing

Regarding percentage of occurrence of voicing in CS samples for TD and DS groups, the results revealed a non-significant difference between the two groups [F(1,33)=2.479, p=0.125, η^2=0.070]. This indicated that there was no delay in the onset in DS group. However, there was a statistically significant group*MA interaction [F(1,33)= 5.261, p=0.028, η^2=0.137]. Therefore, DS group developed at a rate slower than that for TD group. The effect size was medium (η^2=0.137) (see table 5.7). Linear regression was carried out. The results showed that MA was a reliable predictor of performance on this task for TD group [R^2=0.193, F(1,19)=4.303, p=0.053]. However, MA was a non-significant predictor of performance on this task for DS group [R^2=0.157, F(1,16)=2.796, p=0.115]. For TD group, the intercept was 1.9201% and the gradient was 0.027 (see figure 5.3g). The confidence intervals around TD trajectory were between 0.634% and 3.207%. The intercept for DS group was 6.5119% and the gradient was 0.1245 (see figure 5.3g). The confidence limits around DS trajectory were between 0.186% and 13.210%. Examining the trajectories of the two groups, TD and DS trajectories were not parallel. The trajectories were differently trended. TD trajectory was negatively trended, suggesting that TD participants continued to suppress voicing process. On the contrary, DS trajectory was positively trended, indicating that DS participants continued to use voicing process.

8. Assimilation

The ANCOVA results showed that TD and DS groups were significantly different in relation to percentage of occurrence of assimilation in CS sample [$F(1,33)=27.068$, $p=0.001$, $\eta^2=0.451$]. This indicated that DS group started to suppress assimilation at a significantly delayed onset. The effect size was very large ($\eta^2=0.451$). Similarly, there was a statistically significant group*MA interaction [$F(1,33)= 7.311$, $p=0.011$, $\eta^2=0.181$], suggesting that DS group developed at a rate slower than that for TD group. The effect size was medium ($\eta^2=0.181$) (see table 5.7). The results of linear regression showed that MA was not a reliable predictor of performance on this task for TD group [$R^2=0.048$, $F(1,19)=0.908$, $p=0.353$]. Yet, MA was a reliable predictor of performance on this task for DS group [$R^2=0.295$, $F(1,16)=6.267$, $p=0.024$]. For TD group, the intercept was 1.2448% and the gradient was 0.01 (see figure 5.3h). The confidence intervals around TD trajectory were between 0.212% and 2.278%. The intercept for DS group was 16.667% and the gradient was 0.1914 (see figure 5.3h). The confidence limits around DS trajectory were between 9.787% and 23.548%. As the plotted data suggested, TD and DS trajectories were negatively trended. This indicated that participants in both groups continued to suppress assimilation. Additionally, the two trajectories were not perfectly parallel due to the substantially delayed onset at which DS participants started to suppress assimilation.

9. Initial Consonant Deletion

The results of ANCOVA manifested a non-significant difference between TD and DS group in terms of percentage of occurrence of initial consonant deletion (ICD) [$F(1,33)=1.044$, $p=0.314$, $\eta^2=0.031$]. This indicated that there was no delay in the onset in DS group. Similarly, there was a statistically non-significant group*MA mya interaction [$F(1,33)= 465$, $p=0.500$, $\eta^2=0.014$]. Therefore, the two groups continued to suppress ICD at a typical rate (see table 5.7). Linear regression was conducted. The results revealed that MA was a reliable predictor of performance of this task for TD group [$R^2=0.318$, $F(1,19)=8.400$, $p=0.010$]. However, MA was a non-significant predictor of performance in terms of ICD for DS group [$R^2=0.000$, $F(1,16)=0.001$, $p=0.973$]. For TD group, the intercept was 3.1852% and the gradient was 0.0425 (see figure 5.3i). The confidence intervals around TD trajectory were between 1.735% and 4.6355%. The intercept for DS group was 5.8473% and the gradient was 0.0023 (see figure 5.3i). Regarding the confidence limits around the DS trajectory, there was 95% confidence that the tested population intercept was between 0.033% and 11.728%. Detecting the trajectories of the two groups, TD and DS groups were parallel and negatively trended. This indicated that both continued to suppress ICD process at similar onset and rate of suppression when the two groups were matched for MA.

10. Medial Consonant Deletion

The ANCOVA results revealed a significant difference between in terms of percentage of occurrence of medial consonant deletion (MCD) in CS samples for TD and DS groups [$F(1,33)=43.126$, $p=0.001$, $\eta^2=0.567$]. This indicated that DS group started to suppress MCD at a delayed onset. The effect size was very large ($\eta^2=0.567$). There was also a statistically significant group*MA mya interaction [$F(1,33)= 8.379$, $p=0.007$, $\eta^2=0.202$], suggesting that DS group continued to eliminate MCD at a rate slower than that for TD group. The effect size was large ($\eta^2=0.202$) (see table 5.7). The results of linear regression demonstrated that MA was a non-significant predictor of performance on this task for TD group [$R^2=0.128$, $F(1,19)=2.638$, $p=0.122$]. However, MA was a reliable predictor of suppressing MCD for DS group [$R^2=0.322$, $F(1,16)=7.132$, $p=0.017$]. For TD group, the intercept was 0.7156% and the gradient was 0.0092 (see figure 5.3j). The confidence intervals around TD trajectory were between 0.154% and 1.277%. The intercept for DS group was 14.522% and the gradient was 0.1613 (see figure 5.3j). Regarding the confidence limits around the DS trajectory, there was 95% confidence that the population intercept was between 9.087% and 19.956%. TD and DS trajectories were negatively trended, indicating that the two groups continued to suppress MCD process. However, the two trajectories were not perfectly parallel due to the substantial delay in onset in DS group.

11. Final Consonant Deletion

The ANCOVA results showed that there was a significant difference between TD and DS group in terms of percentage of occurrence of final consonant deletion (FCD) in CS samples [$F(1,33)=3.876$, $p=0.057$, $\eta^2=0.105$]. This indicated that DS group started to suppress FCD at a delayed onset. The effect size was small ($\eta^2=0.105$). However, there was a statistically non-significant group*MA mya interaction [$F(1,33)= 0.058$, $p=0.811$, $\eta^2=0.002$]. The two groups continued to suppress FCD process at a typical rate (see table 5.7). The results of linear regression demonstrated that MA was not a reliable predictor of performance on this task for TD group [R^2=0.132, F(1,19)=2.738, p=0.115] and for DS group [R^2=0.017, F(1,16)=0.267, p=0.613]. For TD group, the intercept was 1.9255% and the gradient was 0.0246 (see figure 5.3k). The confidence intervals around TD trajectory were between 0.455% and 3.396%. The intercept for DS group was 8.2226% and the gradient was 0.0421 (see figure 5.3k). Regarding the confidence limits around the DS trajectory, there was 95% confidence that the population intercept was between 0.896% and 15.550%. TD and DS trajectories were parallel and negatively trended. This revealed that the two groups proceeded to eliminate FCD process, although DS group started to suppress FCD at an onset later than that for TD group.

12. Backing

Regrading percentage of occurrence of backing in CS samples for TD and DS groups, ANCOVA results revealed that there was a nonsignificant effect of group factor [$F(1,33)=1.633$, $p=0.210$, $\eta^2=0.047$]. This indicated that there was no delay in the onset in DS group. There was also a statistically non-significant group*MA mya interaction [$F(1,33)=0.820$, $p=0.372$, $\eta^2=0.024$], suggesting that the rate of producing backing was not slower for DS group (see table 5.7). Linear regression was carried out. The results manifested that MA was a marginal predictor of performance on this task for TD group [R^2=0.049, F(1,19)=0.930, p=0.348] and for DS group [R^2=0.016, F(1,16)=0.243, p=0.629]. For TD group, the intercept was 2.4639% and the gradient was 0.0344 (see figure 5.3l). The confidence intervals around TD trajectory were between 1.064% and 5.991%. The intercept for DS group was 7.1671% and the gradient was 0.041 (see figure 5.3l). Regarding the confidence limits around the DS trajectory, there was 95% confidence that the population intercept was between 0.325% and 14.659%. As plotted data illustrated, TD and DS trajectories were not perfectly parallel. The trajectories of the two groups were also differently trended. TD trajectory was negatively-trended, suggesting that TD participants proceeded to suppress backing. However, DS trajectory was positively trended, indicating that DS participant continued to use backing.

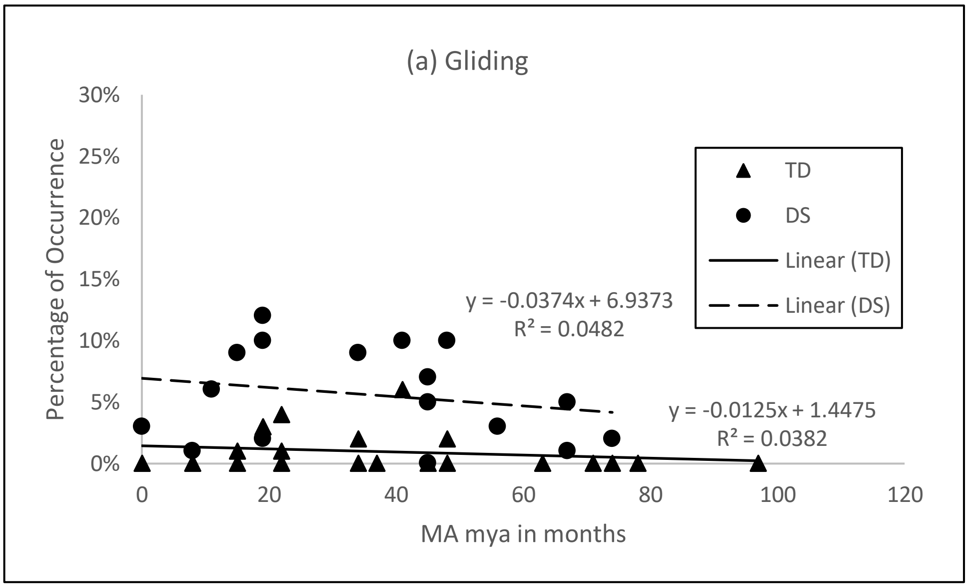
13. Other processes

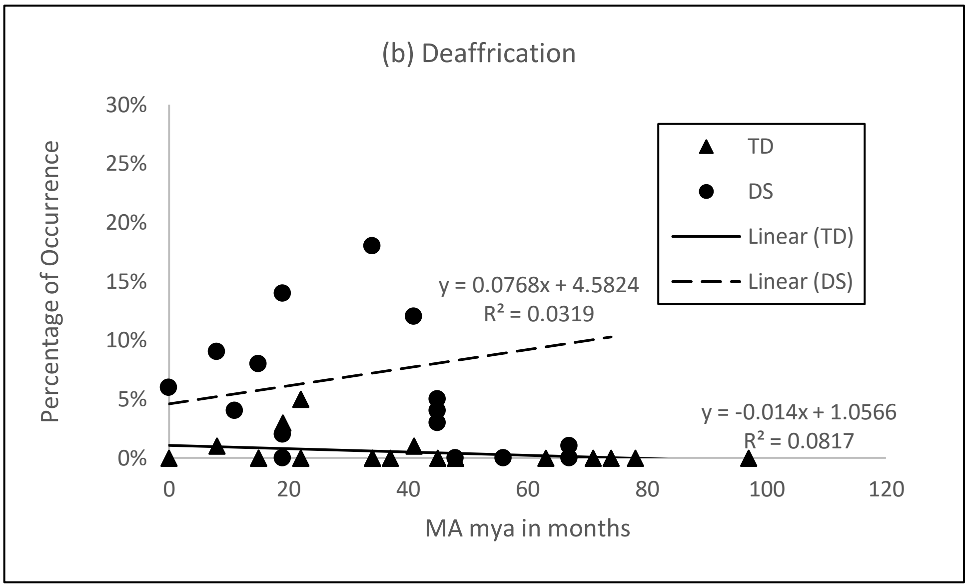
The ANCOVA results showed that there was a non-significant difference between TD and DS groups in terms of percentage of occurrence of other processes in CS sample [$F(1,33)=0.005$, $p=0.943$, $\eta^2=0.000$]. This indicated that there was no delay in the onset in DS group. Similarly, there was a statistically non-significant group*MA interaction [$F(1,33)= 0.242$, $p=0.626$, $\eta^2=0.007$]. The two groups developed at a typical rate when matched for MA (see table 5.7). Linear regression was run. The results revealed that MA was a non-significant predictor of performance on this task for TD group [$R^2=0.026$, $F(1,19)=0.471$, $p=0.501$] and for DS group [$R^2=0.001$, $F(1,16)=0.009$, $p=0.925$]. For TD group, the intercept was 1.8796% and the gradient was 0.0247 (see figure 5.3m). The confidence intervals around TD trajectory were between 1.680% and 5.439%. The intercept for DS group was 2.0691% and the gradient was 0.0046 (see figure 5.3m). The confidence limits around DS trajectory were between 2.278% and 4.4116%. As plotted data illustrated, TD and DS trajectories were not parallel. TD trajectory was negatively trended, indicating that TD participants continued to suppress the occurrence of other processes. On the contrary, DS trajectory was positively trended, suggesting that DS participants continued to use other processes.

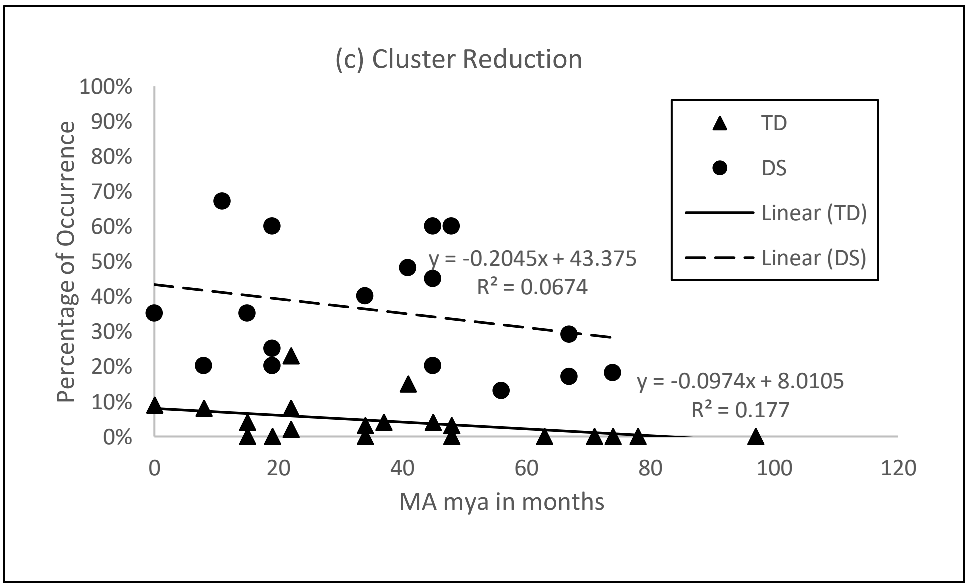
Table 5.7 ANCOVA results for percentages of occurrence of phonological processes in CS samples for TD and DS groups

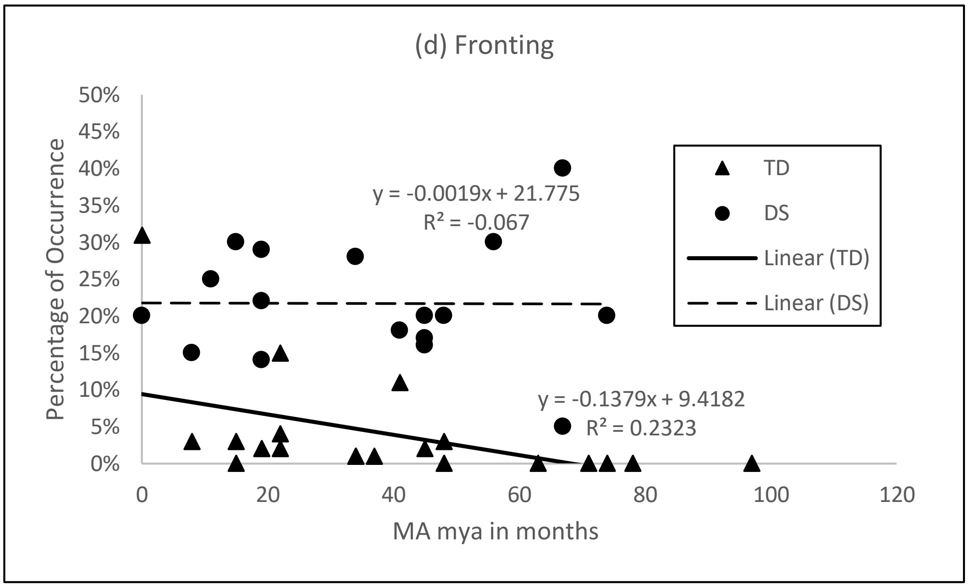
Phonological Processes	Variables	*df*	Mean Square	*F*	*p*-value	Effect Size η^2
Gliding	Group	(1,33)	77.324	9.193	0.005	0.218
	MA mya	(1,33)	12.493	1.485	0.232	0.043
	Group*MA mya	(1,33)	3.094	0.368	0.548	0.011
Deaffrication	Group	(1,33)	31.896	0.703	0.408	0.021
	MA mya	(1,33)	19.737	0.435	0.514	0.013
	Group*MA mya	(1,33)	41.330	0.910	0.347	0.027
Cluster Reduction	Group	(1,33)	3208.787	19.950	0.001	0.377
	MA mya	(1,33)	456.122	2.836	0.102	0.079
	Group*MA mya	(1,33)	57.468	0.357	0.554	0.011
Fronting	Group	(1,33)	391.764	6.996	0.012	0.175
	MA mya	(1,33)	97.860	1.748	0.195	0.050
	Group*MA mya	(1,33)	92.569	1.653	0.207	0.048
Weak Syllable Deletion	Group	(1,33)	19.172	2.328	0.137	0.066
	MA mya	(1,33)	2.549	0.309	0.582	0.009
	Group*MA mya	(1,33)	0.001	0.000	0.990	0.000
Stopping	Group	(1,33)	453.433	7.392	0.010	0.183
	MA mya	(1,33)	5.582	0.091	0.765	0.003
	Group*MA mya	(1,33)	2.182	0.036	0.852	0.001
Voicing	Group	(1,33)	54.096	2.479	0.125	0.070
	MA mya	(1,33)	47.558	2.179	0.149	0.062
	Group*MA mya	(1,33)	114.813	5.261	0.028	0.137
Assimilation	Group	(1,33)	610.282	27.068	0.001	0.451
	MA mya	(1,33)	202.995	9.004	0.005	0.214
	Group*MA mya	(1,33)	164.830	7.311	0.011	0.181
Initial Consonant Deletion	Group	(1,33)	18.183	1.044	0.314	0.031
	MA mya	(1,33)	10.041	0.576	0.453	0.017
	Group*MA mya	(1,33)	8.093	0.465	0.500	0.014
Medial Consonant Deletion	Group	(1,33)	489.047	35.406	0.001	0.518
	MA mya	(1,33)	145.504	10.534	0.003	0.242
	Group*MA mya	(1,33)	115.735	8.379	0.007	0.202
Final Consonant Deletion	Group	(1,33)	101.742	3.876	0.057	0.105
	MA mya	(1,33)	22.244	0.847	0.364	0.025
	Group*MA mya	(1,33)	1.526	0.058	0.811	0.002
Backing	Group	(1,33)	56.755	1.633	0.210	0.047
	MA mya	(1,33)	0.221	0.006	0.937	0.000
	Group*MA mya	(1,33)	28.486	0.820	0.372	0.024
Other Processes	Group	(1,33)	0.092	0.005	0.943	0.000
	MA mya	(1,33)	2.022	0.114	0.738	0.003
	Group*MA mya	(1,33)	4.301	0.242	0.626	0.007

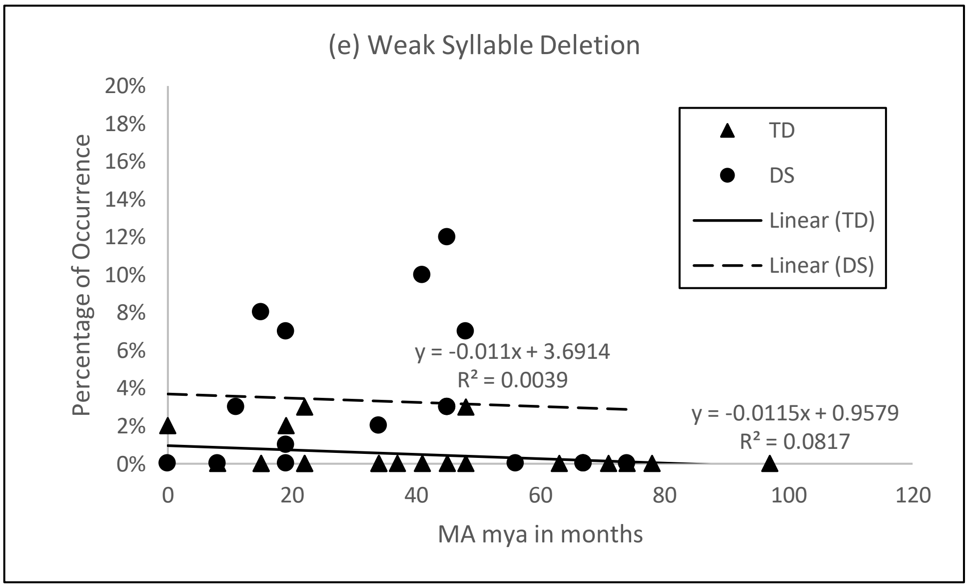
Note: MA mya-Nonverbal mental age measured from youngest age in TD group of children.

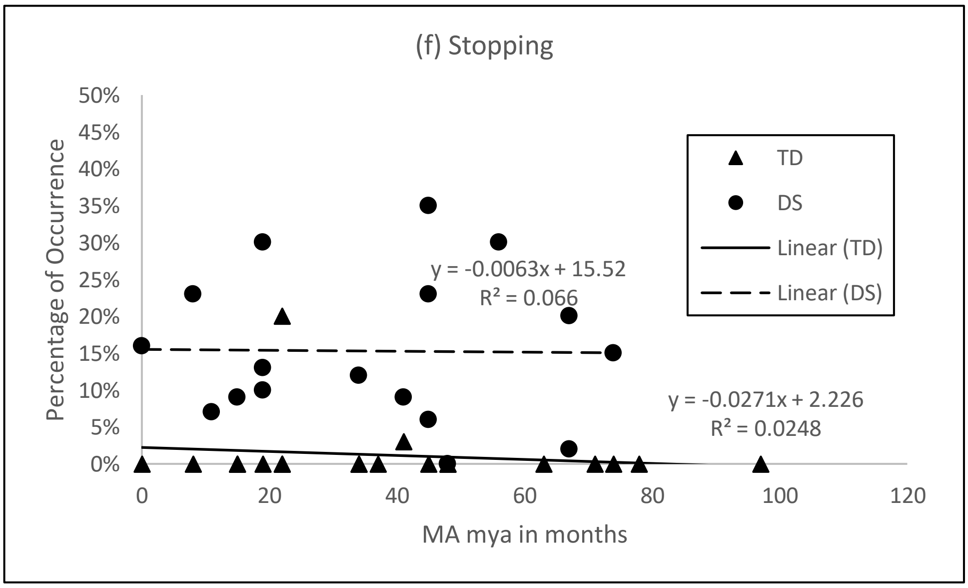

(a) Gliding
30%
25%
20%
15%
10%
5%
0%
Percentage of Occurrence
0
20
40
60
80
100
120
MA mya in months
TD
DS
Linear (TD)
Linear (DS)
y = -0.0374x + 6.9373
R² = 0.0482
y = -0.0125x + 1.4475
R² = 0.0382

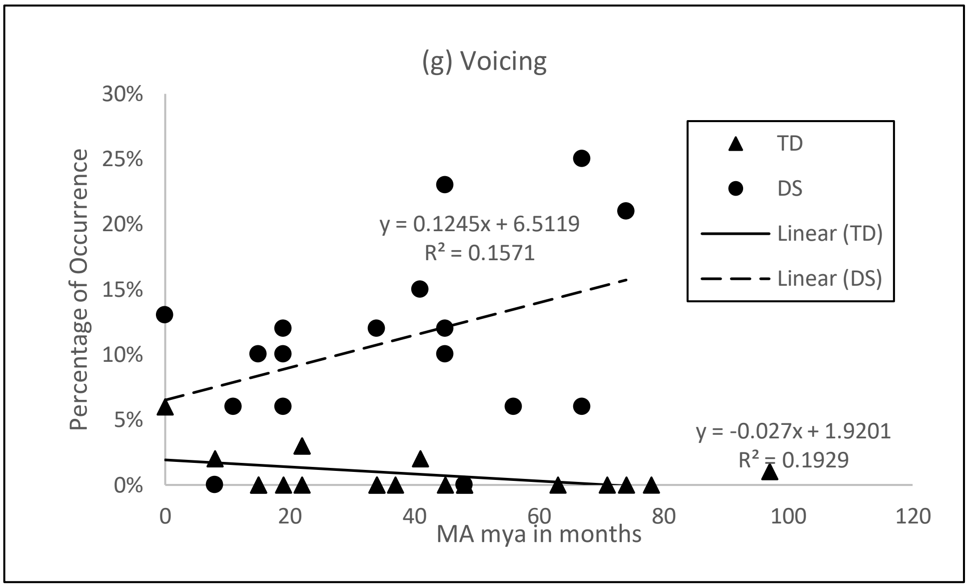

(b) Deaffrication
30%
25%
20%
15%
10%
5%
0%
Percentage of Occurrence
0
20
40
60
80
100
120
MA mya in months
TD
DS
Linear (TD)
Linear (DS)
y = 0.0768x + 4.5824
R² = 0.0319
y = -0.014x + 1.0566
R² = 0.0817

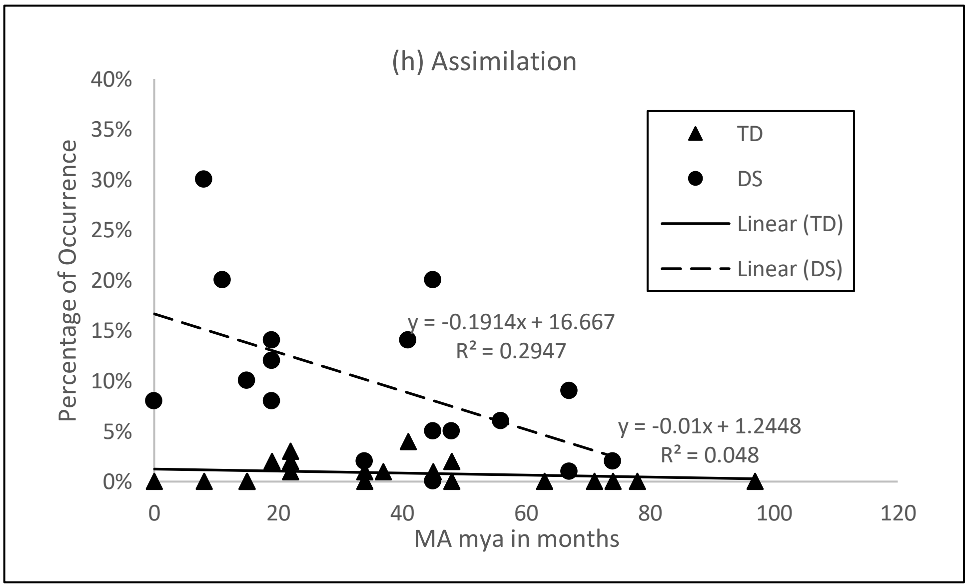

(c) Cluster Reduction
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Percentage of Occurrence
0
20
40
60
80
100
120
MA mya in months
TD
DS
Linear (TD)
Linear (DS)
y = -0.2045x + 43.375
R² = 0.0674
y = -0.0974x + 8.0105
R² = 0.177

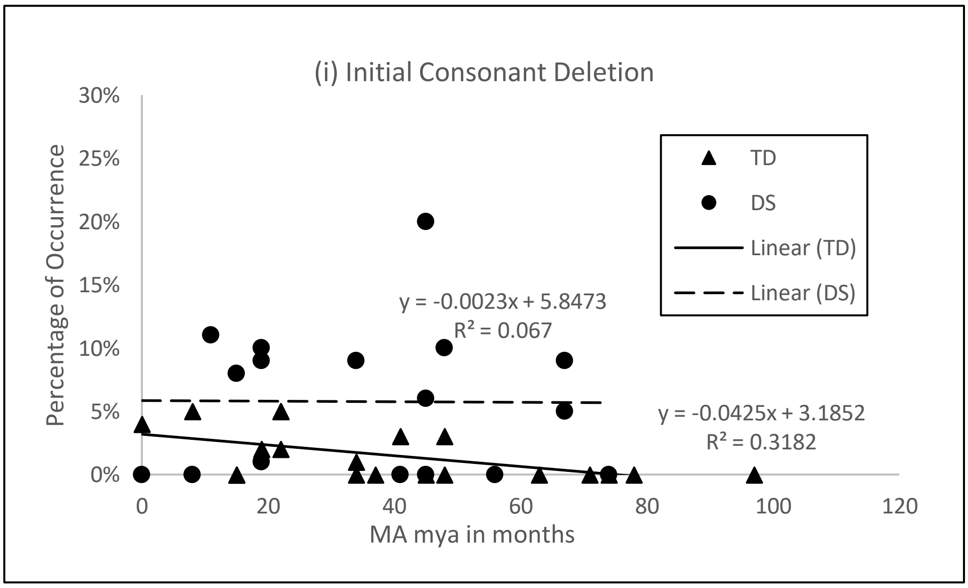

(d) Fronting
Percentage of Occurrence
50%
45%
40%
35%
30%
25%
20%
15%
10%
5%
0%
0
20
40
60
80
100
120
MA mya in months
TD
DS
Linear (TD)
Linear (DS)
y = -0.0019x + 21.775
R² = -0.067
y = -0.1379x + 9.4182
R² = 0.2323

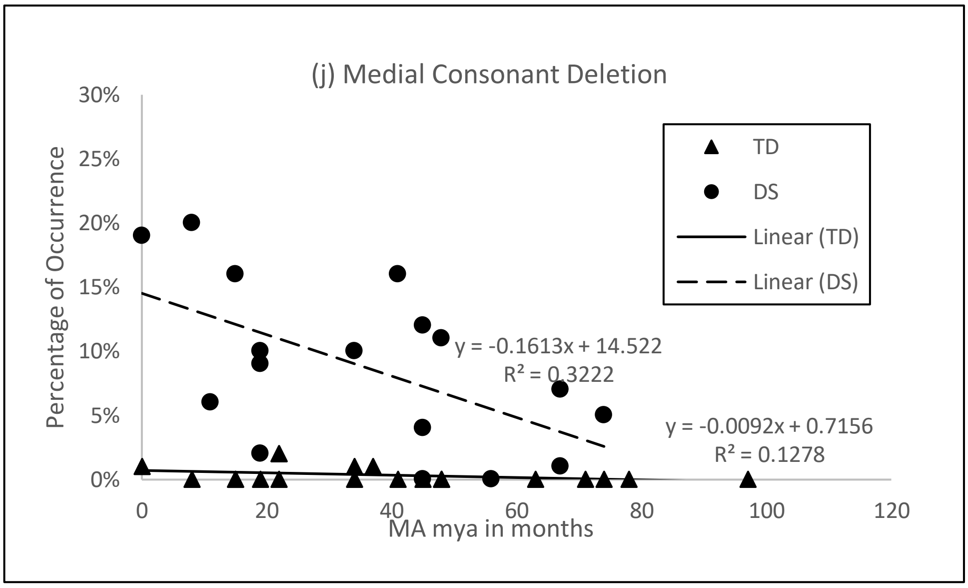

(e) Weak Syllable Deletion
Percentage of Occurrence
20%
18%
16%
14%
12%
10%
8%
6%
4%
2%
0%
0
20
40
60
80
100
120
MA mya in months
TD
DS
Linear (TD)
Linear (DS)
y = -0.011x + 3.6914
R² = 0.0039
y = -0.0115x + 0.9579
R² = 0.0817

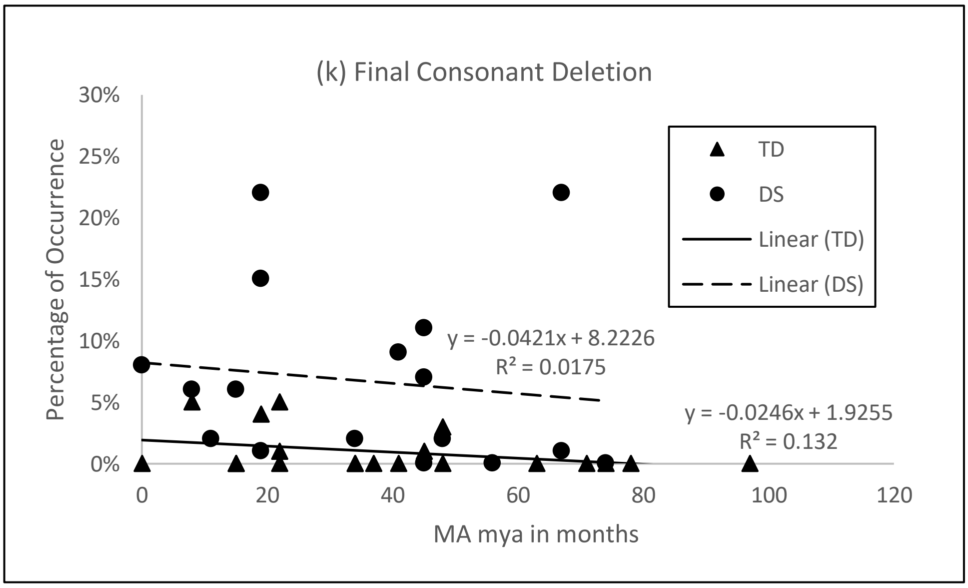

(f) Stopping
Percentage of Occurrence
50%
45%
40%
35%
30%
25%
20%
15%
10%
5%
0%
0
20
40
60
80
100
120
MA mya in months
TD
DS
Linear (TD)
Linear (DS)
y = -0.0063x + 15.52
R² = 0.066
y = -0.0271x + 2.226
R² = 0.0248

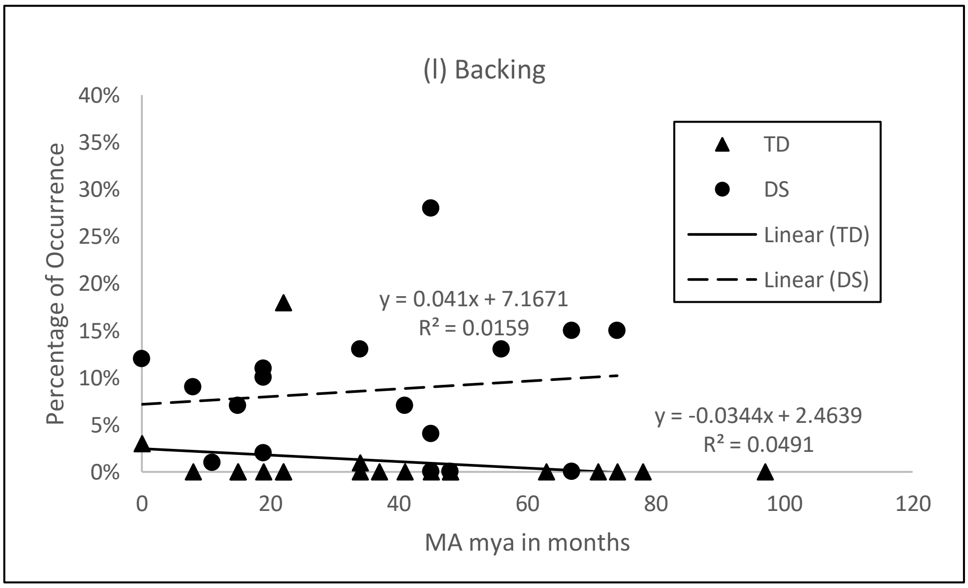

(g) Voicing
Percentage of Occurrence
30%
25%
20%
15%
10%
5%
0%
0
20
40
60
80
100
120
MA mya in months
TD
DS
Linear (TD)
Linear (DS)
y = 0.1245x + 6.5119
R² = 0.1571
y = -0.027x + 1.9201
R² = 0.1929


(h) Assimilation
Percentage of Occurrence
40%
35%
30%
25%
20%
15%
10%
5%
0%
0
20
40
60
80
100
120
MA mya in months
TD
DS
Linear (TD)
Linear (DS)
y = -0.1914x + 16.667
R² = 0.2947
y = -0.01x + 1.2448
R² = 0.048


(i) Initial Consonant Deletion
Percentage of Occurrence
30%
25%
20%
15%
10%
5%
0%
0
20
40
60
80
100
120
MA mya in months
TD
DS
Linear (TD)
Linear (DS)
y = -0.0023x + 5.8473
R² = 0.067
y = -0.0425x + 3.1852
R² = 0.3182


(j) Medial Consonant Deletion
Percentage of Occurrence
30%
25%
20%
15%
10%
5%
0%
0
20
40
60
80
100
120
MA mya in months
TD
DS
Linear (TD)
Linear (DS)
y = -0.1613x + 14.522
R² = 0.3222
y = -0.0092x + 0.7156
R² = 0.1278


(k) Final Consonant Deletion
Percentage of Occurrence
30%
25%
20%
15%
10%
5%
0%
0
20
40
60
80
100
120
MA mya in months
TD
DS
Linear (TD)
Linear (DS)
y = -0.0421x + 8.2226
R² = 0.0175
y = -0.0246x + 1.9255
R² = 0.132


(l) Backing
Percentage of Occurrence
40%
35%
30%
25%
20%
15%
10%
5%
0%
0
20
40
60
80
100
120
MA mya in months
TD
DS
Linear (TD)
Linear (DS)
y = 0.041x + 7.1671
R² = 0.0159
y = -0.0344x + 2.4639
R² = 0.0491

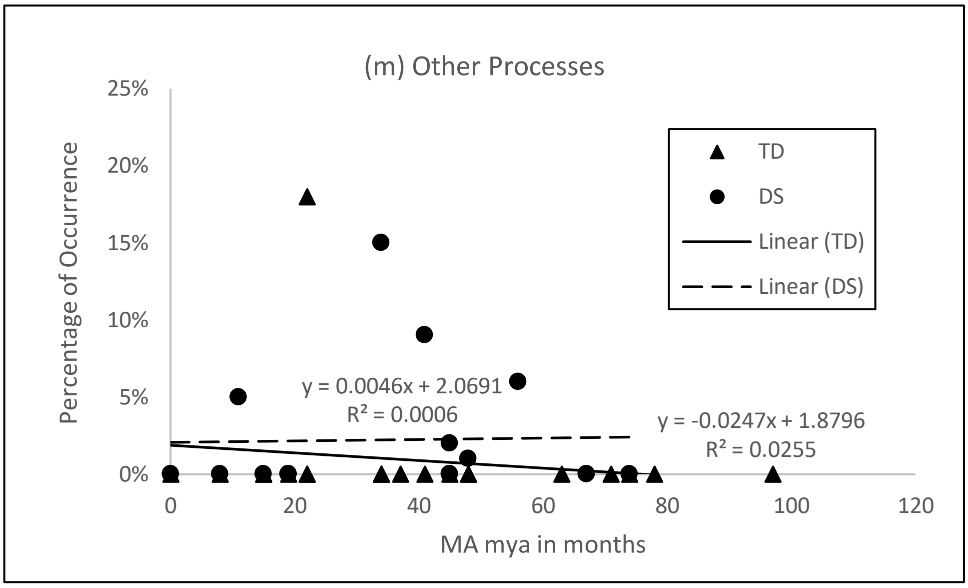


Figure 5.3(a-m). The percentage of occurrence of phonological processes in CS samples for TD and DS groups. The figures illustrate the developmental trajectories for percentages of occurrence of phonological processes in connected speech (CS) samples. Trajectory for TD group is represented with a solid line, and for DS group is represented with a dotted line. MA mya represents rescaled nonverbal mental age measured form youngest age in months in the TD group.

5.3.3 Speech Intelligibility in CS Samples for TD and DS Groups

Preliminarily, the speech intelligibility of the participants' in the TD group and the DS group was subjectively rated by their parents by administering a speech intelligibility rating scale called The Intelligibility in Context Scale (ICS) (McLeod et al., 2012). The descriptive analysis of ICS scores for TD and DS groups is presented (see table 5.8).

Table 5.8 Descriptive analysis of ICS in CS samples for TD and DS groups

Variable	Groups	Mean	*SD*	*SE*	Median	Range	Minimum	Maximum	95% CI for Mean	
									Lower Bound	Upper Bound
ICS	TD	4.41	0.59	0.13	4.50	2	3	5	4.14	4.69
	DS	3.35	0.34	0.08	3.40	1	3	4	3.18	3.53

Note: TD-Typically developing children. DS-Children with Down syndrome. ICS-Intelligibility in context scale assessment. SD-Standard deviation. SE-Standard error. CI-Confidence limits around the mean.

Speech intelligibility was also assessed by analysing the spontaneous speech samples collected during the interactive activities. The participants connected speech samples were rated by 4 five-listener groups of adult native British English-speaking listeners. The listeners orthographically transcribed the words they understood and the unintelligible words. The intelligibility score for each participant was calculated by dividing the total number of words transcribed during listening by the total number of words (including intelligible and unintelligible words) in the sample multiplied by 100. The descriptive analysis of percentage of speech intelligibility was summarised (see table 5.9). The between-participants *t*-test was run to discover the difference between TD and DS groups [t=6.46, p<0.001, d=2.27]. The confidence limits around the estimated population mean difference were between 0.72 and 1.39.

One-way between-participants ANCOVA was run. The results indicated that there was a statistically significant difference between TD and DS groups in relation to percentage of intelligibility [$F(1,33)=16.680$, $p<0.001$, $\eta^2=0.336$], suggesting that DS group produced intelligible speech at a delayed onset. However, there was a non-significant group*MA interaction [$F(1,33)=1.652$, $p=0.208$, $\eta^2=0.048$]. Therefore, the two groups developed at a typical rate when matched for MA (see table 5.10) The results of linear regression revealed that MA was a significant predictor of performance on this task for TD group [$R^2=0.225$, $F(1,19)=5.223$, $p=0.035$]. Yet, MA was a non-significant predictor of performance on this task for DS group [R^2=0.0.015, $F(1,16)=0.236$, $p=0.634$]. For TD group, the intercept was 83.548% and the gradient was 0.1489 (see figure 5.4). The confidence intervals around TD trajectory were between 77.107% and 89.988%. The intercept for DS group was 66.767% and the gradient was 0.0293 (see figure 5.4). The confidence limits around DS trajectory were between 61.338% and 72.196%. As plotted data suggested, TD and DS trajectories were parallel and positively-trended. This indicated that both groups continued to develop speech intelligibility, although DS group developed speech intelligibility at a delayed onset.

Table 5.9 Descriptive analysis of percentage of intelligibility in CS Samples for TD and DS groups

Variable	Groups	Mean	*SD*	*SE*	Median	Range	Minimum	Maximum	95% CI for Mean	
									Lower Bound	Upper Bound
Percentage of Intelligibility	TD	89.45%	8.16	1.82	93%	29%	68%	97%	85.63%	93.27%
	DS	67.82%	5.33	1.29	69%	23%	57%	80%	65.08%	70.56%

Note: TD-Typically developing children. DS-Children with Down syndrome. SD-Standard deviation. SE-Standard error. CI-Confidence limits around the mean.

Table 5.10 ANCOVA test results for percentage of intelligibility in CS Samples for TD and DS groups

Variables	*df*	Mean Square	*F*	*p*-value	Effect Size η^2
Group	(1,33)	722.511	16.680	0.001	0.336
MA mya	(1,33)	158.885	3.668	0.064	0.100
Group * MA mya	(1,33)	71.539	1.652	0.208	0.048

Note: MA mya-Nonverbal mental age measured from youngest age in TD group.

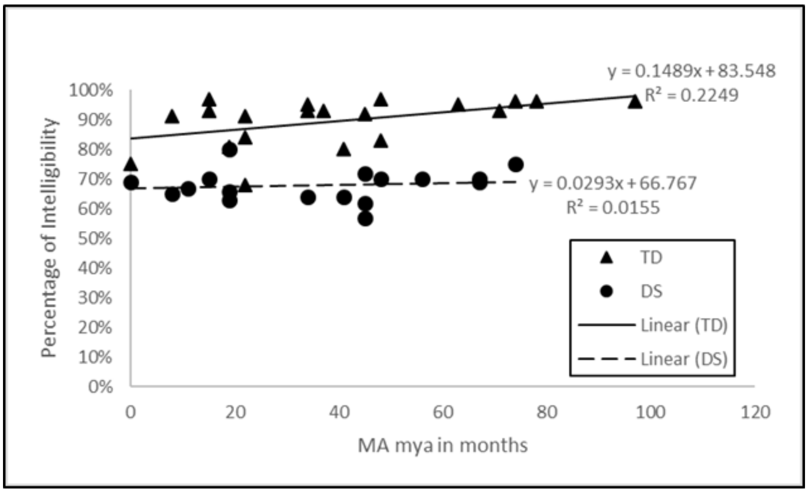


Figure 5.4. The percentage of intelligibility in CS samples for TD and DS groups. The figure illustrates the developmental trajectory of percentage of intelligibility in connected speech (CS) samples. The trajectory for TD group is represented with a solid line, and for DS is represented with a dotted line. MA mya represents rescaled nonverbal mental age measured form youngest age in months in the TD group.

5.3.4 Summary of CS Sample for DS and TD Groups

The qualitative and quantitative measures in CS samples for TD and DS groups were analysed. Qualitatively, the processes that met the five-time occurrence criterion emerged in the CS sample for only five TD participants. The remaining participants either did not use any processes or used processes that were less frequent than five times. Compared to TD group, the processes that met the five-time occurrence criterion appeared in the CS sample of all DS participants, except the CS sample for one DS participant in which only CR process occurred five times.

Quantitatively, the DS participants scored lower that TD participants in terms of six accuracy measures. These included PCC, PVC, PPC, number of occurrences of phonological processes, percentages of occurrence of processes and percentage of speech intelligibility. One-way between-participants ANCOVA was conducted to identify the difference between the two group and identify the type of onset and rate of development. Regarding the type of onset of performance, the results revealed that DS group performed at a delayed onset in terms of PCC, OVC, PPC, number of occurrence of processes, and percentage of speech intelligibility. Nonetheless, DS group developed at a typical rate in terms of these measures. In as far as the reliability of MA in predicting the performance of participants in both groups was concerned, the results showed that MA was a reliable predictor of performance in relation to PCC, PVC, PPC, except number of occurrence of processes in CS samples for TD group. On the other hand, MA was found to be an unreliable predictor of performance in terms of these measures including number of occurrence of processes in CS sample for DS group. Analysing the developmental trajectories for the two groups, TD and DS trajectories were parallel and positively trended in terms of PCC, PVC and PPC. This indicated that the participants in both groups increased production accuracy, although DS group started to crease production accuracy at delayed onsets in terms of these measures. Additional, TD and DS trajectories were parallel and negatively trended in terms of the number of occurrences of processes, although DS group started to reduce/ suppress the number of occurrences of processes at a delayed onset.

In as far as the percentages of occurrence of processes were concerned, the one-way between-participants ANCOVA results revealed that DS group performed at a delayed onset in terms of percentages of occurrence of gliding, CR, fronting, stopping, assimilation, MCD and FCD. Additionally, DS group performed at a rate slower than that for their MA-matched TD counterparts in relation to percentages of occurrence of voicing, assimilation and MCD.

