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Speech and language therapy

A retrospective longitudinal analysis of phonetic and phonological cleft palate speech characteristics

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Declaration of Authenticity and Author's Rights

This thesis is the result of the author's original research. It has been composed by the author and has not been previously submitted for examination which has led to the award of a degree.

Signed

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Contents

List of Figures

List of Tables

Abstract

Longitudinal studies of cleft palate speech (CPS) are rare in number. Most studies focus on phonetic characteristics of speakers with repaired cleft palate. Only few include phonological analysis of CPS. This dissertation was a retrospective, longitudinal analysis of the phonetic and phonological characteristics of CPS. This thesis aimed at describing the nature of phonetic and phonological characteristics of speech outcomes in children with repaired cleft palate with or without cleft lip (CP±L). In contrast to previous research, the current study also investigated which type of articulation characteristic is the most dominant in CPS. In addition, changes in speech performance from age 5 to 15, as well as potential covariates which could explain severity of speech impairment were analysed. Video-recordings of Cleft Audit Protocol for Speech – Augmented (CAPS-A) sessions of children with repaired bilateral cleft lip and palate (BCLP) (n=9), unilateral cleft lip and palate (UCLP) (n=19) and cleft palate (CP) (n=14) at the ages of 5, 10 and 15 recorded at the Dental Hospital in Glasgow were used as materials for narrow transcription. Information on Percentage of Consonants Correct (PCC) and prevalence of phonological processes was retrieved by the software Computerised Profiling (CPro) (Long et al., 2003). Results of this study showed that children with repaired CP±L used more phonetic than phonological characteristics of CPS at all ages, and they improved in their speech with maturation. Furthermore, variance analysis indicated that a combination of factors rather than single main factors explain severity in speech impairment. Findings of this study could inform age-appropriate analysis of CPS in research and in everyday practice of speech and language therapy. In addition, results of this study have shown that it would be advisable to include phonological assessment of CP±L children at an early age in regular audit sessions.

1 Introduction

Cleft lip and/or palate (CL±P) children are born with a cleft in their upper lip and/or their palate. In the UK, 1.2 in 1000 newborns are born with this facial birth defect (Working Group IPDTOC, 2011). CL±P can have an impact on feeding, hearing, dentition and speech.

Orofacial clefts are due to disrupted morphogenesis of lip and/or palate in the early stages of embryological development. Between the fourth and eighth week of embryological development upper lip and jaw evolve. The roof of the oral cavity develops later, between the sixth and eighth week of embryological development. Since timing and developmental process of human lips are different from those of the palate, clefts in the lip can occur independently from cleft palates (CPs) (Burdi, 2006). This is why there are orofacial clefts that only occur in the lip, those that only affect the palate and those that affect both structures. Accordingly, the current dissertation differentiated between the following cleft types based on the classification system of Albery and Grunwell (1993): cleft lip (unilateral, bilateral), cleft lip and palate (unilateral, bilateral) and cleft palate only (hard and soft, soft only).

Prevalence of CL±P differs with cleft type, population group, and gender. On average, 67 % of CL±P have a cleft that affects both lip and palate, the rest only shows clefts in the lip. Depending on geographical area, this proportion varies considerably (Working Group IPDTOC, 2011). About one third (30 – 35 %) of all non-syndromic orofacial clefts are unilateral cleft lip and palates (UCLPs). The rarest and most severe cleft type is bilateral cleft lip and palate (BCLP). One in ten children with non-syndromic clefts is born with this cleft which affects two sides of the upper lip, the primary and potentially also the secondary palate. Asian and Amerindian populations have the highest prevalence of 1:500 CL±P in live births. Caucasians show an incident rate of about 1:1000, whereas African people have the lowest prevalence of 1:2500 CL±P in live births. Regarding sex differentiation in the prevalence of CL±P there are about twice as many males than females reported to have clefts affecting the lips, whilst the number of females with CP is twice as high as that for males (Kohli & Kohli, 2012).

The majority of CL±P does not occur as part of a syndrome (Working Group IPDTOC, 2011). These non-syndromic CL±P have a multifactorial aetiology involving genetic predisposition and environmental factors (Dixon, Marazita & Murray, 2011). Genes that have been found to be associated with the formation of maxillary region, lip and palate in developmental biology have been the starting point for segregation analysis (Schutte

& Murray, 1999). The most recent extensive review of candidate genes for CL±P can be found in Kohli and Kohli (2012). Environmental factors, such as smoking and alcohol abuse during pregnancy or the intake of vasoactive and anticonvulsant medication during pregnancy, only contributed to the likelihood of occurrences of orofacial clefting, they could not be seen as the sole cause for the condition (Puho, Szunyogh, Metneki & Czeizel, 2007; Little, Cardy, Arslan, Gilmour & Mossey, 2004; Lorente et al., 2000).
Comparing phonetic deviations of CPS to non-cleft speech has identified a number of typical features and compensatory strategies associated with CL±P speakers (Persson, Elander, Lohmander-Agerskov & Soederpalm, 2002; Karnell & Demark, 1986; Raud Westberg, 2013). To what extent different types and timing of intervention strategies showed an impact on speech outcomes in CL±P speakers has also been investigated (Dorf & Curtin, 1982; Willadsen, 2012). Often these studies focused on one particular patient characteristic without being able to control for a combination of factors (Kirschner et al., 2000; Pradel et al., 2009). Starting with Hodson, Chin, Redmond and Simpson (1983) CPS research has also integrated phonological analysis. Differentiating between phonetic and phonological speech processes is secured by detailed perceptual analysis and narrow transcription of CPS which allows clinicians to classify speech deviations. Broad or phonemic transcription which does not distinguish between phonetic and phonological speech processes is not appropriate for clinical or research purposes because it oversimplifies speech patterns (Ball, Rahilly & Tench, 1996; Howard & Heselwood, 2002). There has been only few longitudinal research on the phonetic and phonological characteristics of CPS and the effectiveness of treatment protocols so far. This dissertation combined phonetic and phonological methodology to analyse CPS of CL±P children from age 5 to 15 recorded at the Dental Hospital in Glasgow. Different patient characteristics were used to add information on speech outcomes of CL±P speakers at different ages.

Outline of the dissertation Chapter 2 of this dissertation explores the literature available about cleft palate services in Scotland, the impact of orofacial clefting on speech outcomes, as well as the phonological and phonetic characteristics of CPS. This is followed by the research questions derived for this dissertation. Chapter 3 provides an overview of the methodology used including study design, participants, materials, and data and statistical analysis, as well as ethical and other permissions given to conduct the dissertation. The results are presented in chapter 4, and these are discussed in chapter 5. The dissertation concludes with implications for future research drawn from the study, limits to the study and perspectives for further research, as well as a final summary.

2 Literature review

The literature review is organised in sections. Section 2.1 outlines the cleft care management in Scotland. Section 2.2 explores the structures that are affected by orofacial clefts and how they are relevant for speech production in CL±P children. Section 2.3 provides a discussion of past studies that have looked at the phonetic and phonological characteristic of CPS. This leads to the research objectives which are provided in section 2.4.

2.1 Cleft care management in Scotland

In the 1990s there were 59 UK cleft care teams, 7 of which were operating in Scotland. As a result of a survey undertaken on behalf of the Clinical Standards Advisory Group (CSAG), it was recommended that Cleft Lip and Palate Services reduce to fewer specialised national cleft centres (Sandy et al., 1998). In the same year, the Scottish Needs Assessment Programme into Cleft Lip and Palate came to the same conclusion and implemented the establishment of two surgical centres in Scotland. Today, the Scottish Cleft Network consists of two sites, the Royal Hospital for Sick Children in Glasgow and the Royal Hospital for Sick Children in Edinburgh. Paediatric cleft surgery is also performed at the Aberdeen Royal Children's Hospital ('Review of Cleft Lip and Palate Surgical Service in Scotland', 2006).

Health care of children born with craniofacial birth defects in Scotland is managed by the Clinical Network for Cleft Service in Scotland (CLEFTSiS) which was commissioned in 2000 and accredited by the National Health Service (NHS) Quality Improvement Scotland one year later. CLEFTSiS provides standards and protocols for cleft management in Scotland. Among other responsibilities, it implements the standardisation of care pathways and audit protocols ('National Managed Clinical Network for Cleft Lip, Cleft Palate or Cleft Lip & Palate', 2011).

2.1.1 Basic pathway of cleft care in Scotland

The basic pathway of cleft care management in Scotland is regulated by the CLEFTSiS Clinical Network Protocols for all specialists responsible for cleft care. These involve ear, nose and throat specialists (ENTs), audiologists, geneticists, clinical nurses, orthodontists, speech and language therapists (SLTs) and cleft surgeons ('National Managed Clinical Network for Cleft Lip, Cleft Palate or Cleft Lip & Palate', 2011). When a baby with a CL±P is born in the West of Scotland he/she is automatically referred to the

multidisciplinary cleft team in Glasgow at the Dental Hospital. The cleft nurses inform the cleft SLTs about a CL±P baby within a few days after birth.
The first steps of the speech and language therapy (ST) treatment protocol mainly involve informing the parents about expected speech results after surgical procedures and how to encourage their child to speak. Around three months after birth, CL±P children normally receive lip surgery, should they need it. At six months of age, CL±P infants are reviewed at the preventive clinic in Glasgow. If speech issues are identified by the cleft SLT, appropriate intervention strategies are arranged. Between months six and twelve primary palate surgery (PPS) is performed. Follow up ST audits are scheduled at age two, three and five. If there are no speech concerns, the CL±P child is released from ST treatment but still seen for audits. Additional secondary speech surgery (SSS) is performed when deemed appropriate (NHS, 2013).
Between the age of nine and twelve, children with cleft in the alveolus might undergo alveolar bone graft (ABG) ('CLEFTSiS National Managed Clinical Network Audit Timetable 2013/2014', 2013). It is recommended to perform this surgery before canine eruption (usually between 11 and 12 years) (Lilja, 2009). ABG is an orthodontic surgery that repairs bony defects in the alveolar ridge to allow permanent lateral incisor and canine teeth to grow (Rivkin, Keith, Crawford & Hathorn, 2000). Further orthodontic treatment for those children who require it involves monitoring jaw growth and occlusion. Another possible surgical intervention might involve palatal fistulae which impair the separation of oral and nasal cavity. Depending on the size and place of the fistula in the palate they have been reported to affect resonance in speech (Karling, Larson & Henningsson, 1993). If needed, blocks of ST are recommended by the cleft SLT, but not necessarily conducted at the Glasgow Dental Hospital. CL±P children with need for additional ST are often referred to their local community services if they do not live in or in the vicinity of Glasgow (NHS, 2013).
Further factors that might influence speech outcomes of CL±P children are hearing issues and additional learning needs. CL±P are particularly prone to hearing issues as a result of recurrent otitis media (Mody, Schwartz, Gravel & Ruben, 1999) (see section 2.2). In addition, speakers with CL±P who have been diagnosed with learning needs were found to have higher rates of speech impairment than CL±P speakers with normal learning which is why CPS research needs to control for this factor (Strauss & Broder, 1993).
As illustrated above, the cleft care pathway can be highly individual depending on the specific needs of each CL±P child. However, there are similarities between children who share the same cleft type. Children with a CP, for instance, do not need to undergo

lip surgery nor ABG. The following possible factors have been identified to potentially influence speech outcomes in CL±P introduced above: type of surgical intervention (secondary speech surgery (SSS) (Karnell & Demark, 1986), alveolar bone graft (ABG) (Lilja, 2009)), timing of surgical intervention (one- or two stage repair (Chapman et al., 2008; Dorf & Curtin, 1982)), active speech and language therapy (ST) (Bessell et al., 2013), hearing issues (Mody et al., 1999), dentition (Sell, Harding & Grunwell, 1994; Fairbanks & Lintner, 1951), learning needs (Strauss & Broder, 1993), prevalence of palatal fistula (Karling et al., 1993).