On the other hand, the performance for DS group did not show a delay in the onset in relation to percentages of occurrence of deaffrication, WSD, voicing, ICD, backing and other processes. Similarly, DS group performed at a typical rate in terms of percentages of occurrence of gliding, deaffrication, CR, fronting, WSD, stopping, ICD, FCD, backing and other processes.

Investigating the effect of MA on performance for the two groups, the results of linear regression showed that MA was a non-significant predictor of performance for TD and DS groups in terms of percentages of occurrence of gliding, deaffrication, WSD, stopping, FCD, backing and other processes. Comparing the performance of the two groups, MA was a reliable predictor of performance in terms of percentages of occurrence of assimilation and MCD for DS group rather than TD group. Finally, MA was a non-significant predictor of performance in terms of percentages of occurrence of fronting, voicing and ICD in CS sample for DS group rather than TD group. Examining the developmental trajectories for the two groups, TD and DS trajectories were parallel and negatively-trended in terms of the percentages of occurrence of gliding, CR, fronting, WSD, stopping, assimilation, ICD, MCD and FCD. This suggested that the two groups continued to minimise percentage of occurrence of these processes. However, DS trajectory was positively trended in terms of percentages of occurrence of deaffrication, voicing, backing and other processes. This indicated that these processes continued to appear in the CS sample for DS group rather than TD group.

Chapter 6: Results III - Group Study

6.1 Introduction

The results explaining performance in SW samples compared to CS samples for TD and DS groups are presented in detail in the following sections.

6.2 Qualitative Measures in SW Samples Compared to CS Samples

6.2.1 Qualitative Measures: Phonological Processes in SW Sample Compared to CS Sample for TD Group

The type of phonological processes TD participants tended to use frequently in SW sample compared to those occurring in CS sample were analysed according to the criteria in DEAP-Assessment of Phonology (Dodd et al., 2002). The results for TD group showed that phonological processes which frequently occurred for five or more times appeared in SW speech samples of only five participants in TD group. On the other hand, the results showed that the processes used in CS samples which frequently occurred for five or more times appeared in CS speech samples of only five participants in TD group. The rest of participants in TD group either did not use any processes or used processes that were less frequent than five times. In SW and CS samples, the less frequent processes did not meet the five-time occurrence criterion and; therefore, were not considered as error patterns (see chapter 5, section 5.2.1, table 5.1).

6.2.2 Qualitative Measures: Phonological Processes in SW Sample Compared to CS Sample for DS Group

In SW samples, the participants with DS used phonological processes that occurred five times or more, except DS17, aged 10;9 years, who used 9 processes in total none of which met the five-time occurrence criterion. In SW sample of DS11, aged 6;0 years, six types of other processes occurred, for example replacing /k/ with a far back voiceless consonant /q/. The SW sample for DS14, aged 10;11, evidenced the occurrence of 5 types of other processes, for example the insertion of /s/, /d/, or /ə/. In CS samples, all participants with DS used phonological processes that occurred five times or more, except DS17 who used 13 processes in total. DS17, aged 10;9 years, evidenced the use of cluster reduction which met five-time occurrence criterion; while the other processes were less frequent than five times (see chapter 5, section 5.2.1, table 5.2).

6.3 Quantitative Measures in SW Samples Compared to CS Samples for TD Group

Before including MA as a covariate in the ANCOVA analysis, repeated measures t-test was also conducted to investigate the mean difference between SW and CS samples. The group factor was set as IV and the percentages of occurrence of 13 phonological processes were set as DVs in SW and in CS samples (see appendix C). To investigate the difference between SW and CS samples for TD group, one-way repeated-measures ANCOVA test was carried out. The non-verbal MA was set as the covariate. Linear regression was also run in order to analyse the developmental trajectories for each group in relation to non-verbal MA. The group factor was set as IV. In SW and CS samples, DVs included PCC, PVC, PPC, the number of occurrences of phonological processes and percentages of occurrence of phonological processes.

6.3.1 PCC, PVC and PPC in SW Sample Compared to CS Sample for TD Group

1. PCC

The descriptive analysis of PCC was presented (see table 6.1). The ANCOVA results showed a statistically significant difference in PCC in SW sample compared to CS sample [$F(1,18)=17.111$, $p=0.001$, $\eta^2=0.487$], suggesting a reliably higher performance at onset in SW sample rather than CS sample. The effect size was medium ($\eta^2=0.487$). However, there was a non-significant interaction between age and PCC scores [$F(1,18)=2.271$, $p=0.149$, $\eta^2=0.112$], suggesting a difference in the rate of development of PCC in the two conditions (see table 6.2). The results of linear regression revealed that MA was a non-significant predictor of performance in terms of PCC in SW sample [$R^2=0.162$, $F(1,19)=3.479$, $p=0.079$]. Yet, MA was a reliable predictor of performance in terms of PCC in CS sample [$R^2=0.216$, $F(1,19)=4.971$, $p=0.039$]. In SW sample for TD group, the intercept was 91.334% and the gradient was 0.1088 (see figure 6.1a). The confidence intervals around TD trajectory were between 85.56% and 97.10%. In CS sample for TD group, the intercept was 85.347% and the gradient was 0.1552 (see figure 6.1). The confidence intervals around TD trajectory were between 78.46% and 92.22%. The two trajectories were parallel and positively trended.

2. PVC

The descriptive analysis of PVC in SW sample compared to CS sample was presented (see table 6.1). The results of ANCOVA showed that a non-significant difference between SW and CS samples in terms of PVC [$F(1,18)=3.945$, $p=0.062$, $\eta^2=0.180$]. This indicated that TD participants produced PVC at the onset. The effect size was medium ($\eta^2=0.180$). Similarly, there was a non-significant PVC*MA interaction [$F(1,18)=1.755$, $p=0.202$, $\eta^2=0.089$], suggesting the rate of development of PVC in the two conditions was different (see table 6.2). The results of linear regression revealed that MA was a non-significant predictor of performance in terms of PVC in SW sample [$R^2=0.132$, $F(1,19)=2.735$, $p=0.116$]. However, MA was a non-significant predictor of performance on this task in CS sample [$R^2=0.188$, $F(1,19)=4.160$, $p=0.056$]. In SW sample for TD group, the intercept was 91.334% and the gradient was 0.1088 (see figure 6.1b). The confidence intervals around TD trajectory were between 85.56% and 97.10%. In CS sample for TD group, the intercept was 85.347% and the gradient was 0.1552 (see figure 6.1b). The confidence intervals around TD trajectory were between 78.46% and 92.22%. The two trajectories were approximately identical, although the rate of development of PVC was different in SW sample compared to CS sample for TD group.

3.PPC

The descriptive analysis of PPC in SW and CS samples was summarised (see table 6.1). The results of ANCOVA revealed a significant difference between SW and CS samples in terms of PPC for TD group [$F(1,18)=16.593$, $p=0.001$, $\eta^2=0.480$]. This indicated that TD performance in SW sample was better than in CS sample. The effect size was very large ($\eta^2=0.480$). However, there was a non-significant PPC*MA interaction [$F(1,18)=2.125$, $p=0.162$, $\eta^2=0.106$], suggesting the rate of development of PPC in the two conditions was different (see table 6.2). Linear regression tests were carried out. The results demonstrated that MA was non-significant predictor of performance in relation to PPC in SW sample for TD group [$R^2=0.152$, $F(1,19)=3.227$, $p=0.089$]. However, MA was a significant predictor of performance on this task in CS sample [$R^2=0.199$, $F(1,19)=4.246$. $p=0.054$]. In SW sample for TD group, the intercept was 94.59% and the gradient was 0.067 (see figure 6.1c). The confidence intervals around TD trajectory were between 90.61% and 98.27%. In CS sample for TD group, the intercept was 88.501% and the gradient was 0.1147 (see figure 6.1c). The confidence intervals around TD trajectory were between 82.99% and 94.00%. The trajectories of PPC in SW and CS samples for TD group were parallel and positively-trended.

Table 6.1 Descriptive analysis of PCC, PVC and PPC in SW sample compared to CS sample for TD group

Measure	Samples	Mean	*SD*	*SE*	Median	Range	Minimum	Maximum	95% CI for Mean	
									Lower Bound	Upper Bound
PCC	SW	95.90%	7.07	1.58	98%	30%	70%	100%	92.59%	99.21%
	CS	91.50%	8.67	1.94	95%	33%	66%	99%	87.44%	95.56%
PVC	SW	99.50%	0.88	0.19	100%	3%	97%	100%	99.08%	99.92%
	CS	99.15%	1.42	0.31	100%	5%	95%	100%	98.48%	99.82%
PPC	SW	97.25%	4.65	1.04	99%	20%	80%	100%	95.07%	99.43%
	CS	93.05%	6.83	1.52	96%	24%	75%	99%	89.85%	96.25%

Note: TD-Typically developing children. PCC-Percentage of consonants correct. PVC-Percentage of vowels correct. PPC-Percentage of phonemes correct. SW-Single word sample. CS-Connected speech sample. SD-Standard deviation. SE-Standard error. CI-Confidence intervals around the mean.

Table 6.2 Repeated measures ANCOVA results for PCC, PVC and PPC in SW sample compared to CS sample for TD group

Variable	*df*	Mean Square	*F*	*p*-value	Effect Size η^2
PCC	(1,18)	104.062	17.111	0.001	0.487
PCC*MA mya	(1,18)	13.810	2.271	0.149	0.112
PVC	(1,18)	1.852	3.945	0.062	0.180
PVC*MA mya	(1,18)	0.824	1.755	0.202	0.089
PPC	(1,18)	102.460	16.593	0.001	0.480
PPC*MA mya	(1,18)	13.124	2.125	0.162	0.106

Note: TD-Typically developing children. PCC-Percentage of consonants correct. PVC-Percentage of vowels correct. PPC-Percentage of phonemes correct. MA mya-Non-verbal mental age measured in months from youngest age in TD group.

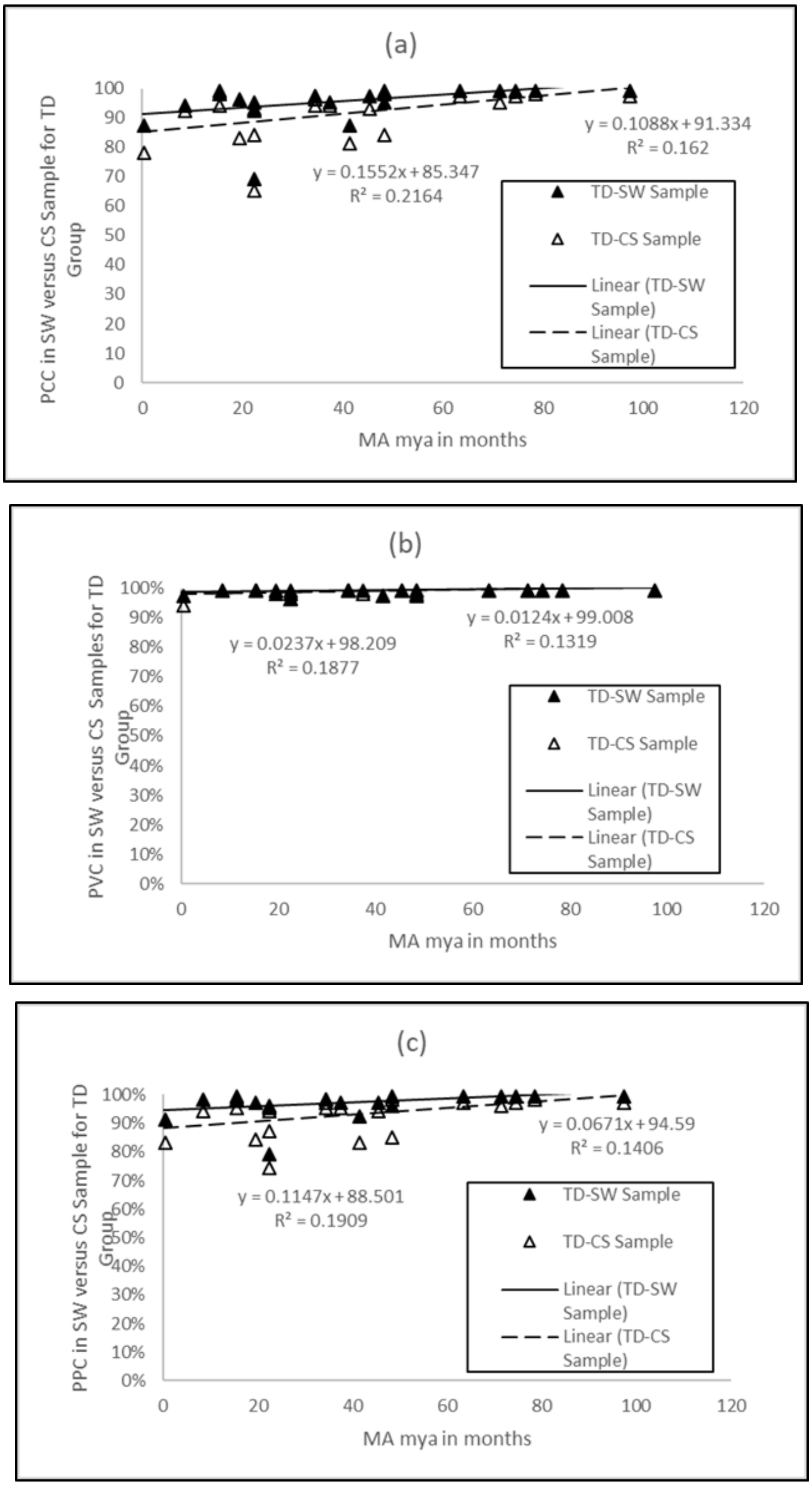


Figure 6.1(a-c). PCC, PVC and PPC in SW samples compared to CS samples for TD group. The figure (a) illustrates the trajectories of percentage of consonants correct (PCC). The figure (b) illustrates the developmental trajectories of percentage of vowels correct (PVC). The figure (c) Illustrates the trajectories of percentage phonemes correct (PPC). The developmental trajectory in single word (SW) sample is represented with a solid line. The developmental trajectory in connected speech (CS) sample is represented with a dotted line. MA mya represents rescaled nonverbal mental age measured form youngest age in months in the TD group.

6.3.2 Phonological Processes in SW Samples Compared to CS Samples for TD Group

The descriptive analysis of the number of occurrences of phonological processes was summarised (see table 6.3). The results ANCOVA indicated that SW and CS samples were significantly different in relation to the number of occurrences [$F(1,18)=9.012$, $p=0.008$, $\eta^2=0.334$]. This indicated that TD groups suppressed processes in CS samples at a delayed onset. The effect size was very large ($\eta^2=0.334$). However, there was a non-significant interaction between age and the total occurrences of processes scores [$F(1,18)=2.232$, $p=0.152$, $\eta^2=0.110$], suggesting the rate of occurrences of phonological processes in the two conditions was different (see table 6.4). The results of linear regression revealed that MA was a non-significant predictor of performance in relation to number of occurrences of processes in SW [$R^2=0.141$, $F(1,19)=2.959$, $p=0.103$] and CS [$R^2=0.170$, $F(1,19)=3.682$, $p=0.071$] samples for TD group. In SW sample, the intercept was 23.267 and the gradient was 0.3018 (see figure 6.2). The confidence intervals around TD trajectory were between 5.91 and 40.61. In CS sample, the intercept was 29.122 and the gradient was 0.3637 (see figure 6.2). The confidence intervals around TD trajectory were between 10.37 and 47.86. The trajectories of SW and CS samples were parallel and negatively-trended, indicating that TD group continued to suppress the occurrence of processes in the two conditions. Yet, in CS sample TD participants started to suppress processes at a delayed onset.

Table 6.3 Descriptive analysis of number of occurrences of phonological processes in the SW sample compared to CS sample for TD group

Variables	Samples	Mean	*SD*	*SE*	Median	Range	Minimum	Maximum	95% CI for Mean	
									Lower Bound	Upper Bound
Number of Occurrences of Processes	SW	11.30	20.89	4.87	5	90	0	90	1.52	21.07
	CS	14.70	22.96	5.31	8	95	0	95	3.95	25.45

Note: TD-Typically developing children. SW-Single word speech sample. CS-Connected speech sample.

Table 6.4 ANCOVA results for number of occurrences of phonological processes in SW sample compared to CS sample for TD group

Variables	df	Mean Square	*F*	*p*-value	Effect Size η^2
Number of Occurrences of Processes	(1,18)	99.506	9.012	0.008	0.334
Number of Occurrences of Processes*MA mya	(1,18)	24.650	2.232	0.152	0.110

Note: MA mya-Nonverbal mental age measured in months in TD group.

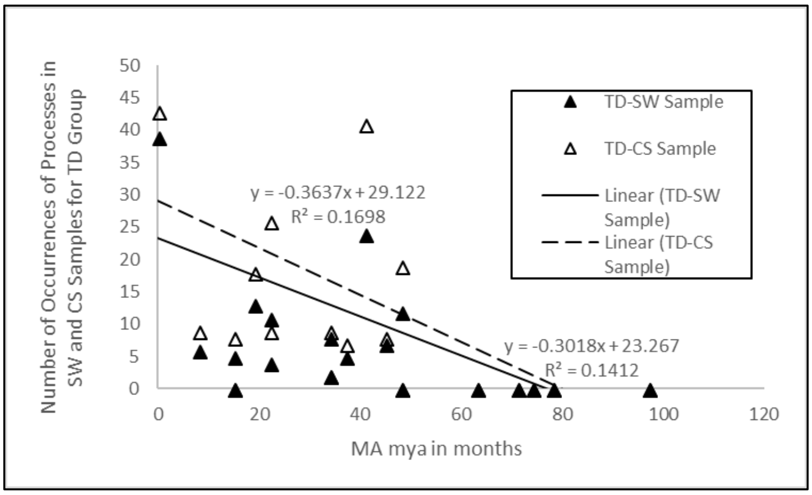


Figure 6.2. The number of occurrences of phonological processes in SW sample compared to CS sample for TD group. The figure illustrates the developmental trajectories of number of occurrences of phonological processes. The trajectory for single speech (SW) is represented with a solid line. The trajectory for connected speech (CS) sample is represented with a dotted line. MA mya represents nonverbal mental age measured form youngest age in months in the TD group.

In SW sample for TD group, the most frequently occurring processes were 3 processes. These included CR, fronting and ICD. However, the less frequent processes appeared in TD participants' speech with percentages of occurrence <1%. These included gliding, deaffrication, WSD, stopping, voicing, assimilation, MCD, FCD, backing and other processes (see table 6.5). On the other hand, in CS sample for TD group, the most frequently occurring processes were 4 processes. These included CR, fronting, ICD and stopping. However, the less frequent processes with percentages of occurrence <1% included deaffrication, WSD, voicing, MCD, FCD, assimilation, backing, gliding and other processes (see table 6.5).

Table 6.5 Descriptive analysis of percentages of occurrence of phonological processes in SW sample compared to CS sample for TD group

Processes	Samples	Mean	*SD*	*SE*	Median	Range	Minimum	Maximum	95% CI for Mean	
									Lower Bound	Upper Bound
Gliding	SW	0.30%	0.97	0.21	0%	4%	0%	4%	0.16%	0.76%
	CS	0.95%	1.66	0.37	0%	6%	0%	6%	0.17%	1.73%
Deaffrication	SW	0.30%	1.12	0.25	0%	5%	0%	5%	0.23%	0.83%
	CS	0.50%	1.27	0.28	0%	5%	0%	5%	0.10%	1.10%
CR	SW	2.35%	4.85	1.08	0%	19%	0%	19%	0.08%	4.62%
	CS	4.15%	6.02	1.34	2.50%	23%	0%	23%	1.33%	6.97%
Fronting	SW	3.05%	5.96	1.33	1%	25%	0%	25%	0.26%	5.84%
	CS	3.95%	7.44	1.66	1.50%	31%	0%	31%	0.47%	7.43%
WSD	SW	0.35%	0.18	0.18	0%	3%	0%	3%	0.03%	0.73%
	CS	0.85%	1.59	0.35	0%	6%	0%	6%	0.10%	1.60%
Stopping	SW	0.90%	3.79	0.84	0%	17%	0%	17%	0.88%	2.68%
	CS	1.15%	4.48	1.00	0%	20%	0%	20%	0.95%	3.25%
Voicing	SW	0.55%	0.78	0.19	0%	2%	0%	2%	0.13%	0.97%
	CS	0.05%	0.22	0.05	0%	1%	0%	1%	0.05%	0.15%
Assimilation	SW	0.70%	0.73	0.16	1%	3%	0%	3%	0.36%	1.04%
	CS	0.85%	1.18	0.26	0%	4%	0%	4%	0.30%	1.40%
ICD	SW	1.00%	1.21	0.27	0%	3%	0%	3%	0.43%	1.57%
	CS	1.50%	1.96	0.43	0%	5%	0%	5%	0.58%	2.42%
MCD	SW	0.25%	0.63	0.14	0%	2%	0%	2%	0.05%	0.55%
	CS	0.35%	0.67	0.15	0%	2%	0%	2%	0.04%	0.66%
FCD	SW	0.85%	1.46	0.32	0%	5%	0%	5%	0.17%	1.53%
	CS	0.95%	1.76	0.39	0%	5%	0%	5%	0.13%	1.77%
Backing	SW	0.80%	2.89	0.64	0%	13%	0%	13%	0.55%	2.15%
	CS	1.10%	4.03	0.90	0%	18%	0%	18%	0.79%	2.99C%
Other Processes	SW	0.65%	2.90	0.65	0%	13%	0%	13%	0.71%	2.01%
	CS	0.90%	4.02	0.90	0%	18%	0%	18%	0.98%	2.78%

Note: TD-Typically developing children. CR-Cluster reduction. WSD-Weak syllable deletion. ICD-Initial consonant deletion. MCD-Medial consonant deletion. FCD-Final consonant deletion. SW-single word speech sample. CS-connected speech sample. SD-Standard deviation. SE-Standard error. CI-Confidence limits around the mean.

The percentages of occurrence of 4 processes were found to be significantly different in SW sample compared to CS sample for TD group. These included gliding, CR, fronting and ICD. The results for all processes were summarised (see tables 6.6. and 6.7).

1. **Gliding**

The results of ANCOVA revealed that the percentage of occurrence of gliding was significantly was significantly different in SW sample compared to CS sample for TD group [$F(1,18)=6.764$, $p=0.018$, $\eta^2=0.273$]. This indicated that TD group continued to use gliding in CS sample at a delayed onset. The effect size was large ($\eta^2=0.273$). However, there was a non-significant gliding*MA interaction [$F(1,18)=1.406$, $p=0.251$, $\eta^2=0.072$], suggesting the rate of occurrence of gliding in the two conditions was different (see table 6.6). The results of linear regression showed that MA was not a reliable predictor of performance in terms of percentage of occurrence of gliding in SW sample [$R^2=0.004$, $F(1,19)=0.069$, $p=0.796$] and in CS sample [$R^2=0.038$, $F(1,19)=0.716$, $p=0.409$]. In SW sample for TD group, the intercept was 0.3922% and the gradient was 0.0023 (see figure 6.3a). The confidence intervals around SW sample trajectory were between 0.48% and 1.26% (see table 6.7). In CS sample for TD group, the intercept was 1.4475% and the gradient was 0.0125 (see figure 6.3a). The confidence intervals around CS sample trajectory were between 0.019% and 2.914% (see table 6.7). As plotted data suggested, the trajectories for SW and CS samples were different. SW trajectory was negatively-trended, indicating that TD participants continued to suppress gliding processes in SW sample. However, CS trajectory was positive-trended, suggesting that TD participants continued to use gliding in CS sample.

2. **Cluster Reduction**

The results of ANCOVA indicated that there was a significant difference between SW and CS samples in terms of percentage of occurrence of CR [$F(1,18)=18.180$, $p=0.001$, $\eta2=0.502$]. This demonstrated that TD group started to suppress CR in CS sample at a delayed onset. The effect size was very large ($\eta2=0.502$). Similarly, there was a significant CR*MA interaction [$F(1,19)=4.515$, $p=0.048$, $\eta2=0.201$], suggesting that TD group continued to suppress CR in SW and CS samples at a similar rate. The effect size was large ($\eta2=0.201$) (see table 6.6). The results of linear regression showed that MA was a non-significant predictor of performance of this task in SW sample [$R^2=0.119$, $F(1.19)=2.439$, $p=0.136$] and CS sample [$R^2=0.177$, $F(1,19)=3.872$, $p=0.065$]. In SW sample for TD group, the intercept was 4.908%

and the gradient was 0.0645 (see figure 6.3c). The confidence intervals around TD trajectory were between 0.82% and 8.99% (see table 6.7). In CS sample for TD group, the intercept was 8.010% and the gradient was 0.0974 and the effect size was 0.397 (see figure 6.3c). The confidence intervals around TD trajectory were between 0.82% and 8.99% (see table 6.7). The SW and CS trajectories were parallel and negatively-trended, indicating that TD participants continued to suppress CR in SW and CS samples. Yet, TD participants started suppressing CR at a delayed onset in CR.

3. Fronting

SW and CS samples were significantly different in terms of percentage of occurrence of fronting [$F(1,18)=6.724$, $p=0.018$, $\eta^2=0.272$]. This indicated that TD group suppressed fronting in CS sample at a delayed onset. The effect size was large ($\eta^2=0.272$). However, there was a non-significant fronting*MA interaction [$F(1,18)=2.858$, $p=0.108$, $\eta^2=0.137$], suggesting the rate of suppressing fronting in the two conditions was different (see tables 6.6). The results of linear regression showed that MA was a reliable predictor of performance on this task in SW sample [$R^2=0.232$, $F(1,19)=5.424$, $p=0.032$] and CS sample [$R^2=0.232$, $F(1,19)=5,446$, $p=0.031$]. In SW sample for TD group, the intercept was 7.4214% and the gradient was 0.1102 (see figure 6.3d). The confidence intervals around TD trajectory were between 2.74% and 12.10% (see table 6.7). In CS sample for TD group, the intercept was 9.4182% and the gradient was 0.1379 (see figure 6.3d). The confidence intervals around TD trajectory were between 3.57% and 15.26% (see table 6.7). the SW and CS samples trajectories were parallel and negatively-trended, indicating that TD participants continued to reduce the occurrence of fronting process.

4. Initial Consonant Deletion

The results of ANCOVA indicated that there was a significant difference between SW and CS samples in terms of percentage of occurrence of ICD [$F(1,18)=7.441$, $p=0.014$, $\eta^2=0.292$]. This indicated that TD group started suppressing ICD in CS sample at a delayed onset. The effect size was large ($\eta^2=0.292$). However, there was a non-significant ICD*MA interaction [$F(1,18)=3.639$, $p=0.073$, $\eta^2=0.168$], suggesting the rate of use of initial consonant deletion in the two conditions was different (see tables 6.6). The results of linear regression showed that MA was a statistically reliable predictor of performance in terms of percentage of occurrence of ICD in SW sample [R^2=0.274, F(1,19)=6.788, p=0.018] and CS sample [R^2=0.318, F(1,19)=8.400, p=0.010]. In SW sample for TD group, the intercept was 1.9682% and the gradient was 0.0244 (see figure 6.3i). The confidence intervals around TD trajectory were between 0.621% and 1.791% (see table 6.7). In CS sample for TD group, the intercept was 3.1852% and the gradient was 0.0425 and effect size was 0.542 (see figure 6.3i). The confidence intervals around TD trajectory were between 0.212% and 2.278% (see table 6.7). The SW and CS trajectories were parallel and negatively-trended, indicating that TD participants continued to suppress ICD, although they started to suppress this process in CS sample at a delayed onset.

6.3.3 Summary of SW Sample Compared to CS Sample for TD Group

The comparison between SW and CS samples for TD group revealed that the performance of TD participants in SW sample was higher than that in CS sample in terms of PCC and PPC, but not in terms of PVC which was similar in both conditions. TD participants produced PCC and PPC in CS sample at a delayed onset and at a rate slower than that in SW sample. On the other hand, TD participants produced PVC at similar onset and rate in both condition. The no-verbal MA was a non-significant predictor of performance in terms of PVC and PPC in both condition. Yet, MA was a reliable predictor of performance in terms of PCC and PPC in CS samples rather than in SW sample. Regarding percentages of occurrence of processes, the results showed that gliding, CR, fronting and ICD were significantly different in SW sample compared to CS sample. TD participants continued to suppress/use gliding, fronting and ICD in CS sample at a delayed onset. Additionally, they tended to suppress/use gliding, fronting and ICD in CS sample at a slower rate than in SW sample. TD participants started to suppress CR in CS sample at a delayed onset, although they continued to suppress the occurrence of CR at a similar rate in both samples. The non-verbal MA was a non-significant predictor of performance in terms of percentages of occurrence of gliding and CR in SW and CS samples, whereas MA was a reliable predictor of performance in terms of percentages of occurrence of fronting and ICD in both samples.

Table 6.6 ANCOVA results for percentages of occurrence of phonological processes in SW sample compared to CS sample for TD group

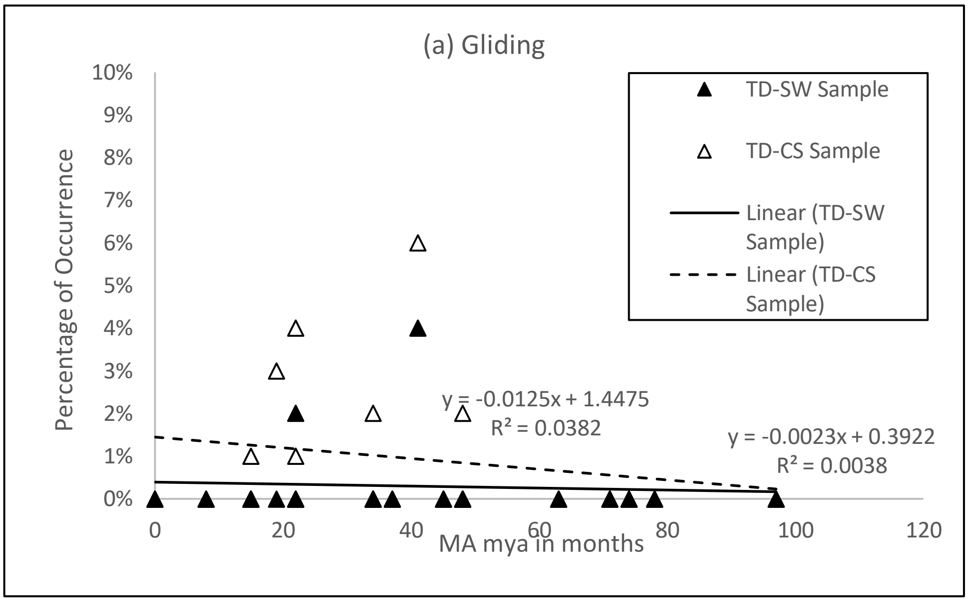
Variables	*df*	Mean Square	*F*	*p*-value	Effect Size η^2
Gliding	(1,18)	3.233	6.764	0.018	0.273
Gliding*MA mya	(1,18)	0.672	1.406	0.251	0.072
Deaffrication	(1,18)	0.693	2.929	0.104	0.140
Deaffrication*MA mya	(1,18)	0.341	1.440	0.246	0.074
CR	(1,18)	27.938	18.180	0.001	0.502
CR*MA mya	(1,18)	6.938	4.515	0.048	0.201
Fronting	(1,18)	11.573	6.724	0.018	0.272
Fronting*MA mya	(1,18)	4.920	2.858	0.108	0.137
WSD	(1,18)	0.076	0.604	0.447	0.032
WSD*MA mya	(1,18)	0.001	0.005	0.946	0.000
Stopping	(1,18)	0.476	1.483	0.239	0.076
Stopping*MA mya	(1,18)	0.098	0.306	0.587	0.017
Voicing	(1,18)	1.475	3.160	0.092	0.149
Voicing*MA mya	(1,18)	0.697	1.493	0.237	0.077
Assimilation	(1,18)	0.004	0.011	0.918	0.001
Assimilation*MA mya	(1,18)	0.051	0.126	0.727	0.007
ICD	(1,18)	4.298	7.441	0.014	0.292
ICD*MA mya	(1,18)	2.102	3.639	0.073	0.168
MCD	(1,18)	0.010	0.092	0.765	0.005
MCD*MA mya	(1,18)	0.007	0.069	0.795	0.004
FCD	(1,18)	0.007	0.004	0.951	0.000
FCD*MA mya	(1,18)	0.092	0.049	0.827	0.003
Backing	(1,18)	1.897	2.618	0.123	0.127
Backing*MA mya	(1,18)	1.057	1.459	0.243	0.075
Other Processes	(1,18)	0.791	1.231	0.282	0.064
Other Processes*MA mya	(1,18)	0.303	0.471	0.501	0.026

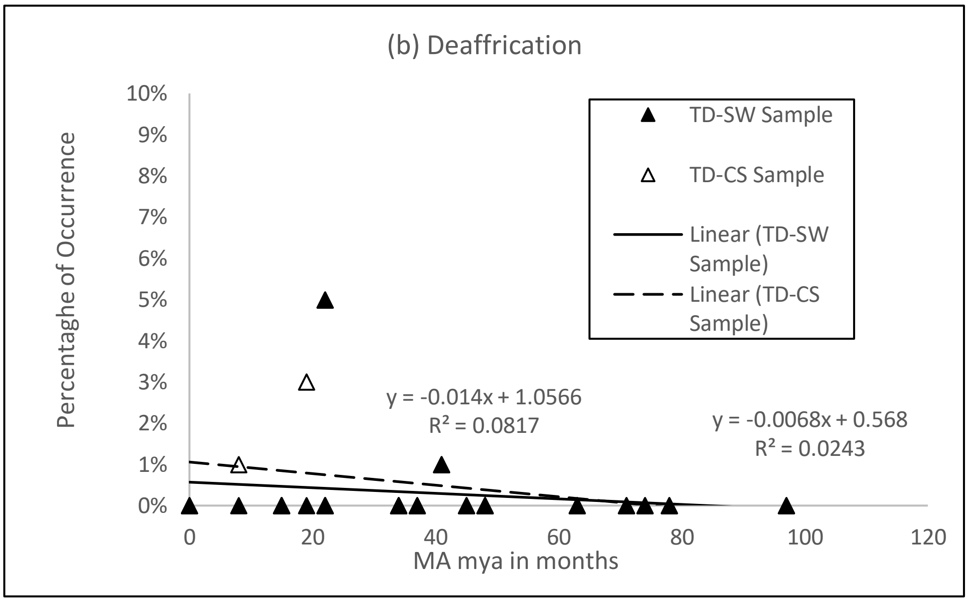
Note: TD-Typically children. CR-Cluster reduction. WSD-Weak syllable deletion. ICD-Initial consonant deletion. MCD-Medial consonant deletion. FCD-Final consonant deletion. SW-Single word speech sample. CS-Connected speech sample. MA mya-Nonverbal mental age measured in months from youngest age in TD group.

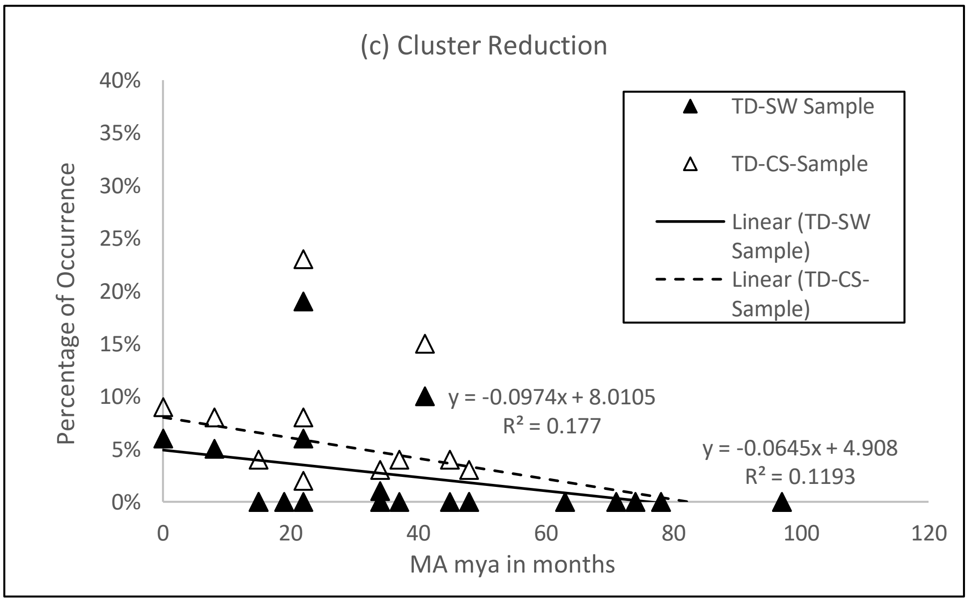
Table 6.7 Intercepts of percentages of occurrence of phonological processes in SW sample compared to CS sample for TD group

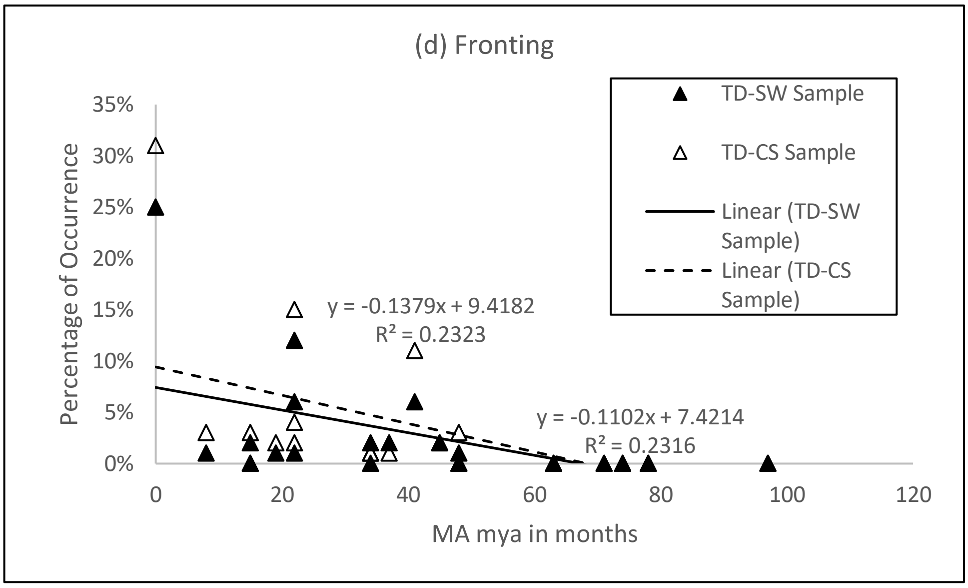
Variables	Samples	Intercept	*SE*	*t*	*p*-value	95% CI Lower Bound	95% CI Upper Bound	Effect Size η^2
Gliding	SW	0.392%	0.41	0.94	0.359	0.48%	1.26%	0.047
	CS	1.448%	0.69	2.07	0.053	0.01%	2.91%	0.193
Deaffrication	SW	0.568%	0.47	1.19	0.248	0.43%	1.56%	0.073
	CS	1.057%	0.52	2.02	0.058	0.04%	2.15%	0.185
CR	SW	4.908%	1.94	2.52	0.021	0.82%	8.99%	0.261
	CS	8.010%	2.32	3.44	0.003	3.11%	12.90%	0.397
Fronting	SW	7.421%	2.22	3.33	0.004	2.74%	12.10%	0.381
	CS	9.418%	2.78	3.38	0.003	3.57%	15.26%	0.389
WSD	SW	0.796%	0.323	2.461	0.024	0.11%	1.47%	0.252
	CS	0.958%	0.430	2.230	0.039	0.05%	1.86%	0.216
Stopping	SW	1.821%	1.598	1.140	0.269	1.53%	5.17%	0.067
	CS	2.226%	1.890	1.178	0.254	1.74%	6.19%	0.072
Voicing	SW	1.207%	0.331	3.652	0.002	0.51%	1.90%	0.426
	CS	1.920%	0.612	3.136	0.006	0.63%	3.20%	0.353
Assimilation	SW	1.206%	0.279	4.330	0.000	0.62%	1.79%	0.510
	CS	1.245%	0.492	2.531	0.021	0.21%	2.27%	0.262
ICD	SW	1.968%	0.441	4.462	0.000	1.04%	2.89%	0.525
	CS	3.185%	0.690	4.615	0.000	1.73%	4.63%	0.542
MCD	SW	0.658%	0.247	2.660	0.016	0.13%	1.17%	0.282
	CS	0.716%	0.267	2.679	0.015	0.15%	1.27%	0.285
FCD	SW	1.976%	0.537	3.676	0.002	0.84%	3.10%	0.429
	CS	1.925%	0.700	2.752	0.013	0.45%	3.39%	0.296
Backing	SW	1.655%	1.211	1.367	0.188	0.88%	4.19%	0.094
	CS	2.464%	1.679	1.467	0.160	1.06%	5.99%	0.107
Other Processes	SW	1.358%	1.224	1.109	0.282	1.21%	3.92%	0.064
	CS	1.880%	1.694	1.109	0.282	1.68%	5.43%	0.064

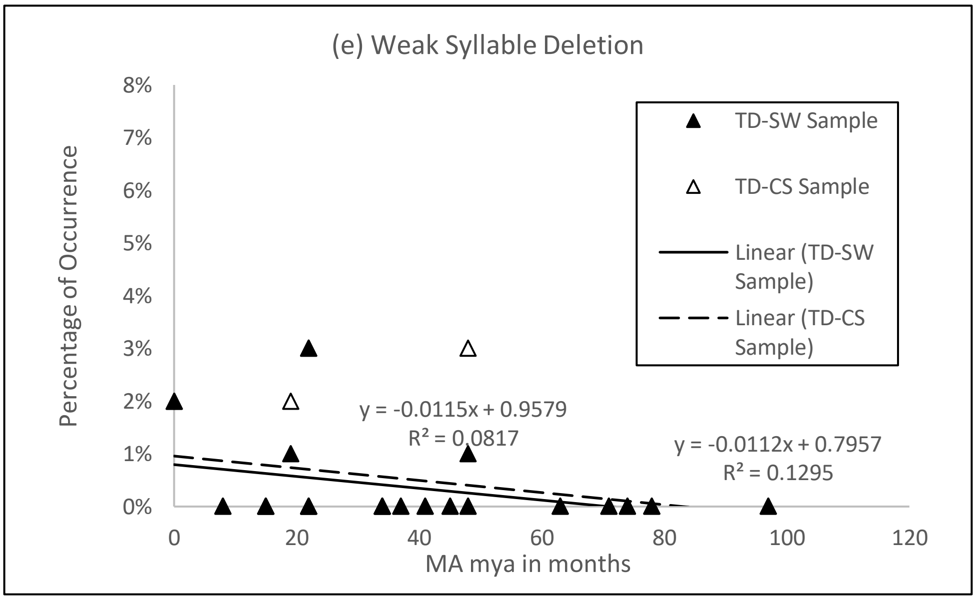
Note: TD-Typically developing children. CR-Cluster reduction. WSD-Weak syllable deletion. ICD-Initial consonant deletion. MCD-Medial consonant deletion. FCD-Final consonant deletion. SW-Single word speech sample. CS-Connected speech sample.

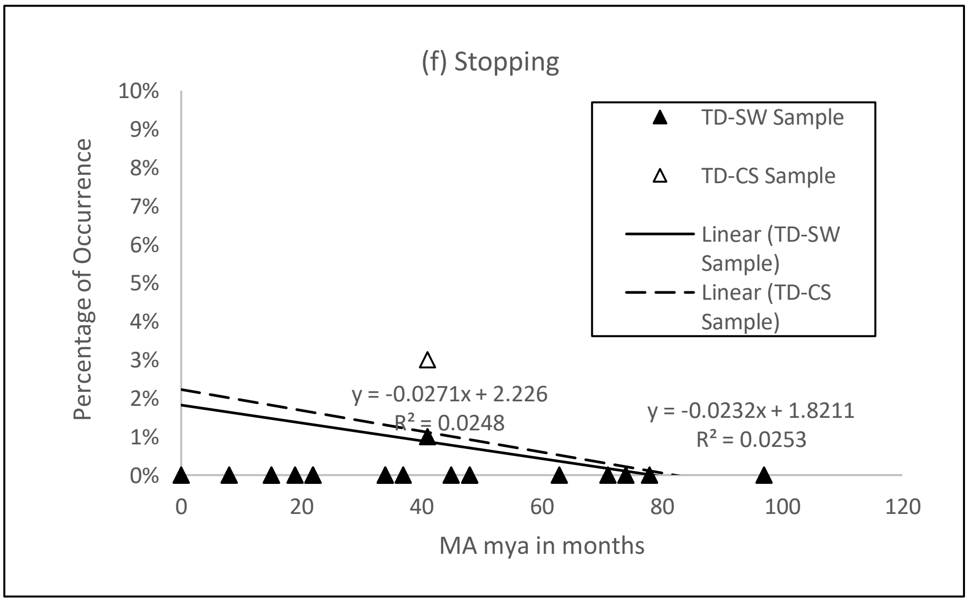

(a) Gliding
Percentage of Occurrence
10%
9%
8%
7%
6%
5%
4%
3%
2%
1%
0%
0
20
40
60
80
100
120
MA mya in months
TD-SW Sample
TD-CS Sample
Linear (TD-SW Sample)
Linear (TD-CS Sample)
y = -0.0125x + 1.4475
R² = 0.0382
y = -0.0023x + 0.3922
R² = 0.0038

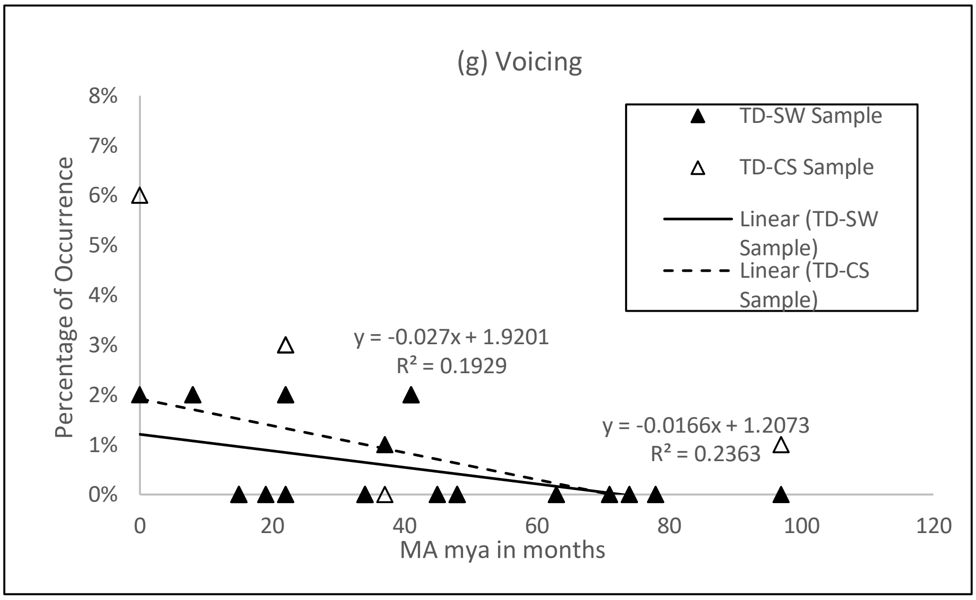

(b) Deaffrication
Percentaghe of Occurrence
10%
9%
8%
7%
6%
5%
4%
3%
2%
1%
0%
0
20
40
60
80
100
120
MA mya in months
TD-SW Sample
TD-CS Sample
Linear (TD-SW Sample)
Linear (TD-CS Sample)
y = -0.014x + 1.0566
R² = 0.0817
y = -0.0068x + 0.568
R² = 0.0243


(c) Cluster Reduction
Percentage of Occurrence
40%
35%
30%
25%
20%
15%
10%
5%
0%
0
20
40
60
80
100
120
MA mya in months
TD-SW Sample
TD-CS-Sample
Linear (TD-SW Sample)
Linear (TD-CS-Sample)
y = -0.0974x + 8.0105
R² = 0.177
y = -0.0645x + 4.908
R² = 0.1193

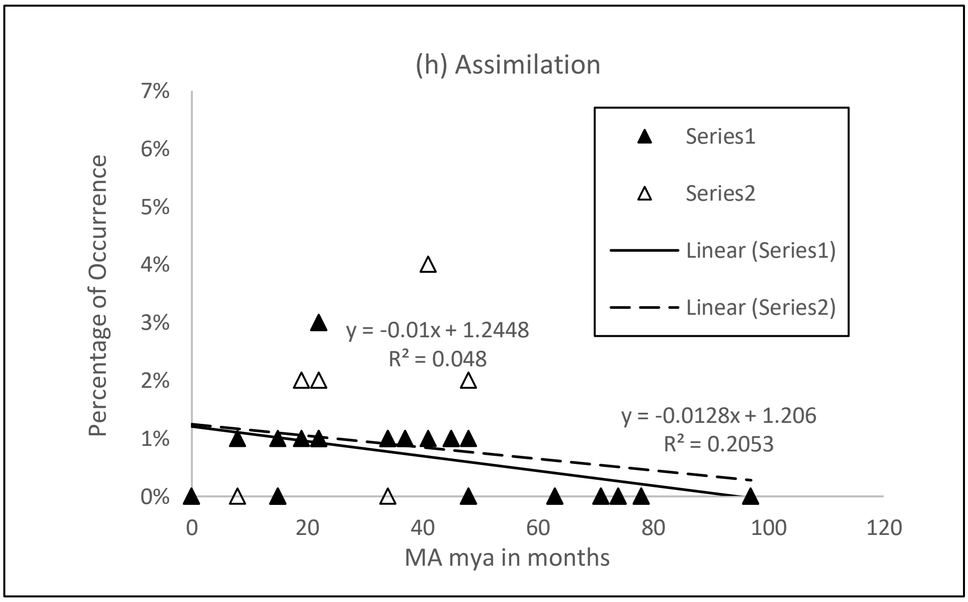

(d) Fronting
TD-SW Sample
TD-CS Sample
Linear (TD-SW Sample)
Linear (TD-CS Sample)
y = -0.1379x + 9.4182
R² = 0.2323
y = -0.1102x + 7.4214
R² = 0.2316
Percentage of Occurrence
35%
30%
25%
20%
15%
10%
5%
0%
0
20
40
60
80
100
120
MA mya in months


(e) Weak Syllable Deletion
TD-SW Sample
TD-CS Sample
Linear (TD-SW Sample)
Linear (TD-CS Sample)
y = -0.0115x + 0.9579
R² = 0.0817
y = -0.0112x + 0.7957
R² = 0.1295
Percentage of Occurrence
8%
7%
6%
5%
4%
3%
2%
1%
0%
0
20
40
60
80
100
120
MA mya in months

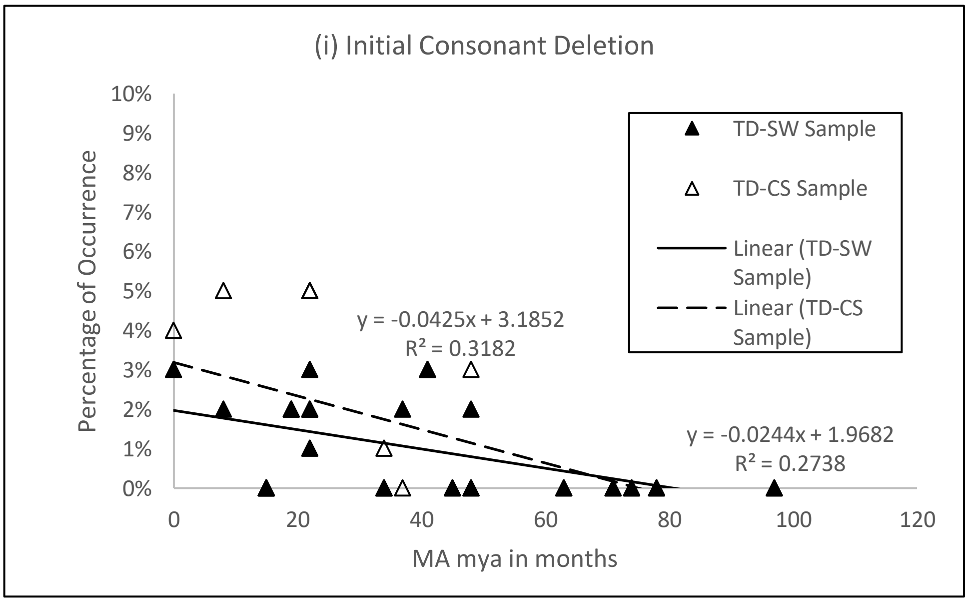

(f) Stopping
TD-SW Sample
TD-CS Sample
Linear (TD-SW Sample)
Linear (TD-CS Sample)
y = -0.0271x + 2.226
R² = 0.0248
y = -0.0232x + 1.8211
R² = 0.0253
Percentage of Occurrence
10%
9%
8%
7%
6%
5%
4%
3%
2%
1%
0%
0
20
40
60
80
100
120
MA mya in months



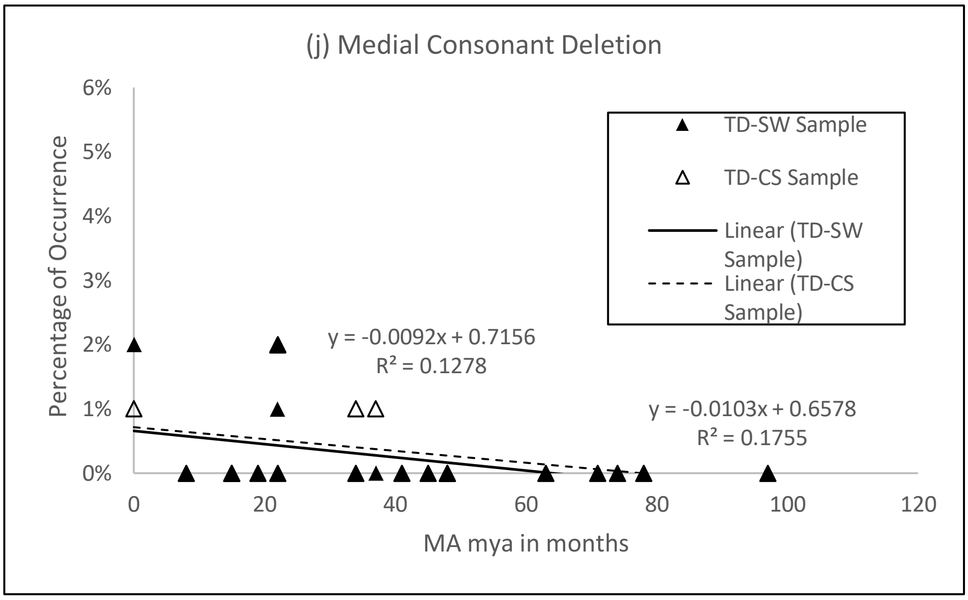
(g) Voicing
Percentage of Occurrence
8%
7%
6%
5%
4%
3%
2%
1%
0%
0
20
40
60
80
100
120
MA mya in months
TD-SW Sample
TD-CS Sample
Linear (TD-SW Sample)
Linear (TD-CS Sample)
y = -0.027x + 1.9201
R² = 0.1929
y = -0.0166x + 1.2073
R² = 0.2363

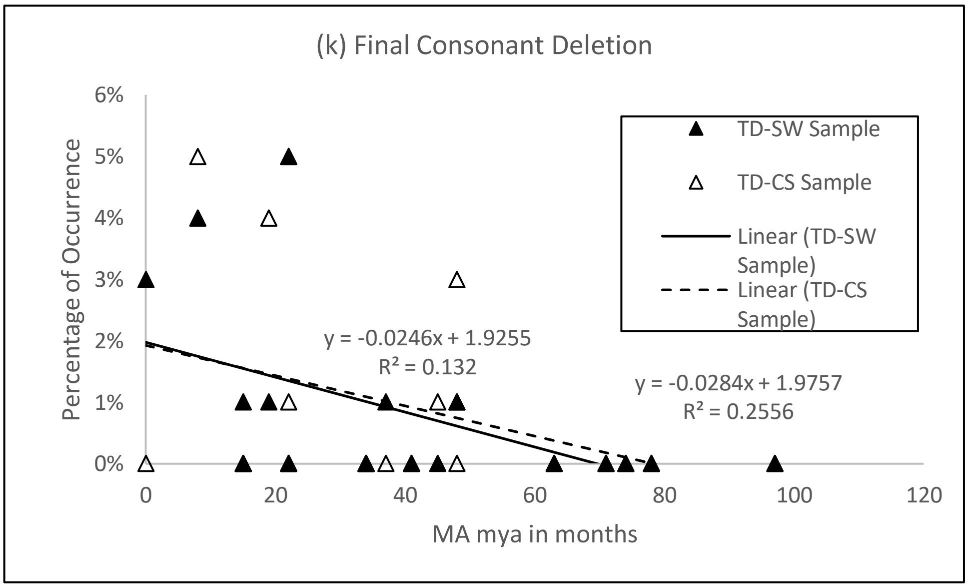


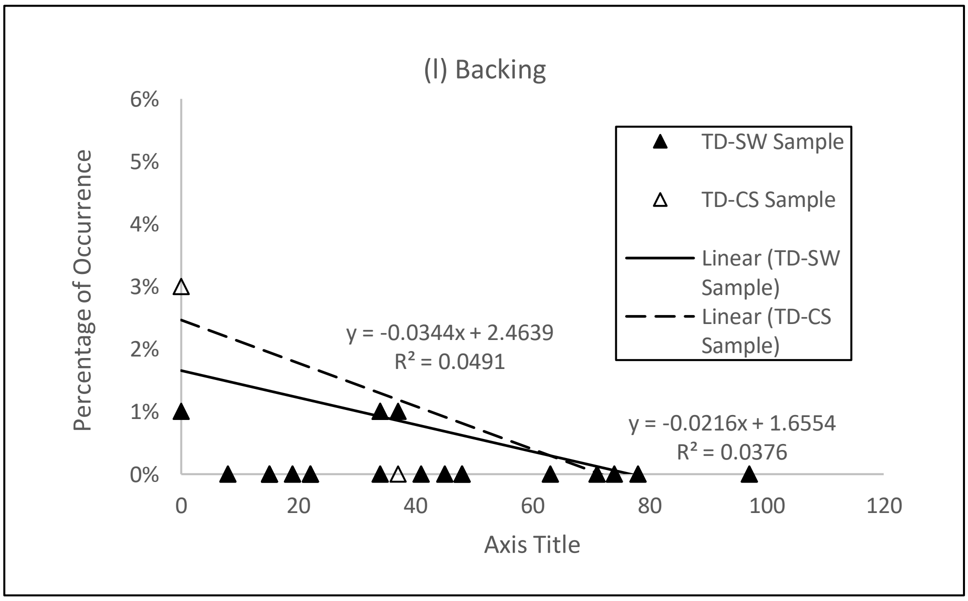
(h) Assimilation
Percentage of Occurrence
7%
6%
5%
4%
3%
2%
1%
0%
0
20
40
60
80
100
120
MA mya in months
Series1
Series2
Linear (Series1)
Linear (Series2)
y = -0.01x + 1.2448
R² = 0.048
y = -0.0128x + 1.206
R² = 0.2053



(i) Initial Consonant Deletion
Percentage of Occurrence
10%
9%
8%
7%
6%
5%
4%
3%
2%
1%
0%
0
20
40
60
80
100
120
MA mya in months
TD-SW Sample
TD-CS Sample
Linear (TD-SW Sample)
Linear (TD-CS Sample)
y = -0.0425x + 3.1852
R² = 0.3182
y = -0.0244x + 1.9682
R² = 0.2738


(j) Medial Consonant Deletion
Percentage of Occurrence
6%
5%
4%
3%
2%
1%
0%
0
20
40
60
80
100
120
MA mya in months
TD-SW Sample
TD-CS Sample
Linear (TD-SW Sample)
Linear (TD-CS Sample)
y = -0.0092x + 0.7156
R² = 0.1278
y = -0.0103x + 0.6578
R² = 0.1755


(k) Final Consonant Deletion
Percentage of Occurrence
6%
5%
4%
3%
2%
1%
0%
0
20
40
60
80
100
120
MA mya in months
TD-SW Sample
TD-CS Sample
Linear (TD-SW Sample)
Linear (TD-CS Sample)
y = -0.0246x + 1.9255
R² = 0.132
y = -0.0284x + 1.9757
R² = 0.2556


(l) Backing
Percentage of Occurrence
6%
5%
4%
3%
2%
1%
0%
0
20
40
60
80
100
120
Axis Title
TD-SW Sample
TD-CS Sample
Linear (TD-SW Sample)
Linear (TD-CS Sample)
y = -0.0344x + 2.4639
R² = 0.0491
y = -0.0216x + 1.6554
R² = 0.0376

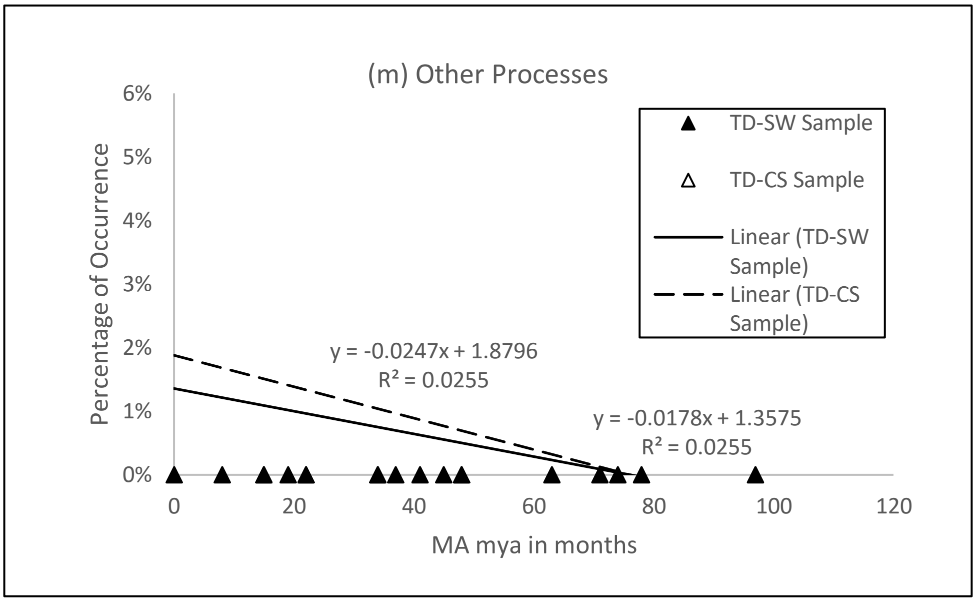


Figure 6.3(a-m). Percentage of occurrence of phonological processes in SW sample compared to CS sample for TD group. Each figure illustrates the developmental trajectories of percentage of occurrence of a phonological processes represented with a solid line in single word (SW) samples, and represented by a dotted line in connected speech (CS) samples for TD group. MA mya represents rescaled nonverbal mental age measured form youngest age in months in the typically developing group.

6.4 Quantitative Measures in SW Samples Compared to CS Samples for DS Group

Before including MA as a covariate in the ANCOVA analysis, repeated measures t-test was also conducted to investigate the mean difference between SW and CS samples. The group factor was set as IV and the percentages of occurrence of 13 phonological processes were set as DVs in SW and in CS samples (see appendix C). To investigate the difference between SW and CS samples for DS group, one-way repeated-measures ANCOVA test was carried out. The non-verbal MA was set as the covariate. Linear regression was also run in order to analyse the developmental trajectories for each group in relation to non-verbal MA. The group factor was set as IV. In SW and CS samples, DVs included PCC, PVC, PPC, the number of occurrences of phonological processes and percentages of occurrence of phonological processes.

6.4.1 PCC, PVC and PPC in SW Samples Compared to CS Samples for DS Group

1. PCC

The descriptive analysis of PCC in SW sample compared to CS sample for DS group was summarised (see table 6.8). The ANCOVA results revealed that SW and CS samples were significantly different in terms of PCC [$F(1,15)=12.941$, $p=0.003$, $\eta^2=0.454$]. This indicated that DS participants produced PCC in CS at a delayed onset. The effect size was very large ($\eta^2=0.454$). However, there was a non-significant PCC*MA interaction [$F(1,15)=0.735$, $p=0.405$, $\eta^2=0.047$], suggesting that the rate of development of PCC in the two conditions was different (see table 6.9). The results of linear regression manifested that MA was a non-significant predictor of performance in terms of PCC in SW sample [$R^2=0.005$, $F(1,16)=0.071$, $p=0.794$] and CS sample [$R^2=0.000$, $F(1,16)=0.001$, $p=0.073$]. In SW sample for DS group, the intercept was 77.32% and the gradient was 0.0205 (see figure 6.4a). The confidence intervals around DS trajectory were between 70.39% and 84.24%. In CS sample for DS group, the intercept was 73.324% and the gradient was 0.0025 (see figure 6.4a). The confidence intervals around DS trajectory were between 66.79% and 79.85%. Examining the trajectories for DS group, SW and CS samples trajectories were different. SW sample trajectory was positively-trended, indicating that DS group continued to produce correct consonants in SW sample. On the contrary, CS trajectory was negatively-trended, suggesting that production of correct consonants proceeded to decrease in CS sample.

2. PVC

The descriptive analysis of PVC in SW and CS samples for DS group was summarised (see table 6.8). The ANCOVA results showed that there was a non-significant difference between SW and CS samples in terms of PVC [$F(1,15)=0.465$, $p=0.506$, $\eta^2=0.030$]. This indicated that DS group started producing PVC in SW and CS samples at the same onset. There was also a non-significant PVC*MA interaction [$F(1,15)=0743.$, $p=0.402$, $\eta^2=0.047$], suggesting that the rate of development of PVC in CS sample was slower than that in SW sample for DS group (see table 6.9). Linear regression was run. The results demonstrated that MA was marginally significant in predicting performance in terms pf PVC in SW sample [$R^2=0.173$, $F(1,16)=3.129$, $p=0.097$] and CS sample [$R^2=0.119$, $F(1,16)=2.032$, $p=0.175$]. In SW sample for DS group, the intercept was 96.024% and the gradient was 0.0139 (see figure 6.4b). The confidence intervals around DS trajectory were between 70.39% and 84.24%. In CS sample for DS group, the intercept was 95.657% and the gradient was 0.0209 (see figure 6.4b). The confidence intervals around DS trajectory were between 66.79% and 79.85%. Both trajectories were positively-trended, although DS participants continued to produce PVC at a slower rate in CS sample rather than SW sample.

3. PPC

The descriptive analysis of PVC in SW and CS samples for DS group was summarised (see table 6.8). The ANCOVA results showed a significant difference between SW and CS samples in relation to PPC [$F(1,15)=42.581$, $p=0.001$, $\eta^2=0.739$]. This indicated that DS participants produced PPC in CS sample at a delayed onset. The effect size was very large ($\eta^2=0.739$). However, there was a non-significant PPC*MA interaction [$F(1,15)=0.788$, $p=0.389$, $\eta^2=0.050$], suggesting the rate of development of PPC in the two conditions was different (see table 6.9). Linear regression was conducted. The results showed that MA was a marginal predictor of performance in terms of PPC in SW sample [$R^2=0.023$, $F(1,16)=0.355$, $p=0.560$] and CS sample [$R^2=0.004$, $F(1,16)=0.067$, $p=0.799$]. In SW sample for DS group, the intercept was 83.855% and the gradient was 0.0383 and was 0.985 (see figure 6.4c). The confidence intervals around DS trajectory were between 78.07% and 89.63%. In CS sample for DS group, the intercept was 77.425% and the gradient was 0.0179 and was 0.980 (see figure 6.4c). The confidence intervals around DS trajectory were between 71.32% and 83.52%. As plotted data suggested, SW and CS samples trajectories were parallel and positively-trended. This indicated that DS group continued to produce correct phonemes, although they produced correct phonemes in CS sample at a delayed onset and rate slower than that in SW sample.

Table 6.8 Descriptive analysis of PCC, PVC and PPC in SW sample compared to CS sample for DS group

Measure	Samples	Mean	*SD*	*SE*	Median	Range	Minimum	Maximum	95% CI for Mean	
									Lower Bound	Upper Bound
PCC	SW	80.35%	7.40	1.79	83%	25%	64%	89%	76.54%	84.16%
	CS	73.24%	6.35	1.54	75%	25%	60%	85%	69.97%	76.50%
PVC	SW	97.18%	1.74	0.42	97%	5%	95%	100%	96.28%	98.075
	CS	96.41%	1.37	0.33	96%	4%	95%	99%	95.71%	97.12%
PPC	SW	85.24%	5.69	1.38	88%	20%	70%	90%	82.31%	88.16%
	CS	78.06%	5.95	1.44	80%	23%	64%	87%	75%	81.12%

Note: DS-Children with Down syndrome. PCC-Percentage of consonants correct. PVC-Percentage of vowels correct. PPC-Percentage of phonemes correct. SW-Single word sample. CS-Connected speech sample. SD-Standard deviation. SE-Standard error. CI-Confidence intervals around the mean.

Table 6.9 Repeated measures ANCOVA results for PCC, PVC and PPC in SW sample compared to CS sample for DS group

Variable	*df*	Mean Square	*F*	*p*-value	Effect Size η^2
PCC	(1,15)	36.702	12.491	0.003	0.454
PCC*MA mya	(1,15)	2.161	0.735	0.405	0.047
PVC	(1,15)	0.311	0.465	0.506	0.030
PVC*MA mya	(1,15)	0.497	0.743	0.402	0.047
PPC	(1,15)	95.028	42.581	0.001	0.739
PPC*MA mya	(1,15)	1.760	0.788	0.389	0.050

Note: DS-Children with Down syndrome. PCC-Percentage of consonants correct. PVC-Percentage of vowels correct. PPC-Percentage of phonemes correct. MA mya-Non-verbal mental age measured in months from youngest age in TD group.

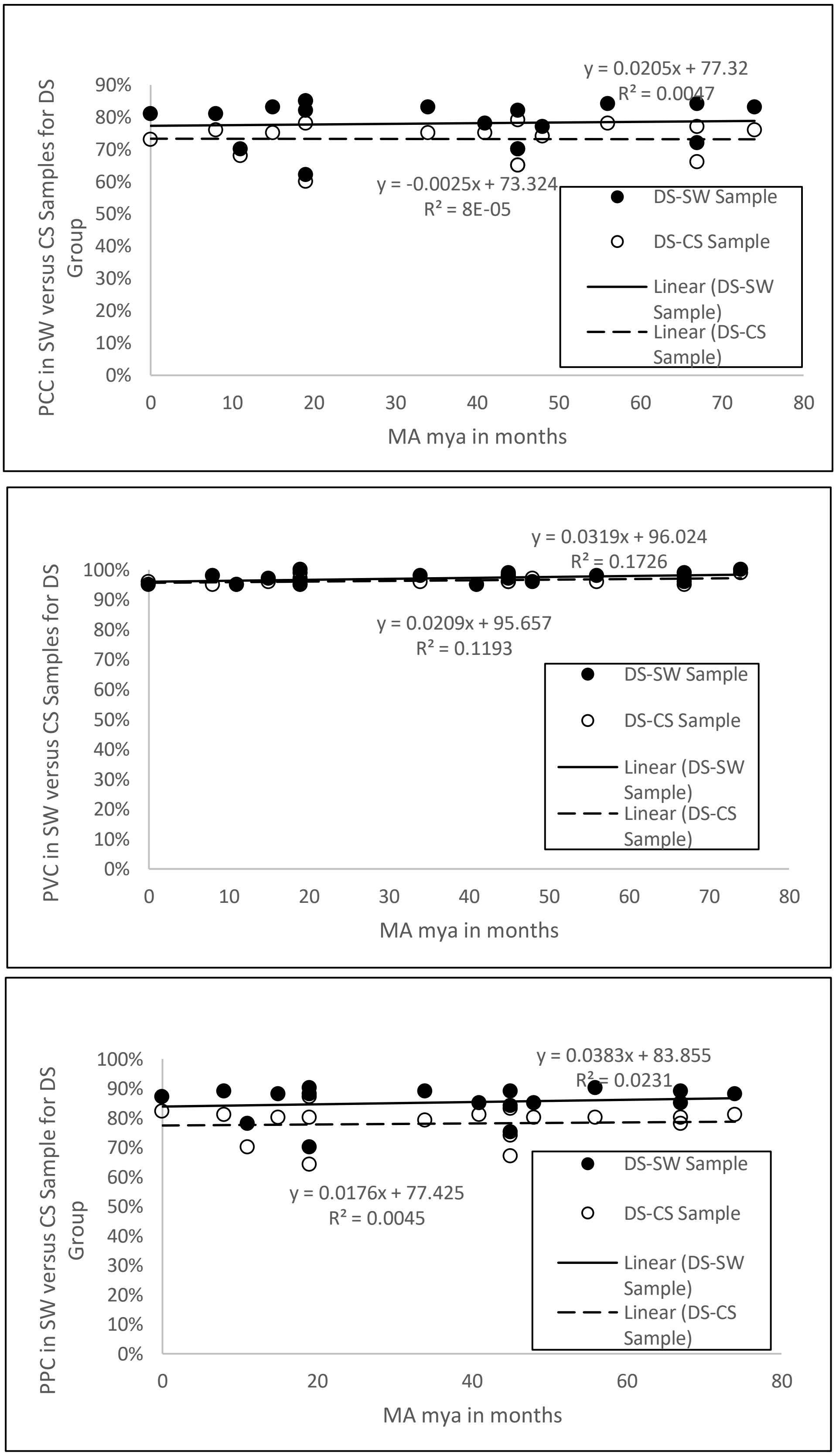


Figure 6.4(a-c). PCC in SW samples compared to CS samples for DS group. The figure illustrates the developmental trajectories of percentage of percentage of correct consonants (PCC) represented with a solid line in (SW) single word samples, and PCC represented by a dotted line in connected speech (CS) samples for DS group. MA mya represents rescaled nonverbal mental age measured form youngest age in months in the TD group.

6.4.2 Phonological Processes in SW Samples Compared to CS Samples for DS Group

The descriptive analysis of the number of occurrences of processes was summarised (see table 6.10). The results of ANCOVA showed that SW and CS samples for DS group were non-significantly different in terms of the number of occurrences of processes [$F(1,15)=0.350$, $p=0.563$, $\eta^2=0.023$]. This manifested that DS group suppressed processes in SW and CS samples at a similar onset. There was a non-significant interaction between the number of occurrences of processes and MA [$F(1,15)=3.240$, $p=0.092$, $\eta^2=0.178$], suggesting that the rate of reducing the number of occurrences of processes in the two conditions was different (see table 6.11). The results of linear regression demonstrated that MA was not a reliable predictor of performance on this task in SW sample [$R^2=0.052$, $F(1,16)=0.827$, $p=0.378$] and CS sample [$R^2=0.007$, $F(1,16)=0.103$, $p=0.752$]. In SW sample for DS group, the intercept was 64.951 and the gradient was 0.3428 (see figure 6.5). The confidence intervals around DS trajectory were between 31.02 and 98.87. In CS sample for DS group, the intercept was 68.009 and the gradient was 0.1226 (see figure 6.5). The confidence intervals around DS trajectory were between 33.69 and 102.32. The SW and CS samples trajectories started from a similar onset from which DS participants continued to suppress the occurrences of processes, although the rate of suppressing processes was slower in CS sample rather than in SW sample. The two trajectories were negatively-trended.

Table 6.10 Descriptive analysis of number of occurrences of phonological processes in the SW sample compared to CS sample for DS group

Variable	**Groups**	**Samples**	**Mean**	***SD***	***SE***	**Median**	**Range**	**Minimum**	**Maximum**	**95% CI for Mean**	
										Lower Bound	**Upper Bound**
Number of Occurrences of Phonological Processes	DS	SW	52.58	33.94	8.23	53	109	9	118	35.13	70.04
		CS	63.59	33.54	8.13	61	110	13	123	46.34	80.83

Note: DS-Children with Down syndrome. SW-Single word speech sample. CS-Connected speech sample. SD-Standard deviation. SE-Standard error. CI-Confidence limits around the mean.

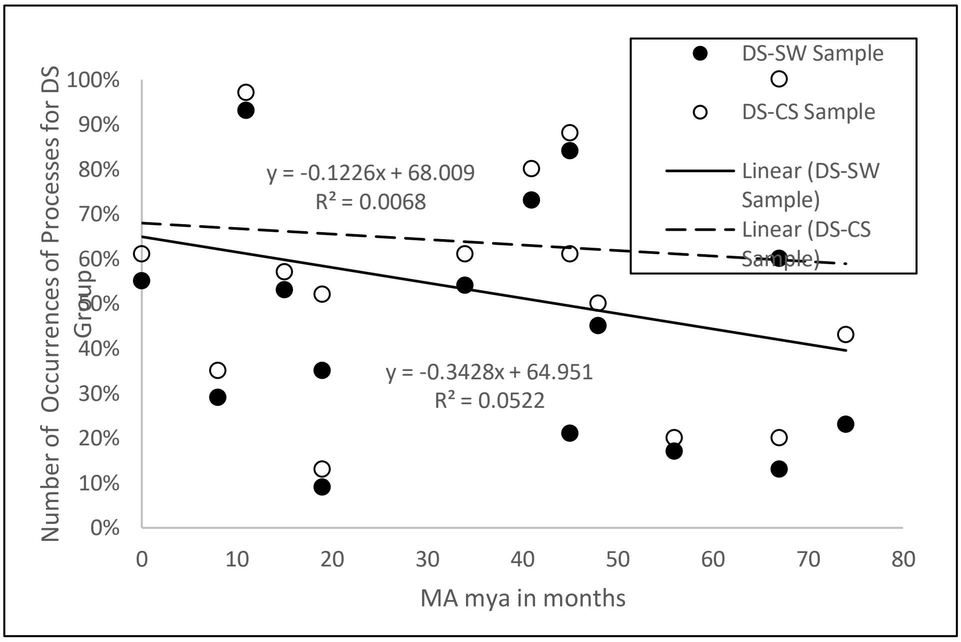


Figure 6.5. Number of occurrences of phonological processes in SW sample compared to CS sample for DS group. The figure illustrates the developmental trajectories of number of occurrences of phonological processes represented with a solid line in single word (SW) samples and represented by a dotted line in connected speech (CS) samples for DS group. MA mya represents rescaled nonverbal mental age measured form youngest age in months in the TD group.

The estimations of percentages of occurrence of processes showed that the most frequently occurring processes in SW samples for DS group comprised of 6 processes: CR, fronting, voicing, assimilation, MCD and deaffrication. In CS samples for DS group, the most frequently occurring processes included 8 processes: CR, fronting, stopping, voicing, assimilation, MCD, FCD and backing (see table 6.12).

Table 6.12 Descriptive analysis of percentages of occurrence of phonological processes in SW samples compared to CS samples for DS group

Processes	Groups	Mean	*SD*	*SE*	Median	Range	Minimum	Maximum	95% CI for Mean Lower Bound	95% CI for Mean Upper Bound
Gliding	SW	4.76%	7.79	1.89	2%	30%	0%	30%	0.30%	8.38%
	CS	5.59%	3.85	0.93	5%	12%	0%	12%	3.60%	7.57%
Deaffrication	SW	5.76%	9.92	2.40	2%	39%	0%	39%	0.66%	10.87%
	CS	7.35%	9.74	2.36	4%	39%	0%	39%	2.35%	12.36%
CR	SW	25.59%	16.40	3.97	25%	65%	2%	67%	17.15%	34.02%
	CS	36.00%	17.82	4.32	35%	54%	13%	67%	26.83%	45.17%
Fronting	SW	18.59%	10.35	2.51	17%	35%	3%	38%	13.265	23.91%
	CS	21.71%	8.06	1.95	20%	35%	5%	40%	17.56%	25.85%
WSD	SW	1.76%	2.41	0.58	2%	8%	0%	8%	0.52%	3%
	CS	3.29%	3.98	0.96	2%	12%	0%	12%	1.25%	5.34%
Stopping	SW	7.29%	7.06	1.71	6%	29%	0%	29%	3.66%	10.935
	CS	15.29%	10.16	2.46	13%	35%	0%	35%	10.07%	20.52%
Voicing	SW	9.12%	7.60	1.84	8%	24%	0%	24%	5.21%	13.035
	CS	11.00%	7.10	1.72	10%	25%	0%	25%	7.35%	14.65%
Assimilation	SW	4.76%	4.07	0.98	45	11%	0%	11%	2.67%	6.86%
	CS	9.76%	7.98	1.93	8%	30%	0%	30%	5.66%	13.87%
ICD	SW	3.82%	3.26	0.79	2%	9%	1%	10%	2.15%	5.50%
	CS	5.76%	5.72	1.38	6%	20%	0%	20%	2.82%	8.71%
MCD	SW	6.18%	5.18	1.25	6%	14%	0%	145	3.51%	8.84%
	CS	8.71%	6.43	1.56	9%	20%	0%	20%	5.40%	12.01%
FCD	SW	4.29%	5.03	1.22	3%	20%	1%	21%	1.71%	6.88%
	CS	6.71%	6.43	1.56	9%	20%	0%	20%	5.40%	12.01%
Backing	SW	3.65%	4.15	1.00	3%	13%	0%	13%	1.15%	5.78%
	CS	8.65%	7.35	1.78	9%	28%	0%	28%	4.86%	12.43%
Other	SW	1.41%	3.28	0.79	0%	11%	0%	11%	0.27%	3.10%
	CS	2.24%	4.23	1.02	0%	15%	0%	15%	0.06%	4.41%

Note: DS-Children with Down syndrome. CR-Cluster reduction. WSD-Weak syllable deletion. ICD-Initial consonant deletion. MCD-Medial consonant deletion. FCD-Final consonant deletion. SW-Single word speech sample. CS-Connected speech sample. SD-Standard deviation. SE-Standard error. CI-confidence limits around the mean.

The results of ANCOVA showed that SW and CS samples were significantly different in relation to the percentages of occurrence of only 4 processes. These included gliding, deaffrication, assimilation and MCD (see tables 6.13 and 6.14).

1. Gilding

The results of ANCOVA revealed a significant difference between SW and CS samples in relation to percentage of occurrence of gliding [$F(1,15)=4.575$, $p=0.049$, $\eta^2=0.234$]. This indicated that DS participants suppressed gliding in CS sample at a delayed onset. The effect size was large ($\eta^2=0.234$). There was also a significant gliding*MA interaction [$F(1,15)=5.008$, $p=0.041$, $\eta^2=0.250$], suggesting that there was a similarity in the rate of suppressing gliding in the two conditions (see table 6.13). Linear regression test was carried out. The results showed that MA was a marginal predictor of performance in terms of percentage of occurrence of gliding in SW sample [R2=0.201, F(1,16)=3.768, p=0.071] and CS sample [R2=0.048, F(1,16)=0.759, p=0.397]. In SW sample for DS group, the intercept was 0.8025% and the gradient was 0.1544 (see figure 6.6a). The confidence intervals around DS trajectory were between 6.35% and 7.96% (see table 6.14). In CS sample for DS group, the intercept was 6.9373 and the gradient was 0.0374 (see figure 6.6a). The confidence intervals around DS trajectory were between 3.07% and 10.80% (see table 6.14). Examining the developmental trajectories, SW and CS samples trajectories were not parallel, yet both were negatively trended. This indicated that DS participants continued to suppress gliding in CS samples at a delayed onset and a slower rate than that in SW sample.

2. Deaffrication

Based on the results of ANCOVA, the percentages of occurrence of deaffrication in SW and CS samples were found to be significantly different [$F(1,15)=5.774$, $p=0.030$, $\eta^2=0.278$]. This indicated that DS participants continued to use deaffrication in CS sample at a delayed onset. The effect size was large ($\eta^2=0.278$). However, there was a non-significant interaction between percentage of occurrence of deaffrication and MA [$F(1,15)=3.873$, $p=0.068$, $\eta^2=0.205$], suggesting that the rate of using deaffrication in the two conditions was different (see table 6.13). Linear regression test was carried out. The results showed that MA was a marginal predictor of performance in terms of percentage of occurrence of deaffrication in SW sample [$R^2=0.167$, $F(1,16)=3.017$, $p=0.103$] and in CS sample [$R^2=0.032$, $F(1,16)=0.494$, $p=0.493$].

In SW sample for DS group, the intercept was 0.7045% and the gradient (see figure 6.6b). The confidence intervals around DS trajectory were between 8.58% and 9.99% (see table 6.14). In CS sample for DS group, the intercept was 4.5824% and the gradient was 0.0768 (see figure 6.6b). The confidence intervals around DS trajectory were between 5.25% and 14.42% (see table 6.14). SW and CS samples trajectories were parallel and positively-trended, indicating that DS participants continued to use deaffrication.

3. Assimilation

The results of ANCOVA indicated that SW and CS samples were significantly different in terms of percentage of occurrence of assimilation [$F(1,15)=11.133$, $p=0.005$, $\eta^2=0.426$]. This indicated that DS participants started to suppress assimilation in CS samples at a delayed onset. The effect size was very large ($\eta^2=0.426$). However, there was a non-significant interaction between assimilation and MA [$F(1,15)=3.582$, $p=0.078$, $\eta^2=0.193$], suggesting that the rate of suppressing of assimilation in the two conditions was different (see table 6.13). The results of linear regression revealed that MA was a non-significant predictor of performance in terms of percentage of occurrence of assimilation in SW sample [R2=0.115, F(1,16)=1.958, p=0.182], whereas MA was a reliable predictor of performance on this task in CS sample [R2=0.295, F(1,16)=6.267, p=0.024]. In SW sample for DS group, the intercept was 6.9681% and the gradient was 0.0611 (see figure 6.6h). The confidence intervals around DS trajectory were between 3.03% and 10.89% 9see table 6.14). In CS sample for DS group, the intercept was 16.66% and the gradient was 0.01914 (see figure 6.6h). The confidence intervals around DS trajectory were between 9.78% and 23.54% (see table 6.14). SW and CS samples trajectories were parallel and negatively-trended. This indicated that DS participants continued to suppress assimilation in both samples. However, DS participants tended to suppress assimilation in CS sample at a delayed onset and at a rate slower than that in SW sample.

4. Medial Consonant Deletion

The repeated measures ANCOVA was run. The results indicated that percentages of occurrence of MCD in SW and CS samples were significantly differently [$F(1,15)=20.659$, $p=0.001$, $\eta 2=0.579$]. This revealed that DS participants suppressed MCD at a delayed onset. The effect size was very large ($\eta 2=0.579$). There was also a significant MCD*MA interaction [$F(1,15)=6.472$, $p=0.002$, $\eta 2=0.301$], suggesting that the rate of suppressing MCD was different in the two conditions. The effect size was large ($\eta 2$=0.301) (see table 6.13). The results of linear regression showed that MA was a non-significant predictor of performance in terms of MCD in SW sample [R^2=0.179, F(1,16)=3.276, p=0.090]. Yet, MA was a reliable predictor of performance on this task in CS sample [R^2=0.322, F(1,16)=7.132, p=0.017]. In SW sample for DS group, the intercept was 9.7119% and the gradient was 0.0979 (see figure 6.6j). The confidence intervals around DS trajectory were between 4.85% and 14.50% (see table 6.14). In CS sample for DS group, the intercept was 14.522% and the gradient was 0.01613 and effect size was 0.684 (see figure 6.6j). The confidence intervals around DS trajectory were between 9.08% and 19.95% (see table 6.14). SW and CS samples were negatively trended, indicating that DS participants continued to suppress MCD. However, DS participants managed to suppress MCD in CS sample at a delayed onset and a rate of suppression slower than that in SW sample.

6.4.3 Summary of SW Sample Compared to CS Sample for DS Group

To sum up, the comparison of SW to CS samples for DS group revealed several significant findings. The results indicated that SW and CS were significantly different in terms of PCC and PPC. This revealed that DS group developed PCC and PPC in CS sample at a delayed onset. However, the two samples were non-significantly different in relation to PVC. Therefore, DS group started to produce PVC at the same onset in the two conditions. Additionally, there were non-significant interactions between PCC, PVC, PPC and MA. This suggested that DS group continued to develop these measures at similar rates in both conditions. Analysing the developmental trajectories of PCC, PVC and PPC in SW and CS samples, it was found that MA was not a reliable predictor of performance in terms of these measures.

Regarding the number of occurrences of processes, the results showed that there was a non-significant difference between SW and CS samples, suggesting that DS group started to suppress the number of occurrences of processes in SW and CS at similar onset. The analysis of trajectories manifested that MA was also a non-significant predictor of performance on this task. The results also revealed that SW and CS samples were significantly difference in terms of percentages of occurrence of gliding, deaffrication, assimilation and MCD. This indicated that DS participants used these processes in CS samples at delayed onsets. Additionally, DS participants produced gliding and MCD at similar rates in SW and CS samples, but they produced deaffrication and assimilation in CS sample at rates slower than these in SW sample. The analysis of trajectories of these processes demonstrated that MA was not a reliable predictor of performance in terms of percentages of occurrence of gliding and deaffrication in SW sample compared to CS sample. This indicated that DS participants continued to suppress gliding and use deaffrication regardless their intellectual abilities. On the other hand, MA was a reliable predictor of performance in terms of percentages of occurrence of assimilation and MCD, suggesting that suppressing these processes was affected by the cognitive abilities in DS group.

Table 6.13 ANCOVA results for percentages of occurrences of phonological processes in SW sample compared to CS sample for DS group

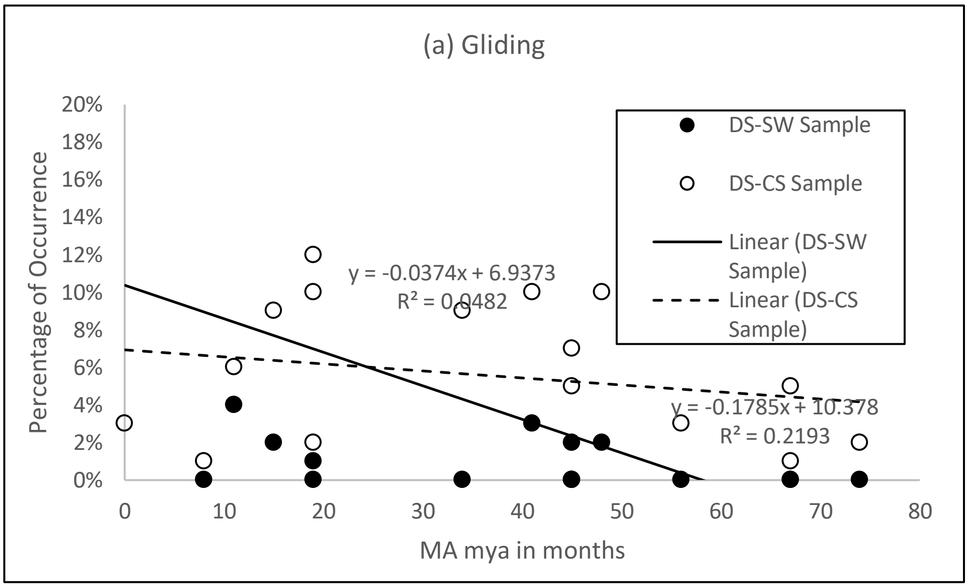
Variables	***df***	**Mean Square**	***F***	***p*-value**	**Effect Size η^2**
Gliding	(1,15)	137.718	4.575	0.049	0.234
MA mya	(1,15)	56.071	1.521	0.236	0.092
Gliding*MA mya	(1,15	150.741	5.008	0.041	0.250
Deaffrication	(1,15)	64.261	5.774	0.030	0.278
MA mya	(1,15)	269.038	1.544	0.233	0.093
Deaffrication*MA mya	(1,15)	43.111	3.873	0.068	0.205
CR	(1,15)	466.006	1.553	0.232	0.094
MA mya	(1,15)	376.040	1.263	0.279	0.078
CR*MA mya	(1,15)	46.119	0.154	0.701	0.010
Fronting	(1,15)	71.189	1.728	0.208	0.103
MA mya	(1,15)	16.798	0.120	0.734	0.008
Fronting*MA mya	(1,15)	18.869	0.458	0.509	0.030
WSD	(1,15)	9.921	2.319	0.149	0.134
MA mya	(1,15)	0.192	0.010	0.921	0.001
WSD*MA mya	(1,15)	0.946	0.221	0.645	0.015
Stopping	(1,15)	182.726	3.743	0.072	0.200
MA mya	(1,15)	0.678	0.006	0.940	0.000
Stopping*MA mya	(1,15)	2.640	0.054	0.819	0.004
Voicing	(1,15)	18.023	0.741	0.403	0.047
MA mya	(1,15)	58.106	0.702	0.415	0.045
Voicing*MA mya	(1,15)	69.088	2.841	0.113	0.159
Assimilation	(1,15)	216.282	11.133	0.005	0.426
MA mya	(1,15)	261.317	5.923	0.028	0.283
Assimilation*MA mya	(1,15)	69.593	3.582	0.078	0.193
ICD	(1,15)	5.332	.372	0.551	0.024
MA mya	(1,15)	1.073	0.034	0.857	0.002
ICD*MA mya	(1,15)	0.551	0.038	0.847	0.003
MCD	(1,15)	53.993	20.659	0.001	0.579
MA mya	(1,15)	273.412	5.379	0.035	0.264
MCD*MA mya	(1,15	16.915	6.472	0.022	0.301
FCD	(1,15)	10.363	0.558	0.467	0.036
MA mya	(1,15)	34.779	0.566	0.463	0.036
FCD*MA mya	(1,15)	0.262	0.014	0.907	0.001
Backing	(1,15)	12.237	0.436	0.519	0.028
MA mya	(1,15)	0.225	0.005	0.945	0.000
Backing*MA mya	(1,15)	22.852	0.814	0.381	0.051
Other Processes	(1,15)	3.514	2.819	0.114	0.158
MA mya	(1,15)	1.750	0.060	0.810	0.004
Other Processes*MA mya	(1,15)	0.537	0.431	0.522	0.028

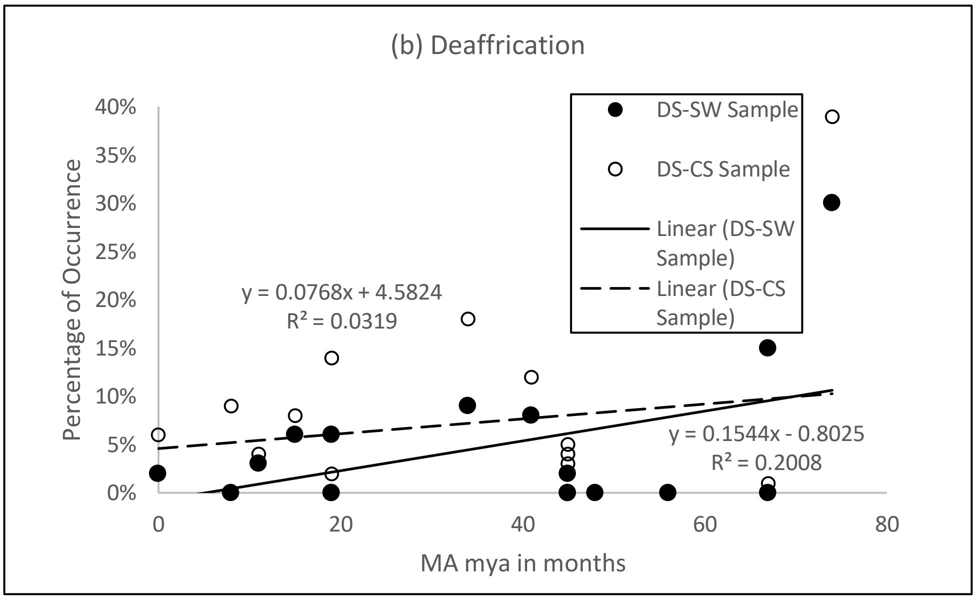
Note: DS-children with DS. CI-confidence limits around the mean. WSD-weak syllable deletion, ICD-initial consonant deletion, MCD-medial consonant deletion and FCD-final consonant deletion. SW-single word speech sample. CS-connected speech sample. MA mya in months-nonverbal mental age measured from months from youngest age in TD group.