2.1.2 National speech audit protocol

Children with repaired CL±P are subject to regular auditing at the age of 5, 10 and 15 with help of the national protocol Cleft Audit Protocol for Speech – Augmented (CAPS-A) which was introduced in 2006 (John et al., 2006). The original Cleft Audit Protocol for Speech (CAPS) was produced in 1997 and set a minimum standard for auditing children with repaired CL±P (Harding, Harland & Razzell, 1997). Some of the video recordings of 5-year old children used in the current study date back to that year. Since both protocols are based on the Great Ormond Street Speech Assessment (GOS.SP.ASS.) sentences (Sell, Harding & Grunwell, 1999) there are no differences between the analysed materials used for the current study from different years of recording. The audit protocol has been developed in addition to GOS.SP.ASS. to provide a less detailed tool suitable for audit studies (John et al., 2006). Cleft Audit Protocol for Speech – Augmented (CAPS-A) is a standardised, valid and reliable audit protocol of CPS of native English speakers. The audit protocol is a tool which gives a structured overview of speech deviations and rates them in relation to their severity to inform further clinical decision making (John et al., 2006).

Audit sessions take approximately 10 minutes. Children are seated in front of a video camera, their face and upper body are visible. The SLT sits next to the camera and is not visible on screen. The session starts off with spontaneous speech elicited through open "Wh-questions" by the SLT. It continues with counting the numbers 1 to 20, and ends with imitating the GOS.SP.ASS. sentences (Sell et al., 1999). Small children are assisted through visual support via standardised pictures that capture the action described in the sentences. Each of the GOS.SP.ASS. sentences focuses on one English consonant by means of high frequency of that consonant in the sentence, e. g. the sentence "Mary came home early." targets /m/ with three instances of that phoneme (see appendix I). As illustrated with this example sentence, the target consonant can be found in word-initial and word-final position. The sentences are not constructed to target word-medial position in particular. Two of the GOS.SP.ASS. sentences only consist of low pressure consonants, such as approximants, and vowels. With these sentences the SLT focuses on resonance of the patient's speech (John et al., 2006).

The CAPS-A tool is split into eight categories: intelligibility, voice, resonance (hyper- and hyponasality), nasal airflow (nasal emission and turbulence), grimace, consonant production, cleft type characteristics (CTC) summary and perceived need. Intelligibility is the most controversial of these categories since it allows for high subjectivity. Sell et al. (1994) advise against including intelligibility in the assessment because of diverse listeners' experience in disordered speech and language, and the fact that intelligibility is affected by various factors including hearing impairments and developmental disturbances. Although intelligibility is included in the official CAPS-A form it is reported to be disregarded in current clinical practice (Crampin, personal conversation, April 2014). It is therefore not considered in the evaluation of children's speech in the current study.

In the CAPS-A tool the severity of speech disorders is assessed by means of a traffic light system first devised by Harland (1996). The CTCs are quantified according to the number of consonants affected. Depending on the particular characteristic, the traffic light system shows how severe cleft speech errors are and whether or not further intervention is necessary. The colour green indicates normal speech. Yellow represents that management of speech errors lies within the domain of ST, whereas red indicates a structural problem that can possibly require surgical procedures supported by ST (see appendix III). High severity ratings in hypernasality, nasal emission, nasal turbulence, weak and/or nasalized consonants, backed oral consonants, non-oral and passive CTCs can possibly indicate structural investigations (John et al., 2006).

2.2 Structural and morphological deviations

CL±P children differ from non-cleft children with regard to their facial morphology and their structure of oral and nasal cavity. These morphological and structural differences affect speech utterances and intelligibility of CL±P children. The following orofacial structures can be affected by CL±P: soft and hard palate, upper lip, dentition and occlusion, as well as middle ear.

2.2.1 Soft and hard palate

The palate forms the roof of the oral cavity and the base of the nasal cavity. It consists of hard and soft palate. The hard palate is comprised of bone structures, while the soft palate is a movable flap that consists of velum and uvula. Several muscles in the oral cavity, tongue and pharynx are connected to the soft palate. Movement of these structures, especially of tongue and pharyngeal wall, influence velar position (Raphael, Borden & Harris, 2006). Most of the variance in velum movement (83 %) can be accounted for by the activity of the levator palatini muscle which elevates the velum (Serrurier & Badin, 2008). The tensor palatini muscle lowers and stiffens the velum. It also opens the eustachian tube and is thus responsible for ear ventilation (Aumüller, Aust, Doll & Engele, 2010; Raphael et al., 2006).

In speech production soft and hard palate function as barriers between oral and nasal cavity. For oral sounds the velum is raised through innervation of the levator palatini muscle. The velum presses softly against the posterior and lateral pharyngeal walls which contract to narrow the opening between pharynx and nasal cavity (velopharyngeal port) resulting in velopharyngeal closure (Raphael et al., 2006; Thorp, Virnik & Stepp, 2013). Lowering the velum allows for the production of nasal speech sounds through coupling of nasal and oral resonating cavities. If the velum does not reach full velopharyngeal closure during the production of an oral sound, the speech sound is accompanied by nasal resonance. Acoustic coupling of the oral and nasal resonating cavities, the asymmetric shape of the nasal cavity and additional resonating in the sinuses change the acoustic properties of speech sounds (Pruthi, Espy-Wilson & Story, 2007).
Even typical speakers showed a certain amount of nasal coupling in their speech, depending on vowel quality or their dialect (Lewis, Watterson & Quint, 2000; Dalston, Neiman & Gonzalez-Landa, 1993). Nasalance scores for typical speakers were higher in sentences that contain high vowels opposed to sentences with low vowels only, this was also true for sustained vowels (Thorp et al., 2013). CL±P speakers seemed to be particular prone to produce high vowels with increased nasal resonance. In an electropalatography (EPG) study Gibbon, Smeaton-Ewins and Crampin (2005) found that CL±P speakers produce high vowels with complete coronal constriction which leads to an increase in nasal airflow. These observations should be taken into consideration in the design of assessment material for speakers with repaired CL±P (Lewis et al., 2000; Kuehn & Moon, 1998).
The current study, however, focused on consonant production in CL±P speakers. Here, velar height can be essential for the contrast between voiceless and voiced obstruents since

pharyngeal cavity enlargement is one possible strategy to decrease supraglottal pressure for the production of voiced obstruents (Raphael et al., 2006). Maintaining the right pressure ratio of supra- and subglottal pressure for the production of voiced obstruents entails more effort than for the production of obstruents without phonation (voiceless). Pharyngeal closure force is higher for voiceless than for voiced obstruents. This is why in typical speakers, voiceless sibilants did not show nasalance in nasometer studies, whereas voiced sibilants showed traces of nasalance in sustained state and in connected speech (Kummer, 2007). Voiced consonants were, therefore, particularly vulnerable in CPS (see section 2.3).

2.2.2 Dentition and occlusion

CL±P children face specific issues in dental occlusion and dentition which directly affect articulation. This is why occlusion type, mixed dentition and other issues concerning dentition are treated as potential factors influencing speech outcomes of CL±P children. Malocclusion class II and class III are the two main types of abnormal occlusion in Angle's (1899) classification system. Each type has subtypes which were not taken into consideration in the current study. In class II malocclusion, the lower dental arch is retracted in relation to the upper arch, whereas class III malocclusion includes retracted upper dental arch.

Maxillary retrusion occurs in 23 – 25 % of children with repaired CL±P (Ross, 1987; Vettore & Sousa Campos, 2011). Class III malocclusion in CL±P speakers emerges because of deformity of the palatal shape before surgical treatment and scarring, as well as loss of tissue following primary palate surgery (PPS) (Ross, 1987; Doucet et al., 2014; Moller, 1994). Class II malocclusion is evident in 59 % of CL±P children. Normal occlusion is found in around 18 % of children with orofacial clefts.

According to Vettore and Sousa Campos (2011) these numbers vary with respect to the cleft types pre-foramen incisor cleft (PIC) and trans-foramen incisor cleft (TIC). PIC involves structures that are anterior to the incisive foramen, e. g. dental arch and lips, while TIC describes clefts that impact on structures posterior to the incisive foramen, e. g. hard and soft palate. In both cleft types, class II malocclusion is the most common, class III shows similar prevalence of 17 % in PIC and 22 % in TIC. Normal occlusion, however, is more commonly found in PIC (33 %) than in TIC (8 %) (Vettore & Sousa Campos, 2011).

Regarding the relationship of dentition and phonetic cleft palate speech (CPS) characteristics, alveolar fricatives are most likely to be affected by deviations in dentition and malocclusion since teeth play a central role in the production of these speech sounds (Laver, 1994). Dentalised realisations of alveolar fricatives have been reported for CP speakers (Sell et al., 1994). Labiodental fricatives can be assumed to be affected by class III malocclusion since physiognomy complicates the approximation of upper canines to the lower lip (Laver, 1994). Class II malocclusion with severe overbite can result in labiodental approximation for bilabial sounds (Moller, 1994). Reduced maxillary width, often reported in CP speakers, confined tongue movements and thus was related to deviations in sibilant production (Fairbanks & Lintner, 1951). Besides that, malocclusion and dental deviations did not necessarily cause issues in articulation since in most cases speakers used compensatory mechanisms to cope with these issues (Moller, 1994).

2.2.3 Upper lip

unilateral cleft lip and palate (UCLP) and bilateral cleft lip and palate (BCLP) children showed significant asymmetry in their upper lip compared to controls (Russell, Kiddy & Mercer, 2014; Meyer-Marcotty et al., 2011). Some patients with repaired cleft lips (CLs) face tight or short upper lips. Lip mobility might be reduced due to the circular lip muscle being separated (Moller, 1994). Thus, all speech sounds that involve this articulator might be affected. For English, these are bilabials /p, b, m/ (Moller, 1994), labiovelar approximant /w/ and postalveolar /ʃ/ which requires lip rounding.

2.2.4 Hearing

According to Pearman (2000) the most common hearing related issue in CL±P children is otitis media which can be the result of abnormal palatal muscle function, especially malfunction of the tensor palatini muscle which opens the eustachian tube and enables ear ventilation. When the middle ear is not properly ventilated it can fill with liquid leading to infections. 80 % of CL±P children face at least temporary ear problems in their life. If persistent, otitis media can lead to severe hearing issues (Pearman, 2000).

Speech sounds that are less intense and higher in frequency tended to be perceived less well by children with otitis media, and they coded phonetic features less accurately than children without first year otitis media (Mody et al., 1999). According to Mody et al. (1999) deficits in perception could impact phonological processing abilities. In addition, subtle deficits in speech perception still persisted in later school years. Therefore, CL±P children who show a record of hearing impairment were expected to display deviations in the realisation of speech sounds with high frequencies, such as fricatives, and low intensity, i. e. all non-sonorant sounds. Presumably, these speech deviations could affect phonological processing.

In summary, structural and morphological deviations of CL±P children can impact their speech. There is high variability in both patient history and structural deviations across CL±P children which needs to be reflected in speech analysis. Most previous studies only focused on one or few patient characteristics in investigating CPS (Raud Westberg, 2013; Russell, Kiddy & Mercer, 2014; Sell et al., 1994). Therefore, the interplay and impact of those features has been poorly understood. This study aimed at investigating the impact of several patient characteristics and their interactions on CPS (see section 2.4).

2.3 Cleft palate speech characteristics

CPS has been usually described in terms of consonant characteristics and resonance based on perceptual analysis. Most characteristics typically associated with CPS can be traced back to velopharyngeal insufficiency (VPI) or insufficient force control of velum and pharynx. Due to scarring, the velum of cleft speakers is often not only shorter than that of non-cleft speakers (Greene, 1960) but also less versatile in its movements (Kuehn & Moon, 1998).