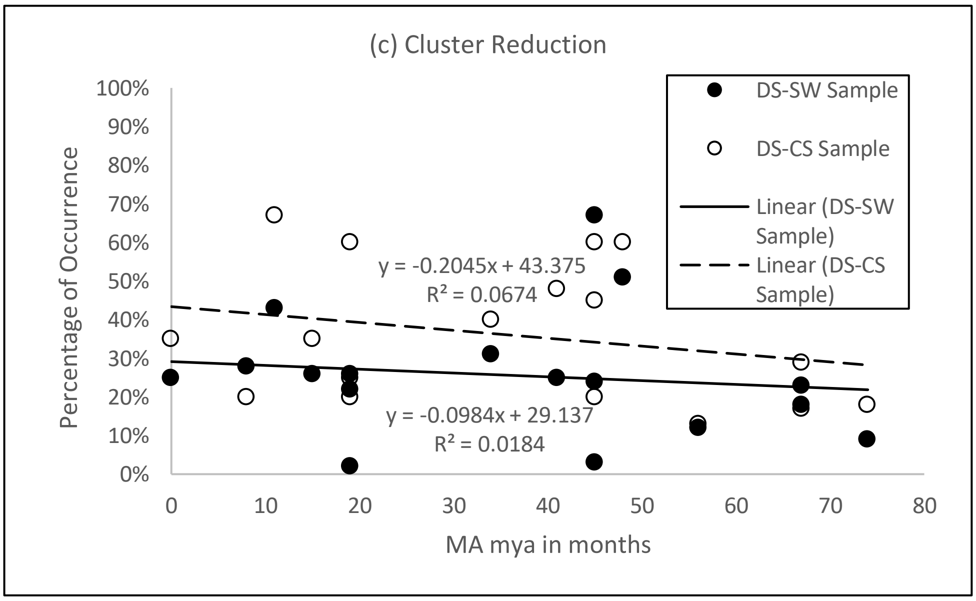
Table 6.14 Intercepts of percentages of occurrences of phonological processes in SW sample compared to CS sample for DS group

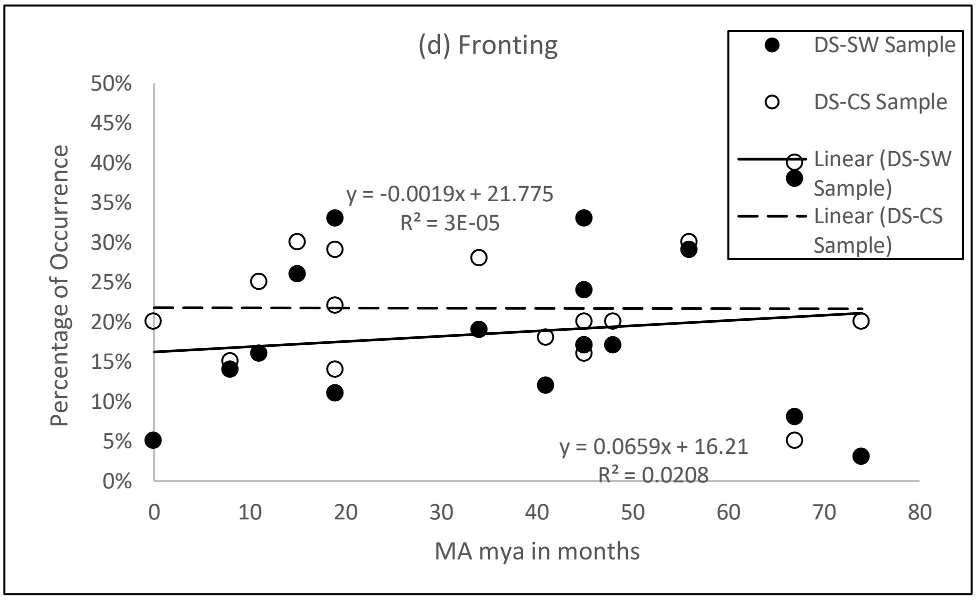
Processes	Samples	Intercepts	*SE*	*t*	*p*-value	95% CI Lower Bound	95% CI Upper Bound	Effect Size η^2
WSD	SW	1.614	1.161	1.391	0.185	0.860	4.088	0.114
	CS	3.691	1.914	1.929	0.073	0.387	7.770	0.199
Stopping	SW	6.605	3.398	1.943	0.071	0.639	13.848	0.201
	CS	15.520	4.893	3.172	0.006	5.091	25.949	0.401
Assimilation	SW	6.968	1.844	3.779	0.002	3.038	10.898	0.488
	CS	16.667	3.228	5.163	0.000	9.787	23.548	0.640
ICD	SW	4.324	1.565	2.763	0.014	0.989	7.660	0.337
	CS	5.847	2.759	2.119	0.051	0.033	11.728	0.230
MCD	SW	9.675	2.263	4.275	0.001	4.851	14.500	0.549
	CS	14.522	2.550	5.695	0.000	9.087	19.956	0.684
FCD	SW	6.099	2.363	2.582	0.021	1.064	11.135	0.308
	CS	8.223	3.438	2.392	0.030	0.896	15.550	0.276
Backing	SW	4.860	1.966	2.472	0.026	0.669	9.051	0.289
	CS	7.167	3.515	2.039	0.059	0.325	14.659	0.217
Other	SW	0.833	1.570	0.530	0.604	2.514	4.179	0.018
Processes	CS	0.005	0.048	0.095	0.925	0.098	0.108	0.001

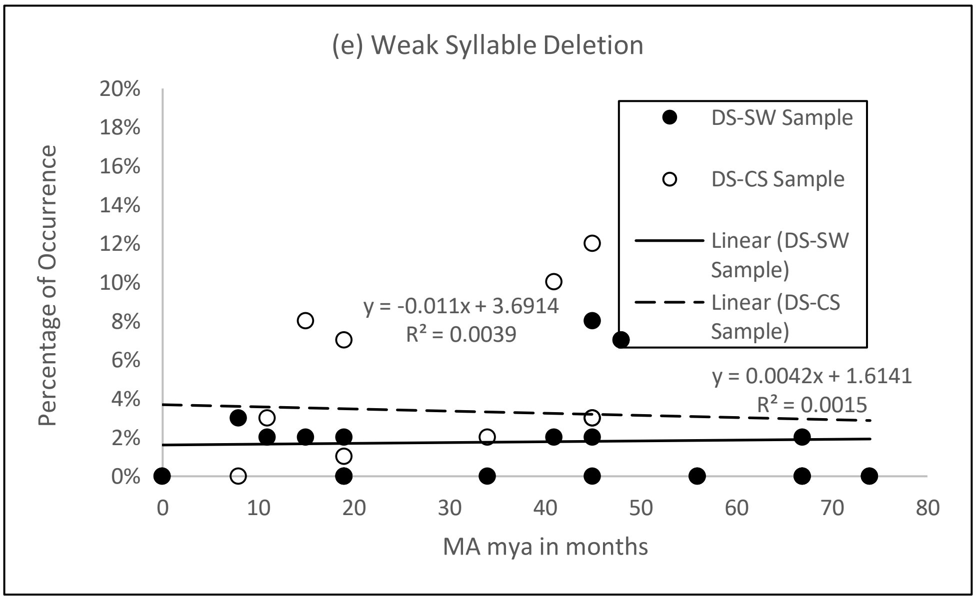
Note: DS-children with DS. WSD weak syllable deletion, ICD-initial consonant deletion, MCD-medial consonant deletion and FCD-final consonant deletion. SW-single word speech sample. CS-connected speech sample.

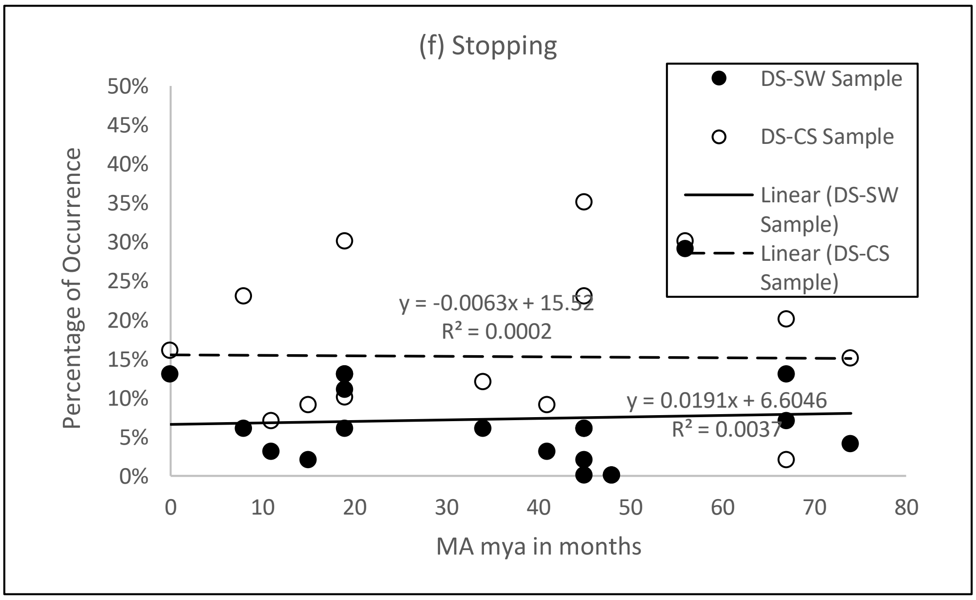

(a) Gliding
Percentage of Occurrence
20%
18%
16%
14%
12%
10%
8%
6%
4%
2%
0%
0
10
20
30
40
50
60
70
80
MA mya in months
DS-SW Sample
DS-CS Sample
Linear (DS-SW Sample)
Linear (DS-CS Sample)
y = -0.0374x + 6.9373
R² = 0.0482
y = -0.1785x + 10.378
R² = 0.2193

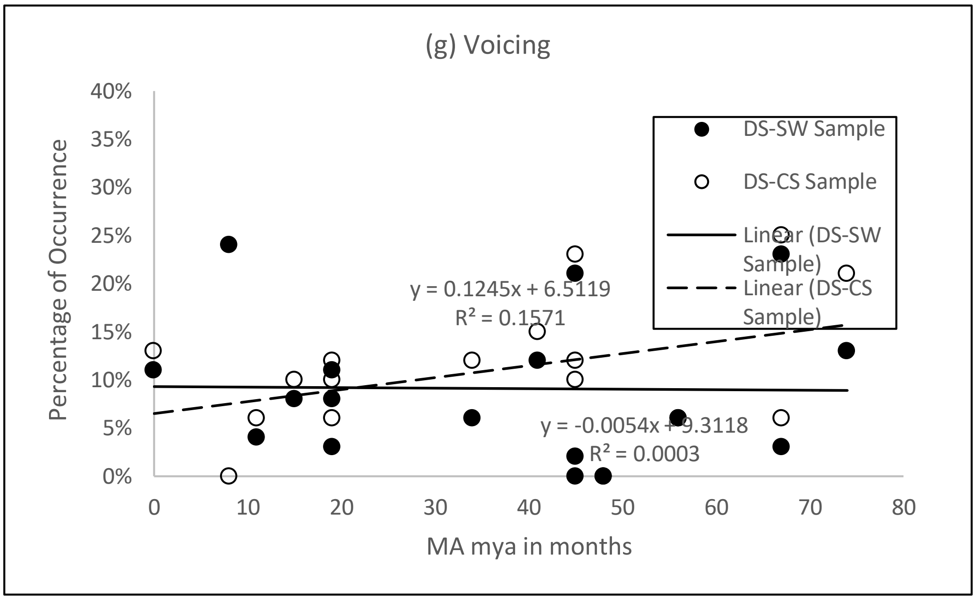

(b) Deaffrication
Percentage of Occurrence
40%
35%
30%
25%
20%
15%
10%
5%
0%
0
20
40
60
80
MA mya in months
DS-SW Sample
DS-CS Sample
Linear (DS-SW Sample)
Linear (DS-CS Sample)
y = 0.0768x + 4.5824
R² = 0.0319
y = 0.1544x - 0.8025
R² = 0.2008

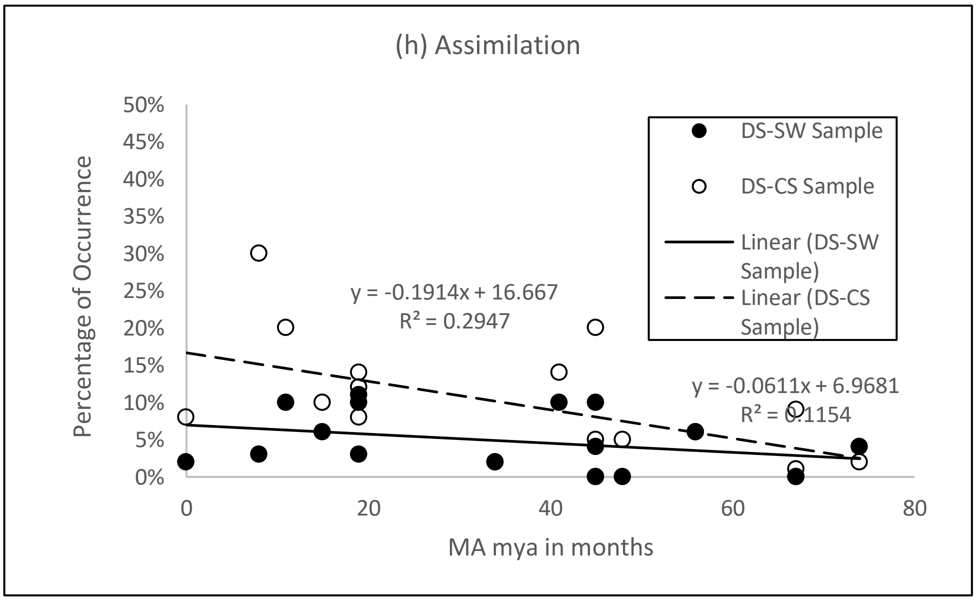

(c) Cluster Reduction
Percentage of Occurrence
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0
10
20
30
40
50
60
70
80
MA mya in months
DS-SW Sample
DS-CS Sample
Linear (DS-SW Sample)
Linear (DS-CS Sample)
y = -0.2045x + 43.375
R² = 0.0674
y = -0.0984x + 29.137
R² = 0.0184

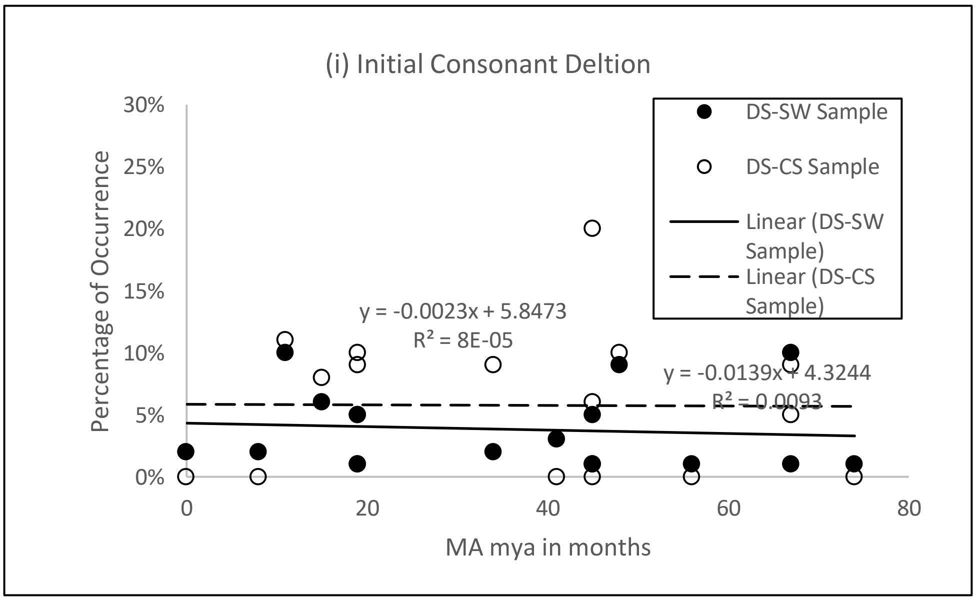

(d) Fronting
DS-SW Sample
DS-CS Sample
Linear (DS-SW Sample)
Linear (DS-CS Sample)
y = -0.0019x + 21.775
R² = 3E-05
y = 0.0659x + 16.21
R² = 0.0208
Percentage of Occurrence
MA mya in months

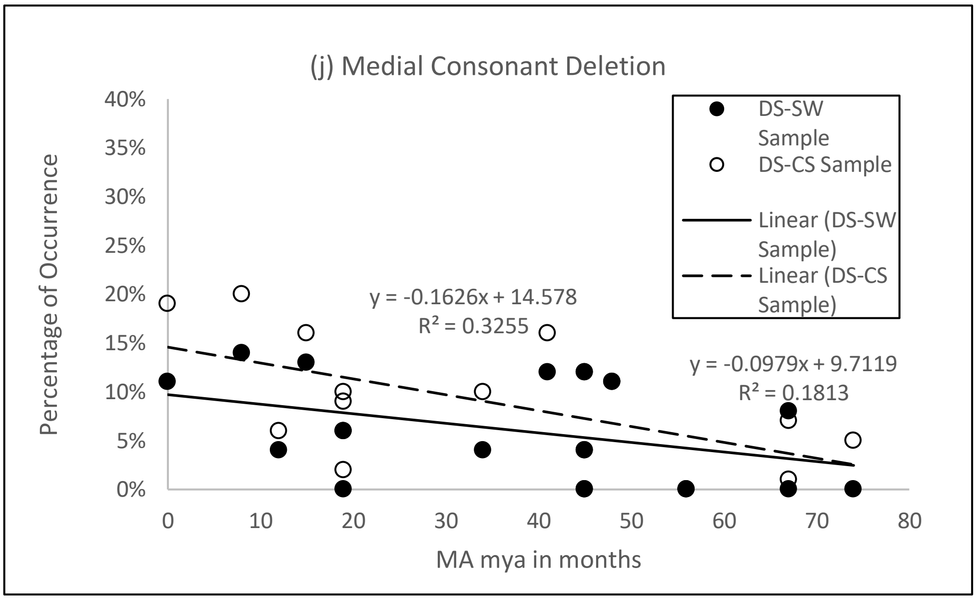

(e) Weak Syllable Deletion
DS-SW Sample
DS-CS Sample
Linear (DS-SW Sample)
Linear (DS-CS Sample)
y = -0.011x + 3.6914
R² = 0.0039
y = 0.0042x + 1.6141
R² = 0.0015
Percentage of Occurrence
MA mya in months

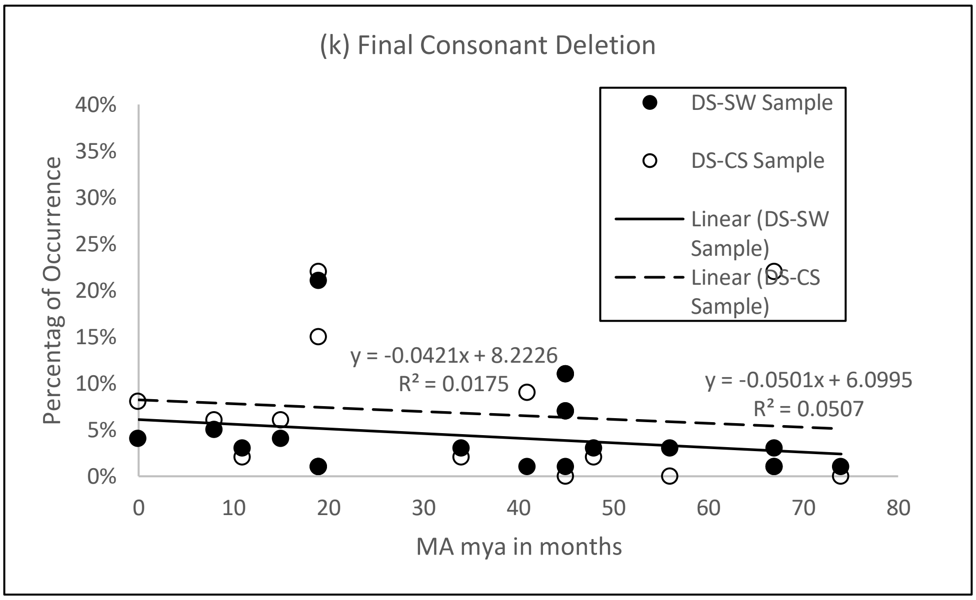

(f) Stopping
DS-SW Sample
DS-CS Sample
Linear (DS-SW Sample)
Linear (DS-CS Sample)
y = -0.0063x + 15.52
R² = 0.0002
y = 0.0191x + 6.6046
R² = 0.0037
Percentage of Occurrence
MA mya in months

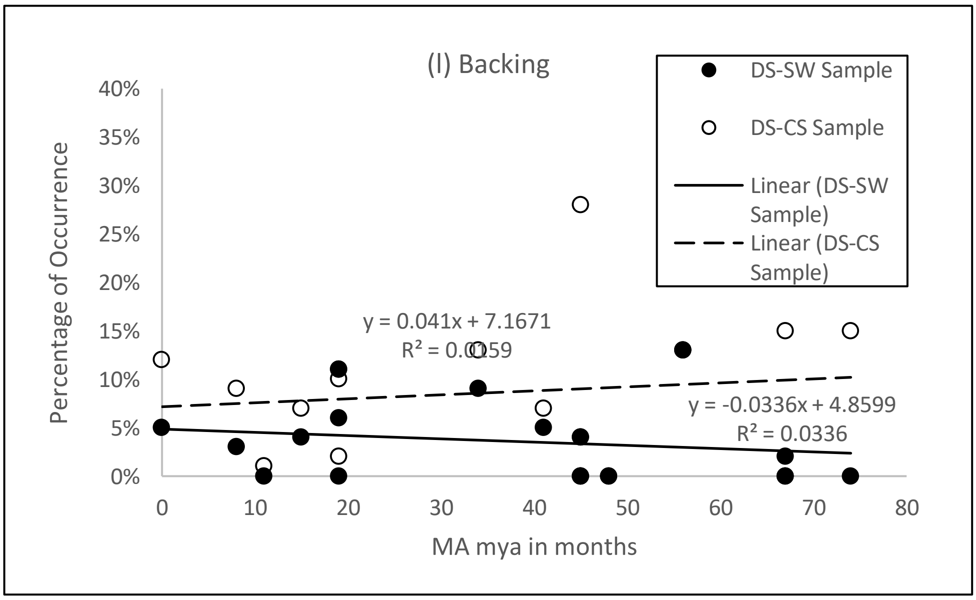

(g) Voicing
Percentage of Occurrence
40%
35%
30%
25%
20%
15%
10%
5%
0%
0
10
20
30
40
50
60
70
80
MA mya in months
DS-SW Sample
DS-CS Sample
Linear (DS-SW Sample)
Linear (DS-CS Sample)
y = 0.1245x + 6.5119
R² = 0.1571
y = -0.0054x + 9.3118
R² = 0.0003


(h) Assimilation
Percentage of Occurrence
50%
45%
40%
35%
30%
25%
20%
15%
10%
5%
0%
0
20
40
60
80
MA mya in months
DS-SW Sample
DS-CS Sample
Linear (DS-SW Sample)
Linear (DS-CS Sample)
y = -0.1914x + 16.667
R² = 0.2947
y = -0.0611x + 6.9681
R² = 0.1154


(i) Initial Consonant Deltion
Percentage of Occurrence
30%
25%
20%
15%
10%
5%
0%
0
20
40
60
80
MA mya in months
DS-SW Sample
DS-CS Sample
Linear (DS-SW Sample)
Linear (DS-CS Sample)
y = -0.0023x + 5.8473
R² = 8E-05
y = -0.0139x + 4.3244
R² = 0.0093


(j) Medial Consonant Deletion
40%
35%
30%
25%
20%
15%
10%
5%
0%
Percentage of Occurrence
0
10
20
30
40
50
60
70
80
MA mya in months
DS-SW Sample
DS-CS Sample
Linear (DS-SW Sample)
Linear (DS-CS Sample)
y = -0.1626x + 14.578
R² = 0.3255
y = -0.0979x + 9.7119
R² = 0.1813


(k) Final Consonant Deletion
40%
35%
30%
25%
20%
15%
10%
5%
0%
Percentag of Occurrence
0
10
20
30
40
50
60
70
80
MA mya in months
DS-SW Sample
DS-CS Sample
Linear (DS-SW Sample)
Linear (DS-CS Sample)
y = -0.0421x + 8.2226
R² = 0.0175
y = -0.0501x + 6.0995
R² = 0.0507


(l) Backing
40%
35%
30%
25%
20%
15%
10%
5%
0%
Percentage of Occurrence
0
10
20
30
40
50
60
70
80
MA mya in months
DS-SW Sample
DS-CS Sample
Linear (DS-SW Sample)
Linear (DS-CS Sample)
y = 0.041x + 7.1671
y = -0.0336x + 4.8599
R² = 0.0336

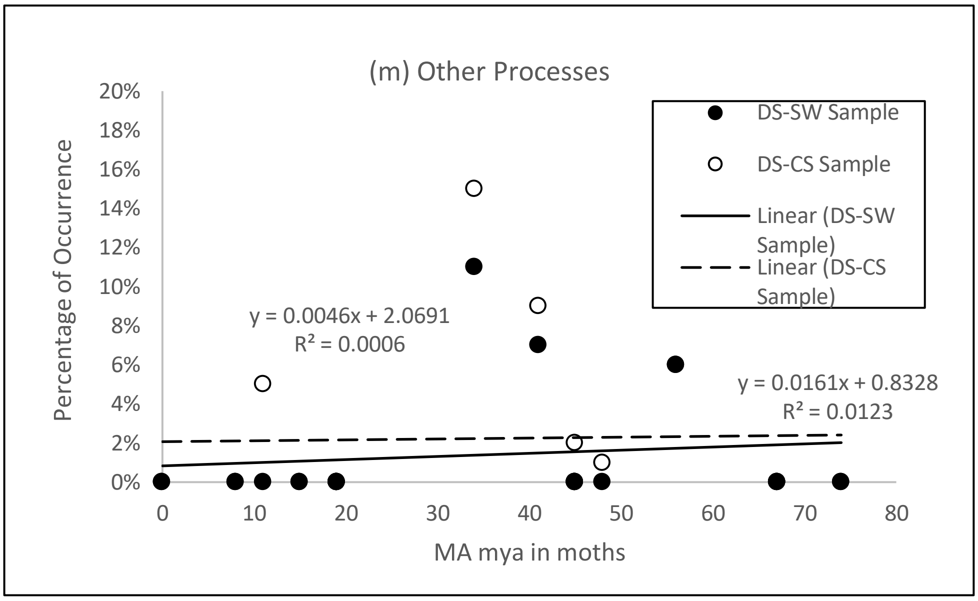


Figure 6.6 (a-m). Percentage of occurrence of phonological processes in SW sample compared to CS sample for DS group. Each figure illustrates the developmental trajectories of percentage of occurrence of a phonological processes represented with a solid line in single word (SW) samples and represented by a dotted line in connected speech (CS) samples for DS group. MA mya represents rescaled nonverbal mental age measured form youngest age in months in the TD group.

Chapter 7: Discussion, Conclusions and Suggestions for Further Research - Group Study

7.1 Introduction

The purpose of the present study was to explore the phonological development in children with DS compared to TD children by analysing SW and CS samples for both groups. Four hypotheses were examined. First, children with DS would have a delayed onset of development of sound production and use of phonological processes in SW samples, CS samples and SW compared to CS samples. Second, children with DS would demonstrate a slower rate of development of sound production and use of phonological processes relative to their MA in SW samples, CS samples and SW compared to CS samples. Third, children with DS would have a delayed onset of development of speech intelligibility in CS samples. Fourth, children with DS would demonstrate a slower rate of development of speech intelligibility relative to their non-verbal mental age in CS samples.

In the present study, a developmental trajectory approach was employed to identify onset and rate of development for children with DS compared to TD children matched for non-verbal MA. The following sections focus on discussing the performance of children in the two groups and present conclusions on the children's performance. In section 7.2, the results of assessment of SW samples for DS group compared to TD group are discussed; while in section 7.3 the results of assessment of CS samples for DS group compared to TD group are explained. In addition, section 7.4 focuses on discussing the similarities and differences observed in relation to the performance of each group in the two experimental conditions separately. Finally, section 7.5 puts forward a number of suggestions for future research.

7.2 SW Samples for DS Group Compared to TD Group

7.2.1 Consonants and Vowels in SW Samples for DS Group Compared to TD Group

The abilities of children with DS to produce consonants in word- initial, medial and final positions in addition to vowels were analysed and compared to TD children. All the phonemes (consonants and vowels) occurring in SW samples whether produced spontaneously or imitatively were included. The consonant inventories for children with DS seemed to be underdeveloped when compared to those of TD children. For example, affricates /ʧ,ʤ/, and interdental fricatives /θ,ð/ were missing in the speech of some children with DS by the age of 12;0 years, and post alveolar fricatives /ʃ,ʒ/ and approximant /ɹ/ were still missing by the age of 10;11 years. The same finding was supported by other researchers (e.g., Dodd and Leahy, 1993; Rosenburg and Abbeduto, 1993; Stoel-Gammon, 1997). It was found that children with DS were able to correctly produce stops, nasals and glides, while they were not able to correctly articulate fricatives, affricates and liquids (Bleile and Schawrtz, 1984; Smith, 1984; Stoel-Gammon, 1980; Stoel-Gammon, 1983). Nonetheless, the seventeen children with DS, aged between 5;5 and 12;0 years, appeared to follow the same sequence of acquisition as younger TD children. For instance, they can accurately produce stops, nasals and glides rather than fricatives, affricates and liquids (Van Bysterveldt et al., 2010).

Most children with DS have a difficulty with the production of back consonants compared to front ones regardless the manner of articulation. For instance, consonants in children with DS aged between 5;5 to 6;9 years were similar to those of TD children aged between 3;0 and 3;9 years, but lacked consonants articulated at the back of the mouth /ʃ,ʒ,ʧ,ʤ,h/ in addition the consonants articulated at the front parts of the mouth /θ,ð,z,ɹ/. It was also observed that many consonants continued to be missing in children with DS even at ages older than 6;0 years. For example, consonants in children with DS, aged between 7;1 and 8;8 years, lacked /v,θ,ð,ʃ,ʒ,d, k,g,r/ and in older children with DS, aged between 10;1 and 10;11 years, the following consonants were missing /k,g,f,θ,ð,s,z,ʒ,ʧ,ʤ,ŋ,r/. Similar findings were reported by previous research (Beleile and Schawrtz, 1984; Smith, 1984; Stoel-Gammon, 1981; 1983; 2001) who reported that children with DS were found to be similar to TD children in terms of the correct production of stops, nasals, and gliding consonants, although the acquisition process tended to be delayed for children with DS. On the contrary children with DS often made more errors when producing fricatives, affricates and liquids. On the other hand, the consonants in TD children, aged between 5;0 and 6;3 years, were fully-developed, and they correctly produced all consonant types. Despite the lack of many consonants, children with DS continued to gradually progress and acquire additional consonants even at older ages when compared to their TD peers. For instance, children with DS, aged between 11;1 and 12;0 years, lacked fewer consonants than younger children with DS; these included /k,g,θ,ð,s,z,ʧ,ʤ/. This definitely indicates that the older children with DS became, the more consonants they could correctly produce. This finding was supported by the quantitative analysis of number of consonants acquired in children with DS compared to TD children when matched for non-verbal MA.

Quantitatively, DS and TD groups were significantly different in terms of the number of consonants they acquired. DS group managed to acquire these consonants at a delayed onset. Therefore, the first research hypothesis (see section 7.1) could be accepted at a p-value<0.05. However, children with DS acquired consonants at a rate similar to that of their MA-matched controls. Thus, the second research hypothesis could be rejected at a p-value>0.05. In SW sample, the developmental trajectory for DS group illustrated that MA was a non-significantly effective predictor of the development of number of consonants acquired when compared to their MA-matched TD peers. Since MA was not a strongly reliable predictor of acquisition of consonants, children with DS developed in line with their TD controls. The cognitive abilities of children with DS, assessed in the present study, did not affect consonant acquisition. This finding was in line with previous studies (Kumin et al. 1994; Sokol and Fey, 2013; Van Bysterveldt et al., 2010) on consonant acquisition in individuals with DS. Despite the controversies about the exact ages of acquisition of consonants for children with DS, their production of consonants was characterised with developmental delay. This was supported in two longitudinal studies by Kumin et al. (1994) and Sokol and Fey (2013). Kumin et al. (1994) discovered that consonant acquisition delay for children with DS, aged between 9 months to 9;0 years, was approximately 5;0 years below that of TD children. In the same context, Van Bysterveldt et al. (2010) also confirmed that children with DS learn sounds through similar stages of sound acquisition as in TD children, but they needed longer time to internalize all the sounds of their phonological systems. In the present study, the findings supported previous research and evidenced the developmental delay of consonant acquisition in DS group compared to their MA-matched TD counterparts.

Comparing children with DS to TD children, they appeared to have fewer difficulties with the acquisition/production of vowels rather than consonants. This was in line with findings reported by Stoel-Gammon (1997) and Van Bysterveldt et al. (2010). In several studies on speech development in children with DS (e.g., Bunton et al., 2007; Stoel-Gammon and Dunn, 1985; Van Borsel, 1996; Van Bysterveldt et al. 2010), it was observed that the occurrence of vowel production errors was less frequent than consonant production errors. In the present study, the analysis of the vowels of children with DS showed similarity in development of vowels in younger TD children. Nonetheless, some of the participants with DS at older ages made fewer vowel errors similar to the ones made by their younger TD counterparts, such as substitutions or deletions; especially for vowels occurring in short syllables or longer word structures (three- or four-syllable words). For instance, a child with DS, aged 6;6 years, deleted short front close-mid vowel /e/ and central open-mid vowels /ə,ʌ/ and substituted the diphthong /aɪ/ with a shorter vowel /æ/. In another example, older children with DS, aged between 8;2 and 10;11 years, omitted the long front close vowel /iː/ and short vowels /e,ə/, and replaced the diphthong /əʊ/ with the long back vowel /ɔː/, and long vowel /iː/ with a short close-mid vowel /ɪ/, /e/ or /æ/. By and large, 6 participants with DS tended to delete/substitute these vowels when occurring in certain contexts, such as unstressed syllables. The errors made by older DS children resembled the ones made by younger TD children, aged between 3;0 and 3;9 years. They tended to delete unstressed short syllables containing the short vowels /ɪ,ə/.

The production accuracy scores of consonants and vowels in addition to the production accuracy of all phonemes targeted for children with DS were lower than those for TD children. The significant differences between the two groups in terms of PCC, PVC and PPC revealed That DS group developed performance on these tasks at delayed onsets. Additionally, DS group continued to increase the accuracy production at a rate of development similar to that of their MA-matched TD controls. Thus, the first research hypothesis was accepted at p-value<0.05, whereas the second research hypothesis was diminished at p-value>0.05. These findings evidenced a developmental delay in terms of PCC, PVC and PPC in DS group. Analysing the trajectories for DS and TD groups, PCC, PVC and PPC trajectories were marginally affected by MA. This implied that cognitive abilities of children with DS could affect their PCC, PVC and PPC scores.

7.2.2 Singleton Consonants and Consonant Clusters in SW Samples for DS Group Compared to TD Group

In as far as the production accuracy of singleton consonants was concerned, PCCs of singleton consonants in SIWI, SIWM, SFWM and SFWF for DS participants were lower than these for TD participants. The study findings also showed that the development of PCCs of singleton consonant in SIWI, SIWM, SFWM and SFWF took place at delayed onsets for DS group compared to TD group when matched for MA. This enhanced accepting the first research hypothesis at a small probability. However, the two groups progressed at a similar rate of development. This supported rejecting the second research hypothesis at large probability level. DS group performed in line with TD group, but they were delayed rather than impaired. MA was of marginal importance in predicting the performance in terms of PCCs of singleton consonants in in SIWI, SIWM, SFWM and SFWF for DS group. This suggested that DS participants developed the production of singleton consonants in line with their TD peers when matched for MA. Additionally, participants with DS demonstrated considerable variability in terms of PCCs of singleton consonants in these four positions, and that PCCs appeared to be affected by consonant position in a given word. This led to conclude that children with DS actively imposed specific structure on the sound production. In this respect, Bleile (1982) found that consonant production accuracy was affected by consonant position. Accordingly, children with DS had a constrained forward-backward consonant ordering in CVC words that the initial consonant should either be identical to the final consonant or articulated at the front part of the mouth. The study revealed that the consonant ordering accounted for the consonant substitutions the children produced. This led to conclude that children with DS actively imposed specific structure on the sound production. In the present study, children with DS produced singleton consonants in SIWM and SFWF more accurately than in SIWI and SFWM. On the other hand, TD children accurately produced singleton consonants in the four positions.

The study findings in relation to PCCC of consonant clusters in SW samples for children with DS compared to TD children PCCCs for DS group were significantly lower than PCCCs in the same word positions for TD group. The results also revealed that DS group and TD group were significantly different. There were delays in the onsets in DS group in terms of PCCCs of consonant clusters occurring in SIWI, SIWM, SFWM, and SFWF. Therefore, the first research hypothesis could be accepted at a p-value>0.05. Additionally, the non-significant interaction between PCCC and MA indicated that DS participants developed production accuracy of clusters in these four positions at a rate similar to that of their MA-matched TD counterparts. This contradicted the second research hypothesis. The analysis of the developmental trajectories of PCCC for DS group demonstrated that MA was a marginal predictor of performance of PCCC in SIWI, SIWM and SFWF rather than SFWM in which MA was a strongly reliable of performance on this task.

In the present study, the findings revealed that the acquisition of singleton consonants as well as consonant clusters tended to be more delayed for children with DS that TD children. Children with DS continued to reduce consonant clusters longer than TD children. This finding was supported by previous research (e.g., Dodd, 1976; Dodd and Thompson, 2001; Iacono, 1998; Roberts et. al., 2005; Stoel-Gammon, 1997). A similar finding was also reported by Iacono (1998), Roberts et al. (2005) and Stoel-Gammon (2001). More to the point, reducing consonant clusters/sequences was the most frequently occurring error in SW samples of children with DS compared to MA matched TD controls. As a result, they use single consonants rather than consonant clusters. Additionally, DS group showed significant differences in relation to PCCCs in the four syllable positions. For DS group, PCCCs in SIWI and SIWM were higher than PCCCs in SFWM and SFWF. The highest PCCC was scored for clusters occurring in SIWI; while the least PCCC was scored in SFWM. TD group also showed significant differences relative to PCCC in the four positions tested. For TD group, PCCCs in SIWM and SFWF were higher than PCCCs in SIWI and SFWM. The highest PCCC was scored in SIWM, whereas the least PCCC was scored in SIWI.

7.2.3 Phonological Processes and Consistency of Errors in SW Samples for DS Group Compared to TD Group

Qualitatively, children with DS frequently used more phonological processes than typically developing children when producing single words. In the present study, all DS participants used phonological processes that occurred five or more times, except one participant with DS, aged 10;9 years, who used only 9 processes which did not meet the five-time occurrence criterion established by Dodd et al. (2002). By and large, the findings indicated that the most frequently occurring processes in SW samples for DS group were CR and fronting in addition to other types of processes. For instance, children with DS, aged between 5;5 and 7;1 years, frequently used CR, fronting, ICD, MCD, FCD, WSD, stopping, backing, assimilation, voicing, and other processes (e.g., replacing /k/ with a far back voiceless consonant /q/). The SW sample for older children with DS, aged between 8;1 and 10;11 years evidenced the recurrent production of FCD and MCD, CR, fronting, stopping, gliding, voicing, assimilation, WSD, deaffrication, and other processes, such as inserting /s,d/. The study findings also revealed that even the oldest DS participants, aged between 11;1 and12;0 years frequently used CR, fronting, voicing, deaffrication, stopping, MCD which considered as non-age-appropriate processes. On the contrary, most TD children appeared to suppress phonological processes by the age of 6;0 years. Nonetheless, the SW sample of TD children younger than 6;0 years evidenced the frequent occurrence of processes which met the five-time occurrence criterion. For instance, four younger TD participants, aged between 3;0 and 5;5 years, used deaffrication, CR, fronting, WSD, stopping, MCD, backing, and other processes, such as substituting initial consonants with a favourite sound /h/. The SW sample of TD child aged 5;5 years evidenced the occurrence of only CR for more than five times. However, the rest of the 16 TD participants either used fewer processes which did not coincide with the five-time occurrence criterion, or the children's SW samples, especially for TD participants aged between 6;0 and 6;3 years did not evidence the use of any phonological processes.

Quantitatively, children with DS extensively used more processes than younger TD children. This finding was in line with findings of previous research (Bleile and Schwartz, 1984; MacKay and Hodson, 1982; Martin et al., 2009; Roberts et al., 2005; 2007). It was reported that preschool and school age children with Down syndrome had phonological errors similar to, but more than those of younger TD children. Children with DS tended to use these errors for a longer time than their TD peers. For instance, Roberts et al., (2005) found that boys with DS produced structural phonological errors more than younger TD boys when matched for MA. In the present study, DS and TD groups were found significantly different in number of occurrences of processes they used. Therefore, DS group continued to use processes at a delayed onset. Accordingly, the first research hypothesis could be rejected. However, DS participants tended to suppress these processes at a rate similar to TD group when matched for MA. The analysis of developmental trajectories of the two groups revealed that MA did not significantly impacted performance in terms of number of occurrences in both groups. This suggested that DS group had a developmental delay rather than disorder. The performance of DS group was in line with that of TD MA-matched controls, yet DS needed longer time to suppress processes. The finding as was also supported by Kumin (1998) who reported that the speech characteristics of children with DS were not unique to the children of this special population. Instead, they had speech delay similar to that of younger TD children.

Regarding the consistency of errors produced by DS group, children with DS were less consistent than TD group. The two groups were significantly different in terms of the consistency measure. DS group managed to reduce inconsistency of the errors they produced at a delayed onset. Yet, they progressed to minimise inconsistency at rate similar to that of TD group. The analysis of developmental trajectories for the two groups indicated that MA marginally affected performance in DS group. Thus, the production of inconsistent errors could be considered as a developmental delay rather than disorder for the DS participants in the present study. The finding was also supported by previous research (e.g., Dodd and Thompson, 2001; Kumin, 1994; 1998; Roberts et al., 2005; Smith and Stoel-Gammon, 1983) that the speech characteristics of children with Down syndrome were not unique to the children of this special population. Instead, they had speech delay similar to that of younger TD children.

The findings of the present study also demonstrated that in SW sample for DS group, the highest percentages of occurrence of processes were associated with CR, fronting, stopping, voicing, assimilation, MCD, and deaffrication, whereas the lowest percentages of occurrence of processes were linked to ICD, FCD, WSD, gliding, backing, and other processes. On the contrary, in SW sample for TD the highest percentages of occurrence were scored for only two processes: CR and fronting, whereas the least percentages of occurrences were observed in the production of gliding, deaffrication, WSD, stopping, voicing, assimilation, ICD, MCD, FCD, backing and other processes. Compared to TD controls, DS group recurrently used more processes than their TD peers. In their analysis of SW sample of children with DS, MacKay and Hodson (1982) showed that approximant deviations and CR were the most recurrently used processes. It was reported that the highest percentage of processes was identified in the speech of participants classified as trainable cognitively impaired children (including children with DS).

Analysing the percentages of occurrences of processes in SW speech samples for children with DS compared to TD children when including MA as a covariate, the two groups were considerably different in the percentage of occurrence of four phonological processes: CR, voicing, assimilation and MCD. This indicated that DS participants started at delayed onsets to suppress these processes. Thus, the first research hypothesis could be accepted at p-value<0.05. Nonetheless, DS participants tended to suppress these processes at a rate similar to that of their MA- matched TD counterparts. Consequently, the second research hypothesis could be rejected. On the other hand, there was non-significant difference between the two groups in terms of the percentages of occurrence of fronting, WSD, stopping, ICD, FCD, backing and other processes. Additionally, the interaction between percentages of these processes and MA was also non-significant. These findings indicated there was no delay in the onset in DS group and, at the same time, DS group either continued to use or suppress these processes at a typical rate. For instance, DS participants managed to suppress ICD, FCD, backing and other processes, but they continued to use fronting, WSD and stopping. The percentages of occurrence of gliding and deaffrication showed a different pattern. Despite the similar onset at which the two groups started to produce gliding and deaffrication, DS group continued to use these processes at a rate slower rate than that for TD group. Thus, DS participants needed longer time to suppress gliding and deaffrication. This finding was supported by previous research (Dodd and Thompson, 2001; Kumin, 1994; 1998; Roberts et al., 2005). The analysis of trajectories of percentages of occurrence of these thirteen processes revealed that MA was not a reliable predictor of performance for DS group. This indicated that their performance could be considered as a developmental delay rather than a disorder. In this respect, the longitudinal study conducted by Smith and Stoel-Gammon (1983) supported the finding that DS group used processes similar to those used by TD peers, although participants with DS were considerably delayed compared to the TD children in suppressing these processes.

7.3 CS Samples for DS Group Compared to TD Group

7.3.1 PCC, PVC and PPC in CS Samples for DS Group Compared to TD Group

The production of connected speech tended to be affected by other language demands including syntactic and pragmatic considerations; therefore, it could be more representative of a child's production skills in a naturalistic context. It was argued that the manipulation of CS samples for phonology assessment purposes would require children to produce longer utterances in naturalistic contexts; therefore, these samples would reflect the children's actual speaking skills and, at the same time, the number and type of sound and sound pattern errors they frequently used in their connected speech (Shriberg and Kwiatkowski, 1980). In the present study, DS participants scored lower PCC, PVC and PPC than TD participants.

Based on the analysis of the connected samples, it was found in previous research that children with DS produce incorrect consonants more than younger TD children matched for MA (Barnes et al., 2009). The findings also showed significant differences between the two groups in terms of PCC, PVC and PPC. This indicated that DS participants produced PCC, PVC and PPC at onsets later than these for TD participants when the two groups were matched for MA. Since the interaction between accuracy measures and MA was marginal, DS were found to develop PCC, PVC and PPC at a rate similar to that of TD participants. The analysis of developmental trajectories demonstrated that MA was not a reliable predictor of the production of consonants, vowels or phonemes. Therefore, DS participants performed in line with TD participants, although their performance was more delayed. The production of speech sounds tended to be more delayed for children with DS compared to younger TD children with similar mental abilities. In a previous study, (Stoel-Gammon, 1980) participants with DS were found to be able to produce most of the target phonemes in specific word positions rather than in other ones. For instance, they produced stops and nasals initially, medially and finally, but they could not produce velar nasal /ŋ/ in any position. They were also capable of producing some fricatives, affricates and glides but not all of phonemes belonging to these consonantal types (Stoel-Gammon, 1980).

7.3.2 Phonological Processes in CS Samples for DS Group Compared to TD Group

Qualitatively, all the participants in the DS group used phonological processes that occurred five times or more except one DS participant, aged 10;9 years, who used 13 processes in total and only CR considered as a sound pattern error. The results for the DS group showed that processes which frequently occurred for five or more times appeared in CS speech sample for DS participants, aged between 5;5 and 7;1 years, were ICD, MCD, FCD, CR, WSD, stopping, backing, assimilation, voicing, gliding, fronting and other process. DS participants aged between 8;1 and 10;11 years, frequently used MCD, FCD, CR, WSD, stopping, fronting, voicing, gliding, assimilation, backing and deaffrication. The CS samples for DS participants, aged between 11;1 and 12;0 years, included fronting, CR, ICD, MCD, FCD, WSD, stopping, backing and assimilation. Regarding TD participants, the findings showed that the phonological processes frequently occurred in CS samples for five or more times appeared in CS speech samples of only five participants aged between 3;0 to 5;5 years. Thus, their CS samples evidenced the recurrent occurrence of deaffrication, CR, gliding, fronting, WSD, stopping, ICD, FCD, backing and other processes, such as substituting initial consonants with a favourite sound /h/. The rest of TD participants either did not use any processes or used processes that were less frequent than five times. As a result, these processes were not considered as sound patterns errors.

The number of occurrences of processes for DS group were higher than these for TD group. In CS samples, DS participants used more processes than TD participants. The longer the utterances became, the errors DS group produced. Therefore, the length of utterances may impact the quantity of processes recurrently appeared in CS samples for DS group. This finding was supported by a previous study (Corsley and Dowling, 1989) which examined the relationships between CR, liquid simplification and sentence length, age, and IQ in 22 children with DS, aged between 6;6 and 12;7 years. The study findings indicated that sentence length could be used as the primary predictor of CR and liquid simplification in speech production of children with DS. In the present study, the findings revealed that a significant difference between DS and TD in terms of number of occurrences of processes in CS sample. Therefore, DS group started to suppress processes at a delayed onset and the first research hypothesis could be rejected at (p<0.05). DS participants appeared to be considerably more delayed than TD participants in terms of suppression of the processes they frequently used in CS samples. Yet, the two groups developed at a typical rate when matched form MA. However, the analysis of developmental trajectories revealed that MA was an unreliable predictor of the differences between the two groups. Thus, the performance of children with DS was aligned to that of TD children. The sound patterns in children with DS were a combination of delayed development and/or atypical errors not seen in TD children. Delayed (developmental) and disordered (non-developmental) patterns were evident by the age of 3;0 years, although the atypical sound errors appeared earlier life years (Cleland et al., 2010; Kent and Vorperian, 2013).

Regarding percentages of occurrence of processes, the most frequently occurring processes for DS group comprised nine processes: CR, deaffrication, fronting, stopping, voicing, assimilation, MCD, FCD and backing. For TD group, the most frequently occurring processes were only five processes: CR, fronting, ICD, backing and stopping. On the other hand, the less frequent processes in CS samples for DS group comprised four processes with percentages of occurrence <6%. These included ICD, WSD, gliding and other processes. The less frequent processes which appeared in TD participants' CS samples with percentages of occurrence <1% included gliding, deaffrication, WSD, voicing, MCD, FCD, assimilation, gliding and other processes. Based on assessments of connected speech samples in previous studies (Barnes et al., 2009; Iacono, 1998), it was found that the most frequently occurring error was reducing consonant clusters/sequences. Children with DS also used these errors more than their TD peers matched for MA. Therefore, they used single consonants rather than consonant clusters (Stoel-Gammon, 2001). The frequent use of CR process could be attributed to the acquisition of consonant clusters which tended to be more delayed for children with DS compared to younger TD children with similar mental abilities. Additionally, children with DS continued to use cluster reduction longer than their TD peers. (Iacono, 1998; Stoel-Gammon, 1980).

The findings revealed that children with DS were significantly different from TD children in terms of percentages of occurrence of six processes. These included gliding, CR, fronting, stopping, assimilation and MCD. This indicated that DS group developed at a delayed onset when compared to TD group. Thus, the first research hypothesis could be accepted. Yet, DS participants proceeded to suppress these processes at a typical rate, therefore, the second research hypothesis could be rejected. Differently, DS group suppressed assimilation and MCD at a rate slower than that for TD. As a result, the second research hypothesis could be rejected. Children with DS used processes similar to those used by typically developing children, although they did that in a slower rate, expressing delay rather than disorder (Corsley and Dowling, 1989). Analysing the developmental trajectories, the results revealed that MA a marginal predictor of performance in terms of percentages of occurrence of gliding, CR, fronting, stopping for DS group. This indicated that DS participants managed to suppress these processes regardless their intellectual abilities, although they started to suppress these processes at a delayed onset. Yet, MA was a strongly reliable predictor of performance in terms of percentages of occurrence of assimilation and MCD. This suggested that these processes continued to appear in the speech of DS participants at older ages and needed for a substantially longer time to be suppressed.

On the other hand, the present study findings showed that there were non-significant differences between DS and TD groups in relation to percentages of occurrence of deaffrication, WSD, ICD, FCD, backing and other processes. This apparently indicated that the two groups suppresses /continued to use these processes at a similar onsets and typical rates. Therefore, the first and second research hypotheses could be rejected at ($p<0.05$). The analysis of developmental trajectories manifested that MA was a marginal predictor of performance in terms of percentages of occurrence of these processes for DS group. More to the point, DS participants proceeded to suppress WSD, ICD, FCD, but they continued to use deaffrication, backing and other processes. Regarding the percentage of occurrence of voicing, DS and TD groups were non-significantly different. This revealed that DS and TD groups started to use voicing at the same onset. Thus, the first research hypothesis could be rejected. However, DS group continued to use voicing at a rate slower than that for TD group who managed to suppress this process, but TD group continued to suppress voicing. Therefore, the second research hypothesis could be accepted. The analysis of developmental trajectories showed that MA was a marginal predictor of performance in terms of percentage of occurrence of voicing for DS groups rather than TD group. This suggested that the performance of DS participants was not impacted by their cognitive impairment.

7.3.3 Speech Intelligibility in CS Samples for DS Group Compared to TD Group

In the present study, the findings revealed that ICS scores for DS group were lower than those for TD group. The parents of children with DS rated their children's speech intelligibility from sometimes to usually being intelligible, whereas parents of TD children rated their children's speech intelligibility from sometimes to always being intelligible. There was a significant difference between the responses of parents of DS and TD participants in terms of their responses to ICS. The understandability of children's speech could be affected by the children's relationship with different types of listeners who they spoke with (Roulstone et al., 2002). Generally, the understandability of speech of children with speech intelligibility problems could also be affected by their relationship with the surrounding individuals whether they were immediate family members or strangers (Flipsen, 1995). In a previous questionnaire-oriented study (Kumin, 2006) in which opinions of parents of children with DS were collected and analysed. The study findings revealed that approximately 60% of the parents (whose children's ages ranged between 1;0 and 21;0 years with mean age of 8;16 years) considered their children's speech as unintelligible. On the other hand, 37% of participating parents reported that they were sometimes unable their children's utterances. It was also reported that parents were continuously faced with the difficulty of understanding what their children with DS said.

The percentage of speech intelligibility was also evaluated by analysing the spontaneous speech collected during the interactive activities. The percentage of speech intelligibility for DS participants were lower than that for TD participants. Intelligibility difficulties for children with DS could be attributed to articulation and phonology problems. In a questionnaire-oriented study, 71% to 94% of parents of children with DS, aged between 4;0 and 21;0 years, intelligibility problems were essentially attributed to articulation and the inability to produce phonemes in the correct context (Pueschel and Hopman, 1993). In a similar way, it was discovered that 80% of parents' responses indicated that most of the speech intelligibility problems stem from articulation difficulties (Kumin, 2006). Differently, in the present study, since participants with DS did not have any oral motor structure problems, the lower percentages of speech intelligibility were correlated with phonology-based errors.

In the present study, DS and TD groups were found to be significantly different in terms of percentage of speech intelligibility. This demonstrated that DS group started to produce intelligible speech at a delayed onset. Thus, the fourth research hypothesis was accepted (see section 7.1). However, DS participants continued to increase percentage of speech intelligibility at a typical a rate when DS and TD groups were matched for MA. Therefore, the fifth research hypothesis was rejected (see section 7.1). Analysing the developmental trajectories for DS group compared to TD group, the results revealed that MA was a non-significant predictor of the production of intelligible speech for DS participants rather than for TD participants. This obviously indicated that the cognitive abilities in DS participants did not impact their development in terms of speech intelligibility and that their performance was aligned to that of MA-matched TD controls. Flipsen (2006) assessed speech intelligibility for 320 typically developing children, aged between 3;1 and 8;0 years. The study findings indicated that speech intelligibility was proportional with CA, i.e. the older the children grew, the more intelligible their speech became.

7.4 SW Samples Compared to CS Samples for DS and TD Groups

7.4.1 PCC, PVC and PPC in SW Samples Compared to CS Samples for TD and DS Groups

The comparison between SW and CS samples for TD group revealed that the performance of TD participants in SW sample was higher than that in CS sample in terms of PCC and PPC, but not in terms of PVC which was similar in both conditions. TD participants produced PCC and PPC in CS sample at a delayed onset and at a rate slower than that in SW sample. On the other hand, TD participants produced PVC at similar onset and rate in both condition. The no-verbal MA was a non-significant predictor of performance in terms of PVC and PPC in both condition. Yet, MA was a reliable predictor of performance in terms of PCC and PPC in CS samples rather than in SW sample.

In a similar way, the comparison of SW to CS samples for DS group revealed findings similar to these for TD group. The results revealed that PCC, PVC and PPC scores in SW sample were higher than these in CS sample. There were significant differences between the samples in terms of PCC and PPC. This indicated that DS participants produced these measures at a delayed onset in CS sample. Thus, the first research hypothesis could be accepted. However, DS group continued produced PCC and PPC in CS sample at a rate slower than that in SW sample. Therefore, the second research hypothesis was proved. This finding was supported by Morrison and Shriberg (1992) who revealed that the participants produced more accurate consonants in CS sample. On the contrary, the finding of the present study was different from the one reported by Iacono (1998). Iacono (1998) found that there were non-significant differences between SW and CS samples for children with DS in terms of PCC and PPC. On the other hand, the samples were non-significantly different in terms of PVC. Yet, there was a significant difference in the rate of producing PVC. That is, DS participants produced correct vowels in CS sample at a rate slower than that in SW sample. This finding was similar to the that obtained by Iacono (1998) who found that there were no significant differences between SW and CS samples in terms of PVC. However, Morrison and Shriberg (1992) discovered that participants produced more accurate pure and diphthong vowels in CS sample. The analysis of PCC, PVC and PPC trajectories in the two conditions demonstrated that MA was not a reliable predictor of development in relation to the three accuracy measures. Thus, the performance of DS participants was in SW sample was line with in CS sample, although their performance in CS sample was characterised with a developmental delay.

7.4.2 Phonological Processes in SW Samples Compared to CS Samples for TD Group

Qualitatively, the comparison of SW samples to CS samples for TD group displayed the processes which met the five-time occurrence criterion and appeared in SW samples for only four TD participants, aged between 3;0 and 5;5 years. These processes included deaffrication, CR, fronting, WSD, stopping, ICD, backing and other processes, such as substituting initial consonants with a favourite sound /h/. For instance, the SW sample of TD child, aged 5;5 years, evidenced the occurrence of only CR. However, the sixteen TD participants either used fewer processes which did not coincide with the five-time occurrence criterion, or the children's SW speech samples, especially for TD participants aged between 6;0 and 6;3 years, did not evidence the use of any processes. In CS samples, the findings showed that the processes frequently occurred for five or more times for only five TD participants, aged between 3;0 and 5;5 years. Thus, their CS samples evidenced the recurrent occurrence of deaffrication, CR, gliding, fronting, WSD, ICD, FCD, stopping, backing and other processes, such as substituting initial consonants with a favourite sound /h/. The other TD participants either did not use any processes or used processes that were less frequent than five times. Therefore, these processes were not considered as sound patterns errors.

Quantitatively, the number of occurrences of processes in SW speech samples were lower than that in CS samples for TD participants. The findings revealed that SW and CS samples were significantly different in terms of the number of occurrences of processes. This indicated that TD participants started to suppress processes in CS sample at a delayed onset. Therefore, the first research hypothesis was accepted. However, they continued to suppress the number of occurrences of processes in CS sample at a rate slower than that in SW sample. The analysis of developmental trajectories demonstrated that MA was a marginal predictor of performance on this task in the two conditions for TD group. The percentages of occurrence of the thirteen phonological processes were estimated. In SW speech samples, the most frequently occurring processes were only two processes: CR and fronting, whereas the least frequent processes which appeared in the TD participants' SW speech samples with percentages of occurrence<1% included gliding, deaffrication, WSD, stopping, voicing, assimilation, ICD, MCD, FCD, backing and other processes. On the other hand, in CS samples for the TD group, the most frequently occurring processes were four processes: CR, fronting, ICD and stopping, whereas the least frequent processes with percentages of occurrence<1% included deaffrication, WSD, voicing, MCD, FCD, assimilation, backing, gliding and other processes.

Regarding percentages of occurrence of processes, the results showed that there were significant differences between SW and CS samples for TD group in terms of percentages of occurrence of gliding, CR, fronting and ICD. This revealed that TD participants started to produce these processes at delayed in CS sample at delayed onsets. Therefore, the first research hypothesis could be accepted. However, TD participants continued to produce gliding, fronting and ICD in CS sample at rates slower than these in SW sample. Thus, the second research hypothesis was accepted. Importantly, TD participants proceeded to suppress fronting and ICD, but they continued to use gliding. On the other hand, TD participants continued to suppress CD in SW and CS samples at a similar rate. The non-verbal MA was a non-significant predictor of performance in terms of percentages of occurrence of gliding and CR in SW and CS samples, whereas MA was a reliable predictor of performance in terms of percentages of occurrence of fronting and ICD in both samples.

7.4.3 Phonological Processes in SW Samples Compared to CS Samples for DS Group

Qualitatively, in SW and CS samples for DS participants the processes that occurred five or more times were regarded as sound pattern errors. In SW sample only one participant with DS aged 10;9 used only 9 processes which did not meet the five-time occurrence criterion established by Dodd et al. (2002). In addition, the same participant with DS used 13 processes in total and only CR met the five-time occurrence criterion in CS sample. The study findings indicated that the most frequently used processes in SW samples were CR and fronting. For instance, children with DS, aged between 5;5 and 7;1 years frequently used CR, fronting, WSD, stopping, backing, assimilation, ICD, MCD, FCD, voicing and other processes, such as replacing /k/ with a far back voiceless consonant /q/. The SW sample for DS participants, aged between 8;1 and 10;11 years, recurrently produced FCD, MCD, CR, fronting, stopping, gliding, voicing, assimilation, stopping, voicing, WSD, deaffrication and other processes, such as inserting /s,d/, or /ə/. The study findings also revealed that DS participants, aged between 11;1 and 12;0 years frequently used CR, fronting, voicing, deaffrication, stopping, MCD which considered as non-age-appropriate processes. In CS samples, the results showed that processes which frequently occurred for five or more times for DS participants, aged between 5;5 and 7;1 years, were ICD, MCD, FCD, CR, stopping, backing, assimilation, voicing, gliding, fronting and WSD and other process. Children with DS aged between 8;1 and 10;11 years, frequently used MCD, FCD, CR, stopping, fronting, voicing, gliding, assimilation, backing, deaffrication and WSD. The CS samples for DS participants, aged between 11;1 and 12;0 years evidenced the recurrent occurrence of fronting, CR, ICD, MCD, FCD, stopping, backing, assimilation and WSD.

Quantitatively, the results showed that the number of occurrences of processes in SW speech sample was lower than that in CS sample. Children with DS performed better in in SW speech samples than in CS samples; i.e., they tended to use less processes when producing single word utterances. This finding was supported in previous research (Andrews and Fey, 1986; Kumin, 2012; Kumin, et al., 1994; McLeod et al., 1994). It was reported that children with speech difficulties tended to use more processes when producing connected speech rather than single word productions. However, in the present study, it was found that SW and CS samples were non-significantly different in terms of the number of occurrences of processes. This indicated that DS participants used processes in SW and CS samples at the same onset. Therefore, the first research hypothesis was rejected. This finding was supported in previous research (Iacono, 1998) who reported that there was no significant difference between the SW and CS conditions in terms of the number of processes occurred. However, DS participants continued to suppress processes in CS sample at a rate slower than that in SW sample. The analysis of trajectories of the number of occurrences of processes in SW sample compared to CS revealed that MA was a marginal predictor of performance on this task for DS participants. This indicated that suppressing processes in SW and CS samples for DS participants was not impacted by the participants' cognitive abilities.

The results also revealed that SW and CS samples were significantly different in terms of percentages of occurrence of gliding, deaffrication, assimilation and MCD. This indicated that DS participants used these processes in CS samples at delayed onsets. Thus, the first research hypothesis was accepted. Additionally, DS participants produced gliding and MCD at similar rates in SW and CS samples. Therefore, the second research hypothesis was rejected. Yet, they produced deaffrication and assimilation in CS sample at rates slower than these in SW sample. Consequently, the second research hypothesis was accepted. The analysis of trajectories of these processes demonstrated that MA was not a reliable predictor of performance in terms of percentages of occurrence of gliding and deaffrication in SW sample compared to CS sample. This indicated that DS participants continued to suppress gliding and use deaffrication regardless their intellectual abilities. On the other hand, MA was a reliable predictor of performance in terms of percentages of occurrence of assimilation and MCD, suggesting that suppressing these processes was affected by the cognitive abilities in DS group. Finally, the inclusion of connected speech in the evaluation of the phonological development of children with speech problems such as children with DS practically has a beneficial effect on understanding the phonological difficulties could affect speech and language development in this special population (Flipsen, 2006; Hoffman and Norris, 2002).

7.5 Suggestions for Further Research

The findings of the present study experimentally attempted to provide information to clinical assessment of school age children with DS who might substantially need speech therapy to develop their speaking skills. The study also explained the phonology-based performance of children with DS compared to TD children so that professional individuals (speech and language therapists) could benefit from the analysis of phonological development of this population and decide how much children with DS approximate normal development. However, the phonological development of DS population needs in depth investigation based on larger samples of participants and speech data to provide reliably representative data essential for making clinical decisions. Thus, it seems beneficial to put forward the following suggestions for future research (MacKay and Hodson, 1982). Regarding the sample sizes, larger number of participants and various age groups from younger to older need to be evaluated. It is also indicated that there is a need for more extensive phonological analyses (focusing on segmental and suprasegmental aspects of speech development) for drawing more substantial conclusions about the phonological development of children with DS (Smith and Stoel -Gammon, 1983). The results of the present study point out to the need for additional research to be conducted to comprehensively investigate the phonological development of children with DS compared to TD children matched for CA and/or MA. The presented study suggested draws attention to the need for comparative studies which tackle phonological development in relation to gender differences, and whether these differences affect speech development in Down syndrome population (Barnes et al., 2009; Roberts et al., 2005).

It is also suggested that there is a need to conduct studies focusing on development of vowel sound acquisition/production and errors; especially, in speech of children with speech problems. This could assist in identifying the difficulties affecting vowel acquisition/production and the effect of phonetic context when occurring in stressed or unstressed syllables. It has been argued that vowel production received research attention less than consonant production, and this might account for the explanation that vowel production seemed to be less difficult than consonant production for children with disordered phonology.

The vowel production errors might impact speech development; therefore, vowel errors needed to be further investigated and described (Grunwell, 1981; Hargrove, 1982; Ingram, 1976; Stoel-Gammin and Dunn, 1985). Besides, the findings of this research suggest conducting studies on the effect of sound position on the organisation of phonemes in the speech of children with DS. A study as such would help highlight constrains on forward-backward consonant ordering that in various word structures and account for the consonant errors/substitutions associated with consonant position. There is also a need for further research to explore the other phonological constraints that children with DS might impose on the sounds they produce (Bleile, 1982).

Part II

Case Study

Chapter 8: Literature Review

8.1 Introduction

Generally speaking, the effectiveness and appropriateness of a particular intervention approach to remediate the speech sound disorders (SSDs) in children was the most frequently arising question among speech therapists (SLTs) (Bernthal et al., 2009; Hodson, 2010). Speech sound disorders comprised of articulation and phonological disorders. Articulation disorders comprised of articulatory problems caused by oral motor/ structural distortions (e.g. cleft palate). Articulation disorders could affect producing speech sounds accurately, therefore, children diagnosed with articulation problems need to be trained to practice producing a given sound and learn to put the related articulators in the correct posture which is required to produce that sound correctly. Phonological disorders included difficulties related to using sounds and sound patterns in correct contexts. Therefore, children diagnosed with phonological problems need to learn the phonological rules of the language. For example, children need to learn that deleting an initial sound affects meaning, as in deleting /t/ and produce *hat* [hæt] as [æt] (Bernthal et al., 2009; Velleman, 2016). Many intervention models have been put forward and developed to treat different types of speech sound disorders in different clinical populations of children.

During the last four decades, intervention programmes have witnessed tangible theoretical and conceptual changes which led to the emergence of various treatment models including the traditional approach (which comprises the oral-motor-based and phoneme-based models), language-based, and phonological pattern-based approaches (Hodson, 1997). Thus, researchers as well as SLTs have had a wide range of choices for selecting the intervention programme that suits the children's ages and disorder severity levels and, at the same time, that best meet their needs (Hodson and Edwards, 1997). Within the oral-motor-oriented intervention framework, highly unintelligible children diagnosed with dyspraxia, childhood apraxia of speech or sensory integration deficit need oral motor-exercises to train them do the articulatory movements correctly. They have articulation difficulties that prevent them from properly using and/or moving speech sound articulators. However, oral-motor exercises are non-speech activities, i.e., they are used to train the children to do the correct articulatory movements to be able to produce speech at later stages. The oral-motor activities include stretching, stroking, icing of lips, and mid line grooving of the tongue. Moreover, the activities are accompanied by non-meaningful sound production. Oral motor intervention need to be based on more decisive diagnoses before referring children to sensory treatment and the approach as a whole lack efficacy evidence (Bernthal et al., 2009; Hodson and Edwards, 1997).

Language-based approaches promotes bombarding the child with language in context rather than focusing on treating individual phonemes. However, a number of researchers argued that targeting the children's whole language may not proliferate intelligibility, especially, for children with highly unintelligible speech and severely disordered phonologies. They also wondered whether targeting language improves disordered phonologies. On the contrary, a number of studies found that treating speech sounds enhances the child's language better than targeting language at the beginning. Moreover, another method that is language-based is the sign language which involves extensively nonverbal activities to enhance the child's expressive communication skills. However, it is highly recommended that clinicians and SLPs refer the child to meticulous diagnosis to help them decide which is the most efficient intervention model and save them time and effort (Bernthal et al., 2009; Hodson, 1982; Hodson and Edwards, 1997).

The phoneme-based intervention procedure continued to be used in 1980s and 1990s. This approach focuses on targeting individual phonemes in the initial position of a word, a phrase, a sentence and, then in a conversation. The same process is to be re-targeted by treating the same phoneme in word-medial and word-final positions until the child achieves 90% mastery of the targeted sound. Despite the emergence of a more developed approaches like the generative phonology emphasizing upon targeting phonological patterns, SLTs continued to use phoneme-oriented procedures. In addition, they usually implement some behaviouristic procedures when they do so. The proponents of this approach have stressed on targeting the sounds that are the most difficult for a child to utter referred to as the 'least phonological knowledge' sounds. They have claimed that learning the most difficult sounds facilitates mastering the less problematic ones (Hodson, 1982; Hodson, 2010; Hodson and Edwards, 1997; Williams, 2003). Similarly, within the pattern-oriented model, the principles of phoneme-oriented model and behaviouristic procedures have been adopted in treating phonological processes (e.g., final consonant deletion) in the sense that SLTs require the children to achieve 95% mastery of the deviant pattern before targeting a following one (Hodson and Paden, 1991; Hodson and Edwards, 1997).

However, through the accumulation of theoretical investigation and clinical practice, the need to more effective approaches that deal with disorders of phonology has been considerably realised (Hodson and Edwards, 1997). In late 1970s, Barbra Hodson and Elaine Paden have made many attempts based on persistent clinical research and practice which resulted in devising and developing the cycles phonological remediation approach. The cycles phonological remediation approach is a phonological pattern-based approach (Hodson and Paden, 1991). It was primarily designed to treat phonological difficulties of highly unintelligible preschool and school aged children, including children with suspected Childhood Apraxia of Speech. It targets sound and sound pattern errors in a cyclical way to help children gradually acquire the correct phonological patterns and, in return, increase their speech intelligibility. The cycles phonological approach has been developed based on clinical research findings obtained throughout the testing of several hundreds of children aged between 2;6 and 14;0 years (Hodson & Paden, 1991; Hodson, 1997).

The present study aims to examine the effectiveness of the cycles approach as described by Hodson (2010) in remediating the phonological processes of a school aged child with DS. It also evaluates the extent to which the cycles-based intervention would help reduce the occurrence of the phonological processes in order to increase the child's speech intelligibility. The following sections present introduction to the theoretical and conceptual underpinnings of the cycles phonological approach, the rationale underlying the use the cycles approach, and explain the target selection strategy and the structure of a typical cycles-based intervention session.

8.2 Cycles Phonological Approach: Theoretical and Conceptual Aspects

As a comprehensive phonological approach for treating the phonological disorders of children with severely disordered phonological systems, the cycles approach was based on a set of developmental phonology theories (e.g., Stampe, 1973; Browman and Goldstein, 1986; Kent, 1997) and seven basic conceptual aspects of children's acquisition process of phonological systems. Theoretically, the approach has been founded on theories of developmental phonology, and gestural phonology (Browman and Goldstein, 1986; Kent, 1997). The approach was also based on a number of theoretical considerations including the theories of natural phonology, generative phonology, non-linear phonology, distinctive features analysis and clinical research (e.g., Stampe, 1973; Chomsky & Halle, 1968;

Goldsmith, 1990), principles of cognitive psychology (e.g., Hunt, 1961; Vygotsky, 1962), phonological acquisition research (e.g., Dyson and Paden, 1983; Grunwell, 1987; Porter and Hodson, 2001; Preiser et al., 1988), and clinical phonology research.

The core phonological theory of the cycles approach was gestural phonology (Browman and Goldstein, 1986; Kent, 1997) which centred around the concept that speech could be considered as a stream of classes of articulatory movements (gestures) and hypothesised that phonological representation depended on speech perception and speech production. Gestural phonology did not include only implications for speech production but also included implications for the literacy skills development. According to Mody (2003, p. 33), literacy acquisition was found to be critically associated with the "integration of recurrent gestural patterns into segmental units." Therefore, the cycles model incorporated metaphonological skills enhancement tasks into the intervention procedure along with speech production tasks. The cycles-based intervention model comprises of seven basic conceptual aspects underlying its general framework. These are described below.

1. The first and most important concept emphasised the gradual nature of the sound acquisition process (Hodson and Paden, 1983; 1991; Willaims, 2003). Since acquisition of sounds in TD children tends to be gradual and time-based, it is plausible to expect that children with phonological problems tend to internalise new sounds/sound patterns at the same gradual pace of speech sound acquisition. The cycles-based intervention approximates the natural way in which speech sounds can be acquired. Thus, through the treatment phase the children are given the opportunity to fluctuate between the correct and incorrect productions of a particular sound/sound pattern before completely being able to produce them correctly on their own. (Hodson and Paden, 1983; 1991; Hodson, 2007; 2010).
2. The second concept focuses on learning sounds and sound patterns through listening. Children learn various sounds and sound structures primarily through listening to adults' speech without deliberately instructing them where to place the speech sound articulators (Hodson and Paden, 1983; 1991; Williams 2003; Hodson, 2010). This concept has drawn attention to the necessity of the inclusion of auditory stimulation technique during the treatment sessions. The auditory stimulation assists children to perceive the acoustic features of a given sound and, at the same time, familiarise children with the sound they cannot produce through continuous exposure to these sounds in context (Hodson, 2007; 2010).

3. The third principle is that speech sound production and perception are interdependently correlated. This indicates that auditory stimulation cannot be separated from speech sound articulation constrains. During the speech sound acquisition process children try to associate kinaesthetic and auditory sensations of the sound sequences they learned (Kamhi, 1992; Williams, 2003). Therefore, they become able to self-monitor themselves when producing spontaneous speech at later sound development stages. This implies that children during the treatment phase need to be helped by making them aware of what a given phoneme sounds (perception) and why it sounds that specific way (production). This gradually improves children's production of the target patterns and promotes rapid internalisation of the newly learned sounds as they become self-aware how to correct themselves and produce more accurate sound patterns (Hodson and Paden, 1983; 1991; Hodson, 2006; 2010). In addition, developing accurate kinaesthetic images and adequate articulatory gestures of the newly acquired sounds/sound patterns could be supported by using facilitative phonetic environments.
4. The phonetic structure of the words used for production practice has considerable effect on the children's ability to pronounce target sounds correctly. Thus, production words need be carefully selected as target sounds tend to be easier to learn in specific phonetic contexts (e.g., word positions and or in vicinity of certain sounds) rather than in other ones, especially, at the early treatment cycles (Hodson, 2010).
5. The cycles intervention model emphasises the concept of acquiring sounds in a natural and play-based treatment environment. Learning sounds requires active engagement during the acquisition process. Friendly playing-based treatment settings would help children gradually and naturally discover the characteristics of the newly learned sounds/sound patterns (Williams, 2003; Hodson, 2007; 2010).
6. Children tend to be innately inclined to generalise the newly learned patterns to non-treated sounds, particularly when the carefully selected target sounds result in effective generalisation. For instance, treating /s/ clusters helps trigger the generalisation to single strident sounds occurring after /s/, and this considerably assists in consolidating the remediation process.
7. From a cognitive psychology viewpoint, children need be provided with optimal learning opportunities which are sufficiently challenging but enjoyable and doable. The treatment activities should be based on optimal learning in which children are offered stimulation one step above their actual performance level during the intervention

(Browman and Goldstien, 1986; Dyson and Paden, 1983; Hunt, 1961; Hodson and Paden, 1991; Vygotysky, 1962;).

The cycles approach was designed and developed to remediate phonological problems of children with highly unintelligible speech but who have potential for speech production (Hodson, 1997,2010). It targets systemic sound pattern errors, i.e., phonological processes rather than individual sounds. One of the most important concepts was that sound patterns and the related sounds need to be gradually acquired in a way similar to natural sound acquisition process in TD children. The cycles approach would help children improve their speech by facilitating the gradual acquisition of the target patterns through a cyclic treatment procedure rather than requiring full mastery of individual phonemes as in the case of the traditional phoneme-based approach.

The cycles approach has a practical adaptability in terms of phonological sound/sound pattern targets selection, treatment time scale and clinical settings. The targets selected should be stimulable, especially in the early treatments cycles, i.e., during the first treatment cycles, the target pattern and the related sounds need to be in line with the child's ability to imitate when these patterns and sounds were modelled. A child might be able to produce a particular sound correctly in isolation or in specific word positions but not in the other positions. For example, a child might say [bæ] for *bat* or *ball*, or [teɪk] for *lake*. A child might know how to produce /t/ but needed to work on producing it in the correct word positions (Kumin, 2012). A new target pattern could be treated even when the previous targeted pattern was not fully mastered because cycles-based treatment tends to be a time-based rather than criterion-based intervention (Velleman, 2016). This would help the child gradually acquire the target patterns. Furthermore, the cycles model promotes the parental participation in the treatment programme. by including a short home programme (2-3 minutes per day) in which the parents/care givers can enjoyably review the picture naming task in a more friendly and enjoyable setting at home (Hodson, 2010). This contradicts the principles of the phoneme-based which focuses on targeting the sounds that are the most difficult for a child to utter referred to as the 'least phonological knowledge' sounds. It was claimed that learning the most difficult sounds would facilitate mastering the less problematic ones (Hodson, 1997). The child would also be required to achieve more than 85% mastery of the deviant pattern before targeting a following one, i.e., it was a criterion-based approach.

Regarding the treatment time scale, the length and the number of the treatment cycles vary according to the child's needs and the disorder severity level. It was also found that the cycles approach was practically effective in remediating phonological patterns in the sense that it required less time (3-4 treatment cycles. i.e. 30-40 hours in total) for treating preschool aged children with severe speech sound disorders. Hodson (1997; 2010) indicated that a child with severe-profound expressive phonological disorders and within the normal cognitive limits might need 2-year intervention programme (65 hours to become intelligible). On the contrary, the oral-motor-based and phoneme-based approaches need a long treatment period of time to get the child achieve the 85%-90% mastery of the target phonemes. For instance, phoneme-based intervention required longer time (nearly 4 years to produce one sound correctly at a time), especially for children with severe-profound expressive phonological difficulties. Furthermore, approaches such as the oral-motor-based and phoneme-based approaches could be used to treat the sound errors in one child at a time. Contrarily, the cycles approach was found to be effectively adaptable to various clinical setting, i.e. it was used in group and individual interventions (Almost and Rosenbaum, 1998; Gillon, 2005; Montgomery and Bonderman, 1989; Rvachew et al., 1999; Tyler et al., 1987; Tyler and Watterson, 1991).

More importantly, the cycles model takes into account the child's intellectual development. Its techniques can practically be adapted to meet the needs of children with cognitive delay and learning disabilities. The treatment materials and activities can easily be tailored to fit the child's level of intellectual development (Hodson, 2010). The approach was successfully adapted for children with cognitive delays, specifically children with DS. The approach has been feasibly adapted for children with cognitive delay by doubling the time for the treated targets (Berman, 2001, as cited in Hodson, 2010, p. 112; Cholmain, 1994; Van Bystervelt et al., 2010).

8.3 Rationale for Using the Cycles Approach for Treating SSDs in Children with DS

The cycles approach was adopted as the treatment model for children with SSDs of unknown origin (Mota et al., 2007; Rvachew et al., 1999; Tyler et al., 1987), and children with more complicated aetiologies, such as repaired cleft palate (Hoson et al., 1983), recurrent otitis media and hearing loss (Churchill et al., 1988; Robins and Chin, 1995), delayed cognitive disabilities (Culatta et al., 2005; Perzas and Paden, 2010), and stuttering disorders (Conture et al., 1993). The cycles-based intervention was evidently found effective in most of the studies independently reviewed by Baker and McLeod (2011) and Law et al. (2012). They found that the cycles procedure considerably reduced the severe phonological difficulties in the treated children and; therefore, considered the cycles phonological approach as a useful model for children with severe phonological problems.

Since most of children with DS have hearing problems (e.g., due to recurrent otitis media), the cycles could be appropriate for them as an intervention model. It was found as an effective treatment procedure in several case studies of children with severe SSDs attributed to hearing problems (e.g. Churchil et al., 1988; Garret, 1986; Gordon-Branann et al., 1992; Robbins and Chin, 1995). Owing to auditory discrimination difficulty which most of children with DS have, it was found to be difficult for them to perceive the differences between sounds. That is why the auditory bombardment technique at the beginning of each treatment session was found to be very helpful in supporting the child to recall the patterns being practiced. Auditory bombardment encourages the child to listen with slight amplification to the target sound pattern in order to enhance the child’s sound awareness and, in return, consolidates the child's short-term memory (Rvachew et al., 2004). In addition, using picture cards reinforce visual learning which is more advanced in children with DS than auditory learning. Visual processing is more active by using picture cards technique. Using cards to activate auditory learning helps children remember the words to enhance auditory processing which is originally slow (Bernthal et al., 2009; Hodson, 2006; 2010). The other difficult area of phonology for children with DS is developing the children’s phonological awareness skills, i.e., the ability to identify and use sounds of language (Fletcher and Buckley, 2002; Kennedy and Flynn, 2003). Highly unintelligible school age children with DS would benefit from the cycles procedure which includes more advanced patterns to improve their metaphonological skills. These include targeting multisyllabic words for which children need to be trained as to how to segment these words into individual sounds/syllables and how to re-combine them.

To sum up, the cycles-based treatment was adopted as the intervention model for the present case study to assist in reorganising the disordered phonology of a child with DS and, in return increase her speech intelligibility. It would help the child to reduce/overcome part of the sound/sound pattern errors negatively affecting her speech. The cycles intervention was adopted to achieve a number of goals:

1. To decrease the number of phonological processes the child used.
2. To increase child’s speech production accuracy.

3. To increase the child's speech intelligibility.

The goal was to help the child generalise the learned patterns to other untreated sounds to emerge unconsciously in her spontaneous speech.

8.4 Cycles Phonological Approach: Target Selection Strategy and Structure

Within the cycles intervention framework, the target selection strategy is confined by the severity level of the child's phonological deficiencies and his/her stimulability level. Hodson and Paden (1983; 1991) devised a developmental reference list of targets including primary, secondary and advanced targets. It has been recommended that the targets for the first treatment cycle should include early developing patterns (e.g. the syllable/word structures and single consonants including the final stops, nasals and glides; and initial nasals and obstruents), anterior/posterior contrasts (velar and alveolar consonants); /s/-clusters, and liquids which could be used contrastively. According to Hodson (2010), the /s/-clusters which are made of stridents clustering with other consonant combinations are preferred to be targeted first for two main reasons. First, because of their influence on the speech intelligibility as a whole; second, they are easier to stimulate and treat, for the unintelligible child who is used to retain the post /s/ consonant.

The target selection depends on the percentage of occurrence of phonological processes and child's stimulability level. Accordingly, the target patterns with higher percentages of occurrence would be prioritised for treatment. For example, if a client scored 45% and 60% for final consonant deletion and consonant cluster reduction processes respectively, it would make more sense to target the latter with 60%. Moreover, the highly unintelligible children need to target the sounds to which they are stimulable first, i.e., the sounds they can produce with least assistance (e.g. by listening to a target word or exemplifying sound articulation). This would definitely motivate unintelligible children to make more correct sound productions and increase their speech intelligibility throughout treatment (Hodson & Paden, 1991; Hodson, 1997; Perzas and Hodson, 2010). Stimulability was one of the basic concepts of cycles approach. It implies targeting stimulable sounds rather than non-stimulable ones helps motivate unintelligible child to make correct speech sound productions and; consequently, increase speech intelligibility. Alternatively, non-stimulable sounds may be stimulated throughout treatment and targeted when the child become capable of producing them correctly (Prezas and Hodson, 2010).

The cycles approach focuses on facilitating the acquisition of appropriate phonological patterns and reorganizing the child's phonological system to increase speech intelligibility. For children with speech intelligibility less than 20%, a 10-15-week remediation cycle could be planned to target deficient phonological patterns in addition to the deficient consonant categories associated with each pattern. In a treatment cycle, each phoneme should be targeted for at least 60 minutes per week (two thirty-minute sessions or three twenty-minute sessions). The length of the cycle depends upon the number of deficient patterns and the number of stimulable sounds in error that the child could produce with assistance. Moreover, target patterns would be recycled whenever necessary (Prezas and Hodson, 2010). According to Hodson (2010), the general structure of a treatment cycle sessions typically includes the following:

1. Reviewing previous session word list and providing the client with auditory stimulation with amplification.
2. Getting the client involved in experiential play production activities during which the client produces the target patterns (e.g. matching, picture naming, crafts, puzzles, etc.).
3. Incorporating metaphonological activities to facilitate developing essential literacy skills, such as syllable segmentation, rhyming and blending.
4. Probing of optimal target phonemes to detect the child's stimulability and determine the target words to be practiced in the following session.
5. Repeating auditory stimulation activity at the end of the session.
6. Getting caregivers involved in a daily two-minute home program which requires reading the session word list to the child and, then, asking him/her to name the relevant pictures.

8.5 Previous Cycles-Based Intervention Studies

The cycles approach was employed and feasibly modified for different clinical settings. For instance, it was adapted for group intervention in the following studies: Tyler et al. (1987); Montgomery and Bonderman (1989); Tyler and Watterson (1991); Almost and Rosenbaum (1998); Gierut (1998); Rvachew et al. (1999); Harbers et al. (1999); Mota et al. (2007). It was also compared to other intervention models (e.g. minimal pairs, maximal oppositions) to treat groups of children with SSDs of unknown origin and various severity levels ranging from moderately to profoundly disordered phonology. Different experimental designs were used in these studies (e.g., between-participants, randomised controlled trial and multiple probe AB designs), different numbers of participants ranging from 2-26 children and variable experiment-specific modifications of the cycles intervention (changing the cycle length, using stimulability procedure and perception training, using listening devices, incorporating phonological awareness skill tasks, learning through computer tasks, etc.). The following sections provide a detailed review of studies on the cycles approach.

8.5.1 Previous Group Studies on the Cycles Approach

The cycles approach can be considered as an economical effective intervention programme that can save time and money with appropriately adjustable schedule. The utility of the cycles-based intervention model in providing group economical intervention service in schools was evaluated by Montgomery and Bonderman (1989). Nine children with severe-profound speech difficulties aged between 3;1 and 4;10 years participated in group intervention programme. The pre-treatment and post-treatment results indicated a remarkable decrease in the number of phonological processes (e.g., final consonant deletion affecting /p,t,k/ as in *duck* [dʌ], consonant cluster reduction /sn/ in *snow* [nəʊ]) the children used in their speech. The study provided additional evidence for the effectiveness of the cycles-based intervention in reducing the sound pattern errors of the participants. However, the study did not indicate whether the children continued to use the newly-learned patterns in everyday interactions. The cycles treatment procedure promoted facilitating the acquisition of the treated patterns and sounds gradually in addition to recycling the problematic patterns which might need additional treatment sessions. Montgomery and Bonderman (1989) recommended implementing the cycles-based intervention model for group intervention programmes for TD children with varying phonological problems and unintelligible speech. However, they doubted the utility of group intervention for children with articulation difficulties and/or genetic disorders.

Almost and Rosenbaum (1998) investigated the effectiveness of early cycles-based intervention in children with severe phonological errors. Their study was considered as a unique one in terms of its experimental design (randomised controlled trial). It added evidence for the effectiveness and efficacy of modified cycles approach which included minimal pairs to target sound contrasts and traditional articulation training. The study included 26 preschool aged children whose ages were below 6;0 years. The processes which were targeted included final consonant deletion (e.g., deleting /v/ in *five* [faɪ]), velar fronting (e.g., /g/ *go* [dəʊ]) and cluster reduction (e.g., /bl/ in *blue* [bu:]). The findings revealed statistically significant differences between the early treatment group and the delayed treatment group. The early treatment group produced more accurate conversational utterances and improved their expressive skills more than the delayed treatment group. The phonological treatment not only increased the children's speech intelligibility and developed their conversational skills, but also positively affected their social behaviour.

Gierut (1998) conducted a multiple baseline design to examine the effectiveness of the cyclic structure of the cycles model in treating singleton sounds and sound clusters. Six children participated with mean age 4;3 years. The participants were randomly assigned to three experimental conditions: (1) treatment of singleton sounds, (2) treatment of sound cluster, and (3) treatment of singleton sound and sound cluster. In the singletons treatment, the children acquired two consonants out of four. In the cluster treatment, the children revealed broad generalisation, as they acquired untreated clusters. Finally, in the singleton-cluster treatment cycle, children made substantial development of their phonological systems. Throughout singleton-cluster treatment, they acquired both treated and untreated consonant singletons and clusters. This experimentally contradicted the findings of singleton only treatment in which children acquired a limited set of consonants. According to Gierut (1998), sound patterns, such as clusters were highly recommended to be targeted to facilitate wider range of generalisation to conversational speech. Hypothesising that the singleton consonants and consonant clusters might be learned in a cyclic way, children keep vacillating between these sound patterns until properly acquiring them. The study results significantly supported this assumption.

Another practical feature of cycles approach is enhancing the children's stimulability and auditory training and perception ability. Rvachew et al. (1999) conducted a combination of group and individual interventions over two experiments to investigate the way stimulability and speech perception training affect the progress of treatment of phonological difficulties. The modified cycles approach was used in both experiments. In the first experiment, 10 children with mean age 4;6 years and diagnosed with moderate to severe phonological disorders received 9 group treatment sessions to remediate three phonological processes (e.g. fricative stopping /f/ in *fan* [pæn], liquid gliding /l/ in *yellow* as [jejəʊ], palatal fronting /ʃ/ in *ship* as [sɪp]). The results revealed that the production of targets to which children were unstimulable and for which they had poor perception ability did not improve in terms of production. In addition, the treatment did improve the children’s production accuracy for more than half of the treatment probes when targeting unstimulabale phonemes to which children had low perceptibility. In the second experiment, 13 children with mean age 4;7 years and diagnosed with moderate to severe phonological errors received 9 cycles-based treatment sessions with a slight modification. The procedure was modified by offering 3 initial individual treatment sessions followed by 6 group treatment sessions. During the individual treatment sessions, each child was offered stimulability training for all of the target phonemes in isolation and then embedded in the target production words. The participants also received a perception training enhanced with visual representations of the targets. The findings of the second experiment showed that children were considerably more responsive to stimulable sounds supported by auditory bombardment. The participants also achieved significant production accuracy for the poorly stimulated and poorly perceived targets after providing stimulability and perception training prior to the implementation of the group intervention. These findings support those of Montgomery and Bonderman (1989) that the cycles model could be feasibly modified and tailored for group intervention programmes in schools. Nonetheless, children needed to target both stimulable and unstimulable sounds. The children also needed to target the well perceived and poorly perceived sounds. As a limitation of the study, because of the small number of participants and insufficient literature about the efficacy of the modified cycles model, it was challenging to analyse the results. The researchers could not decisively contend that the same results might have been obtained if another treatment model other than the cycle approach had been used. Consequently, the efficacy of cycles approach needed further evaluation by randomly assigning participants to modified and unmodified cycles intervention.

Harpers et al. (1999) investigated the effect of phonological intervention on improving the phonological awareness skills in children with severely disordered phonologies, and the phonological awareness improvement gains resulting from phonological treatment. Four children (2 males and 2 females) with mean age 3;5 years and diagnosed with severe phonological impairments were selected. The participants had normal hearing level and normal oral-motor mechanisms, and they had not been previously treated. To examine the impact treatment had on phonological awareness and phonological production improvement, multiple-probe design across children was employed. For each child, five different phonological patterns were targeted. These patterns included initial strident cluster (/st/ in *stop* as [tɒp]), velars (e.g., /k/ in *coat* as [tɔ:t]), singleton stridents (e.g., /s/ in *soap* as [fɔ:p]), final consonants (e.g., /n/ in *rain* [reɪ]) and liquids (e.g., /l/ in *pencil* as [pensu:]). A combination of two intervention frameworks (metaphon and cycles approaches) was applied. The children's parents were involved in the treatment sessions, though they were not aware of the experiment purpose.

The findings indicated that the production of four out of five patterns considerably improved after 6-9 months of intervention. Additionally, phonological awareness improved after the first six intervention sessions. Although the researchers stated that children internalised four out of five patterns and that they began to generalise these new-learned patterns to their conversational speech, the generalisations were not documented or identified in the literature. It would have given more powerful evidence of the phonological improvement, if the researchers had identified or reported examples of such generalizations. The results could have been affected by other factors such as participants' motivation and cooperation during the treatment sessions (Harbers et al., 1999).