2.3.1 Framework of CPS characteristics

There are different frameworks that describe and group CPS characteristics. One of the most influential was introduced by Harding and Grunwell (1998). This framework was based on the differentiation between active and passive cleft speech characteristics. Active processes were defined by Harding and Grunwell (1998) as processes that establish phonemic contrast through alternative strategies for phonologically related targets at risk of being realised because of VPI. In contrast, passive processes did not display alterations in articulation patterns to establish phonemic contrast. For example, /s/ and /n/ share the same place of articulation. In CP speakers /s/ is easily at risk to be simply substituted by the alveolar nasal or to be realised with following nasal emission (passive nasal fricative) due to VPI. Both realisations qualify as passive processes. If /s/ was realised with the pulmonary air stream being actively directed into the nasal cavity, it would be classified as an active nasal fricative according to Harding and Grunwell (1998). Perceptually, active and passive nasal fricatives are very difficult to differentiate, as are

other active and passive contrasts in the framework. This is why the differentiation between active and passive processes was not employed in the current study.
In a recent effort to identify universal parameters to classify CPS characteristics Henningsson et al. (2008) established five broad categories: hypernasality, hyponasality, nasal air emission and/or turbulence, consonant production deviations and voice disorder.
Hypernasality and hyponasality refer to the extent to which nasal and oral resonance area contribute to overall resonance of speech. These resonance characteristics are most readily perceptual on vowels and approximants (Sell et al., 1999). Sell et al. (1994) stated that severe nasality does not only affect these speech sounds but also consonants. They interpreted weak consonant production and the substitution of plosives by homorganic nasals as incidences of hypernasality. In addition, hypernasal resonance deviated voice quality (Trost, 1981).
Nasal air emission occurs when speech sounds, in particular obstruents, are accompanied by air emission through the nose (Trost, 1981). This feature differs from nasal escape in normal speech with respect to phonetic context specificity. Nasal escape of plosives, for instance, occurs when the plosive is followed by a nasal consonant (Laver, 1994). Nasal turbulence is characterised by constriction in the area of the nasopharynx which produces friction when air is released through the nose (Harding & Grunwell, 1998). Occurrence of nasal turbulence suggests a small velopharyngeal gap, whereas a larger velopharyngeal opening is associated with nasal emission and moderate to severe hypernasality (Kummer, Briggs & Lee, 2003). Heavy nasal turbulence is also called nasal snort (McWilliams, Morris & Shelton, 1990).
Numerous studies found a high prevalence of voice disorders in children with repaired CL±P (e. g. Warren, 1986; Hess, 1959; Timmons, Wyatt & Murphy, 2001). Children with inadequate velopharyngeal closure may need to use hard glottal attack in order to increase the sound pressure level which is reduced by nasal damping (Zajac & Milholland, 2014). This causes excessive muscular effort on the larynx which can lead to muscular strain and fatigue in the long run. Thus, the category voice disorder was included in the framework (Henningsson et al., 2008). However, this issue exceeded the scope of the current study.
Henningsson et al. (2008) differentiated between eight phonetic and phonological subcategories of consonant production. The category developmental articulation characteristics subsumes all potential developmental phonological processes in children's speech (Henningsson et al., 2008). Thus, the established classifications by Grunwell (1987) could be used.

The following overview of phonetic characteristics of CL±P speakers reflects the basic framework put forward by Henningsson et al. (2008). The framework is further edited based on a review of various studies on consonant characteristics of CPS.

Phonetic consonant characteristics of CPS

- **Place of articulation**
  - Retraction
    - Palatalisation
      - Alveolar consonants are retracted to palatal place of articulation or they are articulated with additional stridency between coronal blade and hard palate, i. e. they are palatalised. The articulation shifts to the approximate place of the glide /j/ (Trost, 1981).
    - Pharyngealisation
      - Oral consonants are retracted to pharyngeal place of articulation. Pharyngeal fricatives and voiceless pharyngeal stops have been reported as possible compensatory strategies in CPS (Trost, 1981).
    - Glottalisation
      - Glottal stop for oral consonant
      - Glottal fricative for oral consonant
    - Backing
      - Dental or alveolar consonants are retracted to velar or uvular place of articulation. When alveolar consonants are affected it might be possible that velar /k, g/ are also retracted to uvular or pharyngeal place of articulation in order to establish phonemic contrast (Sell et al., 1994).
  - Double articulation
    - Two simultaneous articulations of stops, fricatives or approximants with equal articulatory strength are called double articulation. It can involve front and back lingual articulation or labial and lingual articulation (Ball, 1995). Some double articulation are known as glottal reinforcement where the glottal stop accompanies oral closures (Sell et al., 1994).

- Non-pulmonic speech sounds
  - Non-native consonants with ingressive airflow, such as clicks, voiced implosives or ejectives are produced (IPA, 2005). Sociophonetic research has shown that non-pulmonic sounds also occur in normal speech in English and Scottish speakers (Wright, 2007; McCarthy & Stuart-Smith, 2013; Gordeeva & Scobbie, 2013).

- **Manner of articulation**
  - Nasal fricatives
    - Fricative is realised with nasal emission.
  - Nasal consonant for oral pressure consonants
    - Nasal replaces voiced plosive, often with the same place of articulation. For instance, /b, d, ɡ/ are realised as /m, n, ŋ/ (Sell et al., 1994; Harding & Grunwell, 1998).
  - Weak oral pressure consonants
    - Pressure consonant is realised weak and/or nasalised due to lack of intra-oral pressure. Particularly, voiced obstruents are affected because their production requires cavity enlargement, possibly involving increased velar height (Harding & Grunwell, 1998; Trost, 1981).
  - Devoicing
    - Voiced consonants are devoiced, not as an assimilatory process, but in a voiced context. This characteristic is related to increased velar height for voiced consonants in non-cleft speakers (Harding & Grunwell, 1996) (see section 2.2).
  - Gliding of pressure consonants
    - English sounds /w/ or /j/ replace pressure consonant.
  - Lowering of pressure consonants
    - Plosives are lowered in their place of articulation which can lead to frication (Trost, 1981).

The following list gives an overview of the developmental phonological processes that were investigated in studies that did not only focus on phonetic but also on phonological language skills of children with repaired CL±P. Disordered phonological processes were not included because some of them are at risk to be confused with phonetic characteristics of CPS. Retraction of alveolar consonants to velar consonants, for instance, was interpreted as an instance of disordered processes (Grunwell, 1987), whereas it has been shown that retraction or backing patterns persist in CL±P children because of structural deviations in infancy (Harding & Grunwell, 1996). They were, therefore, treated as phonetic CPS characteristics. The same is true for glottalisation. Glottal substitution of pressure consonants is a typical compensatory strategy due to VPI that is associated with CPS (Sell et al., 1994; Trost, 1981).

Developmental phonological characteristics

- Omissions
  - Final consonant deletion
  - Cluster reduction
  - Liquid deletion
- Substitutions
  - Assimilation
  - Fronting
  - Stopping
  - Context-sensitive voicing
  - Gliding
  - Fricative simplification
  - Cluster simplification
  - Deaffrication

2.3.2 Previous research on CPS characteristics

Comparing outcomes of different studies on CPS is difficult because of their high variability in participants, data collection and documentation, as well as method for measurement and analysis (Lohmander & Olsson, 2004). Several factors have been identified that add to the variability of CPS (see sections 2.1 and 2.2). This section focuses on differences in methodology, such as participants, materials and data analysis, and summarises results of previous studies with focus on phonetic or phonological characteristics of CPS, and how timing and type of intervention strategies possibly influence speech outcomes.

Participants Most studies on CPS investigated speech outcomes in different cleft groups, controlling for syndromic and non-syndromic clefts (Persson, Elander et al., 2002), cleft type and the severity of the cleft (Pulkkinen, Haapanen, Paaso, Laitinen & Ranta, 2001). Differences in speech performance between the three main cleft groups CP, UCLP and BCLP have been found. Comparative analysis of two age-matched BCLP children indicated that while one child was phonologically delayed, the other showed typical phonetic deviations associated with VPI (Lynch, Fox & Brookshire, 1983). There were also differences between subgroups of cleft types found. cleft hard and soft palate (CPh) children at the age of 5 (n=26) showed significantly higher prevalence of hypernasality and retracted articulation than age-matched cleft soft palate (CPs) children (n=25) (Persson, Elander et al., 2002). Additional malformation including those associated with syndromes had significant impact on higher perceptual ratings of hypernasality, velopharyngeal impairment, weak pressure consonants, glottal plosives and retracted oral articulation compared with those for non-syndromic CPs (Persson, Elander et al., 2002; Persson, Lohmander & Elander, 2006). However, syndromes involving facial cleft and additional malformation did not necessarily lead to velopharyngeal impairment in all cases (Persson, Lohmander & Elander, 2006).
The majority of studies that investigated phonological characteristics and all those known to the author which did so with PCC measures (Raud Westberg, 2013; Morris & Ozanne, 2003; Willadsen, 2012; Chapman et al., 2008) analysed speech outcomes of 3-year old, or even younger, children (Estrem & Broen, 1989; Scherer, Williams & Proctor-Williams, 2008). There are only few studies which investigate phonological processes in CL±P children at the age 5 (Chapman, 1993; Hodson et al., 1983) and older ages (Karnell & Demark, 1986).
Since CL±P speakers are not only heterogeneous regarding the extent of their cleft but with respect to their history of intervention approaches many studies focused on comparing participants who have different timing or type of surgery (Kirschner et al., 2000; Raud Westberg, 2013; Karnell & Demark, 1986). These studies did not differentiate participants according to their cleft type (see below). When research on CPS aimed at uncovering differences and similarities between non-cleft and cleft speakers, these studies also included age-matched non-cleft participants (Persson, Elander et al., 2002; Estrem & Broen, 1989; Chapman, 1993).

Materials The type of materials used to analyse CPS is highly variable. Analysis of early speech from CL±P children was usually conducted based on spontaneous speech samples (Estrem & Broen, 1989). Older children and adolescents were mostly tested with standardised articulation tests. These are, however, not standardised internationally. Whereas CAPS-A is the standard assessment to test CL±P children in the UK (e. g. Britton et al., 2014), the Iowa Pressure Articulation Test (IPAT) (Morris, Spriestersbach & Darley, 1961) or the Khan-Lewis Process Analysis (KLPA) (Khan & Lewis, 1986) are used in American studies on CPS (e. g. Karnell & Demark, 1986; Chapman, 1993). The Scandcleft project in Scandinavia has developed its own assessment material for CPS (Lohmander, Willadsen et al., 2009), and studies from research groups associated with this project are based on this material (e. g. Raud Westberg, 2013). In addition, studies with a focus on phonological development in CPS do not necessarily use the same frameworks. This led to differences in the definition of phonological processes (e. g. Morris & Ozanne, 2003; Chapman, 1993).

Data analysis Most previous studies on CPS rated speech variables, such as VPI, nasal airflow or articulation proficiency, based on perceptual judgement on scales from normal to severely disordered (Persson, Elander et al., 2002; Karnell & Demark, 1986). In addition to these scalar ratings, it is common practice to transcribe target consonants or whole utterances narrowly in order to give a detailed description of articulation deviations and to differentiate phonetic from phonological characteristics in CPS (Estrem & Broen, 1989; Morris & Ozanne, 2003). Some studies on CPS also use instrumental measures for assessing nasalance (Pulkkinen et al., 2001) or velopharyngeal closure (Abdel-Aziz, 2013), and others integrate plaster models of the palate into their analysis (Pradel et al., 2009). There are only few CPS studies which use PCC measures (Raud Westberg, 2013; Morris & Ozanne, 2003; Willadsen, 2012; Chapman et al., 2008).
Only half of the CPS studies that analyse speech outcomes with the help of narrow transcription tested reliability of perceptual judgement (Lohmander & Olsson, 2004). Narrow transcripts were reported to have low agreement of under 80 % between equally trained transcribers (Shriberg & Lof, 1991). Willadsen (2012) reported 87.8 % – 95.5 % intertranscriber and 88.1 % – 93.4 % intratranscriber agreement. In order to increase transcription agreement and reliability, narrow consensus transcription (Oller & Ramsdell, 2006), as well as the combination of perceptual assessment with instrumental analysis, such as spectrography (Shriberg & Lof, 1991), have been proposed. In combination these procedures could yield 95 % – 97 % agreement between the narrow transcripts of different transcribers (Amorosa, von Benda, Wagner & Keck, 1985).