In an experimental investigation of the different efficiency criteria for target selection, Rvachew and Nowak (2001) treated 48 preschool children with mean ages 51;46 months and diagnosed with moderate/severe phonological errors. The target sounds were selected in terms of the children's phonological abilities and age-bounded sound mastery. As a result, the subjects were divided into two groups. The first group (referred to as ME) comprised of children whose sounds representing the 'most productive phonological knowledge' or early developing sounds were treated. The second group (referred to as LL) included children whose sounds representing 'least productive phonological knowledge' or later developing sounds were treated. All children received two six-week treatment cycles (12-14 weeks), each of which was preceded by appropriate assessment tests in addition to post-treatment assessment. In ME group four early developing phonemes /t,d,v,l/ occurring in word-initial position were treated for 6 weeks; while in LL group four later developing /θ,ʃ,ʧ,ʤ/ occurring in word-initial position were targeted. During treatment, the children got involved in production activities (e.g., bowling) to imitatively produce syllables and words followed by spontaneous production of words. Then, they imitatively produced patterned sentences followed by spontaneous patterned sentences. Later on, they reproduced sentences modelled and spontaneous sentences. The findings revealed a significant difference between the two groups in terms of treatment progress. The ME group achieved significant progress in acquiring stimulable target sounds in addition to spontaneous emergence of newly-acquired complex phonemes greater than the LL group. This indicated the constructive effect of stimulability on the misarticulating child's phonological development throughout therapy (Rvachew and Nowak, 2001).

8.5.2 Previous Case Studies on Cycles Approach for Remediating Phonological Errors Related to Unknown Origins

Many case studies and multiple baseline single –subject studies examined the efficiency and efficacy of the cycle intervention model in remediating the phonological errors of unknown origin in children whose ages ranged from 3;11 to 7;0 years and were diagnosed with severity level ranging from moderate to profound phonological difficulties (e.g. Galpsey and Stoel-Gammon 2005; 2007; Hodson, 1983; Hodson, 2006; Hodson et al., 1989; Rudolph and Wendt, 2014; Stoel-Gammon et al., 2002). Generally, the researchers evidenced the efficiency and efficacy of cycles intervention in reducing and/or suppressing most of the participants' deficient phonological patterns and increasing speech intelligibility, and at the same time insisted on the need to more research in this domain.

Hodson (1983) highlighted the challenge that SLTs might be faced with when trying to select the appropriate intervention programmes that best remediate the child's phonological difficulties. The utility of two remediation models: the traditional and the pattern-oriented models were compared. Hodson (1983) argued that the phoneme-oriented model could be quite appropriate for children with a small number of erroneous sounds, but it had obvious limitations in treating children with many sound misarticulations. It tended to be both time and effort consuming procedure and, in return, it fulfilled limited progress. Thus, the cycles treatment procedure was developed and adopted to treat children with severe-profound phonological difficulties. In order to prove the utility of such a procedure, Hodson (1983) conducted a case study by administering 45 sessions in 18 months for a child aged 3;11 years whose assessment results showed normal levels of oral-motor structure and hearing. The participant’s speech intelligibility was as low as 10%. The phonology assessment indicated that the child made extensive omissions and multiple substitutions so that her speech was rated as profoundly unintelligible. For example, she entirely deleted all consonant clusters (e.g., /st/ in *star* as [tɑː]) and initial glides and liquids deletion (e.g., /l/ in *leaf* as [iːt], /w/ in *watch* as [ɒt]). Stimulable patterns and sounds were selected as the treatment targets to facilitate the learning process and enhance the acquisition of other problematic patterns and sounds. The child's speech became more intelligible and most of the targets emerged in spontaneous speech so that the child significantly continued to improve even without any further intervention.

Phonology has been considered as a significantly indispensable language component that critically influences the development of children's literacy skills (Hodson et al., 1989). It has been argued that language intervention for profoundly unintelligible children might help increase their utterances but could severely decrease their speech intelligibility. Thus, a phonological intervention could function as a catalyst in developing other language aspects, such as syntax. This argument led Hodson et al. (1989) to conduct a case study to examine the association between phonology, reading and writing skills development. A child aged 5;0 years with profoundly impaired expressive language skills and poor phonology was treated via cycles approach. The study results indicated remarkable speech development and improvement in the production of morphological inflections. The post-treatment assessment results revealed a transference from profound to mild level of phonological disorder severity. The findings revealed that the child made non-significant progress when language and phonology were simultaneously targeted. However, the child’s speech intelligibility considerably improved when focusing on gradual acquisition of correct phonological patterns and then followed by language intervention. The study findings support the viewpoint that the child needed to focus on one aspect at a time (either phonology or language), but not both of them simultaneously to obtain the desired treatment outcome.

In other case studies (e.g., Hodson 2006; Rudolph and Wendt, 2014; Stoel-Gammon et al., 2002), the findings were in line with Gierut (1998) and Almost and Rosenbaum (1998). For example, Stoel-Gammon et al. (2002) conducted a case study to evaluate the effectiveness of the basic components of the cycles treatment procedure: auditory bombardment, production practice activities, and parent involvement. A four-year old child with severe phonological errors and delayed expressive language skill was treated. The phonology assessment revealed that his speech was characterized by final consonant deletion (e.g., /t/ in *bat* as [bæ/), velar fronting (e.g., /k/ in *cup* as [tʌp]), stopping (e.g., /v/ in *van* as [bæn]), cluster reduction (e.g., /-sk/ in *mask* as [mæk]), and gliding of liquids (e.g., /l/ in *log* as [jɒg]). Accordingly, the target patterns were selected and treated over two 50-minute sessions per week over two treatment cycles. The treatment goal was to get the participant engaged in age-appropriate production activities that help gradually and positively modify his erroneous patterns into correct ones. The study findings indicated that cycles intervention effectively helped the child increase his speech intelligibility, retain the learned patterns and finally generalise the corrected pattern to the other untreated sounds to appear in his daily speech.

Hodson (2006) implemented cycles approach to treat a 7-year old child with profound phonological difficulties and highly unintelligible speech which resulted in literacy learning difficulties. The child also had mild hearing loss. The speech samples elicited throughout the assessment revealed percentages of occurrence higher than 40% for five phonological deviations including omissions of consonants in sequences, omissions of postvocalic singleton consonants, liquid deviations, strident deviations, and velar deficiencies. The most frequent phonological process was gliding of /l/, as in *leaf* is produced as /jeɪ/, glottal stop used as a replacement or insertion as in *black* /bwæʔ/ in addition to stopping. He also made some unusual nasal substitutions, as in *snake* /meɪʔ/ and *thumb* /θʌŋ/ (Hodson, 2006). The optimal primary target patterns were selected depending on the assessment results. After completing the first cycle, the findings showed that most of the primary target patterns, except liquids, which indicated slow progress, were emerging in the child's spontaneous speech (Hodson, 2006). The study explained the flexibility of the cycles treatment procedure in introducing the target patterns and sounds to the child. The child was introduced to a new pattern even before entirely mastering the previous one. This was found to be quite practical in increasing both the treatment efficiency and efficacy.

In another case study conducted by Galspey and Stoel-Gamon (2005), the application of scaffolding scale of stimulability (SSS) to phonological disorders was investigated. The scaffolding scale of stimulability could be a diagnostic indicator of the child's ability to produce the target patterns correctly when provided with appropriate stimulating cues. For this purpose, a child aged 3;7 years with severe phonological disorders was treated using the cycles phonological approach. The scaffolding scale of stimulability was run before and after treatment. The child showed remarkable progress in suppressing the target phonological processes. Glaspey and Stoel-Gammon (2005) contended that stimulability was a very important constituent of the phonological-based treatment structure because it assisted in identifying the sounds the child could correctly produce with least training effort and, in return, facilitate the improvement of other more difficult sounds. In addition, it helped the SLTs in the target selection process and the decision-making process as to what appropriate strategies they could use to enhance the child's production progress. These statements substantially coincided with the principal concepts of the cycles framework, which emphasises upon starting therapy with the most stimulable sounds and adjusting the treatment techniques accordingly.

In another case study conducted by Galpsey and Stoel-Gammon (2007), the cycles-based intervention procedure was implemented to evaluate the application of dynamic assessment as compared to static assessment in phonological disorders. A 4-year old child with moderate phonological disorders was treated. The study focused on analysing the difference between static assessment void of perceptual support and dynamic assessment which included auditory support. The child's initial assessment results revealed that his speech had several processes like cluster reduction, gliding liquids, stopping of stridents, deaffrication and occasional velar fronting. The child had a cycles-based treatment (two sessions per week for six months). The dynamic and static assessments were regularly used during treatment to assess the child's progress. In as far as the intervention model used was concerned, the child showed a remarkable progress after treatment in terms of the processes he suppressed and the sounds he correctly produced. Galpsey and Stoel-Gammon (2007) discussed two important issues with which the child assessment and treatment procedures were very closely related. These included the optimal match and stimulability. Hodson and Paden (1991) stressed that "optimal learning occurs if a match is found first and then stimulation is provided exactly one step above the child's current performance level" (p. 84).

In a more recent study, Rudolph and Wendt (2014) directly examined the efficacy of cycles approach to remediate the SSDs of three children (2 males and 1 female) whose ages ranged from 4;3 to 5;3 years. They had moderate-severe/severe phonological disorders. They received 2 treatment cycles (18 months) during which three patterns were targeted in each cycle. For instance, /s/-cluster (e.g., /sp/ in *spear* as [peə]) was selected to be treated for the three participants. Despite of individual differences and degrees of progress, the 3 participants showed significant achievements in terms of production during the treatment sessions and after completing the treatment cycles. The findings supported the researchers' expectations that the participants generally improved after completing treatment cycles and more importantly they maintained what they learned. This evidenced the efficacy of cycles approach, yet it was important to take into account the limitations this model might have and try to modify it so that it could fulfill the different disordered cases. Cycles approach may not be appropriate for treating all of the types of SSDs because this depends on the client's intelligibility level and responsiveness to treatment. Although all the participants improved, they achieved progress and generalized the newly learned patterns to different degrees. The differences could be attributed to several factors, such as the children's perception ability, sound stimulability and order of treatment, which were not assessed or even referred to in the study.

8.5.3 Previous Studies on Cycles Approach for Remediating Phonological Errors Related to Complicated Aetiologias

During the last two decades there has been a growing interest in examining the efficacy and efficiency of the cycles approach in remediating the phonological disorders of children diagnosed with more complex aetiologies, such as mild/severe hearing loss (Gordon-Brannan et al., 1992), repaired palate (e.g., Hodson et al., 1983), cochlear implantation (Robbins and Chin, 1995), stuttering (Conture et al., 1993), cognitive delay disorders (Culatta et al., 2005), Childhood Apraxia of Speech (CAS) (Perzas & Paden, 2010), dyspraxia (Hodson & Paden, 1983) and learning disability (Hodson and Paden, 1991).

Hodson et al. (1983) used the cyclic intervention procedure to treat a child aged 5;0 years who had repaired cleft palate. He was also diagnosed with recurrent otitis media and mild conductive hearing loss. It was a great challenge because there were not any supportive linguistic data on children with cleft palates available at that time. The cycles approach was found to be a practical treatment procedure as it increased intelligibility in a child with extensive misarticulations due to palatal problems in addition to mild hearing impairment. The child internalised the newly learned patterns (e.g., velars and consonant clusters) and continued to generalise the phonological improvement to other patterns in his conversational speech. More importantly, the participant progressed in terms of academic achievement, i.e., he got educationally successful in developing metaphonological skills (e.g., phonics and spelling).

Hodson and Paden (1991) treated the phonological disorder of a child aged 3;6 years diagnosed with recurrent otitis media and fluctuating hearing in addition to oral-motor sequencing problems. After receiving 3-month phoneme-oriented treatment and sign language training, the child received phonology-based intervention programme. His speech was highly unintelligible and characterised by excessive occurrence of phonological processes (e.g., final consonant deletion, cluster reduction, velar fronting). After 35-week treatment sessions, the targeted patterns were gradually emerging in the child's speech.

Gordon-Brannan and Hodson (1992) examined the efficiency of the cycles phonological approach by clinically treating the phonological disorders of a child aged 4;6 years and diagnosed with unusual hearing loss: "a mild conductive loss in the low frequencies, hearing within normal limits in the middle frequencies, and a moderate sensorineural loss in the high frequencies" due to recurrent otitis media and effusion. He had average receptive language skills, but poor expressive language skills. His intelligibility was impaired, and percentages of correct consonant productions ranged from 8% to 29% according to initial phonological assessment results. He showed a limited number of consonants acquired for he was not capable of producing consonant classes other than stops, nasals and glides. He used assimilation, cluster reduction, velar fronting and liquid deviations frequently. The assessment results helped outline the treatment cycles, prioritise which phonological patterns should be targeted first, and facilitate further investigation of phonetic transcriptions of actual productions which display stimulable patterns. After 35-week treatment sessions, the targeted patterns, except /ɹ/, were gradually emerging in the client's speech. The child's treatment was completed by age of 6;5 years for he was generally intelligible. The participant was re-assessed three months later and was able to maintain intelligibility gains he achieved throughout the treatment sessions.

Robbins and Chin (1995) investigated the effectiveness of phonological treatment on developing the phonological system of a child aged 3;5 years with multichannel cochlear implantation. For this purpose, a comprehensive treatment programme comprised of four basic elements was designed. The programme included (1) oral-motor training which was offered to help the child expand her limited phonetic repertoire, (2) cognitive-linguistic training to help her learn speech contrasts, (3) using the cycles treatment model to identify her phonological disorders, and (4) using multiple talkers during treatment sessions to present the child to conversational speech in natural context. A modified cycles-based intervention model was used to treat the participant's phonological errors, although it was not originally designed to remediate hearing-impaired children. The child was profoundly unintelligible and seemed to have no notion about her voice because she was completely deaf before having the cochlear implant. However, she was capable of imitating mouth postures and movements. After applying the cycles treatment procedure, the child became capable of producing proper approximation of the treated sounds and was positively developing her phonological and linguistic skills in the desired direction.

There has also been research into the effectiveness of cycles-based intervention in remediating the phonological difficulties of children with different cognitive delay and learning disabilities including children with DS (Cholmain, 1994; Conture et al., 1993; Culatta et al., 2005; Hodson and Paden, 1983; Hodson and Paden, 1991; Perzas and Hodson, 2010). For example, Hodson and Paden (1983) conducted a case study to examine the effectiveness of the cycles approach in treating the sound pattern errors of a child aged 5;11 years diagnosed with severe developmental dyspraxia, seizure spasms and mild hearing loss. Previously, the child received traditional phoneme-based and oral-motor treatments in a special education preschool classroom, but he achieved very poor progress. The child's speech was highly unintelligible; therefore, was referred to a phonology-based intervention. The results indicated that most of the target patterns (e.g., /s/-clusters and liquid deviations) gradually started to emerge in the child's speech. The study emphasised upon the stimulabality concept in the sense that it would be more effective to start the first treatment cycles with stimulable sounds and sound patterns as a basis to enhance the emergence of other more difficult patterns.

In another case study, Hodson and Paden (1991), treated a child aged 14;0 years with learning disabilities by implementing the cycles procedure. The participant was severely unintelligible with poor metaphonological skills necessary for literacy learning. His speech was predominated by extensive use of sound substitutions (e.g., /l/ was substituted for /w/, /j/, and /ɹ/), medial and final consonant deletion, cluster reduction, and so on. Due to the participant's learning disabilities, he needed to learn the target patterns through creative treatment activities (e.g., baseball board games activity), and incorporating oral reading activities based on reading materials at a level optimally below the participant's actual academic level. The minimal pairs technique was also included to get the child aware of phonemic contrasts. After two 6-week treatment cycles, the post treatment results revealed a very significant improvement in terms of speech production and the suppression of the phonological processes in single word production. More importantly, the parents reported that his speech became more intelligible after treatment.

Perzas and Hodson (2010) applied the cycles model to a child aged 3;5 years. He had a very limited phoneme repertoire with extensive final consonant deletions and consonant cluster reductions. The child's speech was found to have similar characteristics to that of children with CAS. He also had a medical history of chronic upper respiratory infections and recurrent otitis media. He received cycles treatment sessions (one 60-minute session per week) over three treatment cycles in addition to a daily 2-minute home programme taught by the parents. The results indicated that his speech became more intelligible in a way that positively influenced his early school years. Despite the progress the client achieved, there was still much more to find out about the efficacy of cycles approach and the ways in which it could be modified and implemented to remediate the phonological errors of children with different severity levels and aetiologies (Perzas and Hodson, 2010).

A case study of a child aged 4;2 years with cognitive delay was conducted by Culatta et al. (2005). The child had extensive phonological and language difficulties which needed to be targeted to increase his intelligibility. Culatta et al. (2005) stated that it was a challenging case study of a participant with cognitive impairment, deficit attention as well as phonological and language disorders. Culatta et al. (2005) decided to start with phonology treatment because for an irresponsive child it was found to be practically appropriate to embed the target phonological targets within meaningful interactive contexts to facilitate the learning process and obtain the treatment desired outcome. A meaning-based phonological intervention was adopted as the treatment procedure. Regarding the treatment of phonological errors, a modified cycles-based intervention was adopted. The target patterns were recurrently produced within a meaningful context and reviewed. The participant's parents also took part in the treatment sessions. The child actively participated in most of the treatment activities showing attention level that exceeded 10 minutes. The intervention programme helped the child comprehend all the treatment tasks and learn the target patterns (e.g., weak syllable deletion *banana* produced as [nɑːnə], final consonant deletion, cluster reduction). The client was able to generalise the learned patterns and words to conversational speech in and out clinic and in different contexts.

In a pilot study, Cholmain (1994) treated 6 highly unintelligible children with DS aged between 4;1 and 5;6 years. The cycles-based intervention model was adopted, and it included amplification and exposure to the contrastive values of phonemes in order to increase speech intelligibility. The intervention procedures were individually tailored to suit each participant, and designed to include three basic components: amplification, word production cards and sound production cards. The study results showed considerable improvement of the children’s phonologies within a short time (2 weeks) in that children successfully began to reorganise their phonological systems. For instance, two children transitionally began to perceive and use /g/ instead of /d/ when backing of fricatives was targeted. Another change occurred when the three children reduced the use of non-English pharyngeal sounds when final consonant deletion was treated. The speech of children with DS showed that lateral fricatives began to gradually emerge instead of being previously stopped or deleted. The results also showed improvement of children’s speech intelligibility. The findings reached in this pilot study indicated that the treatment assisted in speeding up the children’s phonological development. Because of the lack of the control group and the small number of participants with DS, the improvement achieved could only be considered in terms of general trends rather than the conditions of a controlled investigation. Therefore, it was necessary to use multiple baseline measure points prior to intervention commencement to allow children to be their own controls. The stability of the baseline measures and the improvement achieved during the intervention implementation indicated that the cycles-based treatment procedure helped children learn the treated targets and develop their phonological systems. Cholmain (1994) considered the improvement achieved in the first two treatment weeks as an impetus given to start the phonological development and, in return, increase speech intelligibility. One of the strengths of the cycles-based intervention programme was the use of the auditory training along with targets amplification techniques which included modelling and imitating the target words. These techniques were found to be effective due to DS children's histories of hearing losses and attention and sound sequencing deficits. The use of perceptual training with sound amplification helped children focus on their attention on the targets without attention distraction. These techniques enhanced revitalising the children's cognitive abilities and facilitated focusing the children's attention on perceiving the target patterns and sounds.

Conture et al. (1993) conducted a challenging study in which they treated the phonological errors of stuttering children. Children who stutter may have learning, behavioural, or cognitive disabilities. For these reasons treating the phonological disorders of stuttering children was considered to be challenging in terms of the decision-making process as to which intervention programme would be the most beneficial (Arndt and Healey, 2001). Conture et al. (1993) designed an intervention programme which targeted the phonological and stuttering disorders simultaneously in stuttering children and compare the results to those of children who stutter but did not have phonological disorders. Eight (7 males and 1 female) monolingual English-speaking children were selected and divided into two groups. The mean age of the four stutter-phonology children (SP group) was 5;8 years, and for the stutter children (S group) was 5;9 years. The treatment programme lasted for one year during which the children participated in group treatment session (one 45-minute session per week). Both groups received the same stuttering treatment in which parent-child group approach was used. It aimed at changing the inappropriate 'temporal aspects' and 'physical tension' that characterized their speech production. The clinicians encouraged the children to start and continue conversing smoothly with less rapidity and unnecessary physical effort to develop speech fluency. On the other hand, children in SP group received the modified cycles phonological intervention. The intervention focused on suppressing target phonological processes including interdentalisation (e.g., /s/ in *soap* as [θəʊp]), lateralization, gliding of liquids (e.g., /l/ in *look* as [jʊk]), velar fronting, cluster reduction, etc.) and improving sound productions. One process was targeted at a time for 3-4 sessions in which a specific sound/sound sequence was treated. Regarding stuttering treatment for both groups, the results generally showed general decrease in stuttering. The phonology treatment results indicated an average decrease in the use of phonological processes which reflected improvement of SP children's phonology. Yet, there was a significant change of some processes like velar fronting and stopping. Thus, SP children improved in both childhood stutter and phonology disorders; while S group improved only in stuttering group. Consequently, the study findings promote treating phonology and stuttering disorders simultaneously.

8.5.4 Previous Comparative Studies on Cycles Approach

Tyler et al. (1987) compared the effectiveness of phonological pattern-based models: the minimal pair and the cycles approaches. Four children aged between 3;1 and 5;1 years, had normal hearing and oral mechanisms; yet, they exhibited moderate to severe phonological disorders. The participants were divided into two groups. The first group were treated via the minimal pair model within which sounds rather than patterns were targeted contrastively (e.g., /s/ in *sew* [su:] versus /t/ in *toe* [tu:]) The second were treated by using the modified cycles approach to eliminate processes of velar fronting, /s/-cluster reduction, liquid cluster reduction (e.g., /bl/ in *blue* as [bæt]), final consonant deletion, backing and depalatalization (e.g., /ʃ/ in *fish* as [fɪt]). The results showed that participants in both groups made correct productions of the target patterns and the related sounds, and that the untreated sounds began to emerge gradually, but with less accuracy than the treated targets. By and large, both models were found to be effective as children began to use the acquired patterns in their spontaneous utterances during the follow-up sessions. However, the cycles-based intervention assisted the children to supress three phonological processes in a short time. On the other hand, the minimal pair procedure helped children supress one phonological process in a slightly longer time than with the cycles procedure.

Tyler and Watterson (1991) compared the effects of two different intervention approaches, viz. the phonological pattern-based approach (cycles approach) and language-based approach (script approach). It was explained that children with functional SSDs of unknown origin could have both phonological and language impairment, and it was contended that phonological impairment and language impairment should be treated interdependently. Previous research indicated that phonological and language disorders were found to be apparently interrelated (Hodson et al., 1983; Hodson et al., 1989). Tyler and Thompson (1991) examined the language and phonological improvements achieved by the participants with severe language and phonological impairments. Twelve children aged between 3;7 and 5;7, diagnosed with severe language and phonological disorders were assesses and treated. The children were paired and divided into two groups. The initial assessment showed that they scored one year below their CAs with relatively poor speech intelligibility. The first group received a phonological pattern-based intervention (cycles approach). The cycles procedure was implemented to treat 6 processes (final consonant deletion, stopping, velar fronting, gliding of liquids, cluster reduction and weak syllable deletion). The second group received language-based intervention (script approach). The children in both groups attended two sessions per week over nine weeks.

The results displayed important comparisons between pre-treatment and post-treatment MLUs and PCCs. They indicated that there were non-significant differences between these two measure means within the script and cycles models separately. However, a significant difference was found between script and cycles approach in terms of child improvement. Thus, language intervention made little improvement in MLU and non-significant change in PCC. Moreover, it considerably improved only treated patterns; while it regressively affected the untreated patterns. On the other hand, the phonological treatment facilitated progress in MLU and PCC and the children improved both treated and untreated patterns. For this reason, it was suggested that language-based intervention might not lead to improvement in language and phonology domains; while phonological intervention was found to be positively associated with progress in both domains, viz., phonology and language skills. However, the difference of the efficacy of the two approaches was not significant.

Tyler and Watterson (1991, p.155) discussed the differences between the phonological processes-based (cycles) and language-based (script) models, although the children treated via these models had diverse speech and language severity levels. In the phonological intervention group, children had moderate-severe/severe disorders, whereas children in the language intervention group had moderate-mild/moderate impairments. The discrepancy in the severity level between the two groups might raise doubts about the assessment of the real efficiency of the models used. The children received an extremely short time interventions in both groups (eight weeks). The authors hypothesised that children's progress in each of the frameworks under investigation depended on the interrelationship between the clients' phonological and language impairments. The study results supported their suggestion as they found that language intervention resulted in constructive development in language but discouraging change in phonological skills. On the contrary, the phonological intervention facilitated positive and beneficial changes in language as well as phonology. To sum up, language intervention may improve language but not phonology; while phonological intervention could improve language and phonology.

Mota et al. (2007) examined the effectiveness of three phonological intervention approaches: cycles, maximal oppositions and ABAB-Withdrawal and Multiple Probes approaches. Twenty-one participants (15 males and 6 females) aged between 4;0 and 7;10 years diagnosed with phonological disorders took part in the three intervention models mentioned above. Prior to treatment all children's speech were evaluated via a battery of assessments including evaluation of: language, articulation phonemic perception, psychomotor, phonological awareness, working memory, vocabulary evaluation, etc. The findings showed that the three models were influential in terms of the number of the patterns learned. There were no statistically significant differences between intervention models as they considerably improved the participants' phonologies and helped them generalize the learned patterns. Consequently, the researchers concluded that the three models were effective in suppressing the target phonological disorders and elaborate their phoneme inventories.

Chapter 9: Methodology - Case Study

9.1 Ethics, Recruitment and Consent

The Research Ethics Committee at University of Reading approved conducting a case study on treating phonological processes in children with DS. The study poster was advertised in the Speech Therapy Clinic at University of Reading (see appendix A). After reviewing the study poster advertisement, a volunteering family of a school aged child with DS contacted the principal researcher. A cover letter (see appendix A) was sent to the volunteering family to officially invite them to participate in the speech intervention programme. The family has also been provided with the study information sheet, consent form (see appendix A) and child assent forms (see appendix A). The child and the parent signed assent and consent forms, respectively.

The family was informed that participation was on a voluntary basis, and that they could withdraw from the intervention at their discretion. The family was asked to read the information sheet and was encouraged to ask questions about the study. A three-question demographic information sheet (see appendix B) was also given to the family. The demographic information sheet consisted of (yes/no) questions about the participant's vision and hearing problems, the communication languages other than English she has been using at home or school. Additionally, the child's parent was asked to complete a questionnaire (see appendix B) about the child's physical development, speech and language development and any previous intervention the child had received. Regarding the participant's information storage, the participating family was assured that all the personal information and the audio files of the treatment sessions would only be accessed by the investigators. The arrangements for the storage of the personal information and audio files were fully explained. The participant's personal information and data were all stored electronically on a password-secured computer. The paper copies of all of the participant's files were kept in a locked cabinet. The participant was given a letter label to be anonymised.

9.2 The Participant

S is an English-speaking child with DS aged 6;9 years. She met the following selection criteria for participating in the current study, which were similar to other studies (Iacono, 1998; Van Bysterveldt et al., 2010). These included: (1) she was a monolingual British English-speaking child; (2) she was diagnosed with DS (trisomy 21); (3) she had relatively normal vision and hearing levels;(4) she had no serious oral-motor structure malfunctioning/distortion; (5) she had no serious medical conditions such as infections, birth heart defects, respiratory infections; (6) she was not receiving additional speech and language therapy service during the intervention programme. The child's parents completed a questionnaire in which they reported that the child's speech was unintelligible and that the family members sometimes have been struggling to understand most of what she said. The child looked physically active and was capable of climbing, swimming, holding objects, scribbling with crayons, drawing shapes (e.g. circles), writing basic letters, cutting with scissors, and so on. The child was not diagnosed with dysarthria (e.g. oral motor malfunctioning, atypical tone, etc.) or CAS (e.g. groping, incorrect sound sequencing in utterances).

The child's parents reported that she began to babble during the first 6 months of age and spoke her first words (e.g., *mum*, *dad*) by age of 1;6. The parents noted that the child had a vocabulary of approximately 50 words and she sometimes was able to use two-word utterances at the age of 3;5 years. The child received a private speech and language therapy service usually every week during term time only. By the age of 4;0 years, the child was capable of using 3-word utterances, although she did so only during the speech therapy sessions rather than in daily situations. By the age of 5;8 years, the child's receptive and expressive language skills were assessed by administering Clinical Evaluation of Language Fundamentals Preschool-2 (CELF Preschool-2) (Semel et al., 2006). She appeared to have difficulty with regular and irregular plurals, possessive pronouns, 3rd person singular, present progressive verbs, regular and irregular past tense verbs, future tense, comparatives and superlatives and reflexive pronouns. However, the participant was able to name pictures of people, objects, and actions. She managed to name and give approximate descriptive words for four items (e.g. *bike* for riding/cycling, *present* for wrapping, *paper* for newspaper). On the other hand, she could not name/describe four items (e.g. *binoculars*, *calculator*, *calendar*, *audience*).

In as far as speech was concerned, the child's parent reported that her speech tended to be highly unintelligible when she was 5;8 years. The child was not able to produce two- or more syllable words correctly and tended to reduce them to one-syllable words, for example, t*oothbrush*, *music box*, *cowboy hat*, *television*, partly because she was not familiar with some of these words (e.g. *cowboy hat*), and partly because the nature of the structure of these words (multi-syllabic words) that she could not produce them correctly even when modelling was offered. Regarding structural phonological deviations, she omitted initial, final and across syllable boundaries consonant sequences. She was capable of producing correct single /s/ and

/k/ sounds with assistance, but not when occurring in clusters as these two sounds became more difficult to produce so she deleted them, as in *clouds* [laʊdz]; *spoon*, [pu:n].

The consonant cluster and consonant sequence reduction either by making omissions or substitutions were frequently occurring in the child's speech. For example, /s/ in *star* [stɑ:] was omitted and in *music box* the consonant sequence was deleted, the word being produced as [bɔ:]. In TD children, consonant cluster reduction process should be suppressed by the age of 5;0 years (Kumin, 2008; Kumin et al., 1994). According to Bliele and Schwartz (1984), cluster reduction processes tended to be used by younger children with DS, however, the participant was almost six, but was extensively using the cluster reduction pattern which turned to be a developmental sound pattern error. The emergence of single /s/ could stimulate the correct production of /s/ in clusters. Another significant clinical observation was that she primarily appeared to be quite stimulable to most of the consonants. She was trying to imitate the sounds as they were produced by the researcher. She could produce close approximation of modelled sounds which she did not produce in the first production trial, such as /ʤ, s, z, ð/.

Given the phonological difficulties the participant with DS had, the second part of the present study focused on treating some of her sound pattern errors by using the cycles phonological approach. Prior to assessment and intervention commencement, the participant was provided with a simple explanation for each activity. For example, the child was told that she was invited to play some word games (e.g., a pop-up pirate game). In addition, due to the communication and learning problems the participant had, the intervention sessions were observed by the parent. This chapter is dedicated to describing the procedures employed, such as initial assessment results, the intervention planning and the activities as follows:

9.3 Pre-intervention Assessment

The participant's cognitive ability, overall language development and speech were assessed via standardized and non-standardised tests prior to the beginning of the intervention. The initial assessment measures were all administered in the Speech Therapy Clinic based in the School of Psychology in the University of Reading. The assessment measures are described below:

9.3.1 Non-verbal Assessment

9.3.1.1 Coloured Progressive Matrices (CPM): Procedure and Scoring

The Raven's – Educational: Coloured Progressive Matrices (CPM) is a standardised test that assesses the general ability in children aged between 4;0 and 11;0 years (Raven, et al., 2008). See more detailed explanation about the test in Chapter 3 Section 3.4.1.1. The child scored 8 for subtest A and 3 for subtest A_B and 2 for subtest B. The total raw score was 13. Her age equivalent was less than 4;0 years, i.e. less than 48 months. The standard score was 80 and the percentile rank was 9. The confidence level chosen was 97.5% at a *p*-value =0.025with a +/-2 difference from the raw score, i.e. the raw score range was from 13 to 17 and the standard score range was 75-85 and percentile rank from 5 to 16.

9.3.2 Assessment of Speech and Language Abilities

9.3.2.1 *Clinical Evaluation of Language Fundamentals Preschool-2: Procedure and Scoring*

CELF Preschool-2 (Semel et al., 2006) is an assessment tool that allows identifying and diagnosing language difficulties in children aged between 3;0 and 6;0 years. It was administered to evaluate the participant's general language abilities by running the core language subtests: sentence structure (SS), word structure (WS), and expressive vocabulary (EV). First, SS subtest was administered to evaluate the child’s ability to comprehend spoken sentences with gradually increased sentence length and complexity. The subtest also allowed evaluating the child's developmental skills which were related to the early learned sentence structures. Second, WS subtest assessed the participant's ability to use word structure rules to recognise and perceive inflections, derivations to indicate different word meanings in addition to comparisons (e.g. plurals affixed to nouns, third person singular s affixed to verbs, -ed suffix to form the past tense). WS subtest assessed the child's knowledge of the morphological rules to expand word meaning and form new word structures by adding inflections (e.g. comparative and superlative suffixes derive new words from base words and use of referential pronouns.). It also evaluated the participant's use of appropriate pronouns when referring to people, objects and possessive relationships. The child's correct response was scored 1; while her incorrect response was scored 0. In addition, a zero score was used when the child made no response. All the scores were added together to get the total raw score. The items and sentence types in error were analysed. The test outcome provided a preliminary description of the word structure and morphological rules the child was able to recognise. See word structure table analysis on page 11 in the record form. Third, EV subtest evaluated the child's ability to name the pictures of people, objects and actions. The child's ability to name these entities facilitates communication skills in social and academic settings. Similarly, the materials for this subtest were available in the stimulus book 1 and the record form. During the test, the researcher points to a picture, read the stimulus phrase and then pause to listen to the child's response. On the record form, the participant's correct response could be scored 2 or 1, 0 for no response. The test must be stopped after 7 consecutive 0 scores. However, the child was able to respond alternately to the test items. The child's responses that were not listed on the record form were also written down for later scoring consideration. The record form contained a reference table for analysing the expressive vocabulary items produced by the participant.

Each of the three subtests lasted for 15 minutes followed by a 5-minute break before starting the following subtest. The materials used for administering the subtests were picture-based tasks in the test stimulus book 1 in addition to a record form. In the stimulus book 1, the tests directions were explained. In each subtest section, the verbal stimuli for the child were written in blue print and directions to the examiner were written between square brackets []. The researcher started each of the subtests with doing the example and trial items (1 example and 2 trials for each of the three subtests) to model the test tasks and encourage the child to get engaged in the activity. Prompting, repetition and encouragement were offered whenever needed. For example, when the child did not understand the task, or when she was not able to respond within 10 second, the item was repeated for her to elicit the required response. The testing sessions took place in a quiet clinic room. The testing procedure was as follows: the researcher practised running the three core language subtests before assessing the participant. The originally allocated time for running the three subtests was 15-20 minutes. However, the test for the present participant with DS lasted 40 minutes due to her age and her relatively poor language abilities. At the beginning of the test, the researcher tried to establish a good rapport with the participant to encourage her to respond to the test items. During the testing session, the child was well motivated to respond to all of the three subtests items, although it took her a slightly longer time to complete all the test items. The child was seated into a table and the stimulus book was put in front of her, as the researcher read the test items to elicit the correct responses. The stimulus book was well-set on the table so that the target item page was facing the child; while the directions page was facing the researcher. The researcher read the directions when presenting the items to the participant. At the end of each subtest, the child was offered a short break in order not to interrupt the subtest administration and to ensure the child's being sufficiently motivated to respond to the following subtest items.

The results from the core subtests of CELF Preschool-2 were summarised (see table 9.1). A core language score was obtained by summing the scaled scores from the SS 6, WS 5 and EV 6 subtests, the total of which was converted into a standard score 75 by using the standardised test tables. The core language score is a norm-referenced standard score that helped comparing the language performance of the participant with DS to that of the TD children of the same age. The core language score is based on a normalised standard score scale that has a mean of 100 and a standard deviation of 15. Thus, a score of 75 indicated that the child's language performance was nearly 2 standard deviations below the mean. The participant's core language standard score was 75 which was between the confidence interval limits 67-83 at the 95% level. The 95% confidence level covered the broadest range of scores and provided the highest degree of confidence that the child's score obtained was within the range specified. This indicated that her language development level was low range-moderate within -1.5 to -2 SD below the mean of 100, i.e., she had a language disorder.

Table 9.1 Summary of results CELF Preschool-2

	Raw Score	**Sum of Subtest Scaled Scores**	**Standard Scores**	**Confidence Interval at 95%**	**Percentile Rank**	**Age Equivalent**
Core Language	52	17	75	67-83	5	-
SS	16	-	6	3-9	9	4;8
WS	14	-	5	2-8	5	4;3
EV	22	-	6	4-8	9	4;8

Note: SS-Sentence structure. WS-Word structure. EV-Expressive vocabulary.

Regarding the SS subtest, the participant was not able to produce prepositional phrases (e.g., towards the girl), copula and infinitive (e.g., *is ready, to go*), negation (e.g., *…is not climbing*), relative and subordinate clauses (e.g., *…who is holding*, *…before she ate*), and indirect requests (e.g., *should not you…?*). WS subtest was the lowest score, i.e., it was in the low developmental range. She was not able to produce regular plurals (e.g., *horses*), possessive nouns and pronouns (e.g., i), future tense (e.g., *will slide*), regular and irregular past tense (e.g. climbed, fell), subjective and reflexive pronouns (e.g., *she, he, herself*), and superlatives (e.g., *fastest*). The SS subtest raw score was 16. The child appeared to have difficulty with regular and irregular plurals, possessive pronouns, 3rd person singular, present progressive verbs, regular and irregular past tense verbs, future tense, comparatives and superlatives and reflexive pronouns. In the EV subtest, she managed to name and give approximate descriptive words for four items (e.g. *bike* for riding/cycling, *present* for wrapping, *paper* for newspaper). On the other hand, she could not name 10 illustrations (e.g. *binoculars*, *calculator, calendar*, *audience, scales, wheelchair, award, trophy, sports, branch*).

9.3.2.2 Diagnostic Evaluation of Articulation and Phonology-Assessment of Phonology: Procedure and Scoring

The SW sample was collected via running DEAP-Assessment of Phonology (Dood et.al, 2002). More illustration about DEAP-Assessment of Phonology is presented in chapter 3 section 3.4.2.1.

9.3.2.3 Clinical Linguistics Educational Assessments and Resources: Procedure and Scoring

In order to obtain a large SW sample and establish an accurate phonological analysis of the participant's speech, DEAP-Assessment of Phonology was combined with the non-standardised CLEAR assessment (Keeling and Keeling, 2006). More illustration about DEAP-Assessment of Phonology is presented in Chapter 3 Section 3.4.2.2. The same qualitative and quantitative measures estimated in the group study were also calculated in the case study.

9.3.2.4 Diagnostic Evaluation of Articulation and Phonology–Word Inconsistency: Procedure and Scoring

DEAP-Word Inconsistency assessment evaluated the participant's ability to produce three realisations of the same test item. More illustration about DEAP-Word Inconsistency is presented in chapter 3 section 3.4.2.3.

9.3.2.5 Assessment of CS Sample: Procedure and Scoring

The CS samples could be considered as a reliable measure of consonant production because the production of connected speech tends to be affected by other language demands, and it could be more representative of a child's production skills in a naturalistic context (Shriberg and Kwiatkowski, 1980). Consequently, the spontaneous CS sample was also included and analysed. The procedure followed for collecting the CS sample was similar to the procedure followed for collecting CS samples for the group study. More illustration about CS sample collection is presented in Chapter 3 Section 3.4.2.4.

9.3.2.6 Assessment of Speech Intelligibility using ICS

The speech intelligibility of the participant was subjectively rated by her parent. The parent was provided with a speech intelligibility rating scale ICS (McLeod et al., 2012). The ICS was used to rate the clarity of the speech of preschool or school aged children with disordered speech. More illustration about ICS is presented in Chapter 3 Section 3.4.2.5. Speech intelligibility was also assessed by analysing the spontaneous speech samples collected during interactive activities. Spontaneous speech sample was collected by using two activities: story reading and playing with toys. The sample also included the utterances obtained from parent-child/ researcher-child interactions. The participant's speech intelligibility was assessed by using her spontaneous utterances which included 50 utterances approximately totalling 100 words with 'yes' and 'no' words excluded from the sample. More illustration about speech intelligibility assessment is presented in chapter 3 section 3.4.2.5.

9.4 Assessment Data Analysis

After transcribing the participant's SW sample collected via DEAP-Assessment of Phonology and CLEAR assessments, the child's productions were analysed to obtain the qualitative and quantitative measures mentioned above (see Chapter 10 for more details about the analysis of the speech assessment results).

9.5 Experimental Design for Intervention

A single case, multiple-baseline design across behaviours was manipulated to evaluate the effectiveness of the cycles-based intervention in improving the speech production accuracy of a child with DS. The single-subject design is an experimental methodology that has been used for decades in various fields of study, such as speech therapy, psychology, special education, and so on (Riley-Tillman and Burns, 2009, p.8). It comprises a collection of experimental methods developed to investigate whether the dependent variables have undergone a considerable change due to the application of the independent variable and whether the change caused by the independent variable could be generalised to the untreated behaviours.

The design gives the opportunity for systematic replication of the intervention outcome and collecting evidence that the effect of the intervention model used could achieve similar improvement in other participants with similar speech problems. Thus, the single subject design helps "document the effect of intervention, assess the role of intervention in the observed change, and decide if that information has some general programming utility" (Riley-Tillman and Burns, 2009, p.9). The single subject design requires allocating an experimental control. To be more specific, multiple single-subject designs are considered to be valuable when the participants involved in the study are heterogeneous or when few subjects (even one participant) are available (Logan et al., 2008). The design involves a series of single-subject A-B (non-intervention/intervention) designs which, by staggering the start of intervention across behaviours, allows replicating any of the intervention effects.

Based on the initial speech assessment results, two sound pattern errors (behaviours) were selected to be treated: /s/ cluster reduction with three related sounds /sp/, /st/, and /sn/; and velar fronting with two related sounds /k/ and /g/ in word-initial and word medial positions. The cycles-based intervention was alternately applied to each behaviour. One of the advantages of the multiple single subject design was that it allowed systematic replication of the observed treatment effects. This design helped ensure that the intervention model used would be effective in future when being used for remediating the same target patterns within the same experiment structure and the same intervention model (Riley-Tillman and Burns, 2009, p. 10). In this design the intervention effect was replicated so that more confidence could be established that the change of behaviour was a result of the intervention model (independent variable) and not due to other external variables. However, in this design even if the improvement of the target behaviour might be the result of some unknown variables, the change in the target behaviour could still be attributed to the application of the intervention. To replicate the intervention effect, intra-subject direct replication was manipulated in an attempt to explain the actual intervention effect. Thus, practically, the same participant, the same experiment structure, and the same intervention model were used in the intervention phases with an intervening non-intervention phases. This experimental design tended to be useful in that it increased confidence that the change taking place could be due to the intervention application and that there was a genuine relationship between the treatment procedure and the target pattern.

In the present case study, the cycles treatment procedure (the independent variable) was applied to the target patterns (behaviours representing the phonological patterns). Additionally, experimental control was created when the participant's production of the treated targets improved; while the production of the targets that have not yet been treated remained unchanged. According to the cycles treatment procedure, the first target pattern was treated and then treatment was applied to the second pattern even before the first pattern was entirely remediated. This revealed that the progression of the cycles treatment was time-based rather criterion-based. The control items were recurrently assessed to discover the production stability or decline before targeting the next pattern.

9.5.1 Target Selection

Based on the initial speech assessment data collected via using DEAP-Phonology Assessment (Dodd et al., 2002) and CLEAR (Keeling and Keeling, 2006), two phonological processes were targeted: cluster reduction and fronting. The target selection process was made up in terms of: the percentage of occurrence of the phonological process $\geq$ 40%, the developmental appropriateness of the child's age, and the effect of the phonological process on the child's speech intelligibility (Tyler et al., 1987). Consequently, the cluster reduction (/s/ cluster with three target sounds /sp-/, /st-/ and /sk-/ with 4 target words per each cluster), and velar fronting (initial and medial /k/ and /g/ with 2 target words per each sound totalling 4) were selected (see table 9.2 in appendix D).

9.5.2 The Intervention Programme Schedule

Following the procedure in Rudolph and Wednt (2014), the present study consisted of three main phases: the baseline measurement points, the intervention, and the follow-up phases. They are as follows:

9.5.2.1 Baseline Phase

Five baseline sessions were run and completed a week prior to starting the intervention phase. The baseline measures were administered over four weeks and completed a week prior to the beginning of the intervention. The baseline measures helped obtain an accurate measurement of the existence of the target pattern before applying the cycles-based intervention procedure. The baseline measures yielded clear measurements of whether the intervention to be employed would lead to the improvement. The data could also be used as a standard for measuring the effectiveness of the intervention in helping improve the child's speech. During the baseline sessions, all the treatment targets and the generalisation items (45 target words) were evaluated. During the baseline sessions, the child spontaneously produced the intervention and the generalisation items, i.e., the participant was not provided with modelling, repetition or prompting.

9.5.2.2 Intervention Phase

The intervention phase consisted of two treatment cycles (cycle I and cycle II) separated by a one-week break. The first cycle (cycle I) lasted for three weeks, and in each week the child was seen two times (two 60-minute sessions). The same intervention schedule was implemented throughout the second cycle (cycle II). The sessions were either run in the Speech and Language Therapy Clinic in the University of Reading, at the participant's school or at the participant's own house. The target patterns were treated alternately, i.e., one pattern was targeted every week with one of the related target sounds. Thus, the child was seen two times a week, and each time the child practised one pattern with one related target sound. For instance, during week1 /s/ cluster was targeted with the target sound /p/ over two sessions. The next week, velar fronting pattern was targeted with the target sound /k/ over two sessions, and so on and so forth. Each cluster was targeted for 2 hours. The first and the second sessions targeted initial /sp-/ clusters embedded in a four-word set (2 one-syllable words and 2 two-syllable words). The third and fourth sessions targeted the velar fronting process in a four-word set (2 one-syllable and 2 two-syllable words). The fifth and sixth sessions targeted initial /st-/ cluster in a five-word set (4 one-syllable words). The seventh and eighth sessions targeted velar fronting process in a four-word set (2 one-syllable words and 2 two-syllable words). The ninth and tenth session targeted /sn/ cluster in a four-word set (2 one-syllable words and 2 two-syllable words). Finally, the last two sessions targeted the fronting process in a four-word set (2 one-syllable words and 2 two-syllable words). The production words were selected to be within the child's vocabulary repertoire and they were checked with child parent to be included in the treatment wordlist. The number of words and the length and number of the treatment activities were prepared to suit the participant's attention span (Van Bysterveldt et al., 2010) (see tables 9.2 and 9.3 in appendix D).

During the intervention, the targets sounds were divided into two sets: target items (set A) and control items (set B). The treatment was applied to set A over two successive sessions (2 hours); while set B was elicited in the end of every treatment session to monitor the effect of the cycles treatment procedure. The treatment was then applied to the second target pattern in the same way. The design as such allowed controlling the irrelevant variables and also helped regularly examine the effect of cycles intervention on the treated items as differentiated from the untreated ones without intervention disruption. Because the cycles approach was time-based rather than criterion-based, the next pattern was targeted within a similar time scale even if the previous one has not been fully mastered. For example, the researcher started to treat fronting process even if the former pattern (cluster reduction) has not been fully mastered.