Phonetic CPS characteristics Longitudinal analysis of CPS allows the identification of phonetic and phonological patterns in speech outcomes. Speech outcomes from children with isolated CP from the age of 3 to 10 showed that retracted articulation is not present at the ages of 7 and 10 (Persson, Lohmander & Elander, 2006). Compensatory mechanisms, such as glottal stops and pharyngeal fricatives, almost completely disappeared by the age of 10 years in all UCLP, BCLP and CP children (Karnell & Demark, 1986).
Pulkkinen et al. (2001) found that nasal air emission is significantly reduced from the age of 3 to the age of 8 in CP and UCLP children. In addition, hypernasality increased from the ages 3 to 6 and decreased from 6 to 8, while occurrence of weak pressure consonants decreased constantly throughout the age 3 to 8. Regarding CPS characteristics Persson, Lohmander and Elander (2006) found that children with moderate to severe perceived VPI at age 5 show moderate VPI at age 7 and 10. The authors also showed that CL±P children with only mild VPI at age 5 show no perceptual traces of VPI in their speech at age 7 or 10. This meant that speech performance at age 5 predicts speech outcomes at age 10 in CL±P speakers (Persson, Lohmander & Elander, 2006).

These studies on phonetic characteristics of CPS have shown that speech improves with maturation. In contrast, Karnell and Demark (1986) have found in their longitudinal study on CL±P children that some participants with marginal velopharyngeal competence score lower articulation scores after the age of 12 although they have shown improvement at an earlier age. The authors assumed that rapid growth in puberty might be responsible for these lower scores. Furthermore, Van Demark, Hardin and Morris (1988) found that even if velopharyngeal competence is achieved, it does not necessarily persist until later stages in life. Changes in velopharyngeal competence during puberty were not severe but required further treatment in about one third of all cases.

When analysing CPS one should keep in mind that consonant characteristics of CPS are consonant and language-specific. Not all segments are equally affected by VPI. Higher percentages of incorrect articulations of /s/ compared to the number of incorrect realisations of /t/ and /k/ was singled out as the common denominator of all cleft groups (Persson, Lohmander & Elander, 2006). Also, Karnell and Demark (1986) found that articulation deviations were more frequent in fricatives and affricates than in plosives. When comparing studies on CPS with CL±P speakers with different native languages one should be aware that there are language-specific characteristics in CPS that are related to the respective phonetic inventory and phonological system of a language; not all cleft characteristics are universal (Baranian, Wells & Harding-Bell, 2014; Al-Awaji, Howard & Wells, 2014).

Only a few studies used PCC measures to analyse CPS (Morris & Ozanne, 2003; Raud Westberg, 2013; Willadsen, 2012; Chapman et al., 2008). Morris and Ozanne (2003) found a mean PCC of 67.5 % in 3-year old CL±P children with normal expressive language skills, and age-matched children with speech delay (SD) scored significantly lower in that measure (m=41.3 %). Raud Westberg (2013) only gave information on Percentage of Consonants Correct – Adjusted (PCC-A) in 3-year old UCLP children (m=68 %). Willadsen (2012) reported a comparatively high mean PCC of 82 % for 3-year old children with hard palatal repair at 12 months of age. With regard to PCC per speech sound class, both Morris and Ozanne (2003) and Chapman et al. (2008) found PCC to be in descending order for glides, nasals, plosives, fricatives, liquids/affricates and clusters. Glides (89.59 % – 97.9 %) and nasals (82.95 % – 95.6 %) reached the highest PCC scores in these studies in the groups with early hard palate repair and normal expressive language respectively. Stops (58.68 % – 80%) and fricatives (52 % – 54.96 %) took a mid-table position in both studies, whereas the 3-year olds performed poorest in affricates (39.3 % – 39.34 %), liquids (32.90 % – 38.3 %), and clusters (32.3 %) (Morris & Ozanne, 2003; Chapman et al., 2008).

When CPS was compared to normal speech, less than 10 % of non-cleft speakers had mild velopharyngeal impairment (Persson, Lohmander & Elander, 2006). Other studies found no characteristics of CPS in control speakers (Persson, Elander et al., 2002; Chapman, 1993). Since there were no control speakers in the current study the reference data for PCC measures by Austin and Shriberg (1996) was used. The authors provided reference data for PCC measures by analysing 1,386 conversational samples for speakers with normal speech acquisition (NSA) at their current age and speakers with age-inappropriate SD between the ages of 3 and 8 years. Speakers who retain speech deviations past the age of 9 were classified as showing Residual-Errors (REs). Shriberg, Lewis, McSweeny and Wilson (1997) differentiated between three subgroups of RE speakers. The most common group formed RE-1 speakers who show residual common distortions in their speech past the age of 9. Information on their performance was included in the extract from Austin and Shriberg's (1996) reference data in appendix II table 19.

On average, children with residual common clinical distortions (RE-1 group) performed within the mean range of NSA children in all PCC measures but Late-8. Here, RE-1 at 9 to 11;11 and 12 to 17;11 performed poorer than their age-matched normally developed peers (Austin & Shriberg, 1996). Correct production of the Late-8 speech sounds /ʃ, θ, s, z, ð, l, r, ʒ/ was thus seen as the main distinguishing feature between RE-1 and NSA.

Phonological CPS characteristics Normal English-speaking children acquire all English speech sounds by the age of 7 or 8 (Ingram, 1991). The prevalence of developmental speech sound patterns, so called phonological processes, at certain ages hints at the child's progress in speech acquisition (Grunwell, 1987). There have been several studies that report on the phonological development of children with repaired CL±P (Hodson et al., 1983; Estrem & Broen, 1989; Chapman, 1993; Karnell & Demark, 1986; Morris & Ozanne, 2003). It has been suggested that structural differences such as VPI, hearing issues or palatal fistula, influence children with repaired CP in their phonological development (Estrem & Broen, 1989).

Studies on early speech and babbling found that CL±P children were slower in the acquisition of speech sounds than their non-cleft peers (Scherer, Oravkinova & McBee, 2013). The authors also showed that cleft children acquire a significantly lower number of high-pressure consonants at the age of 12, 16 and 24 months than non-cleft children, whereas numbers of low-pressure consonants did not differ significantly. This also meant that CL±P children do not catch up in the production of high-pressure consonants with their non-cleft peers right after their primary palate surgery (PPS). With regard to place of articulation, CL±P children proved to lack behind except for the production of velar sounds which is similar to that of non-cleft children by the age of 24 months (Scherer, Oravkinova & McBee, 2013).
Velar omissions and fronting, cluster reduction and cluster deletion, stopping and stridency omission, glottal replacement and liquid deviations have been observed in the first case study to investigate phonological characteristics in CPS (Hodson et al., 1983). Further phonological differences between cleft and non-cleft children could to certain extent be traced back to differences in physiology. Estrem and Broen (1989) found that children with repaired CP produce a significantly higher number of words that contain word-initial sonorants than their non-cleft peers. Cleft children had a tendency for higher numbers of words starting with [-coronal] sounds, while the non-cleft group preferred to produce words with initial [+coronal] speech sounds. At a young age, children with repaired CP tended to target more words that contain low pressure consonants. These overall patterns did not hold for all individuals with repaired CL±P (Estrem & Broen, 1989). When typical phonetic characteristics of CPS prevailed until a late stage of development, they could be interpreted as developmental deviation. In a longitudinal study from ages 3 to 10 Persson, Lohmander and Elander (2006) reported on one CP participant with developmental coordination disorder and severe language impairment. The child

produced fronted /k/ while retracting /t/ at age 7. At this later stage of development, glottal articulation was also persistent in this child (Persson, Lohmander & Elander, 2006).

In a longitudinal study, Chapman (1993) investigated the occurrence of phonological processes in the speech of 30 CL±P children and an equally sized group of children without facial clefts at the age of 3, 4 and 5. At ages 3 and 4 CL±P children analysed with the KLPA (Khan & Lewis, 1986) showed significantly more overall instances of phonological processes than their non-cleft peers. These differences at an early age between cleft and non-cleft groups did not prevail at the age of 5. Voicing was more frequently found in the non-cleft group, while deaffrication, syllable reduction, liquid/glide replacement and stop replacement were significantly more frequent in CP speakers at age 3 than in age-matched non-cleft peers. In CL±P children backing was reduced in frequency, the older the child got. At age 5, only cluster reduction was found to be a productive process in CL±P children, i. e. it occurred at least in 20 % of possible cases, but it did not reach productivity level in non-cleft peers (Chapman, 1993).

Morris and Ozanne (2003) compared phonetic and phonological skills of 20 CL±P children at age 3 that show delayed (n=9) or normal (n=11) expressive language skills at the age of 2. Narrow transcription of video tapes analysed using the profile of phonology (PROPH) component of the computer software Computerised Profiling 9.7.0 (CPro) (Long, Fey & Channel, 2003) showed that 67 % of the CL±P children with delayed expressive language development make use of glottal stops as compensatory articulation at age 3, whereas there was no usage reported of compensatory strategies for the group with normal language development. Regarding the occurrence of phonological processes Morris and Ozanne (2003) found that the delayed group shows disordered processes, such as medial consonant deletion, glottal insertion and nasal preference, as well as developmental processes. Occurrences of nasal assimilation, cluster reduction and final consonant deletion were significantly more numerous in the delayed CL±P group than in the CL±P group without language delay. However, the latter group showed significantly higher occurrences of fricative simplification. From the PCC speech profile of the group with delayed expressive language at age 3, Morris and Ozanne (2003) concluded that the group would qualify for phonological disorder rather than delay. Poor production of early nasals which are unaffected by VPI, glottal stop as compensatory articulation also found in non-cleft children with phonological disorder and poor realisation of late developing speech sounds, such as liquids, suggested this conclusion.

Cleft care management and CPS Efficacy and success of CL±P management are measured by facial growth and speech outcomes of children with repaired CL±P (Kuehn & Moller, 2000). Clinicians are particularly interested in the ideal timing and type of primary palatal and secondary speech surgery for future speech outcomes and facial growth (Karnell & Demark, 1986; Dorf & Curtin, 1982; Willadsen, 2012). Both surgeries can be performed in two separate stages. Which approach is more preferable has been discussed in research (Kirschner et al., 2000; Raud Westberg, 2013; Chapman et al., 2008). It is, however, difficult to compare studies concerned with these issues since they vary in surgical technique under investigation, definitions of early and late repair, and a combination of the two when evaluating one- and two-stage palate surgery. For the management of UCLP alone, 194 different protocols have been established in 201 different European cleft centres (Shaw et al., 2001).

Various authors agreed that **primary palatal repair** is recommended before the onset of speech production, between 11 and 13 months of age (Chapman et al., 2008; Hardin-Jones & Jones, 2005; Dorf & Curtin, 1982; Willadsen, 2012). CL±P children with PPS performed at around 11 months of age had a significantly bigger consonant inventory, higher scores in nasals and liquids correct, less hypernasality and better ratings in articulation proficiency at the age of 3 than age-matched CL±P children with timing of PPS at the age of 15 months (Chapman et al., 2008). Whether or not even earlier repair would be beneficial for CL±P children is debated. Kirschner et al. (2000) have investigated speech of 40 UCLP children with soft palate repair between 3 and 7 months and 50 UCLP with soft palate repair later than 7 months of age. Speech outcomes with respect to nasal resonance, nasal air emission and articulation deviations did not suggest that UCLP children benefit from early timing of soft palate repair nor from later repair. Copeland (1990), on the other hand, found in her study on very early palatal repair in 100 CL±P children with palatal repair performed before 6 months of age that 87 % of these children show acceptably intelligible speech at the age of 5. Copeland (1990) further described that very good speech results at the age of 5 seem to decrease in number when palatal repair is performed after the age of 4 months. With regard to timing of palatal repair, Dorf and Curtin (1982) stated that chronological age alone should not be used as a determining factor. The authors suggested that phonemic development should be tested through early speech assessment starting at 6 months of age.