Based on modified cycles-based intervention, the treatment sessions were administered as follows (Hodson, 2010):

1. The very first session of the intervention programme was started with the listening activity in which the child listened to the target words spoken by a native speaker (a native postgraduate student). The words were recorded via H4n digital recorder. Then, the sound files were transferred to the researcher's password-secured Lenovo laptop, system type (32-bit operating system and x64-based processor)), and played by using the MS-Media Player, through which the child listened to the target words. This technique aimed to develop auditory awareness of the target pattern through listening.
2. Auditory discrimination: Following the listening task, the child was provided with auditory discrimination activity of the target pattern for at least 3-5 minutes by using the 'same vs. different' concept. At the beginning, to get the child aware of this concept, she was shown two identical pictures (e.g., yellow circles; two identical teddy bears) for the 'same' concept; while two other different pictures (e.g., a blue square and a

green circle; a car and a teddy bear pictures) represented the ‘different’ concept. On the same basis, to get the child aware of the target pattern word and realise it as different from its nonsense counterpart word, the child listened to both words and was asked to say whether they were different or same. For example, the child listened to three minimal pair words: spoon/ spoon, poon /poon, and spoon/poon. She had to tell whether they sound the same or different. If the child could recognise the correct target word, then she stuck it on board. The same activity was repeated with the other target words in every treatment session.

3. Speech activities: These included getting the child to name the pictures representing the target items. The words were elicited by asking the child “what’s this?” If the child could not name the picture, she was given an indicative cue (e.g., saying something that the picture was not representing). The child was also provided with assistive modelling and tactile cues of the target sound. For example, to make the child aware of the continuity of /s/, the sound was modelled and facilitated by pointing to the mouth and then slide the finger over and along the arm. Moreover, by completing the second session of a target sound, the same treatment procedure was followed, and the other two target word sets were elicited as intervention control items. For example, in the end of the second intervention session of /sp-/ words, the three-word sets were elicited, i.e. the/st-/ and /sk-/ control word sets and /st-/ target word set. To get the child engaged in the word elicitation activity, the production cards of the three sets were stuck at the back of laminated ladybirds which were hidden in a box full of colourful balls. Thus, the child tried to find and pick a ladybird and named the picture stuck at the back.
4. To maximise the child’s learning progress, and maintain her level of motivation and interest, various production activities (experiential play) were designed and implemented in every treatment session. These included: picture matching, picture sticking, finding hidden pictures stuck at the back of laminated ladybirds, rabbit hop, frog hop, throwing the dice, completing the spider, dragon and butterfly puzzles, and so on. The child was provided with assistance (modelling the sound, giving tactile cues) whenever needed, particularly during the first treatment cycle.
5. Repeating the auditory stimulation activity in the end of the treatment session. The child re-listened to the same recorded list of words used at the beginning of the session.
6. The intervention also included a short (2-5 minute per day) home programme to be accomplished by the parent at home. At the end of each treatment session, the child’s parent was given two sheets: the first was the activity sheet (see appendix D) in which

the listening and production tasks were explained in detail; the second was the home programme sheet (see appendix D) in which the parent indicated the tasks completed by the child or any other note.

9.5.2.3 Post Treatment Speech Assessment

After completing the treatment cycles, the participant's speech was reassessed a week later. The same assessment tools were administered. These included: DEAP-Assessment of Phonology, CLEAR, and DEAP-Word Inconsistency Assessment. In addition, the child's spontaneous connected speech was also assessed by encouraging the child to describe the same picture story (Frog, where are you?), and create her own story out of the pictures. The session lasted for one hour and took place in a quiet room in the participant's own house. In a similar way to the pre-assessment session, the post-treatment assessment session was recorded via employing a high quality digital voice recording device (H4next Handy Recorder) placed approximately 2-3 feet from the child. The post-treatment assessment helped monitor the speech production improvements achieved.

9.5.2.4 Follow-up Phase

By completing the intervention programme, the child's ability to generalise the learned patterns to speech were evaluated by eliciting single words (generalisation items) in a picture naming task (see table 9.2 in appendix D). The follow-up phase comprised three sessions and it was run one month after the intervention was completed. During the follow-up sessions, the participant was required to produce the generalisation items (21 target words 3 words per each sound) on her own without any prompting or modelling offered. The pictures were displayed as power point slides on a Lenovo. All the sessions of the three phases were administered by the researcher, and the sessions took place at the participant's own house. To sum up, the child's production of the target patterns would be expected to gradually and positively progress from baseline throughout the intervention. The change occurred would also be expected to be generalised to the untreated (generalisation) items. The treatment activities and materials were carefully selected and prepared to suit the child's needs. Additionally, the activities were designed to be within the child's attention span which lasted for 5-10 minutes.

9.6 Reliability

The SW and CS samples were manually transcribed by using the broad phonemic transcription. The inter-rater procedure followed for the group study was also used for the case study. More illustration about inter-rater reliability is presented in chapter 3 section 3.6. For the SW speech data, the reliability of agreement between the transcriptions of the independent inter-raters was determined by calculating Cohen's Kappa coefficient by using the crosstabs in the SPSS software. The results showed that Cohen's Kappa Coefficient was considerable significant [k=0.828, p=0.001]. This obviously revealed a strongly reliable agreement between the two inter-raters. The percentage of the transcription agreement between the transcriptions of the two inter-raters was 96%. For CS speech data, the results demonstrated that Cohen's Kappa Coefficient was significant [k=0.722, p=0.001]. This obviously showed a strongly reliable agreement between the two inter-raters. The percentage of the transcription agreement between the transcriptions of the two inter-raters was 95.1%.

9.7 Speech Assessment Data Analysis

After transcribing the participant's SW sample, the speech data was analysed to obtain the qualitative and quantitative measures previously mentioned (see chapter 3 sections 3.4.2.1, 3.4.2.2. and 3.4.2.3). Regarding the baseline, intervention and follow-up data, these were analysed by employing the visual analysis method in addition to statistical analysis. The visual analysis is the most widely used data analysis method in single-subject research studies (Riley-Tillman and Burns, 2009). It is considered as the typical data analysis method that allows simultaneously analyse the visual components of data sets within each phase. It included: level, immediacy, variability (standard deviation), and trend (slope) (Zhan et al., 2001; Rudolph and Wendt, 2014). These components helped clinically compare the participant's performance in the baseline, intervention and follow-up phases (Riley-Tillman and Burns, 2009). The changes in these components assisted in measuring and evaluating the child's responsiveness to the cycles-based intervention approach implemented in the present study. Clinically, visual analysis has been found to be a convenient graphic analysis method that visually depicts the child's performance within a phase and between the various intervention programme phases (Zhan et al., 2001). The visual analysis visually clarifies whether the target processes have undergone any changes and whether these changes occurred due to the intervention application.

First, analysing the changes at the level of the data sets in terms of data mean in the baseline, intervention and follow-up phases were compared to assess the way the target processes change when the cycles treatment procedure was applied. Second, analysing the change in immediacy depicted the change in the target processes immediately after applying the cycles treatment procedure, i.e., whether the intervention brought about an immediate effect. Third, analysing the change in variability determined the range of variation in terms of standard deviation within phases. That is, it identified the degree to which the data sets within and between phases were consistent. This was defined in terms of high and low data values within a phase. The change in variability helped inspect the amount of overlap between phases, i.e., whether the variation in performance within the baseline was different from that in the treatment phase. Finally, analysing the change in trend in terms of slope of data sets depicted the rate of change with a phase, i.e., it assisted in identifying whether the outcome data within a particular phase was increasing, decreasing or remaining constant.

The visual representation of the outcome data was supported by statistical analysis of the difference between the participant's scores within the baseline and the treatment phases using the two-standard deviation band method (Nourbakhsh and Ottenbacher, 1994). For this purpose, two statistical procedures were manipulated where they were found to be appropriate: (1) the mean of the baseline scores and a two-SD band were devised across the baseline and the intervention phases. The intervention phase scores were set outside the banded area as an indicative of significant change in the target processes; or (2) the celeration line method (split-middle method of trend estimation) to assess whether the outcome data were increasing, decreasing, or remaining stable within the different phases. Therefore, a best-fit line was applied to the data points in the baseline phase and, then, in the intervention phase to evaluate the effectiveness of the cycles treatment procedure by comparing the proportion of data points above and below the line in the baseline and intervention phases.

The effect size is defined in terms of the percentage of nonoverlapping data (PND) (Shadish et al., 2008). PND has been considered as the simplest effect size that is estimated to provide an accurate interpretation of the outcome data and the effectiveness of the treatment procedure. However, PND has its own limitations. The PND value has an indefinite sampling distribution and indefinite reliability so that no confidence intervals could be calculated. It is also based on one data point rather than a group of data, (which tended to be more reliable), and it was based on the highest point in the baseline phase which can be an outlier (Riley-Tillman and Burns, 2009; Shadish et al., 2008). In the present study, the calculation of PND entailed specifying the data points in the intervention phase which were higher than the highest data point in the baseline phase; and, then, dividing this number by the total of intervention data points. It helped compare the distribution of the data values in the intervention phase to the distribution of the data values in the baseline phase. That is, it helped compare the treatment effect which was reflected in the intervention data points over exceeding the highest data point in the baseline phase.

Regarding phoneme representation in SW and CS samples, each phoneme was allocated a score out of two for those occurring in word-initial and word-final positions; while for phonemes occurring in word-initial, -medial and -final positions, they will be given a score out of three per phoneme. The PCC scores in the three positions was calculated. The range of phonemes which the child produced included consonants and vowels pronounced in correct or incorrect contexts. Additionally, the correct initial and final consonant productions in SW sample were compared to those in CS sample. All sound productions in response to single word cards were included in the phonological analysis of SW sample.

For CS sample, the 90-70-225 sampling rule put forward by Morrison and Shriberg (1992) was used. This sampling rule helps compare continuous speech samples containing either 90 word types, 70 utterances, or a total of 225 words, whichever criterion is met first during the transcription process. In the present study, all words in addition to semi word productions were counted and transcribed. Yet, only meaningful production (words that can be glossed) were included in the phonological analysis. Accordingly, the total number of words was calculated. (Morrison and Shriberg, 1992; Iacono, 1899). The analyses of SW and CS samples comprised of (1) PCC of consonants occurring initially, medially and finally, (2) PVC, and (3) type, frequency and percentages of occurrences of phonological processes (Iacono, 1998).

The consonants produced were analysed in terms of two parameters: word position (word initial and word final positions) and the voicing feature. The consonants and vowels were presented illustrating the English consonant productions in word initial and final positions. In addition, the percentages of occurrence of phonological processes (number of occurrences of a process divided by total opportunities, multiplied by 100) were identified in the child's speech samples. The clinical criteria proposed by Dodd et al. (2002) was used to identify the phonological processes expected to occur in SW and CS samples. The child's MLU was calculated in accordance with the procedure put forward by Miller (1981). MLU was estimated by counting the number of morphemes of the first 50 intelligible utterances and, then dividing the total number of morphemes by the total number of utterances. Since there was no systematic difference between the participant's spontaneous and facilitated responses, both types of production were scored in the same way, i.e. they were counted as correct productions (Smith and Stoel-Gammon,1983).

To address the research questions and find whether there was a statistically significant difference between the participant's production of the target probes across the baseline, intervention, maintenance and follow-up phases, Wilcoxon signed-rank test for repeated measures was used. Wilcoxon test was also used to compare the child's speech production accuracy in terms of the phoneme production accuracy and the phonological processes the participant used in SW and CS samples. The dependent variables tested included percentages of occurrences of phonological processes in the baseline, intervention, maintenance and follow-up phases, PCC, PVC and PPC in pre-treatment and post-treatment. To sum up, the data analysis and the statistical test provided information on the following:

1. Consonants and vowels acquired: The consonants and vowels produced during SW and CS samples elicitation were determined in terms of the number of occurrences (e.g., if the child was able to pronounce /m/ in word-initial, -medial and -final positions, then the child made 3 correct productions of /m/ out of 3 occurrences, and so on for the rest of the phonemes. All sounds that were obtained from SW and CS samples were included regardless of whether they were produced in the correct on incorrect context.

2. Phoneme production accuracy (consonants and vowels with concentration on consonants): PPC, PVC and PCC of consonants occurring in word initial and word final positions of the target words in SW and CS samples were calculated. Wilcoxon signed-rank test for repeated measures determined the differences across phases.

3. Phonological processes: In both SW and CS samples, the percentages of occurrences of the phonological processes were calculated. The results helped determine the most frequently used phonological processes and analyse these processes in more detail. In addition, lower/higher percentage of occurrence of a given phonological process also assisted in specifying the extent the participant could approximate the adult-like performance (e.g. the lower the percentage of occurrence of a particular phonological process was, the nearer the child sound pattern production to the adult-like production would be). The differences of the occurrences of the phonological processes in the

child's speech in SW and CS samples were identified using a Wilcoxon signed-rank test.

9.8 Pre-treatment Speech Assessment – SW Sample

Prior to beginning the intervention programme, the participant's speech was assessed using both standardized and non-standardised tests. Two speech samples were collected: SW and CS samples. The SW sample was collected by administering DEAP-Assessment of Phonology (Dodd et al., 2002) and CLEAR (Keeling and Keeling, 2006). The participant's responses were manually transcribed by using the broad phonemic transcription. The results showed that the participant's PCC was 72%; while her PVC was 95% (see table 9.4). This indicated that the child had more difficulty with consonant production than vowel production. She had more difficulty producing singleton consonants occurring in SIWI position than in SFWF position. She mostly omitted initial consonants clusters and PCCC was 15%, and PCCC of final consonant clusters 25%; while for cross syllable boundaries consonant sequences the PCCC in SIWM and SFWM were 0%, 0%, respectively. She was capable of producing correct single /s/ with assistance, but not when occurring in clusters as this sound became more difficult to produce when combined with other sounds. Thus, she deleted /s/ as in *slide* [laɪd]. In the similar way, the child fronted /k/ and /g/ sounds and substituted them by /t/ and /d/, especially in word-medial position. For example, /k/ was replaced by /t/ in *cat* [tæt], and /g/ in *gate* was replaced by /d/ in [deɪt].

Table 9.4 Percentages of correct production of singleton consonants and consonant clusters in DEAP-phonology and CLEAR in pre-treatment assessment

DEAP-Phonology & CLEAR			PCC of Singleton Consonant				PCCC of Consonant Clusters			
PCC	**PVC**	**PPC**	**SIWI**	**SIWM**	**SFWM**	**SFWF**	**SIWI**	**SIWM**	**SFWM**	**SFWF**
72%	95%	78%	75%	76%	70%	79%	15%	0%	0%	25%

Note: PCC-Percentage of consonants correct. PVC-Percentage of vowels correct. PPC-Percentage of phoneme correct. SIWI-Syllable initial word initial. SIWM-Syllable initial word medial. SFWM-Syllable final word medial. SFWF-Syllable final word final

The phonemic transcription of the participant's speech revealed that she could produce the sounds /z, s, p, b, m, n, k, t, d, l, w, r, ʃ, j/. The speech evaluation results showed that the total of occurrences of phonological processes was 96. According to Hodson (2010), the severity level of expressive phonological disorder between 51 and 100 could be rated as moderate. However, the participant tended to be highly unintelligible when producing more complex prolonged phonetic context, such as multisyllabic words (e.g., *toothbrush* [brʌʃ], *blindfold* [blaɪndfəʊd]).

The consonant cluster reduction either by making omissions or substitutions frequently occurred in the child's speech. The assessment items included 51 consonant clusters occurring in word-initial, -medial and –final positions. She reduced 40 of them by sound omission. The percentage of occurrence of cluster reduction was 42% (see table 9.5). For example, /s/ in *stairs* [steəz] was omitted. In TD children, consonant cluster reduction should be suppressed by the age of 5;0 years (Kumin, 2008; Kumin et al., 1994). However, the participant was almost seven, but was extensively using the cluster reduction pattern. Yet, she was found to be stimulable to pronounce singleton /s/ regardless of word position. The emergence of single /s/ could stimulate the correct production of the same sound when occurring in clusters. Another significant clinical observation was that she primarily appeared to be quite stimulable to most of the consonants. She was able to imitate the sounds which were modelled by the researcher. She showed close approximation of the modelled sounds which she could not produce in the first production trial, such as /f, v, ʤ, z, ð, ŋ/.

Additionally, she demonstrated difficulty in producing /k/ by replacing it with a far more back uvular fricative consonant /χ/, particularly in word final position, but she was able to imitate the sound correctly as it was modelled by the researcher. She also replaced /k/ with /t/ and /g/ with /d/, therefore, the second frequently used phonological pattern in her speech was velar fronting 25% (e.g., *kitchen* produced as [tɪtən], *gate* produced as [deɪt]). Velar fronting was also found to be a pervasive process in the child's speech. It was a non-age-appropriate process as it should be typically supressed by the age of 3;6 years (Bowen, 2011). The participant's speech was characterised by extensive substitutions and omissions which were summarised (see table 9.5). Based on the assessment results, cluster reduction and velar fronting were the most pervasive phonological processes that characterised the child's speech as they occurred more than five times. In addition, she deleted unstressed short syllables and was found to be experiencing difficulty in producing words with two or more syllables or producing cross boundary consonants. She was not able to produce two- or more syllable words, for example, *toothbrush*, *blindfold*, *vacuum cleaner*, and so on. Although she was able to pronounce initial consonants in CVC words, she substituted some of them with front bilabials, nasals or glides rather than back consonants which she found more difficult to produce.

Table 9.5 Summary of frequency and percentages of occurrence of phonological processes of SW sample in pre-treatment assessment

Processes		Occurrence		Percent of Occurrence		Examples
Gliding		7		8%		[fɪʃɪŋ]→[wɪʃɪŋ], [zebrə]→[wewə]
Deaffrication		5		6%		[wɒʧ]→[wɒʃ], [brɪʤ]→[bɪdz]
CR		40		42%		[plʌg]→[lʌg], [spaɪdə]→[paɪdə]
Fronting		23		25%		[kæt]→[tæt], [rɒkɪt]→[rɒtɪt]
WSD		3		4%		[təmɑ:təʊ]→[mɑ:təʊ],[bənɑ:nə]→ [nɑ:nə]
Stopping		0		0%		
Voice		0		0%		
Assimilation		10		11%		[jeləʊ]→[leləʊ], [feðə]→ [fefə]
CD	Initial		6		7%	[rɪvə]→ [və], [weli:z]→[li:z]
	Medial	12	6	14%	7%	[bɪskɪts]→ [bɪtɪt], [mʌŋki:]→ [mʌki:]
	Final		0		0%	
Backing		0		0%		
Other Processes		0		0%		
Total		96				

Note: CR-Cluster reduction. WSD-Weak syllable deletion. CD-Consonant deletion.

The child was capable of producing correct single /s/ sound with assistance, but not when occurring in clusters when /s/ was combined with other sounds that it became more difficult to produce. Therefore she deleted them as in *clouds* [laʊd], *spoon*, [pu:n]. The frequent occurrence of /s/-cluster reduction process and velar fronting processes reduced the child's speech intelligibility; therefore, the first treatment week was dedicated to targeting words with /sp/. Training her to produce /s/-clusters could improve her speech production and increase her speech clarity. The second week, velar fronting was targeted initially and medially.

To sum up, the frequent use of cluster reduction and fronting in addition to the other recurrently occurring non-age-appropriate processes (e.g., gliding, assimilation), decreased the participant's speech intelligibility. Therefore, the most frequently used processes with highest percentage of occurrence were targeted. These included /s/-cluster and velar fronting. The child needed to learn to produce these two patterns with the related target sounds at an early age to improve her speech intelligibility. Thus, to treat this deviation, it was preferred to target /s/ in clusters rather than as a single sound so that it could be generalised to single /s/ without even being targeted directly. To facilitate the correct production of the target patterns, auditory amplification, sound articulation modelling, use of tactile cues techniques were implemented to maximise the treatment positive effect on the child's production accuracy. In accordance with the gestural phonology, which is the core phonological theory of the cycles approach, (Browman and Goldstein, 1986; Kent, 1997) the phonological representation of a sound pattern is based on an interdependent correlation between perception and production. Therefore, auditory stimulation should be combined with sound articulation in the sense that during practising the target pattern the child would try to associate kinaesthetic and auditory sensations of the treated sound pattern. (Kamhi, 1992; Williams, 2003). Moreover, the use of kinaesthetic images can help the child correct the sound he/she is producing. The therapist models and can use mirror to show the child how to correctly produce the target sound (Hodson and Paden, 1983; 1991). This would assist the child to self-monitor herself when producing spontaneous speech at later sound development stages after completing the treatment. This would also gradually improve child's production of the target processes and promote rapid internalisation of the newly learned sounds as she would become self-aware how to correct herself and produce more accurate /s/-clusters and initial and medial velars (Hodson and Paden, 1983, 1991; Hodson, 2006, 2010). Based on the speech assessment results, two three-week treatment cycles were designed. The two treatment cycles targeted /s/-cluster pattern with three sounds /p/, /t/ and /n/ and initial and medial velar fronting of /k/ and /g/.

9.9 Pre-treatment Speech Intelligibility and MLU Assessments – CS Sample

In a preliminary evaluation of the participant's speech intelligibility, the ICS assessment was administered. The scores of ICS assessment ranged from 1 indicating low functional speech intelligibility to 5 indicating high functional speech intelligibility. The rating scores on a five-point scale included: 1= never, 2= rarely, 3= sometimes, 4= usually, 5= always. The child's parent answered the seven questions in the ICS form and subjectively rated the child's speech. The parent's answers reflected the extent to which her child was able to express herself and her needs clearly when speaking to immediate family members and individuals other than the family members. The seven questions were scored 3, 3, 3, 3, 2, 3, and 2, respectively. Based on the parent's answers, the results showed that the child's speech intelligibility was sometimes understood by immediate (e.g., the parents, siblings) and extended (e.g., aunts, uncles, cousins) family members, friends, and teachers at school. However, she was rarely understood by acquaintances and unfamiliar individuals. The average ICS score was 2.71; therefore, the child was sometimes to rarely understood by other individuals. The parents and siblings, teachers and close friends were more probably capable of understanding the participant than the distant acquaintances and individuals who the child was not familiar with.

Speech intelligibility was also assessed by analysing the spontaneous speech samples collected during the interactive activities (story reading and playing with toys). The sample also included utterances obtained from parent-child/researcher-child interactions. The participant was found to interact more smoothly with her parent that she felt more motivated to produce spontaneous speech as much as she could. The participant's speech intelligibility was assessed by using her spontaneous utterances which included 50 utterances nearly totalling 100 words. The spontaneous speech recording was edited to a length of two-minute speech excerpt recording. In fact, it was hard to elicit spontaneous utterances, and this could partially be a sign of actual speech difficulties, and partially an indication of unwillingness to speak.

Additionally, five adult native British English-speaking listeners listened to the child’s speech and rated her speech intelligibility. The listeners orthographically transcribed the words they understood and unintelligible words. The percentage of intelligible words was calculated by dividing the total number of intelligible words by the total number of words transcribed during the listening session multiplied by 100. Due to familiarity with the child and directly administering the assessment sessions, the researcher was able to perceive 67% meaningful words. However, the five listeners perceived 57%, 55%, 60%, 59%, and 55% words, respectively. The mean percentage of speech intelligibility was 57.20% with *SD*=2.28% (see table 9.6). There was an obvious difference between the percentage of utterances perceived by the researcher and the percentage of utterances perceived by the listeners. Most of the spontaneous utterances were single word utterances. The participant’s MLU was also estimated and it was 1.42 with age equivalent ranging from 18 to 21 months. This indicated that the child’s expressive language was far below expressive language level appropriate for her chronological age, i.e., she revealed delayed speech and language development.

Table 9.6 Descriptive analysis of percentage intelligibility by the listeners in pre-treatment intelligibility assessment

Mean	***SD***	***SE***	**Median**	**Range**	**Minimum**	**Maximum**	**95% Confidence Interval for Mean**	
							Lower Bound	**Upper Bound**
57.20%	2.28%	1.02%	57%	5%	55%	60%	54.37%	60.03%

Chapter 10: Results, Discussion and Conclusions

10.1 Results

10.1.1 Speech Production Accuracy during Baseline, Treatment and Maintenance Phases: Cycle I

The visual analysis depicted the participant's performance within and across the baseline, treatment and maintenance phases in cycle I (see figure 10.1). The visual analysis helped inspect whether the treated processes had undergone any changes, and whether these changes had occurred due to the implementation of the cycles treatment procedure, or by chance alone. The outcome data were compared across phases in terms level (mean), trend (slope) and variability (*SD* of data points within and across phases). In addition, descriptive statistics details of these phases in cycle I were summarized (see table 10.1). Before the beginning of the intervention programme, five baseline measurement points were administered over 5 weeks to obtain an accurate measurement of the existence of the target pattern before applying the cycles-based intervention procedure. The means and *SD*s for /s/ cluster and velar fronting processes during the baseline phase were displayed (see table 10.1). The baseline measures allowed a clear measurement of whether the intervention employed was the cause of the improvement occurrence. The data could also be used for measuring the effectiveness of the intervention in helping improve the child's speech production. The visual analysis indicated that the child's performance was low for all the elicited items during the baseline phase

The total words elicited during the baseline phase prior to the beginning of cycle I was 45 words (21 words for /s/ cluster and 24 words for velar fronting). The percentage of the correct production of /s/ cluster and velar fronting was very low during the baseline phase when compared to the percentages of correct production of the same target processes during the treatment, and maintenance phases. Looking at figure 10.1 (A), the level of the baseline data was below the level of the intervention data points. This indicated that there was a substantial improvement of the production of the target processes. Therefore, the mean percentage of correct production during the baseline phase was 10% (*SD* 1.85%); while the mean percentage of the correct production of these processes during the treatment and maintenance phases were 81% (*SD* 6.43%), and 52.17% (*SD* 7.23%), respectively. In addition, within the treatment phase, there was an immediate increase in the correct production of the target processes after the application of the cycles treatment procedure. The data in the baseline phase did not show considerable variability, while in the treatment and maintenance phases it was positively increasing. The baseline data also tended to be consistently variable with *SD* 1.85%. In the baseline phase the production accuracy ranged from 9% to 13%. In the treatment and maintenance phases the production accuracy ranged from 73% to 92% and 43% to 62%, respectively. This revealed that there was no overlap between the child's scores in the baseline phase and the scores in the rest of the phases. The visual analysis of the data outcome in the baseline phase was nearly neutrally trended, therefore, the cycles treatment effect was not predictable from the baseline data. Regarding the effectiveness of the cycles-based intervention for improving the child's speech production accuracy, the statistical difference between the participant's scores within the baseline and the treatment phases was obtained by employing two statistical methods: (1) the two-standard deviation band method, and (2) split-middle method of trend estimation.

The mean of correct production in the baseline phase and the two-standard deviation band were plotted across the baseline and the treatment phases. The two-standard deviation band was calculated 1.23%, and the lower and upper bands around the baseline mean were 8.77% and 11.23%, respectively. The results showed that more than two consecutive data points in the treatment phase were outside the two-standard deviation bands. This indicated that there was a significant change in the production accuracy after applying the cycles treatment procedure. The split-middle method of trend estimation was based on drawing an estimated celeration line across the middle of the baseline data points and extended with the same slope through the treatment data points. The celeration line assisted in identifying the trend of the outcome data, i.e., whether the correct production was increasing, decreasing, or remaining stable within the different phases. The results showed that all the treatment data points were positively trended above the best-fit line; therefore, the treatment resulted in a significant change in the accuracy of production of the target processes. In order to assess the difference between the child's performance during the baseline phase and the treatment phase, a binomial distribution test was run. The obtained (p=0.016) and this revealed that there was a significant difference between the phases in term of production accuracy. The same was also true for the maintenance phase.

10.1.2 Speech Production Accuracy during Baseline, Treatment, Maintenance and Follow-up Phases: Cycle II

During the second treatment cycle which lasted for three weeks (two sessions a week), the participant's performance continued to improve. The mean percentages of the correct production of /s cluster and velar fronting during the treatment and follow-up phases were higher than that during the baseline phase. The mean percentage of the correct production in the treatment and follow-up phases were 85.08% (SD 6.32%) and 82.17% (SD 5.83%); while the mean percentage in the baseline phase was 12% (SD 3.105). Looking at figure 10.1 (B), the level of the baseline data was below the level of the treatment data points. This indicated that there was a substantial improvement of the production of the target processes. In addition, within the treatment phase, there was an immediately continuous increase in the correct production of the target processes after the application of the cycles treatment procedure. The data in the baseline phase did not show considerable variability, while in the treatment and follow-up phases it was positively increasing. Thus, baseline data tended to be marginally variable with SD 3.10%. In the baseline phase the production accuracy ranged from 9% to 17%. In the treatment and follow-up phases the production accuracy ranged from 75% to 94%, and 77% to 89%, respectively (see table 10.1). This indicated that the child's scores in the baseline phase did not overlap with the scores in the treatment and follow-up the phases. The visual analysis of the data outcome in the baseline phase was nearly neutrally trended; therefore, the cycles treatment effect was not predictable from the baseline data.

Regarding the effectiveness of the cycles-based intervention for improving the child's speech production accuracy, the statistical difference between the participant's scores within the baseline and the treatment phases was also obtained by using the two-standard deviation band method and the split-middle method of trend estimation. Thus, the mean of correct production in the baseline phase and the two-standard deviation band were plotted across the baseline and the treatment phases. The two-standard deviation band was calculated ±1.21%, and the lower and upper bands around the baseline mean were 10.79% and 13.21%, respectively. The results showed that more than two consecutive data points in the treatment phase were outside the two-standard deviation bands. This indicated that there was a significant change in the production accuracy after applying the cycles treatment procedure. The split-middle method of trend estimation was drawn to estimate the celeration line across the middle of the baseline data points and extend it with the same slope through the treatment data points. The results showed that all the treatment data points were positively trended above the best-fit line; therefore, the treatment resulted in a significant change in the accuracy of production of the target processes. In order to examine whether there was a statistically significant difference between the child's performance during the baseline phase and the treatment phase, a binomial distribution test was run. The obtained (p=0.016) indicated that there was a significant difference between the phases in term of production accuracy. The same was also true of the child's production during the follow-up phase when compared to the baseline phase. The obtained (p=0.011) revealed a statistically significant difference between follow-up and baseline phases in relation to the child's performance in the two phases. Regarding estimating the effect size of the present single-subject study which was a nonlinear model-based study, the effect size was defined in terms of PND. For the treatment progress during cycle II, the PND score was 100%, i.e., there was no overlap between the highest data point in the baseline and the data points in the treatment and follow-up phases. Consequently, the child continued to progress as the production accuracy increased in the sense that there was a large effect of the cycles-based intervention on the child's performance in cycle II.

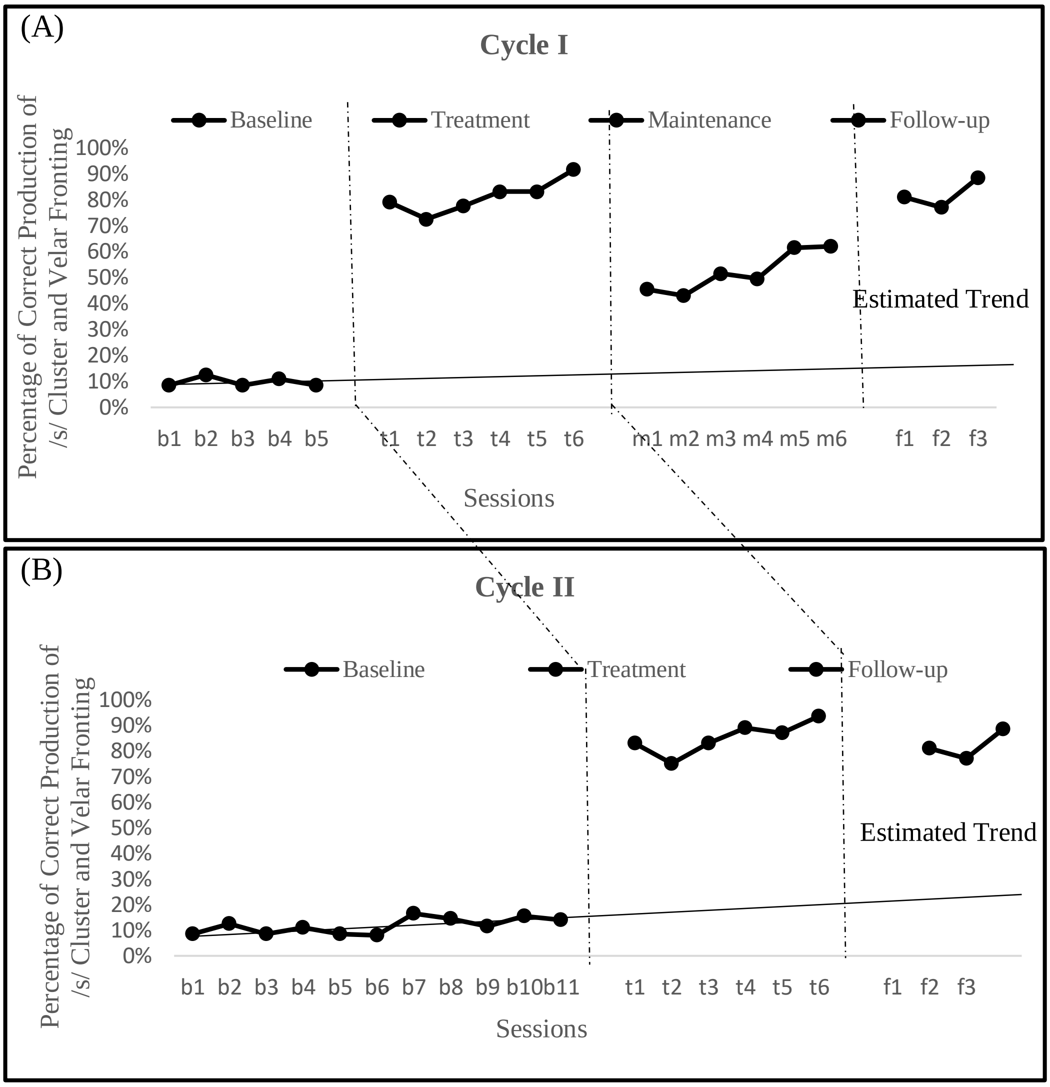


Figure 10.1 Production accuracy for /s/ cluster and velar fronting processes during the baseline, treatment, maintenance & follow-up phases

10.1.3 Comparisons of Baseline, Treatment, Maintenance and Follow-up Phases: Cycle I and Cycle II

The results of all the possible pair-wise comparisons between phases were obtained. Eight pair-wise comparisons were conducted; these included: (1) baseline1 vs treatment1, (2) baseline1 vs maintenance, (3) baseline1 vs follow-up, (4) treatment1 vs follow-up, (5) baseline2 vs treatment2, (6) baseline2 vs follow-up, (7) treatment2 vs follow-up, and (8) treatment1 vs treatment2. The non-parametric Wilcoxon-signed rank tests was carried out to compare the differences across phases in terms of accuracy of production of the target processes. The significance level was ≤0.05 to identify any significant differences across phases.

In cycle I, the percentages of correct production of the target processes during the baseline and treatment phases were compared. It was hypothesised that there would not be a significant change in the production of /s/ cluster and velar fronting processes after applying the cycles treatment procedure. The median in baseline1 data was 9%, but after applying the intervention it highly increased in treatment1 81.50% (see table 10.1). The results of Wilcoxon test revealed a significant difference between the child's productions in the baseline1 and treatment1 phases [z=2.023, p=0.043], with a large effect size (r=0.61) (see table 10.2). Comparing baseline1 to maintenance, the results showed that the median for the maintenance 50.50% was higher than the median for the baseline1 9% (see table 10.1). The results of Wilcoxon test indicated that there was a statistically significant difference between the child's performance in these two phases [z=2.023, p=0.043], with a large effect size (r=0.61) (see table 10.2). The follow-up median of 81% was higher than the baseline median of 9% (see table 10.1). The results of Wilcoxon statistic test manifested a highly significant difference between the two phases in terms of percentages of correct production of the two target patterns [z=2.023, p=0.043], with a remarkably large effect size (r=1.16) (see table 10.2). However, the results showed that there was a nonsignificant difference between the treatment and the follow-up scores. The median for treatment 81.50% was nearly equal to the median for the follow-up 81% (see table 10.1). The results of Wilcoxon test showed a nonsignificant difference in relation to correct production of target patterns [z=-0.210, p=0.833], with marginal effect size (r=0.07) (see table 10.2).

In treatment cycle II, the baseline2 was compared to the treatment2. Applying the cycles-based intervention, the median in treatment2 85% was found to be higher than the median in baseline2 11.50% (see table 10.1). The Wilcoxon test was run. The results revealed that there was a remarkably significant difference between the two phases in terms of the correct production of target /s/ clusters and velars [z=2.207, p=0.027], with large effect size (r=0.53) (see table 10.2). The follow-up median 81% was higher than baseline2 median 11.50% (see table 10.1). The results of Wilcoxon test showed a remarkably significant difference between the two phases in terms of the percentage of correct production of the target patterns [z=2.201, p=0.028], with a large effect size (r=0.58) (see table 10.2). Comparing the follow-up and treatment2 phases, the follow-up median 81% was lower than the treatment median 85% (see table 10.1). The Wilcoxon test was carried out. The results showed that there was a non-significant difference between the two phases in relation to the percentage of production of the target processes [z=1.051, p=0.293], with a marginal effect size (r=0.35) (see table 10.2). The median for treatment1 81.50% was lower than the median for treatment2 85% (see table 10.1). The Wilcoxon test was run. The results showed that there was a significant difference between treatment1 and treatment2 [z=2.207, p=0.027], with a highly large effect size (r=0.63) (see table 10.2).

Table 10.1 Descriptive analysis and effect size calculation in cycle I and cycle II during the baseline, treatment, maintenance and follow-up phases

Cycles	Phase	Mean	*SD*	*SE*	Median	Range	Minimum	Maximum	95% CI for Mean		Effect Size
									Lower Bound	Upper Bound	
Cycle I	Baseline	10%	1.85%	0.83%	9%	4%	9%	13%	7.49%	12.11%	
	Treatment	81%	6.43%	2.62%	81.50%	19%	73%	92%	74.34%	87.83%	100%
	Maintenance	52.17%	7.23%	2.95%	50.50%	19%	43%	62%	43.77%	60.56%	100%
Cycle II	Baseline	12%	3.10%	0.93%	11.50%	9%	8%	17%	9.64%	13.81	
	Treatment	85.08%	6.32%	2.58%	85%	19%	75%	94%	78.44%	91.72%	100%
	Follow-up	82.17%	5.83%	3.37%	81%	11%	77%	89%	67.66%	96.67%	100%

Table 10.2 The results of Wilcoxon test of comparisons of baseline, treatment, maintenance and follow-up phases in cycle I and cycle II

Phases Comparisons	*z*	*p*-value	*r*
Baseline1 versus Treatment 1	2.023	0.043	0.61
Baseline1 versus Maintenance	2.023	0.043	0.61
Baseline1 versus Follow-up	2.023	0.043	1.16
Treatment1 versus Follow-up	0.210	0.833	0.07
Baseline2 versus Treatment2	2.207	0.027	0.53
Baseline2 versus Follow-up	2.201	0.028	0.58
Treatment2 versus Follow-up	1.051	0.293	0.35
Treatment1 versus Treatment2	2.207	0.027	0.63

10.1.4 Post-treatment Speech Assessment of SW and CS Samples

The phonemic transcription of the post-treatment speech assessment revealed that the participant became able to produce consonants /f, v, z, s, p, b, m, n, k, g, ʒ, ʤ, ð, ʃ, t, d, l, w, r, ʃ, j/ more than those in pre-treatment assessment. Completing the treatment cycle I and cycle II, the participant's SW sample was re-assessed by administering DEAP-Assessment of Phonology (Dodd et al., 2002), CLEAR (Keeling and Keeling, 2006), and DEAP-Word Inconsistency (Dodd et al., 2002). The results showed that PCCs of singleton consonants in post-treatment were higher than in pre-treatment assessment. The child scored PCCs of singleton consonants 84% in SIWI, 87% in SIWM, 74% in SFWM and 83% in SFWF, respectively (see table 10.3). The participant also scored PCCCs in post-treatment higher than in pre-treatment assessment. The child scored PCCC of consonant clusters 60% in SIWI, 50% in SIWM and 63% in SFWF (see table 10.3). However, she for scored 0% PCCC in SFWM in pre- and post-treatment assessments. The results showed that the total of occurrences of phonological processes was reduced to 83 occurrences in post-treatment assessment. The target processes /s/-cluster reduction was reduced to 35%, and velar fronting was reduced to 21% (see table 10.4).

Table 10.3 Percentages of correct production of singleton consonants and consonant clusters of SW sample in pre- and post-treatment assessment

	Production of All Sounds			Production of Singleton Consonant				Production of Consonant Clusters			
Assessment	**PCC**	**PVC**	**PPC**	**SIWI**	**SIWM**	**SFWM**	**SFWF**	**SIWI**	**SIWM**	**SFWM**	**SFWF**
Pre-Treatment	72%	95%	78%	75%	76%	70%	79%	15%	0%	0%	25%
Post-Treatment	81%	95%	85%	84%	87%	74%	83%	60%	50%	0%	63%

Note: PCC-Percentage of consonants correct. PVC-Percentage of vowels correct. PPC-Percentage phonemes correct. SIWI-Syllable initial word initial. SIWM-Syllable initial word medial. SFWM-Syllable final word medial. SFWF-Syllable final word final.

Table 10.4 Summary of frequency and percentages of occurrence of phonological processes of SW sample in post-treatment assessment

Processes	Occurrence	Percentage of Occurrence	Examples
Gliding	7	8%	[fɪʃɪŋ]→[wɪʃɪŋ], [zebrə]→[wewə]
Deaffrication	5	6%	[wɒʧ] →[wɒʃ]
CR	30	35%	[gri:n]→[ri:n], [splæʃ] →[slæʃ]
Fronting	18	21%	[fɪŋgəz]→[bɪdəz], [rɒkɪt]→[rɒtɪt]
WSD	3	4%	[təmɑ:təʊ]→[mɑ:təʊ], [bənɑ:nə]→ [nɑ:nə]
Stopping	0	0%	
Voice	0	0%	
Assimilation	10	7%	[jeləʊ]→[leləʊ], [feðə]→ [fefə]
ICD	5	6%	[rɪvə]→ [və], [weli:z]→[li:z]
MCD	5	6%	[bɪskɪts]→ [bɪtɪt], [mʌŋki:]→ [mʌki:]
FCD	0	0%	
Backing	0	0%	
Other	0	0%	
Total Processes	83		

Note: CR-Cluster reduction. WSD-Weak syllable deletion. ICD-Initial consonant deletion. MCD-Medial consonant deletion. FCD-Final consonant deletion.

Regarding the post-treatment CS samples assessment, speech intelligibility and MLU were re-evaluated. The results of post-treatment assessment ICS revealed that the child's speech intelligibility was between sometimes to usually understood by immediate (e.g., the parents, siblings) and extended (e.g. aunts, uncles, cousins) family members, friends, and teachers at school. The intelligibility of the child's spontaneous speech was re-evaluated by the same five adult native British English-speaking listeners. The median of percentage of speech intelligibility in post-treatment assessment 67% was higher than that in pre-treatment assessment 57% (see table 10.5). Wilcoxon test was carried out. The results showed a statistically significant difference between pre- and post-treatment in terms of percentage of speech intelligibility [$z=2.060$, $p=0.039$], with very large effect size ($r=0.65$). The results of post-treatment assessment also revealed the participant's MLU was 1.90 with age equivalent between 21 to 24 months. It was higher than the MLU calculated during the pre-treatment assessment which was 1.42 with age equivalent between 18 to 21 months.

Table 10.5 Descriptive analysis of percentage intelligibility by the listeners in pre- and post-treatment intelligibility assessment

Mean	*SD*	*SE*	Median	Range	Minimum	Maximum	95% Confidence Interval for Mean	
							Lower Bound	Upper Bound
57.20%	2.28%	1.02%	57%	5%	55%	60%	54.37%	60.03%
66%	2%	1%	67%	5%	64%	69%	63.98%	68.82%

10.2 Discussion

The present case study introduced the cycles-based intervention model to remediate specific phonological processes which recurrently occurred in the speech of a school aged child with DS. The child took part in a series of standardised and non-standardised pre- and post-treatment assessments and cycles-based treatment procedure for six weeks. The study demonstrated clinically and statistically significant improvements in terms of speech production accuracy and speech intelligibility. The improvement achieved supported the available evidence for the effectiveness of the cycles approach for treating the phonological processes of children with highly unintelligible speech.

10.2.1 Speech Production Accuracy during Baseline, Treatment, Maintenance and Follow-up Phases: Cycle I and Cycle II

The visual analysis of the participant's performance within and across the baseline, treatment, maintenance and follow-up phases in cycle I and cycle II helped inspect whether the treated processes had undergone any changes, and whether these changes had occurred due to the implementation of the cycles treatment procedure, or by chance alone. The child's production of the target processes was analysed and compared across phases. The baseline measurement evidenced the existence of the target patterns before applying the cycles procedure. The comparison of the baseline phase to the treatment phase provided an excellent picture of whether the cycles intervention employed was the cause of production improvement. The graphical analysis indicated that the child's performance was low for all the elicited items during the baseline phase prior to the commencement of the entire intervention programme (see figure 10.1 and table 10.1). Therefore, the mean percentage of the correct production of /s/ cluster reduction and velar fronting processes was very low during the baseline phase when compared to the mean percentage of correct production of the same processes during the treatment, maintenance and follow-up phases. This revealed that there was a substantial improvement in terms of the production of the target processes (see figure 10.1 and table 10.1). The cyclic structure of the treatment allowed moving to treat the next pattern even when the first target has not been entirely remediated. The cyclic procedure for targeting the selected phonological processes assisted in accelerating the production improvements (Rudolph and Wendt, 2014). The study findings showed that cycles procedure positively affected the production of target processes, yet, this effect was not predictable in the baseline phase.

The production of target patterns continued to develop positively throughout cycle II. The production accuracy of /s/ cluster and initial and medial velars during the treatment and follow-up phases were found to be higher than these during the baseline phase. This indicated that there was a substantial improvement of the production of target processes. The production in the baseline continued to reflect marginal variability when compared to production in the treatment and follow-up phases. The production in baseline phase was neutrally trended; while in the treatment and follow-up phases in it was positively increasing. The cycles-based intervention was found to be significantly effective in improving the child's speech production accuracy in the sense that more than two consecutive data points in the treatment phase were found to be outside the two-standard deviation bands. This indicated that there was a significant change in the production accuracy after applying the cycles treatment procedure. Additionally, all the treatment data points were positively trended above the best-fit line; therefore, the treatment resulted in a significantly noticeable change in production of target processes. The same was also true for the maintenance and the follow-up phases. With a large effect size in the treatment, maintenance and follow-up phases, the present study evidenced that the child continued to progress as the production accuracy increased in the sense that there was a large effect of the cycles-based intervention on the child performance in cycle I and cycle II. Comparing the baseline, treatment, maintenance and follow-up phases, the study findings revealed that during cycle I and cycle II, the child achieved clinically and statistically significant improvement in terms of maximising the accuracy of speech production, reducing the occurrences of the target processes and increasing speech intelligibility. The alternative hypotheses were refuted at a significance level ≤ 0.05 and that the child's production improvement unlikely occurred by chance. The findings of the present case study were consistent with the ones obtained by Cholmain (1994) and Dodd et al. (1994) who found that a phonological pattern-oriented approach, such as the cycles approach, resulted in significant speech improvements within almost short successive treatment cycles.