There is disagreement about the benefit of two-stage over one-stage palatal repair. According to Grundlach, Bradach, Filippow, Stahl-de Castrillon and Lenz (2013) closing the palate in one stage at the recommended age for palatoplasty (between 11 and 13 months) would be obstructive to palatal growth and leads to higher frequency in anterior cross-bite. In contrast, Pradel et al. (2009) found that cleft lip and palate (CLP) children do not benefit from a two-stage procedure of palatal repair (at ages 10;5 and 28;3 months) compared to a one-stage combination of these two procedures at the age of 12;9 months. In their study, the two-stage procedure led to significantly higher ratings of resonance and nasal escape at the age of 4 than in CLP with one-stage repair. These differences were mainly evened out at the age of 6 although children with two-stage repair did not reach the same level of speech skills as the group with one-stage repair. In addition, dental arch and transverse dimension of the palate were significantly smaller in those children who underwent a two-stage palatal repair (Pradel et al., 2009). Raud Westberg (2013) disagreed with both views. In her study based on perceptual assessment of speech and PCC-A the author could not find significant differences in speech outcomes between the investigated UCLP group with one-stage primary palate repair and the UCLP comparative group with two-stage surgical intervention.

Secondary speech surgery is a speech corrective surgical intervention (see section 2.1). Whether or not a child receives secondary speech surgery depends mainly on his/her speech performance in regular audits, such as the CAPS-A (John et al., 2006). Karnell and Demark (1986) investigated the influence of secondary speech surgery (SSS) on speech outcomes in a longitudinal study from age 4 to age 16. They compared speech outcomes of CL±P children with poor speech at age 4 who received SSS by the age of 8 (n=31) and CL±P children who should have received SSS based on poor performance at age 4 but did not receive such treatment until the age of 8 (n=24). Comparing speech results of both groups showed that CPS characteristics, such as nasal air emission and hypernasality, prevail in those children who did not receive SSS by the age of 8. All in all, Karnell and Demark (1986) argued that SSS is one of the key factors for competent velopharyngeal function since participants receiving this treatment performed better at articulation tests at a late stage in development than their controls. However, their study did not control for any other variables than SSS, and results of articulations tests were presented with descriptive and not inferential statistics.

In summary, there are a number of studies that have focused on CPS characteristics. Most of them investigated phonetic features of CL±P speakers, some combined phonological and phonetic analysis. No previous research has systematically investigated whether phonetic or phonological CPS characteristics were more prevalent in speech outcomes. Previous research has found that CL±P speakers improve in their speech with maturation (Pulkkinen et al., 2001; Karnell & Demark, 1986; Persson, Lohmander & Elander, 2006). CL±P children seemed to deviate in their phonological development from non-cleft children (Estrem & Broen, 1989), and they were delayed in their early phonological development compared to phonologically normally developed children (Chapman, 1993). There were contradicting findings about the effect of timing and type of surgical interventions on speech outcomes (Pulkkinen et al., 2001). Studies which analysed factors influencing speech outcomes of CL±P children usually focused on a small number of patient characteristics rather than a broad range of features that characterise CL±P speakers (Kirschner et al., 2000; Pradel et al., 2009). Review of previous CPS research has uncovered that most studies use small sample sizes of 5 to 20 participants (Lohmander & Olsson, 2004; Britton et al., 2014). Furthermore, studies with a longitudinal approach are rare (e. g. Persson, Lohmander & Elander, 2006) and sometimes only yield descriptive information due to lack of data at certain age points and dropouts (e. g. Karnell & Demark, 1986). The current study filled the need for a retrospective, longitudinal analysis of phonological and phonetic CPS characteristics.

2.4 Objectives

1. Little is known about the prevalence of phonetic and phonological characteristics at different ages because of the small number of longitudinal studies. The current study assessed the extent and the nature of these phonological and phonetic deviations. Previous studies have found evidence for differences in phonological development between cleft and non-cleft children (Estrem & Broen, 1989; Scherer, Williams & Proctor-Williams, 2008). It is, however, not clear whether these differences pertain at an older age which is why phonological processes were analysed at all ages. By these means, analysis processes were kept constant for all age groups. In addition, it can be hard to differentiate if older children show delayed process development because of their earlier phonetic deviations which is why phonological analysis of older cleft children can help investigate this issue.

    - All studies that analyse phonological development in CL±P children only investigate children up to the age of 5 (Chapman, 1993). Only few productive processes, mainly omissions, were found at this age (Chapman, 1993). However, it is not clear whether these results also hold for larger cohorts and whether CL±P children at later ages show age-appropriate phonological development.
    - Phonetic characteristics of CPS, such as velopharyngeal impairment, weak

pressure consonants and hypernasality, were significantly more prevalent in 5-year of CL±P children compared to non-cleft peers (Persson, Elander et al., 2002) and predictive of prevailing features at age 10 (Persson, Lohmander & Elander, 2006). The majority of articulation characteristics at age 5 and later ages was, therefore, presumably phonetic in nature.

2. Changes in speech performance of phonetic and phonological characteristics throughout the years 5 to 15 were investigated, and speech patterns were potentially uncovered.
   - Based on Persson, Lohmander and Elander (2006), Karnell and Demark (1986), Van Demark and Morris (1983) and Pulkkinen et al. (2001) it was assumed that cleft palate with or without cleft lip (CP±L) children improve in their speech as they grow older.
3. The current study had the potential to identify possible factors which influence speech performance of CP±L children, such as cleft type, timing and type of surgical procedures or hearing issues and occlusion.

3 Methodology

The current study was a comparative analysis of phonetic and phonological characteristics of CPS at the ages 5, 10 and 15 based on CAPS-A data collected at the Dental Hospital in Glasgow. In this section participant details are provided followed by a description of the design of the materials and the statistical analysis used for analysis. Finally, ethical and other permissions are presented.

3.1 Participants

The West of Scotland multidisciplinary cleft team based in the Dental Hospital in Glasgow has been collecting standardised speech assessment data from children with repaired CP±Ls for more than 15 years. To date, around 100 children have been assessed with the CAPS-A audit at the age of 5, 10, and some participants also at the age of 15. In the current study, video recordings of 50 boys and girls at the age of 5 and 10 were chosen for analysis aiming at having equally sized groups of different cleft types balanced for gender. Participants who were video recorded with sufficient loudness and little background noise were preferred. When the video recorder was placed at too large a distance from the child

the recording was low in volume. Also, in some recordings, siblings were playing in the background. Those cases were excluded from the analysis (see 3.2 for more information on materials).
There was an additional recording at the age of 15 years for 15 of these children. The size of the sample was reduced in the course of the analysis due to lack of patient data (n=4) and the occurrence of syndromic orofacial clefts which performed significantly poorer than children with non-syndromic clefts (n=4) (see table 16). The reduced sample size consisted of 42 children with two recordings at age 5 and 10. For 14 of them there were additional recordings at age 15. The entire sample of 42 children at ages 5 and 10 was called cohort and the smaller sub-sample of 14 children with recordings at 5, 10 and 15 was named sub-cohort in the following.
Since the database at the Dental Hospital reflected that not all cleft types are equally prevalent in the population and in both genders (see section 1) not all groups analysed in the cohort had the same size. The group of UCLP children was the largest with a total of 19 children. There were 14 CP children and 9 children with repaired BCLP in the sample. In total, there were 26 boys and 16 girls in the cohort.

Table 1: Comparative analysis of group characteristics

Parameter	Characteristic	CP	UCLP	BCLP
Gender	female	7	7	2
	male	7	12	7
Timing primary palate surgery (PPS)	before 11 mon	8	11	4
	11 - 13 mon	4	4	1
	after 13 mon	1	0	0
	NA	1	4	4
Type of secondary speech surgery (SSS)	n[1]	9	12	7
	ph[2]	1	5	1
	re[3]	4	2	1
SSS	no	3	3	2
	yes	2	3	0
	NA	0	1	0

1 None.
2 Pharyngoplasty.
3 Re-repair.

Parameter	Characteristic	CP	UCLP	BCLP
Alveolar bone graft (ABG)	no	14	1	0
	yes	0	18	9
Timing ABG	before 9 yr	NA	2	0
	9 - 12 yr	NA	16	9
	after 9 yr	NA	0	0
Block ST 5	n	5	6	2
	y	9	13	7
Block ST 10	n	9	9	3
	y	5	10	6
Block ST 15	n	11	15	7
	y	2	1	2
	NA	1	3	0
Hearing 5	n	7	9	6
	y	7	10	3
Hearing 10	n	12	14	6
	y	2	5	3
Hearing 15	n	10	14	6
	y	3	2	3
	NA	1	3	0
Dentition 5	n	9	10	3
	II	3	0	0
	III	1	4	4
	asym	1	0	0
	NA	0	5	2
Dentition 10	n	5	0	2
	II	6	2	1
	III	1	10	4
	asym	1	0	0
	NA	1	7	2
Dentition 15	n	4	0	2
	II	7	1	1
	III	1	8	4

Parameter	Characteristic	CP	UCLP	BCLP
	asym	1	0	0
	NA	1	10	2
Learning needs	no	14	16	9
	yes	0	3	0
PRS	no	11	19	9
	yes	3	0	0

More than half of the CP±L children (n=23) received PPS before 11 months of age. 9 children had PPS between the 11 and 13 months of age. Only one child was reported to have had PPS after 13 months of age. Most of the children in the cohort did not receive SSS (n=28). 14 children underwent SSS with five of them receiving this treatment at two stages. In order to describe groups and not individuals type of SSS was categorised as the main two surgeries used which were pharyngoplasty (n=7) and re-repair (n=7).
There was a division within the three cleft groups in the parameter existence of ABG. While none of the children in the CP group (n=14) underwent ABG surgery, all BCLP children (n=9) and almost all with UCLP did (n=18). None of the ABGs was performed later than at 12 years of age. Only two children of the cohort underwent ABG before they were 9 years old. All other CP±L children received ABG between the age of 9 and 12 (n=25).
In total, there were only three children in the cohort with reported learning needs. These three children had repaired UCLP. Regarding prevalence of PRS only the CP group showed instances of PRS (n=3) (see table 1). Since neither CP±L children with learning needs nor with PRS performed significantly poorer than children without learning needs or without PRS these participants were included in the cohort analysis (see table 17 and 18).
As for parameters measured at age of recording there were twice as many children at age 5 in active ST (n=28) than children who did not require ST at this age (n=14). At age 10, half of the cohort received active ST, while the other half did not. At age 15, only few cases of CP±L children (n=5) required additional blocks of ST.
With regard to hearing issues, most of the children in the BCLP group were stable throughout the years 5 to 15, i. e. for two out of three children with hearing issues reported status at 5 prevailed until the age of 15. Children with hearing issues in the groups

CP ($n_{yes\ 5}$=7, $n_{yes\ 10}$=2) and UCLP ($n_{yes\ 5}$=10, $n_{yes\ 10}$=5) decreased in number from 5 to 10 and stayed fairly stable from 10 to 15. There were more children without hearing issues at 10 and 15 in the groups CP (n_{10}=12, n_{15}=10 (NA=1)) and UCLP (n_{10}=14, n_{15}=14 (NA=3)) than children with hearing issues ($n_{CP\ 10}$=2, $n_{CP\ 15}$=3; $n_{UCLP\ 10}$=5, $n_{UCLP\ 15}$=2).

In accord with the clinical classification of structural issues related to dentition, CP±L children were characterised by the malocclusion types as defined by Angle (1899). Occlusion type stabilised at age 10[4]. At age 5, occlusion type III was already established in the CP and BCLP groups, whereas most UCLP children at age 5 had no reported malocclusion. These were established at age 10 with more children displaying type III than any other type. One of the CP children displayed asymmetrical occlusion which did not fit into the categories of malocclusion.

Regional variability In the current study, regional variability of the participants was controlled to avoid counting typical vernacular characteristics as phonetic or phonological errors of CPS. Since only children who are living in the West of Scotland area are treated by the cleft team situated in Glasgow it is highly likely that children analysed here were speakers of Scottish English and its vernaculars spoken in this area. All of the children had English as their native language (Crampin, patient data, 2015).