10.2.2 Post Treatment Assessment of SW Sample

Prior to the beginning of intervention, the number of the acquired consonants was limited. This could be attributed to the point that the participant tried to avoid the sounds that she did not acquire or master yet, for she had a moderate speech delay (Iacono, 1998). Consequently, she could not produce /f, v,θ,ð, g, ʒ, ʤ, ŋ/. Nonetheless, the child was found to be stimulable to produce these consonants with facilitation, i.e., she was capable of imitating the sounds modelled by the researcher when occurring in isolation devoid of context (Dodd et al., 2003). The production difficulty emerged when sounds occurred in specific phonetic contexts. Since the child did not have oral-motor structure abnormalities, she did not have articulation difficulties, except that she needed a slight articulation modelling for few sounds, such as /f,v,θ,ð,ʤ,k,g/. This finding was in line with Barnes et al (2006) study which indicated that children with DS who did not have articulation difficulties needed to immediately be trained to produce sound and sound combinations in context rather than focusing on merely learning the correct articulatory movements dissociated from speech. According to Barnes et al. (2006), focusing on articulation would not be a sufficient treatment procedure to help them produce speech accurately. Thus, it was realised that children with DS need a more comprehensive intervention that merges oral-motor tasks with phonology acquisition activities to improve speech production (Van Bysterveldt et al., 2010). The results of post-treatment speech assessment evidenced the increase in the number of consonants acquired. Thus, additional sounds emerged in her speech with slight facilitation whenever needed.

In SW sample, the child’s speech accuracy measures before and after applying the cycles treatment showed improvement in consonants production as well as the decrease in the use of target processes. The vowels production remained constant during pre-and post-treatment speech assessment. Regarding the accuracy measures of singleton consonants and consonant clusters occurring in various word positions, the child demonstrated noticeable improvement during the post treatment speech assessment compared to the pre-assessment. However, the child did not improve the production of consonant clusters occurring in SFWM position during the pre- and post-treatment assessments. The study findings demonstrated that the positive changes in the child’s speech production during the post-treatment speech assessment was brought about by applying the cycles-based intervention procedure. The present study findings coincided with the findings in previous studies conducted by Cholmain (1994), Dodd et al. (1994) and Van Bysterveldt et al. (2010).

The participant became able to produce correct initial /s/-clusters and initial and medial /k/ and /g/ sounds spontaneously or with the least assistance. Yet, she needed more assistance to produce velar sounds in word-medial position. One of the characteristics of the cycles approach is that it is a pattern-based approach, therefore it was appropriate to address the phonological processes that occurred in the participant's speech (Cholmain, 1994; Rudolph and Wendt, 2014). The results of post-treatment speech assessment showed that the total of occurrences of phonological processes was reduced, particularly the occurrences of the target processes /s/-cluster reduction and velar fronting. The was found to be stimulable to pronounce singleton /s/ regardless of word position. The emergence of single /s/ assisted stimulate the correct production of /s/ when occurring in clusters. Additionally, she demonstrated the ability to produce /k/ either spontaneously or with assistance rather than replacing it with the uvular fricative /χ/, particularly in word final position. The speech assessment results showed that the other processes that were not targeted were also reduced though not entirely supressed (see table 10.4). Although the total occurrence of the phonological processes was lowered to 83, the child's severity level of expressive phonological disorder was still rated as moderate (between 51and100). Therefore, she might need further treatment cycles to maximise her production accuracy and reduce the occurrence of phonological processes in her speech. For instance, the participant was able to produce /s/ in two-consonant clusters (e.g., *smile* [smaɪl], *slide* [slaɪd], but not in three-consonant clusters (e.g., *splash* [plæʃ]). Regarding the velar fronting process, the child managed to produce initial /k/ and /g/. However, she needed more training so that she could produce medial velars as well. Generally, being able to produce /s/-clusters and initial velars correctly contributed to improving the child's speech intelligibility.

10.2.3 Post Treatment Assessment of CS Sample

The parent's subjective responses to post-treatment ICS assessment reflected the extent to which her child was able to express herself and her needs clearly when speaking to immediate family members and individuals other than the family members. Based on these responses, the child's speech intelligibility was between sometimes to usually understood by immediate (e.g., the parents, siblings) and extended (e.g., aunts, uncles, cousins) family members, friends, and teachers at school. However, she was still rarely understood by acquaintances and unfamiliar individuals. The speech intelligibility tended to be one of the major problems that a child with Down syndrome faced. That is, the typical and atypical phonological processes affected the child's speech clarity. Buckley and Le Prevost (2002) explained that the speech problems in children with Down syndrome involve a three-level difficulty consisting of planning, articulation and phonology which collectively decrease speech intelligibility.

In CS sample, the intelligibility of the child's spontaneous speech was re-evaluated by the same five adult native British English-speaking listeners. The post-treatment intelligibility assessment results showed improvement in the child's speech intelligibility level. The listeners' mean percentage was higher than the percentage obtained in the pre-assessment. However, the researcher's score remained higher than the listeners' mean score because of the familiarity with the participant's speech. The main goal of the cycles-based intervention was to help children with DS increase intelligibility via treating the phonological processes which greatly affected their speech intelligibility and persist to appear in their speech even at ages older than 5;0 years. The cycles procedure targeted the deficient phonological patterns. This would substantially help increase the children's awareness of sound use in suitable contexts through a great variety of experiential play activities (Hodson and Paden, 1983; 1991).

Before applying the cycles procedure, the child tended to avoid producing more complex word structures and sounds and sound sequences. Most of the child's spontaneous utterances were single word utterances which included simple word structures (one-/two-syllable words) and sounds and sound sequences that could produce. Therefore, the child's MLU in pre-treatment assessment was shorter than that in post-treatment assessment. This tendency could be correlated with the sound and sound pattern errors which could be maximised as the syntactic complexity of utterances increased (Stoel-Gammon, 1990). This indicated that the child's expressive language was far below expressive language level appropriate for her age, i.e., she revealed delayed speech and language development. In the same context, Miller and Leddy (1998), as cited by Iacono (1998), stressed that speech difficulties might result in limited speech intelligibility which, in return, negatively could affect language development. The phonological difficulties could affect the morphological structure of the participant's utterances, such as plurality, possessiveness, and/or tense morphemes in the sense that the child might tend to delete or substitute the sound structure of these morphemes and, in return, affect the syntactic development as well as reduce speech intelligibility. During the post treatment assessment, the participant's MLU was slightly higher than the MLU calculated during the pre-treatment assessment. This indicated that the child's expressive language was far below expressive language level appropriate for her chronological age, i.e., she revealed delayed speech and language development.

10.3 Conclusion and Suggestions for Further Research

Throughout the present research, the cycles-based intervention applied to the /s/-cluster and velar fronting processes provided experimental evidence for the effectiveness of the cycles approach in remediating the target processes. All the elements of the cycles intervention model contributed to improving the participant's speech production and speech intelligibility. The pre- and post-treatment speech assessment provided an explanation of the participant's phonological system. It presented an analysis of the child's phonetic repertoire of the sounds that she could produce spontaneously and with facilitation. It also helped analyse the error sound patterns that characterised the child's speech and affected her speech intelligibility. The child's performance positively improved in terms of the accuracy measures: PCC, PVC and PPC and the production of single consonants and consonant clusters in the SIWI, SIWM, SFWM and SFWF, and the occurrences of phonological processes after applying the cycles treatment. However, the production of medial clusters did not show any improvement. The number of the consonants acquired was slightly increased to include few more sounds were added, such as the velars and affricates which the child was able to produce either spontaneously or with stimulation.

Regarding phonological processes, the occurrences of the target /s/-cluster and velar fronting processes was significantly reduced. The implementation of the cycles treatment procedure contributed to reducing the occurrences of the target processes. Additionally, the improvement of the production of /s/-clusters and initial velars could be attributed to the cyclic nature of the intervention procedure applied. The pre-treatment assessment results revealed that the most frequently occurring phonological processes were cluster reduction and fronting. Although the occurrences of the other processes persisted to exist, the post-treatment assessment revealed that the percentages of occurrence of /s/-cluster and velar fronting processes were minimised. Since these processes still exited in the child speech, these processes needed to be further targeted until the child completely suppress them.

In as far as the child's speech intelligibility was concerned, there was slight improvement in the child's intelligibility. That is, the parents and siblings, teachers and close friends were more probably capable of understanding the participant than the distant acquaintances and individuals who the child was not familiar with. The implementation of the cycles-based intervention helped child relatively increase her speech intelligibility via treating and reducing the occurrences of the target phonological processes which greatly impacted her speech intelligibility and persisted to appear in their speech even at an age older than 5;0 years.

Additionally, the improvement of participant's MLU indicated that the child's expressive language skills could be enhanced by reducing the occurrence of phonological processes.

With regards to the intervention programme, the child's performance during the baseline phase evidenced the existence of the target patterns before applying the cycles treatment procedure. In cycle I, the immediate effect of the cycles procedure was manifested, i.e., there was a substantial improvement of the production of the target processes. In cycle II, the participant's performance continued to develop positively; while during the baseline phase remained stable. In a similar way, in the maintenance and follow-up phases the target production was increasingly improving. The study findings evidenced the effectiveness of the cycles-based intervention in improving the child's speech production accuracy. There were statistically significant differences between the baseline phase and the treatment, maintenance, and follow-up phases in term of production accuracy. However, it was found that there was a statically nonsignificant difference between the child performance in the treatment and follow-up phases. This suggested that the child manged to maintain the treated patterns and the related sounds. The study findings also showed that there was a significant difference between the treatment phases in the two treatment cycles. The findings demonstrated that the child's production continued to improve increasingly throughout cycle II.

The clinical application of a particular intervention model mainly depends on the child's characteristics (physical, physiological and cognitive characteristics) in addition to the type of the phonological difficulties he/she has. The effectiveness of a given intervention procedure also needs to be evaluated to ensure its practicality in treating the target phonological errors. In as far as the effectiveness of the cycles approach is concerned, the results of the present case study form an important contribution to the available research about the effectiveness of this model in remediating the target processes. However, further research is still needed to explore its efficacy and effectiveness in treating phonology-based errors and assisting in reconstructing the children's phonological systems (Cholmain, 1994). There are needs to examine the effectiveness of cycles approach in remediating the phonological errors in larger samples of participants belonging to various populations and to add further evidence of treatment effectiveness in conducting well-controlled study designs. This can ensure the validity of representativeness of the obtained results and the possibility of generalising the findings to whole populations (Baker and McLeod, 2011; Hodson et al., 1983; Hodson et al., 1989). Further studies are also needed to investigate the utility of the cycles approach for group intervention settings, taking into consideration the important correlation between phonology and the other language components (syntactic and pragmatic aspects) and the child's specific needs (Montgomery and Bonderman, 1989; Tyler and Watterson, 1991).

10.4 Conclusion of Part I and Part II

Speech tends to be the most cognitively and physiologically demanding communicative skill for children with DS. A combination of various anatomical, physiological and neurological factors differently could affect speech development for children with DS, particularly, the production of speech sounds. Due to the developmental and learning difficulties they have, children with DS, who are the focus of the present study, are at high risk for phonological development difficulties. The phonological development in children with DS is interdependently correlated with speech intelligibility. However, phonology-based intervention programmes were not given high priority. The present study is an attempt to address several gaps in the available research. Thus, study focused on (1) analysing the development of phonology in DS population (within the age range tested) during the production of single words and spontaneous connected speech, (2) the inclusion of large number of participants, (3) comparing the performance of DS participants to that of TD controls, and (4) presenting a holistic phonology-based intervention model to remediate phonological errors. The study has been divided into two parts. Part one focused on discovering the phonological similarities and differences between two groups of DS and TD participants. Part two focused on the implementation of the cycles phonological approach and its effectiveness in remediating the phonological processes occurring in a school age child with DS.

Experimentally, the first part revealed that DS participants develop their phonological systems in a similar way to TD participants, but they continued to develop their phonological skills (acquiring the entire range of English consonants and vowels, using sounds in the correct context, and reducing/suppressing the occurrence of phonological processes) with an obvious delay. The different sampling conditions demonstrated the performance of DS participants. DS participants performed in SW production better than in CS production in terms of sound production accuracy and the use of phonological processes. The findings of the group study could be beneficial for speech-language therapists in two respects. First, it explained the order of sounds they acquired and which consonants appeared to be difficult to be early acquired and could be acquired at later stages. It also identifies the most difficult to suppress and frequently occurring processes which need to be prioritised for immediate intervention. Second, the findings of the group study highlighted the significance of phonology and its effect of speech intelligibility. Therefore, these findings promoted on targeting phonological errors in order to increase speech intelligibility. The second part of the research presented the cycles phonological approach to remediate the phonological processes of a school age child with DS. The implementation of the cycles-based intervention helped relatively increase the child's speech intelligibility via treating and reducing the occurrences of the target phonological processes which greatly impacted her speech intelligibility and persisted to appear in her speech even at an age older than 5;0 years. Additionally, the improvement of participant's MLU indicated that the child's expressive language skills could be enhanced by reducing the occurrence of phonological processes, i.e., by helping her re-organise phonological rules for combining sounds into meaningful units (e.g. syllables, words, phrases, sentences).

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Appendices

Appendix A: Information Sheet, Poster, Assent and Consent Forms and Cover Letter

A1. Information Sheet for Group Study

Information Sheet

Title of Study: Speech sound development in children with Down syndrome compared to typically developing children

Supervisors:	Email:	Phone:
Dr. Vesna Stojanovik	v.stojanovik@reading.ac.uk	0118 378 7456
Prof Jane Setter	j.e.setter@reading.ac.uk	0118 378 6089
PhD researcher:		
Najwa Yousif	n.s.y.yousif@pgr.reading.ac.uk	

I am currently a third-year PhD student at the University of Reading and for my research I am investigating speech development in children with Down syndrome compared to typically developing children.

We would be grateful to you if you could assist us by participating in our study. The aim of the study is to explore the development of the speech sound systems in children with Down syndrome. We are trying to find out how speech sounds develop in children with Down syndrome between the ages of 5;0 and 12;0 years. We also would like to find out which sounds the children can produce, whether some sounds are harder than others and whether the position of a sound in a word affects its production. For example, if a child has difficulty with producing the sound ‘s’, we would like to know whether it matters where in the word this sound is (beginning, middle, end).

The study will include two groups: (1) 20 children with Down syndrome aged between 4 and 12; and (2) 20 typically developing children aged between 3;0 and 6;0 years. Each participant in either group will be seen twice over two one-hour sessions at the University of Reading or in the participant’s school, or at the participant’s house if that is the only option suitable for the parent and child. During the session, the children will be asked to name various pictures, engage in telling short stories, point at pictures. We would like to audio record the child’s speech so that we could analyse it further. The audio recordings will be deleted as soon as the analyses of the speech patterns had been done.

The data will be kept confidential and securely stored, with only an anonymous number identifying it. Information linking that number to your name will be stored securely and separately from the data you provide us. All personally identifying information collected for the project will be destroyed after completion of the writing up of the project. Consent forms will be kept for 5 years in a securely locked cabinet, separate from the data.

Taking part in this study is completely voluntary; you may withdraw at any time without having to give any reason and this will not affect your child's educational provision in any way. Please feel free to ask any questions that you may have about this study at any point. You can contact us on the email addressed/telephone numbers provided above.

This application has been reviewed by the University Research Ethics Committee and has been given a favourable ethical opinion for conduct.
All investigators on this project have had criminal record checks and have been approved by the School to work with children.

Thank you for your help.

Dr. Vesna Stojanovik, Prof. Jane Setter and Najwa Yousif

A2. Poster for Group Study

Speech Sound Development in Children with Down Syndrome

We are running a research study at the University of Reading which focuses on speech sound development in children with Down syndrome who are between 5;0 to 12;0 years of age. The aim of the project is to explore and analyse the speech sound systems of children with Down syndrome. The study findings will provide useful information about speech development in Down syndrome and help speech and language therapists in the decision-making process about the most suitable intervention models.

The study will be based on comparing the speech sound development in two groups: children with Down syndrome group and typically developing group. Each child's speech in both groups will be assessed over two one-hour sessions. Each child will be seen individually accompanied by a parent/caregiver. If you are interested for your child to take part, please contact Vesna Stojanovik (PhD supervisor, v.stojanovik@reading.ac.uk or 0118 378 7456), or Najwa Yousif (PhD student in Clinical Language Sciences, n.s.y.yousif@pgr.reading.ac.uk) for further information.

A3. Consent for Group Study

Consent Form

I, …………………………………… agree for my child ....to participate in the study of the speech sound development in children with Down syndrome, being conducted by Dr. Vesna Stojanovik, Prof. Jane Setter and Najwa Yousif at the University of Reading. I have seen and read a copy of the Participants Information Sheet and have been given the opportunity to ask questions about the study and these have been answered to my satisfaction. I understand that all personal information will remain confidential to the investigators and arrangements for the storage and eventual disposal of any identifiable material have been made clear to me. I understand that participation in this study is voluntary and that I can withdraw at any time without having to give an explanation.

I am happy to proceed with my participation.

Signature ---

Name (in capitals) ---

Date ---

A4. Cover Letters for Parents and Schools

Cover Letter for Parents

Dear Parents,

I am a PhD student at University of Reading/ School of Psychology and Clinical Language Sciences/ Clinical Language Sciences Department. I am studying the speech sound development in children with Down syndrome as compared to typically developing children. For this research project, I need to recruit 20 monolingual English-speaking typically developing children whose ages are between 3;0 and 6;0 years; and 20 Children with Down syndrome whose ages are between 5;0 and 12;0 years old.

I would be most grateful if you could disseminate the project information to parents, friends, and acquaintances. The project information sheet and consent form for the parents to families of monolingual English-speaking typically developing and children with Down syndrome are attached to this post. You may contact me on the email (n.s.y.yousif@pgr.reading.ac.uk). I would be most grateful if you could pass this information to families of typically developing children of mixed ages between 3;0 and 6;0 years, and families of children with Down syndrome of mixed ages between 5;0 and 12;0 years and gender (female and male).

Thank you very much for your help in advance.

Best regards

Najwa Yousif

PhD Student
School of Psychology & Clinical Language Sciences
University of Reading
Reading, RG6 6AL
Phone: 0118 378 7456

Email: n.s.y.yousif@pgr.reading.ac.uk

Cover Letter for Schools

Dear Sir/ Madam,

I am a PhD student at University of Reading/ School of Psychology and Clinical Language Sciences/ Clinical Language Sciences Department. I am studying the speech sound development in children with Down syndrome as compared to typically developing children. For this research project, I need to recruit monolingual English-speaking children with Down syndrome whose ages are between 5;0 and 12;0 years; and 20 typically developing children aged between 3;0 and 6;0 years. Each participating child will be rewarded the following: (£5+a story book+a play-dough tub).

I would be most grateful if you could disseminate the project information attached to this email to families of monolingual English-speaking children with Down syndrome and typically developing children. If families would like to take part, they need to contact me directly. I would be most grateful if you could pass the project information and poster to families of children with Down syndrome and typically developing children within the age range mentioned above and of mixed gender (female and male).

Thank you very much for your help in advance.

Best regards

Najwa Yousif

PhD Student
School of Psychology & Clinical Language Sciences
University of Reading
Reading, RG6 6AL
Email: n.s.y.yousif@pgr.reading.ac.uk

A5. Information Sheet for Case Study

Information Sheet

Title of project: Speech Intervention for Children with Down Syndrome

Supervisors:	Email:	Phone:
Dr. Vesna Stojanovik	v.stojanovik@reading.ac.uk	0118 378 7456
Prof Jane Setter	j.e.setter@reading.ac.uk	0118 378 6089
PhD researcher:		
Najwa Yousif	n.s.y.yousif@pgr.reading.ac.uk	

Aims of the study

This study is concerned with treating the speech problems of children with Down syndrome (DS). It is well known that some children with DS can have severely to profoundly disordered phonology due to different factors. They either cannot easily be combined and sequence sounds in syllables and words or can produce a limited set of sounds. The study aims to use an approach called the Cycles intervention programme which aims to target the speech sound disorders of children with DS.

What is involved in participating in the study

Initially, your child's speech will be assessed. The assessment will take place in two 40-minute sessions. This will include standardised assessments such as the Diagnostic Evaluation of Articulation and Phonology (Dodd et al., 2002) which involves naming a set of pictures. The children's receptive and expressive language skills will be assessed using subtests of the Clinical Evaluation of Language Fundamentals – (CELF-4). This includes repeating sentences, following directions and pointing to pictures as well as naming pictures. The participants' non verbal skills will also be assessed using the Mullen Scale of Early Learning (Mullen, 1995) which includes block building or matching objects with pictures. After the assessment, there will be a period of 2-3 weeks when we won't see your child and then after this 'no treatment' period, we will begin the Faculty of Life Sciences intervention. The intervention will last six-week and there will be 18 sessions (3 sessions per week). During each intervention session, the participant will be exposed to the target sounds (20 words during 30 seconds per session). He/she will also be involved in production activities (e.g. matching, picture naming, games, puzzles, etc.). The listening activity will be repeated in the end of the treatment session. The intervention includes a short home programme in which the parents/caregivers read the word list to the child and, then, ask him/her to name the relevant pictures. The assessment and treatment sessions will take place in a child friendly room at the University of Reading or in the child's school. The treatment sessions will stop at the end of the intervention period as it will not be feasible to carry on with the intervention. All sessions will be audio recorded so that the data can be further analysed.

What are the possible advantages and disadvantages of taking part?

Advantages of taking part: The cycles-based intervention may decrease the sound errors of the participants, thus, increasing their speech production accuracy, adding to speech clarity and intelligibility. Disadvantages: The intervention programme requires the parents/caregivers to practice the treatment word lists within a short home programme. This may overload already busy families. Also, there is no guarantee that the intervention will lead to improved intelligibility in each individual child.

Do I have to participate?

Participation in the study is completely voluntary and the parents are free to withdraw their children from the project at any time. They can do so without this affecting any care or services the children may be receiving now or may receive in the future.

Confidentiality:

Any personal information given will remain confidential. The treatment sessions will be recorded and securely saved on the researcher's computer. Additionally, all personal data will be stored securely in a locked cupboard. Personal information will be kept for 5 years and then disposed. Anonymised data may be kept at the University for future research.

Who has reviewed and approved this study?

This application has been reviewed by the University Research Ethics Committee and has been given a favourable ethical opinion for conduct.

All investigators on this project have had criminal records checks and have been approved by the School to work with children. If you would like to know the outcome of the study, you are welcome to contact us to request this. If you would like your child to take part in this study please contact Vesna Stojanovik (v.stojanovik@reading.ac.uk) who will send you consent forms. You will then need to complete and send back one copy of the consent form and keep the second copy of the Information Sheet/Consent Form for your own future reference. If you have any questions you can contact us on the phone numbers at the top of the Information Sheet. If, for any reason, you do not wish for your child to take part in this study, this would not affect your child's educational provision in any way. You can withdraw your consent at any point during the study.

What expenses and/or payment or equivalent be made for participation in the study?

The researcher will not be paying the participants for taking part in the intervention study, but she will be paying the travelling expenses for the parents bringing their children to the university.

Contact details for further questions, or in the event of a complaint

For more information, the participants parents/caregivers may contact the principal investigator Dr.Vesna Stojanovik (v.stojanovik@reading.ac.uk), or the researchers Najwa Yousif (n.s.y.yousif@pgr.reading.ac.uk).

Thank you for your help.

A6. Poster for Case Study

Speech Intervention for Children with Down Syndrome

We are running a research study at the University of Reading which focuses on speech intervention in children with Down's syndrome who are between 5-7 years of age. The aim of the project is to improve the speech intelligibility of children with Down syndrome who have difficulties with speech, especially if those unknown to the child find it difficult to understand them. If you are interested in participation for your child to take part, please contact Najwa Yousif (PhD student in Clinical Language Sciences, n.s.y.yousif@pgr.reading.ac.uk) or Vesna Stojanovik (PhD supervisor, v.stojanovik@reading.ac.uk) for further information.

A7. Consent for Case Study

Consent Form

I, …………………………………… agree for my child ....to participate in the study on speech intervention in children with Down's syndrome being conducted by Dr. Vesna Stojanovik, Prof. Jane Setter and Najwa Yousif at the University of Reading. I have seen and read a copy of the Participants Information Sheet and have been given the opportunity to ask questions about the study and these have been answered to my satisfaction. I understand that all personal information will remain confidential to the investigators and arrangements for the storage and eventual disposal of any identifiable material have been made clear to me. I understand that participation in this study is voluntary and that I can withdraw at any time without having to give an explanation.

I am happy to proceed with my participation.

Signature --

Name (in capitals) --

Date --

A8. Child Assent Form for Case Study

Assent Form

Title of the study: Speech Intervention for Children with Down Syndrome

The researcher will verbally explain to the participants in a child friendly way the intervention procedure by exemplifying a particular treatment activity and what they are requested to do if they wish to respond. For example, they will be shown a number of the picture cards representing words containing given target patterns and show them how they can practice producing these words. The verbal explanation facilitates best understanding of the intervention study on the part of the children and gives them the opportunity to express their willingness to proceed or not. That is, the child will recurrently be asked whether like to do the task or they do not want to do so.

Project researcher – who am I?

Hello, I am Najwa. I am studying at CLS department

and am doing a project for speech improvement.

I have so many pictures to name, match or cut and glue. Would you like to play with these with me?

It will take no longer than 40  **minutes.**

You can say YES or NO. It is up to you whether you take part. I will show what we can do.

Listen to the words, please! "Snake", "snail"

What is this? That's right! "Snake", "snail"

Now, can you stick it to a match Picture?

Do you want to see more pictures?

Let's play cut and glue game! Point to the picture you want to cut. Can you name it for me? Good job! Let's glue it!

Do you want to proceed?

or

Child Name ________________________ Signature_________________________

Date_____________________________

A9. A Cover Letter for Parents

Cover Letter for Parents

Dear Parents,

I am a PhD student at University of Reading/ School of Psychology and Clinical Language Sciences/ Clinical Language Sciences Department. I intend to conduct a speech intervention study in children with Down syndrome. For this research project, I need to recruit monolingual English-speaking children with Down syndrome whose ages are between 5;0 and 7;0 years.

I would be most grateful if you could disseminate the project information to parents, friends, and acquaintances. The project information sheet and consent form for the parents to families of monolingual English-speaking children with Down syndrome are attached to this post. You may contact me on the email (n.s.y.yousif@pgr.reading.ac.uk). I would be most grateful if you could pass this information to families of children with Down syndrome of ages between 5;0 and 7;0 years and of mixed gender (female and male).

Thank you very much for your help in advance.

Best regards

Najwa Yousif

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University of Reading
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Phone: 0118 378 7456

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Appendix B: Demographic Information and Parent Questionnaire Form

B.1 Demographic Information for Group and Case Study

Demographic Data

1. Does the child have and hearing and vision medical history? If yes, would you kindly provide a scanned copy of the latest hearing and vision test results, please?
2. Are any languages other than English spoken at home? Does your child use a language other than English for communication at home?
3. Has the child received speech therapy service within the last 12 months? If yes, when did it take place and for how long it lasted?

B.2 Parent Questionnaire

Parent Questionnaire

Please complete this questionnaire and e-mail it to either Vesna Stojanovik (v.stojanovik@reading.ac.uk) or to Najwa Yousif (n.s.y.yousif@reading.ac.uk). Feel free to include any additional information which you may consider to be helpful in the section at the end entitled Any Other Information. The information you provide is treated as confidential and will only be available to the two researchers on the project.

Personal details:

Child's name: ______________________________________

Child Birth Date: ---------------------------------- Age: ------------------------- Sex: ------------------

Address: --

Contact Telephone: ---

Mother's or Father's Name: ---

Birth History

1. During the pregnancy, did the mother experience any unusual illness, condition, or accident, such as German measles, Rh incompatibility, false labour, etc? If so, please describe

   Length of Pregnancy: --------------------------- Birth Weight: ------------------------------
2. Were there any problems with the delivery, such as breech birth, Caesarean, etc.? If so, please describe

Conditions immediately following birth:

1. Did the infant have trouble starting to breathe? Was infant blue? Jaundiced? Did infant have sucking or swallowing difficulty? Feeding problems? Seizures? Scars/rbruises?

   Other problems? Was birth weight regained quickly?

DEVELOPMENTAL HISTORY

1. Approximate age when child:
   - Held up head alone Sat alone without support: -----------
   - Pulled to standing position Began to crawl: -------------
   - Walked without assistance Fed self with spoon: ---------
   - Slept through the night: ------------
   - Could dress self, except for tying: ----------

2. Does child seem to be Right-handed/Left-handed?
3. Is the child awkward in using his/her hands?
4. Does he/she?
   - Open doorknobs? Hold and scribble with a crayon?
   - Draw shapes/write letters? Cut with scissors?
5. Does he/she have any difficulty tolerating loud noises/specific sounds?
6. Does he/she fall or lose balance easily?
7. Does he/she:
   - Climb stairs using alternate feet?
   - Push riding toy/pedal & ride tricycle or big wheel?
   - Skip? Hop on one foot?

- Climb on high play equipment?

Speech and Oral Motor History

1. Language(s) spoken in the home: --
2. Did he/she have any difficulty:
   - Nursing or taking a bottle?
   - Transitioning to baby food? Eating any solid foods?
   - Drinking from a cup? Drinking with a straw?
   - With reflux?
   - Chewing, swallowing, or clearing food from mouth?
   - Tolerating a variety of food textures and tastes?
3. Does he/she:
   - Drool? Suck thumb, fingers, or pacifier?
   - Chew on his/her fingers, toys, or blanket? Blow bubbles from a wand?
   - Snore?
   - Appear to breathe mostly through the nose/mouth?
4. Please list the approximate age at which your child began to:
   - coo? Make babbling sounds (for example, "gaga")?
   - Use jargon (speech that is unintelligible however, has inflectional pattern similar to adult speech)?
   - Say his/her first word?
5. What was it?
   - Use rising inflection to ask questions (cookie?)
   - Use 2-3 single words spontaneously besides "mama - dada" (not imitation)?
   - Use 2-word phrases to communicate (Me go, Mama eat?)?
   - Have approximately a 50 word vocabulary?
   - Use sentences?
6. How does your child express his/her ideas? Describe:
7. Did speech learning ever seem to stop for a period? If so, did it correspond to any specific event (ear infections, stress, illness)?
8. Has the child ever spoken better than he/she does now?
9. Has there been a change in the child's speech in the last six months? If so, describe:
10. Can you understand everything the child says? Yes/No
11. Can others understand everything the child says? Yes/No

12. Please explain whether your child seem to have any trouble:
    - Understanding and following directions? Yes/No
    - Understanding story sequences? Yes/No
13. Does your child stutter: get stuck on words, repeat words, or restart sentences? Yes/No
14. Is your child's voice: hoarse? too soft/loud? too nasal? high or low-pitched?
15. Does the child seem to be aware of a speech difficulty? If so, describe:
16. Has the child had a speech examination prior to this time? When, where and with whom?
17. Has he/she ever received speech therapy? When, where, and with whom?
18. Does he/she receive speech therapy at this time? Where and with whom?
19. Are there any instances of hearing, speech-language, or learning disabilities in the family (siblings, parents, grandparents)? Please describe:
20. Would you enclose any previous evaluation and progress reports, please?

HEALTH HISTORY

Please describe the most recent exams (pediatrician, allergist, ENT, neurologist)

21. Child's Present Weight: ----------------------- Child’s Present Height: ------------------------
22. When/where has his/her hearing been screened? --------------------- Pass/Fail: --------------
23. Any concerns?
24. When/where has his/her vision been screened? ----------------------- Pass/Fail: -------------
25. Any concerns?
26. Would you enclose the test results, please?
27. Please indicate the illnesses, injuries, and any surgeries the child has had, the child's age and severity of the illness.

Illness/ Surgeries	Age	Mild, Average, Severe	Hospitalisation	Date(s_
Ear infection				
High fevers				
Tonsillitis				
Bronchitis				
Allergies				
Seizures (convulsions)				
Chicken pox				
Injuries/accidents				
Tonsillectomy, Adenoidectomy				
Myringotomy/ Tubes Inserted				
Other (please describe)				

28. Were there noticeable changes in the child's speech immediately following any illness? If so, please describe:

Personal and Family History

1. Other children in the family:

Name(s)	Age/Grade	Any Known Problems

2. Does your child's play involve:
   - independent play (parallel play)?
   - pretend play? (imagination)
   - cooperative play? (games, shared play)
3. How does your child get along with other children in the family?
4. How does your child get along with friends/playmates?
5. What are his/her favourite activities, toys, characters, etc?
6. What type(s) of discipline work(s) best for this child?
7. How long can he/she attend to TV or listen to a story/ occupy him (her) self with toys?
8. Has he/she been seen by a psychologist/social worker/psychiatrist for behaviour management?
9. Would you enclose any reports or relevant material, please?

School History

1. What school does he/she currently attend? ---

   Grade: ------------------------------------

Address: --

Teacher: ---

2. At what age did the child start school? Where?
3. What are the child's usual grades?
4. Have teachers noted any areas of difficulty? Please describe:
5. How does he/she get along with others at school?
6. Does he/she receive any supportive services (tutoring, occupational therapy, counselling, other)? Please describe:
7. If there is additional information which you feel will help us to understand your child and his problem better, please describe:

I give my permission for these records on to be sent to the above listed professionals.

Parent Name:---

Signature: ---

Dated:---

Appendix C: The T-Test Results for Group Study

C1: Phonological Processes in SW Samples for DS Compared to TD Group

T-test results for percentages of occurrence of phonological processes in SW samples for TD and DS groups

Accuracy Measures	Groups	Mean	*SD*	*t*-value	*p*-value	*SE*	*df*	Mean Difference	95% CI of Difference	
									Lower Bound	Upper Bound
Gliding	TD	0.30%	0.97	2.54	0.016	1.75	35	4.46	0.90	8.02
	DS	3.94%	8.62							
Deaffrication	TD	0.30%	1.12	6.04	0.001	3.84	35	23.23	15.43	31.04
	DS	5.76%	9.92							
CR	TD	2.35%	4.85	6.04	0.001	3.84	35	23.23	15.43	31.04
	DS	25.59%	16.40							
Fronting	TD	3.05%	5.96	5.69	0.003	2.72	35	15.53	10.00	21.07
	DS	18.59%	10.35							
WSD	TD	0.35%	0.81	2.46	0.019	0.57	35	1.41	0.25	2.57
	DS	1.76%	2.41							
Stopping	TD	0.90%	3.79	3.50	0.002	1.82	35	6.39	2.68	10.10
	DS	7.29%	7.06							
Voicing	TD	0.05%	0.22	5.34	0.001	1.69	35	9.06	5.62	12.51
	DS	9.12%	7.60							
Assimilation	TD	0.70%	0.73	4.39	0.001	0.92	35	4.06	2.18	5.94
	DS	4.76%	4.07							
ICD	TD	0.60%	1.27	5.01	0.001	1.71	35	8.56	5.09	12.04
	DS	2.29%	3.21							
MCD	TD	0.25%	0.63	5.07	0.001	1.16	35	5.92	3.55	8.29
	DS	6.18%	5.18							
FCD	TD	0.15%	0.48	2.92	0.006	1.17	35	3.44	1.05	5.83
	DS	3.12%	5.45							
Backing	TD	0.80%	2.89	2.44	0.020	1.16	35	2.84	0.48	5.20
	DS	3.65%	4.15							
Other	TD	0.65%	2.90	0.74	0.45	1.01	35	0.76	1.30	2.82
	DS	1.41%	3.28							

Note: TD-Typically developing children. DS-Children with Down syndrome. CR-Cluster reduction. WSD-Weak syllable deletion. ICD-Initial consonant deletion. MCD-Medial consonant deletion. FCD-Final consonant deletion. CI-Confidence limits around the mean.

C2. Phonological Processes in CS Samples for DS compared to TD Group

T-test results for percentages of occurrence of phonological processes in CS samples for TD and DS groups

Phonological Processes	Groups	Mean	*SD*	*t*-value	*p*-value	*SE*	*df*	Mean Difference	95% CI of Difference	
									Lower Bound	Upper Bound
Gliding	TD	0.95%	1.66	4.87	0.001	0.95	35	4.63	2.70	6.57
	DS	5.59%	3.85							
Deaffrication	TD	0.50%	1.27	3.12	0.004	2.19	35	6.85	2.39	11.30
	DS	7.35%	9.74							
CR	TD	4.15%	6.02	7.51	0.001	4.23	35	31.85	23.24	40.45
	DS	36%	17.82							
Fronting	TD	3.95%	7.44	6.96	0.001	2.55	35	17.75	12.57	22.93
	DS	21.71%	8.06							
WSD	TD	0.50%	1.05	3.02	0.005	0.92	35	2.79	0.91	4.67
	DS	3.29%	3.98							
Stopping	TD	1.15%	4.48	5.62	0.001	2.51	35	14.14	9.03	19.25
	DS	15.29%	10.16							
Voicing	TD	0.05%	0.22	6.22	0.001	1.63	35	10.15	6.83	13.46
	DS	11%	7.10							
Assimilation	TD	0.85%	1.18	4.94	0.001	1.80	35	8.91	5.25	12.57
	DS	9.76%	7.98							
ICD	TD	1.50%	1.96	3.27	0.004	1.36	35	4.26	1.49	7.03
	DS	5.76%	5.72							
MCD	TD	0.35%	0.67	5.78	0.001	1.44	35	8.35	5.42	11.28
	DS	8.71%	6.43							
FCD	TD	0.95%	1.76	3.94	0.001	1.91	35	7.54	3.66	11.42
	DS	6.71%	7.20							
Backing	TD	0.95%	4.01	4.03	0.001	1.91	35	7.69	3.82	11.57
	DS	8.65%	7.35							
Other Processes	TD	0.90%	4.02	0.98	0.33	1.36	35	1.33	1.42	4.09
	DS	2.24%	4.23							

Note: TD-Typically developing children. DS-Children with Down syndrome. CR-Cluster reduction. WSD-Weak syllable deletion. ICD-Initial consonant deletion. MCD-Medial consonant deletion. FCD-Final consonant deletion. CI-confidence limits around the mean.

C3. Phonological Processes in SW compared to CS Samples for TD Group

T-test results for percentages of occurrence of phonological processes in SW sample compared to CS sample for TD groups

Processes	**Groups**	**Mean**	***SD***	***t*-value**	***p*-value**	***SD***	***SE***	***df***	**Mean Difference**	**95% CI of Difference**	
										Lower Bound	Upper Bound
Gliding	SW	0.30%	0.97	2.94	0.008	0.98	0.22	19	0.65	1.11	1.88
	CS	0.95%	1.66								
Deaffrication	SW	0.30%	1.12	1.28	0.21	0.69	0.15	19	0.20	0.15	0.52
	CS	0.50%	1.27								
CR	SW	2.35%	4.85	4.21	0.001	1.90	0.42	19	1.80	0.42	2.69
	CS	4.15%	6.02								
Fronting	SW	3.05%	5.96	2.07	0.052	1.94	0.43	19	0.90	0.01	1.81
	CS	3.95%	7.44								
WSD	SW	0.35%	0.18	1.37	0.18	0.48	0.10	19	0.15	0.07	0.37
	CS	0.50%	1.05								
Stopping	SW	0.90%	3.79	1.42	0.17	0.78	0.17	19	0.25	0.11	0.61
	CS	1.15%	4.48								
Voicing	SW	0.55%	0.78	0.11	0.121	0.22	0.10	19	0.05	0.00	1.02
	CS	0.85%	1.59								
Assimilation	SW	0.70%	0.73	0.76	0.45	0.87	0.19	19	0.15	0.26	0.56
	CS	0.85%	1.18								
ICD	SW	1.00%	1.21	1.98	0.06	1.35	0.30	19	0.60	0.03	1.23
	CS	1.50%	1.96								
MCD	SW	0.25%	0.63	1.00	0.33	0.44	0.10	19	0.10	0.10	0.30
	CS	0.35%	0.67								
FCD	SW	0.85%	1.46	2.27	0.035	1.57	0.35	19	0.80	0.06	1.53
	CS	0.95%	1.76								
Backing	SW	0.80%	2.89	0.56	0.57	1.18	0.26	19	0.15	0.40	0.70
	CS	1.10%	4.03								
Other Processes	SW	0.65%	2.90	1.00	0.33	1.11	0.25	19	0.25	0.27	0.77
	CS	0.90%	4.02								

Note: TD-Typically developing children. DS-Children with Down syndrome. CR-Cluster reduction. WSD-Weak syllable deletion. ICD-Initial consonant deletion. MCD-Medial consonant deletion. FCD-Final consonant deletion. CI-Confidence limits around the mean.

C4. Phonological Processes in SW Compared to CS Samples for DS Group

T-test results for percentages of occurrence of phonological processes in SW samples compared to CS samples for DS group

Processes	Groups	Mean	SD	t-value	P-value	SD	SE	*df*	Mean Difference	95% CI of Difference Lower Bound	95% CI of Difference Upper Bound
Gliding	SW	4.76%	7.79	0.81	0.42	8.34	0.02	16	1.64	2.64	5.93
	CS	5.59%	3.85								
Deaffrication	SW	5.76%	9.92	0.35	0.72	10.21	2.47	16	0.88	4.37	6.13
	CS	7.35%	9.74								
CR	SW	25.59%	16.40	1.80	0.09	23.84	5.78	16	10.41	1.84	22.67
	CS	36.00%	17.82								
Fronting	SW	18.59%	10.35	1.44	0.16	8.92	2.16	16	3.11	1.47	7.70
	CS	21.71%	8.06								
WSD	SW	1.76%	2.41	2.21	0.04	2.85	0.69	16	1.52	0.06	2.29
	CS	3.29%	3.98								
Stopping	SW	7.29%	7.06	3.44	0.003	9.58	2.32	16	8.00	3.07	12.92
	CS	15.29%	10.16								
Voicing	SW	9.12%	7.60	1.05	0.30	7.36	1.78	16	1.88	1.90	5.66
	CS	11.00%	7.10								
Assimilation	SW	4.76%	4.07	3.06	0.007	6.71	1.62	16	5.00	1.54	8.45
	CS	9.76%	7.98								
ICD	SW	3.82%	3.26	2.86	0.011	4.98	1.21	16	3.47	0.90	6.03
	CS	5.76%	5.72								
MCD	SW	6.18%	5.18	3.93	0.001	2.64	0.64	16	2.52	1.16	3.89
	CS	8.71%	6.43								
FCD	SW	4.29%	5.03	2.55	0.021	5.79	1.40	16	3.58	0.60	6.57
	CS	6.71%	7.20								
Backing	SW	3.65%	4.15	2.76	0.014	7.45	1.80	16	5.00	1.17	8.83
	CS	8.65%	7.35								
Other Processes	SW	1.41%	3.28		0.044	1.55	0.37	16	0.82	0.02	1.62
	D	2.24%	4.23								

Note: TD-Typically developing children. DS-Children with Down syndrome. CI-confidence limits around the mean. CR-cluster reduction, WSD-weak syllable deletion, ICD-initial consonant deletion, MCD-medial consonant deletion and FCD-final consonant deletion.

Appendix D: Cycles-Based Intervention Programme for Case Study

D1. Target Processes and Sounds

Table 9.2 The target words for cycle1 and cycle2 and generalisation items

Target Patterns	Target Sounds	Treatment Items	Generalisation Items
Cluster Reduction	/sp/	spider, speaking, spoon, spade	sponge, spinning, spill
	/st/	star, stairs, stone, storm	stool, starfish, steam
	/sn/	snow, sniffing, snipping, snail	snoring, sneezing, snorkel
Fronting	Initial /k/and /g/	key, go, cake, got, kangaroo, coast, gave	coffee, goat, cow, goose, king, gate
	Medial /k/ and /g/	Helicopter, fingers, stickers, pocket, hugging	rocket, sugar baking, digging cycling, dragon

D.2 Intervention Schedule – Cycle I and Cycle II

Table 9.3 The treatment schedule for the cycles-based intervention

Target Pattern	Weeks	Sessions	Target Sound	Time
Cluster Reduction	Week1	Session1	/sp-/	1 hour
		Session2		1 hour
Fronting	Week2	Session1	Initial &Medial /k/&/g/	1 hour
		Session2		1 hour
Cluster Reduction	Week3	Session1	/st-/	1 hour
		Session2		1 hour
Fronting	Week4	Session1	Initial &Medial /k/&/g/	1 hour
		Session2		1 hour
Cluster Reduction	Week5	Session1	/sn-/	1 hour
		Session2		1 hour
Fronting	Week6	Session1	Initial &Medial /k/&/g/	1 hour
		Session2		1 hour

D3. A Sample Intervention Activity Sheet

Activity Sheet - Week3

Activity 1 - Listening

The child will put on an amplifying headphone set and listen to the target words for three times. The same activity will be repeated by the end of the session.

Activity 2 - Listening

To get the child aware of the 'same vs. different' concept, the child will be shown two same yellow circles for 'same' concept, while a blue square and a green circle for 'different' concept. On the same basis, to get the child aware of the target pattern word and realise it as different from its nonsense counterpart word, the child will listen to both words and tell whether they are different or same. For example, star vs. tar. The activity steps are as follows:

1. Ask the child to listen to five minimal pair words: star/ star, stick/tick, stone/tone, ticker/ticker, and stop/top.
2. Ask the child each time they listen to these pairs to tell whether they sound the same or different.
3. If the child could recognise the correct target word, then she stick it on board.

Activity 3 – Production - Picture naming

The activity steps are as follows:

1. To get the child's attention, the researcher points to each picture separately.
2. Ask the child to name each picture by asking her "what is this?"

Activity 4 – Production - Experiential play games:

This activity included play four experiential games, these are as follows:

A. **Throwing the dice:**
    1. The picture word cards with the spots same as those on the dice will be distributed on the table.
    2. Ask the child to throw the dice.
    3. Ask the child to pick the matching card (card carrying the same number of spots).
    4. Ask the child to turn the card up and name the picture picked.

B. Frog hop: A simple game to get the child repeat naming each picture card twice.

1. 10 laminated lily pads, with the target picture words stuck at the back of each, are distributed on the floor.
2. Ask the child to grab the frog toy and pretend it hops around to jump over the pads.
3. Ask the child to name the picture at the back of each pad the frog reaches.

C. Say and Stick:

1. Put the word production pictures on table (two different pictures at a time).
2. Point to a specific picture on the board.
3. Ask the child to select the correct picture.
4. If the child chooses the correct picture, ask her to name it and stick on the board.

D. Power Point Picture Naming: In the end of each intervention session, the target, baseline and generalisation items are elicited by encouraging the child to name the representative pictures of those items. Thus, the child will be asked a simple question 'What is this?' For the target items, child will be provided with modelling and prompting, but for the baseline and generalisation items, the child will be required to produce these items on her own without prompting or modelling.

D4. A Copy of Home Programme Sheet

Tick the box if you had done an activity and add any notes (how the child did, whether she was engaged, how well she responded)

Date 28th Oct. – 3rd Nov. 2016	**Activity 1: Listening to the target words**	**Activity 2: Naming Picture cards**	**Notes**
Friday 28th			
Saturday 29th			
Sunday 30th			
Monday 31st			
Tuesday 1st			
Wednesday 2nd			
Thursday 3rd			
Friday 4th			