Local vernaculars and Standard Scottish English (SSE) form the sociolinguistic continuum in Scotland[5] (Aitken, 1984; Macafee, 1983). There are three vernaculars spoken in Scotland: Scots, Highland English and Gaelic (Macafee, 1983). The West dialect of Scots underlies the non-standard English spoken in greater parts of the West of Scotland.

The main difference between SSE and Southern Standard British English (SSBE) lies in their vowel systems (Scobbie, Gordeeva & Matthews, 2006). Since this analysis focused on the phonetics and phonology of consonants these differences could be disregarded. With respect to consonants there are 25 phonemes in SSE, most of them similar to the phonemes in SSBE. SSE shows three distinctive consonants phonemes: the glottal stop, often counted as the 26 consonant of SSE, the voiceless, labialised velar approximant (/ʍ/) and the voiceless, velar fricative (/x/). The two latter speech sounds are both low in frequency (Scobbie, Gordeeva & Matthews, 2006). /x/ can be found in some words of Gaelic origin, e. g. in <loch> /lɔx/ (Macafee, 1983). It was not part of the target sounds in the CAPS-A sentences.

4 For UCLP this was only assumed due to missing data at age 15.

5 Scobbie, Hewlett and Turk (1999) remarked that these poles are oversimplified since SSE has a lot of accents and Scottish vernaculars display many dialects.

The following list summarises dialectal allophonic variants for SSE consonants. If produced by one of the participants, these allophonic variations were not counted as incorrect productions of the target sound. For instance, glottalisation of pressure consonants is characteristic for CPS as a type of compensatory articulation due to insufficient velopharyngeal closure (see section 2.3). However, it is also typical for SSE speakers to replace /t, k, p/ with a glottal stop in specific phonetic contexts (Stuart-Smith, 2003). Depending on the phonetic context of glottalisation the transcriber decided whether this phenomenon was analysed as an instance of allophonic variation or as a phonetic CPS characteristic.

- t-glottalisation in pre- and intervocalic, and prepausal position (Stuart-Smith, 2003)
- postvocalic /k, p/ glottalised when homorganic nasal follows (Stuart-Smith, 2003)
- /ʍ/ as variant of /w/ (Scobbie, Gordeeva & Matthews, 2006)
- /x/ in Gaelic lexemes (Scobbie, Gordeeva & Matthews, 2006)
- /t, d, n/ often dentalised (Scobbie, Gordeeva & Matthews, 2006; Macafee, 1983)
- /l/ realised with dark quality (Scobbie, Gordeeva & Matthews, 2006; Macafee, 1983)
- /s/ and /z/ as retroflex sibilants (Macafee, 1983)
- Cockney variant: /θ/-fronting to /f/ (Kerswill, 2003)
- /θ/ in word-initial and word-medial CV as /h/ (Lawson, 2009)

3.2 Materials

The data used in the current study consisted of the 20 CAPS-A sentences with high pressure consonants which are part of the regular CAPS-A audit (see section 2.1 and target transcription in appendix I). The SLT conducting the audit was familiar with all children. Variability of the clinician was kept to a minimum of two different SLTs who were responsible for the audit sessions. They agreed on assertive sentence prosody for all 20 CAPS-A sentences.

The audit sessions were video recorded with the internal microphone of a Canon Legria FS200 video recorder in a quiet room in the Dental Hospital in Glasgow. All recordings were transferred from the SD card of the video recorder and saved in the database of the

cleft specialists. At the very early stages of the instalment of regular audit sessions a VHS video recorder was used as equipment. Usage of two different recording equipment had no noticeable impact on the quality of the recording. Video-recordings were converted into 320 kbps mp3-files with a sampling rate of 26 kHz. Background noise was not minimised in the recordings since random noise was in the frequency regions that are crucial for the perception of speech sounds (up to 3 kHz) (Fastl & Zwicker, 2006). If this noise was filtered by means of spectral reduction there would be an immense loss of information, especially with regard to velopharyngeal and nasal friction that is typical of CPS (see section 2.3).
The CAPS-A sentences have been specifically designed to analyse CPS. To that means, they contain all English pressure consonants in different word positions (see section 2.1). Besides that, they allow for a representative speech sample to assess phonological and phonetic characteristics of CPS with more than 100 words (Konst, Rietveld, Peters & Prahl-Andersen, 2003). Because of their basic vocabulary and syntax they are easy enough to imitate for children at the age of 5. Also, these standardised sentences were chosen for analysis rather than spontaneous speech because they guaranteed comparable and stable phonetic context (see target transcription in appendix I).
The drawback to that method was that imitated sentences could not be regarded as natural as spontaneous speech. Although it has been proposed to use spontaneous speech that is elicited in the CAPS-A audit in addition to the standardised sentences for analysis purposes (John et al., 2006), this possibility was not exhausted in the current study because the participants were highly variable in the amount of spontaneous speech they produced, and for some children intelligibility was reduced to the extent that the transcriber could not identify the respective target transcription with absolute certainty. Another potential drawback to the kind of data used in the current study was that imitation of the SLT's speech characteristics was a possible disruptive factor to the naturalness of children's speech outcomes.

3.3 Data analysis

In the current study, CPS was analysed with an approach that incorporates phonetic and phonological aspects. This strategy aimed at discriminating typical speech patterns in phonological development from speech patterns that could be traced back to structural issues related to CP±L, such as VPI, reduced lip mobility or malocclusion. The analysis process consisted of several steps: narrow transcription, reliability measurements, transfer of transcript to computer software CPro, automatic PCC measurement, and statistical analysis.

Narrow transcription Narrow transcription is widely recognised as the clinical standard for the assessment of CPS (Howard & Lohmander, 2012). The term narrow transcription refers to the detailed, phonetic transcription of connected speech. Broad transcription which solely gives information on phonemic status of speech utterances is an impractical option for the description of disordered speech because it cannot rule out that a disorder is not purely phonological (Ball, 1995). Detailed transcriptions allow for a high amount of depth in the analysis (Howard & Heselwood, 2002). In accord with Ball (1995), the current study described speech outcomes on a subphonemic level, i. e. utterances were analysed as consisting of allophones of target phonemes, as well as non-native sounds that are not part of the target phoneme system.
At first, the video recordings were screened for sufficient quality on site of the Dental Hospital and turned into audio files. Second, narrow transcription was performed in the soundproof ST speech lab in the University of Strathclyde based on the audio track of the video file. The speech analysis software Praat 5.3.76 (Boersma & Weenink, 2014) was used to display the spectrograms of the audio samples. This process which combines perceptual and visual information of the audio signal is called two-tier transcription (Howard & Heselwood, 2011). The speech samples were repeated in loops of up to 10 seconds until the transcriber judged this part to be transcribed correctly and moved on to the next part.
In case of doubt, the video file was consulted to help identifying labial segments (Howard & Heselwood, 2002) and gain information on facial movements and background noise. Coupling perceptual assessment with instrumental analysis also helped identifying double articulation conclusively (see section 2.3). However, the transcriber was aware that visual information can in some instances also be misleading. Speech perception can be immensely influenced by visual information (McGurk & MacDonald, 1976). This is why visual consultation of the videos was kept to a minimum and only used for helping with the perceptual analysis of the speech of some children.
The quality of transcripts depended heavily on the transcriber's subjective experience in analytic listening (Howard & Heselwood, 2002). The transcriber conducting the current study was trained in transcribing disordered speech from audio recordings, as well as in narrow transcription of normal speech with a broad sociophonetic range. The transcriber was a German native speaker. Since auditory analysis of speech is influenced by the phonetic background of the transcriber's native language (Laver, 1994) the

transcriber familiarised herself with the relevant literature on Scottish English phonology and pronunciation, e. g. Aitken (1984), Scobbie, Gordeeva and Matthews (2006), Stuart-Smith (2003), prior to the transcription process.
The phonetic symbol systems employed in the current study are the International Phonetic Alphabet (IPA) (IPA, 2005) and the extended International Phonetic Alphabet Symbols for Disordered Speech (extIPA) (Duckworth, Allen & Ball, 1990). The phonetic alphabet introduced by the International Phonetic Association in 1888 has been established as the standard symbol system for the representation of the actual pronunciation of speech sounds (International Phonetic Association, 1999). As a result of the progress report "Phonetic representation of disordered speech" (PRDS, 1980) extIPA was designed (Duckworth et al., 1990). Both charts are regularly revised. The extIPA contains additional symbols for consonant and vowel characteristics, as well as for suprasegmentals that cannot be expressed by the IPA repertoire (Ball et al., 1996). The CAPS-A tool feeds from both symbol charts for transcribing CPS. The usage of non-standardised symbols for CPS, as introduced by Trost (1981) and used by several other investigators (e. g. Morris & Ozanne, 2003), was not desirable given the prevalence of the extIPA.

Reliability measurements In the current study, reliability of phonetic transcription was addressed by measuring intra-judge and inter-judge reliability. 10 % of the sample was transcribed twice by the investigator and by an equally trained phonetician. The transcripts were compared segment by segment. Deviations relating to primary articulation (e. g. voicing, place and manner of articulation for consonants; rounding, height and backness for vowels) counted twice as much as slight differences between the transcripts which relate to secondary articulation (e. g. palatalisation, velarisation and labialisation). Intra-judge reliability rating reached a total of 89.63 % (3.50 %). Intra-judge reliability of the 5-year recordings was lower (87.46 % (3.19 %)) than for the recordings at 10 (91.80 % (2.37 %)). This difference was not significant ($\chi^2(4)$=0.45, p=.98). Inter-judge reliability was only slightly below intra-judge reliability at 85.52 % (0.65 %).

Transfer to Computerised Profiling Information from the narrow transcripts was transferred into the computer software CPro (Long et al., 2003). The PROPH segment of this tool was designed for the assessment of the phonological development of children. The CAPS-A sentences were entered as a word list. PROPH generated target realisations automatically based on an inbuilt dictionary of SSE (see target realisations in appendix I). These automatically generated target realisations were double-checked by the investigator.

For each recording, the narrowly transcribed realisation including diacritics was entered. CPro only allowed for one diacritic per segment. In case of more than one change to the target realisation the transcriber used one of the PROPH diacritics that were not otherwise in use to translate the meaning of two diacritics. For instance, the PROPH diacritic for derhotacised ("-") was not vital for the current study with a focus on consonants which is why this symbol was used to denote nasal emission and palatalisation occurring together. Realisations that could be traced back to the child's vernacular (see section 3.1), as well as weak realisations due to connected speech processes were not counted as articulation deviations (see list below). Excluding these predictable speech processes from the analysis of CPS ensured that only speech patterns connected to phonetic or phonological aspects of CPS were included in the analysis. Furthermore, backing and glottalisation are not marked as phonological disordered processes but as phonetic speech deviations (see section 2.3).

List of connected speech processes

- Reduction in frequent segments (deletion possible) (Jurafsky, Bell, Fosler-Lussiert, Girand & Raymond, 1998)
  - /pʌpe ɪz/ - /pʌpe [...] z/;
  - /rɔbɪn ɪn ə/ - /rɔbɪn [...] ə/
- Deletion of /h/ because of aspiration of preceding /t/ (Klatt, 1975)
  - /hɛrt hər/ - /hɛrt [...] ər/
- Final consonant deletion in word at the end of utterance not counted (Slifka, 2006)
  - /nɛst/ - /nɛs[...]/

Automatic PCC measurement Among other information, the PROPH segment of CPro rendered various measures of PCC (Shriberg & Kwiatkowski, 1982; Shriberg, Austin, Lewis, McSweeny & Wilson, 1997), as well as an extensive phonological process analysis, mainly based on Grunwell (1987), Shriberg and Kwiatkowski (1982) and Smit, Hand, Freilinger, Bernthal and Bird (1990). The PROPH profile listed all targeted words and their realisations (see example in appendix IV). These automatic measurements formed the basis of the phonetic and phonological analysis of CPS in the current study. Phonological processes were treated as productive when they reached 20 % process usage based on McReynolds and Elbert (1981).

Regarding the age range of the participants in the current study (5 to 15 years) it should be noted that PCC measures have proved to be good outcome measures for children between the ages of 3 and 8 (Shriberg, Lewis et al., 1997; Austin & Shriberg, 1996). Results for the age groups 10 and 15 should therefore be analysed with caution and compared to reference data from Austin and Shriberg (1996) for age-matched groups.

PCC Based on narrow transcription of conversational speech samples PCC expressed the percentage of correctly articulated consonants of a target sample (Shriberg & Kwiatkowski, 1982), and it indicated the severity of speech dysfunction (McCartney, 2012). It was seen as an indicator of allophonic mastery (Shriberg, Lewis et al., 1997). Common clinical distortions, uncommon clinical distortions and deletions or substitutions were counted as incorrectly articulated when measuring PCC.
Dentalised or lateralised sibilant fricatives or affricates and labialisation or velarisation of /l/ or /r/ were interpreted as common clinical distortions based on studies on age-dependent normalisation of clinical distortions. Uncommon clinical distortions were defined as articulatory deviations associated with disordered speech, including CPS (Shriberg, 1993). As a result of a validation study Shriberg and Kwiatkowski (1982) established four categories of severity: $> 90\,\%$ = mild, $65 - 85\,\%$ = mild-moderate, $50 - 65\,\%$ = moderate-severe, and $< 50\,\%$ = severe.

PCC-A The measure Percentage of Consonants Correct – Adjusted (PCC-A) counted uncommon clinical distortions and deletions or substitutions as incorrect, whereas it identified common clinical distortions as correct. According to Shriberg (1993), PCC-A was designed to be specifically sensitive towards speech delay.

PCC-R The parameter Percentage of Consonants Correct – Revised (PCC-R) only counted deletions and substitutions as incorrect (Shriberg, 1993). It was originally devised to ensure high inter-rater reliability. Speech clinicians could use this measure for broad transcripts of disordered speech (McCartney, 2012). In a follow-up study on Shriberg (1993), Shriberg, Lewis et al. (1997) found that not PCC-A but indeed PCC-R provided the better separation of scores for speakers with NSA and speakers with SD. The authors further stated that phonemic mastery is best reflected by this measure.

Table 3: Summary of categorisation of phonetic and phonological CPS characteristics

Main categories	Characteristic		
Phonological			
Omissions	• FinConsDel[6]	• ClusRed[7]	• LiquidDel[8]
	• (Redup)[9]		
Substitutions	• VelarAss[10]	• NasalAss[11]	• Voicing
	• VelarFront[12]	• PalatFront[13]	• EarlyStop[14]
	• LaterStop [15]	• Gliding	• Deaff[16]
	• FricSimp[17]	• ClusSimp[18]	• (Redup)
Phonetic			
Phonetic omissions	• Elision		
Phonetic additions	• DoubleArt[19]	• Nonpulmonic	• GlottRein[20]
Phonetic substitutions	• Palatalisation	• Backing	• Pharyngealisation
	• Glottalisation	• NasalSub[21]	• NasalFric[22]
	• Gliding PC [23]		
Distortions	• Weakening	• Lowering	• NasalEm[24]
	• NasalTurb[25]	• Devoiced	• Lateralised
	• Dentalised	• Percussive	• Interdentalised
	• Linguolabialised	• Dentolabialised	

Table 3 summarises all phonetic and phonological CPS characteristics analysed in the

6 Final consonant deletion.
7 Cluster reduction.
8 Liquid deletion.
9 Reduplication.
10 Velar assimilation.
11 Nasal assimilation.
12 Velar fronting.
13 Palatal fronting.
14 Early stopping.
15 Later stopping.
16 Deaffrication.
17 Fricative simplification.
18 Cluster simplification.
19 Double articulation.
20 Glottal reinforcement.
21 Nasal substitution.
22 Nasal fricative.
23 Gliding of pressure consonant.
24 Nasal emission.
25 Nasal turbulence.

current study. All phonological processes were counted and identified automatically by CPro with the exception of backing of alveolars and glottal substitution which were not counted as phonological but as phonetic characteristics of CPS. Gliding of fricatives, included in the original CPro list of phonological processes, was also not treated as a phonological characteristic of CPS since fricatives are pressure consonants. Therefore, these type of phonetic articulation errors were counted as gliding of pressures consonants. /s/ and /z/ distortions were counted as phonetic characteristics of CPS because CL±P children are known to be prone to malocclusion (Ross, 1987). Distortion of alveolar fricatives could therefore be linked back to physiological reasons. Neither context-sensitive voicing, stopping of liquids, epenthesis, flapping nor phonological sound additions which are included in the list of phonological processes analysed by CPro (see table in 6) were included in list 3 because they did not occur in the data. Phonetic characteristics were all those articulation deviations which were not identified as phonological by CPro. All phonetic CPS characteristics that affected secondary articulation were identified as distortions. Phonetic substitutions affected primary articulation.

It should be kept in mind that palatalisation could also be used to describe secondary articulation of the target sound (e. g. /t/ - /tʲ/). However, instances of palatalisation as secondary articulation were rarely found in the data. In most cases palatalisation was observed as a form of retraction, as explained in section 2.3. For reasons of simplification, reduplication was either analysed as omission (e. g. in /rɪŋɪŋ/ - /ɪŋɪŋ/) or as substitution (e. g. in /dɪrtɪ/ - /dɪrdɪ/).

Instances of atypical processes, such as sound additions and glottal substitution, were counted as phonetic deviations. Glottal substitution was one of the main phonetic characteristics of CPS. Sound additions, as defined in PROPH, were rare in number, and the type of sound additions identified by CPro were likely to be due to cleft-related issues (e. g. addition of nasal in /ðə/ - /ðən/).

3.4 Statistical analysis

Statistical analysis was performed with the statistical software R 3.1.1 (R Development Core Team, 2014) using statistical hypothesis tests and variance analysis. Shapiro-Wilk-tests on the PCC data of the three groups showed that not all PCC measures follow normal distribution. As a result, the nonparametric statistical tests for repeated measures, Wilcoxon signed-rank test, was used as an alternative to the paired Student's t-test. Paired comparisons were conducted on the age 5 and the age 10 group which each consisted of 42 CP±L children. Analysis of the sub-cohort included additional paired

comparisons between 14 CP±L children of the cohort at age 10 and age 15. Speech performance at age 5 for these children was given in graphics and tables for demonstration purpose. Additional Wilcoxon signed-rank tests for the sub-cohort at age 5 and 10 were redundant because these children were included in the cohort, and these tests could have led to type I errors. In addition to between comparisons, intragroup comparisons were conducted and neighbouring categories were tested for significant difference. This statistical analysis added valuable information about the distribution of different phonetic or phonological characteristics of CPS within an age-group (see section 4).
Variance analysis of the PCC measures was conducted in order to uncover variables that explain severity of speech impairment in CP±L children. Multivariate variance analysis was performed by using MANOVA[26]. The six characteristics gender, cleft type, timing of PPS, dentition and hearing issues at 10, as well as age were identified as possible factors in agreement with the SLTs of the West of Scotland cleft team. Two MANOVAs were calculated: one for the cohort and another one for the sub-cohort.

Table 4: Possible factors in variance analysis

Patient characteristic	Factor level
Gender	male female
Cleft type	CP UCLP BCLP
Timing of PPS	before 11 months between 11 - 13 months after 13 months
Dentition at age 10	normal type II type III
Hearing issues at age 10	yes no
Age	5 10 15

Detailed analysis of the characteristics of the cohort in section 3.1 has shown that occlusion type and hearing issues were (relatively) stable at age 10. Since gender and

26This parametric method was used in accord with statistics advisor at Strathclyde University.

cleft type were fairly equally distributed in the cohort and independent from other characteristics they were included in the following variance analysis. Timing of PPS and its impact on facial growth and speech has been lively discussed in research (see section 2.3). This is why this characteristic was included in the variance analysis as a potential covariate. In addition, the variable age was also part of the variance analysis. In total, there were six variables which was the allowed maximum for the sample size analysed in the current study ($\sqrt{42} = 6.48$).
This selective process entailed excluding characteristics with few information for each participant, such as type of primary palate, and unbalanced group sizes, such as learning needs and PRS. Characteristics that have been identified to be dependent on cleft type, such as existence and timing of ABG, were not included in the following variance analysis. The characteristic type of SSS was not included because there was no available data on a control group, i. e. there was no information on speech performance of CP±L children who reportedly needed SSS but did not receive the treatment, as in Karnell and Demark (1986). The same was true for the characteristic block of active ST. There was lack of information on children who should have received additional ST and were not treated. Above that, neither quantity nor quality of the ST were documented. Whether or not CP±L were diagnosed with palatal fistulae could not be taken into consideration in the variance analysis because there was no information on size and place of the fistula. Depending on its size and place in the palate it did not necessarily influence speech (see section 2.1).

3.5 Ethical and other permissions

Since the data analysed in the current study had been collated on the premises of the NHS Dental Hospital in Glasgow, the study required approval by NHS Research Ethics in addition to NHS R&D approval. The study gained approval by the Proportionate Review Sub-committee of the Dyfed Powys Research Committee on 26 February 2014 (see letter with favourable opinion in appendix VI). Parents gave their consent to medical video and audio recordings for monitoring treatment. Caldicott Guardian Approval for reviewing the audio data off-site was given on 28 March 2014. This research will be published in summary wording on the NRES website (http://www.nres.nhs.uk/).

4 Results

First, detailed analysis of the types of phonetic deviations and phonological processes used and their proportional distribution drew a clear picture of the nature of CPS in the cohort. Second, the measures PCC, PCC-A, PCC-R and PCC for all speech sound classes were compared between the groups of 5-, 10- and 15-year old children in order to investigate changes over time. Finally, variance analysis was conducted to help explain differences in the severity of speech impairment.
Other than using age as an indicator of phonological processes one cannot possibly differentiate between omissions due to connected speech, i. e. deletion, and omissions as phonological processes. This is why tests for phonological development aim to elicit single word utterances in naming tests. For that reason results were presented both including omissions as phonological processes, and excluding omissions. In that way, results of this study were comparable to others that include omissions and investigate phonological development in cleft children until the age of 5, while at the same time being sensitive towards the issue of including omissions for connected speech test material. Alternative results disregarding omissions were marked with „$“ in all tables and figures.

4.1 Nature and extent of CPS characteristics

One objective of the current study was to quantify the types of CPS characteristics that CP±L children produce at age 5, 10 and 15. First, the PROPH segment of CPro gave detailed information on the phonological process usage based on the definitions given in appendix IV. Second, proportional distribution of phonetic characteristics of CPS were measured based on the definition of CPS characteristics given in section 2.3. Third, mean percentages of phonological and phonetic CPS characteristics were given with respect to their proportional distribution. This error profile allowed the assessment of articulation characteristics and how their proportional distributions changed over time.

4.1.1 Phonological characteristics

This section summarises findings on process usage of phonological processes as defined in CPro (see appendix IV). Mean percentages of process usage showed that there is a number of phonological processes which were only used infrequently and a few processes which were used frequently. Phonological process usage above the productivity threshold of 20 % process usage was only reached for cluster reduction ($) at age 5 and was close to that threshold at age 10. This result held only true when omissions were counted as phonological processes. All other phonological process were below that threshold at ages 5 and 10 (see table 5).

Table 5: Mean percentage of most frequent phonological processes used at age 5 and 10 in %

Phonological process	Age 5	Age 10
$ClusRed	34.24 (21.97)	19.86 (11.33)
$LiquidDel	12.17 (8.91)	9.52 (8.18)
$FinConsDel	16.10 (14.44)	4.79 (5.75)
LaterStop	10.48 (7.13)	6.02 (6.05)

Intragroup differences: cohort Cluster reduction ($) at age 5 and 10 had significantly higher numbers of process usage than all other categories of phonological processes. Whereas percentages of process usage of final consonant deletion ($), liquid deletion ($), and later stopping did not differ from each other significantly at age 5, at age 10 liquid deletion ($) had significantly higher process usage than later stopping (V=193.5, p=.02) and final consonant deletion ($) ($V$=180.5, p<.01). The latter two categories of phonological processes did not differ significantly in their number of usage at age 10 (V=243.5, p=.24). When omission were disregarded due to the issue of differentiating them from elision in connected speech, only the above results for later stopping were found.

Intergroup differences: cohort Comparison of the phonological process usage at 5 and 10 showed that CP±L children at age 5 use significantly more nasal assimilation (V=143, p<.01), final consonant deletion ($) ($V$=782, p<.01), palatal (V=61.5, p<.01) and velar fronting (V=208, p<.01), cluster reduction ($) ($V$=753, p<.01), and later stopping (V=623, p<.01) in possible cases than at age 10. All of those processes were defined as developmental. Higher numbers of process usage at age 5 in the rest of the phonological processes analysed by PROPH did not reach significance level (see figure 1).

Sub-cohort Analysis of process usage in the sub-cohort showed that cluster reduction ($) was used more often in possible cases than any other phonological process in age groups 5 ($m_{\text{ClusRed 5}}$=38.36 % (17.05 %)), 10 ($m_{\text{ClusRed 10}}$=24.93 % (8.24 %)), and 15

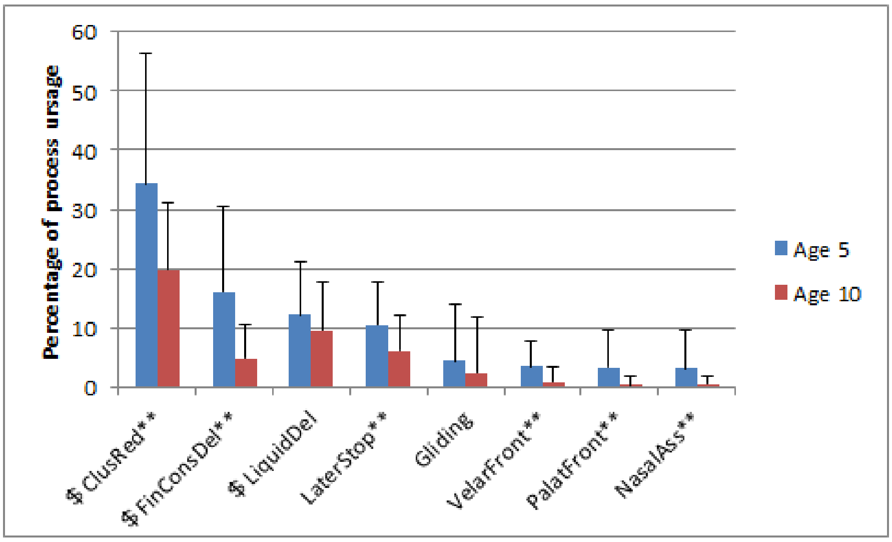

Figure 1: Mean percentage of phonological process usage at 5 and 10 (**p<.01)

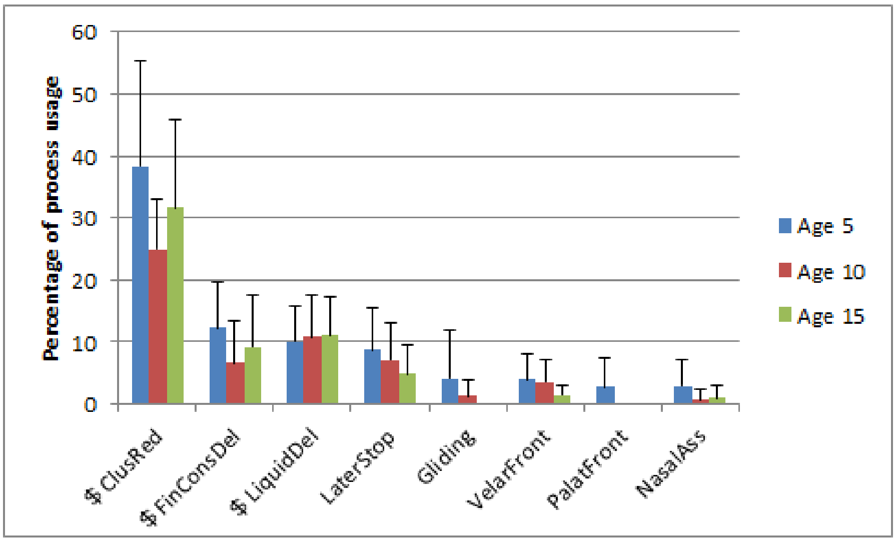

Figure 2: Mean percentage of phonological process usage at 5, 10 and 15 (*p<.05)

($m_{ClusRed\ 15}$=31.57 % (14.18 %)). Throughout all age groups, liquid deletion ($) and final consonant deletion ($) showed above 5 % process usage. For the sub-cohort with fewer participants, there was no palatal fronting observed at ages 10 and 15. Furthermore, there were no instances of reduplication at age 5, no process usage of early stopping and context-sensitive voicing at age 10, as well as no instances of gliding, fricative simplification nor additions in the age 15 group. There were no significant intergroup differences in phonological process usage observed for age groups 10 and 15 (see figure 2).

In summary, phonological process usage decreased from age 5 to age 10. At age 15 phonological processes of omission ($), such as cluster reduction, final consonant deletion and liquid deletion, increased in their process usage compared to age 10. These differences did not, however, reach significance level. The most prominent phonological process at all ages was cluster reduction ($). When omissions was not counted due to issues with the obtained speech data, these findings summarised here did not occur.

4.1.2 Phonetic characteristics

Phonetic characteristics of CPS were subsumed under other distortions, substitutions, additions, and deletions in the PROPH profile (see section 3.3). The phonetic CPS characteristics and their explanations can be found in section 2.3. The phonetic consonant characteristics dentolabial, linguolabial, interdental, percussive, lateralised and dentalised have been added to the original list in the course of the perceptual analysis of the audio and video data.

Cohort Figure 3 displays the proportional percentages of types of phonetic characteristics of CPS which were significantly different between the age groups of 5 and 10. In sum, palatalisation, nasal emission, lowering and backing made up half of the phonetic CPS characteristics at age 5 and 10. Other prominent CPS phonetic features in both age groups were devoiced or dentalised consonants. In total, these six characteristics formed about 70 % of the phonetic CPS characteristics found.

Comparative analysis using the Wilcoxon signed-rank test showed that nasal emission (V=591, p<.01), nasal turbulence (V=222, p<.01), and nasal fricatives (V=92, p=.01), as well as backing (V=610, p<.01) made up a significantly higher percentage of the total of phonetic CPS characteristics at 5 than at age 10. Lowering (V=230, p<.01) and weakening of pressure consonants (V=134, p<.04), on the other hand, formed a smaller percentage of the phonetic CPS characteristics at 5 than at age 10 (indicated in figure 3,

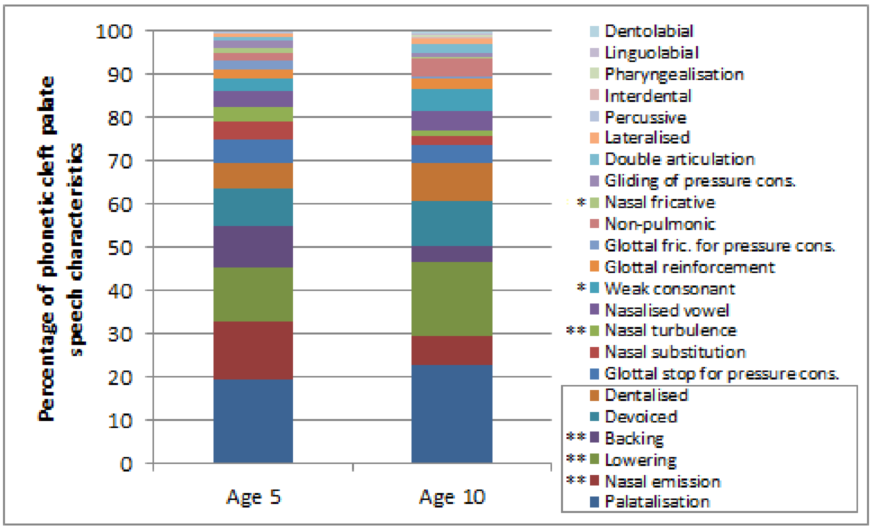

Figure 3: Mean percentage of types of phonetic CPS characteristics at 5 and 10 - extended (*p<.05, **p<.01)

see also table 6).

Table 6: Mean percentage of significantly different proportions of phonetic CPS characteristics at 5 and 10 in %

Phonetic characteristic	Age 5		Age 10	
Backing	9.73	(10.19)	3.88	(7.25)
NasalEm	13.21	(10.63)	6.87	(10.71)
NasalTurb	3.62	(6.12)	0.88	(1.90)
NasalFric	1.43	(2.93)	0.45	(2.18)
Lowering	12.34	(9.46)	16.96	(10.67)
Weakening	2.90	(4.15)	4.89	(6.28)

Sub-cohort Descriptive analysis of the sub-cohort with additional information on speech outcomes at age 15 showed similar results for the percentage of phonetic CPS characteristics. As observed above, the six categories palatalisation, nasal emission, lowering, devoiced, and dentalised made up the majority of the phonetic CPS characteristics found in the speech outcomes of all age groups.

Comparative analysis showed that there are few significant differences in the proportional distribution of phonetic CPS features between the three age groups of the sub-cohort. CP±L children at 10 had a higher percentage of nasal emission compared to the same

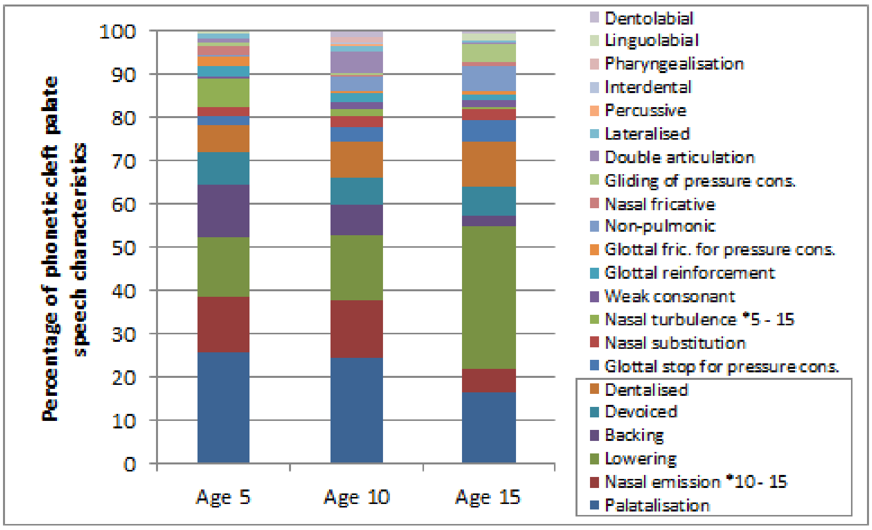

Figure 4: Mean percentage of types of phonetic CPS characteristics at 5, 10 and 15 - extended (*p<.05, **p<.01)

children at age 15 (V=63, p<.01) (see figure 4).

Summing up, analysis of the proportional distribution of phonetic CPS characteristics uncovered which types of phonetic deviations were the most prominent in the overall usage. Palatalisation made up the largest percentage of phonetic deviations at age 5 and 10. Its percentage distribution did not change significantly from 5 to 10, nor from 10 to 15. Other prominent phonetic features changed significantly from age 5 to 10. Proportional distribution of nasal fricative, emission and turbulence, as well as backing decreased from age 5 to 10, while weakening and lowering increased. The only significant change in proportional distribution of phonetic deviations from age 10 to 15 was the decrease of nasal emission.

Qualitative analysis As explained in section 2.3, consonant characteristics of CPS are consonant specific which is why this qualitative analysis investigated which speech sound class was affected by which phonetic characteristics of CPS. To that means, instances of phonetic deviations per speech sound class stratified by place and manner of articulation have been recorded and analysed.

Nasal friction was observed on few fricatives. Only /s, z, ʃ/ were vulnerable to this process. While nasal emission occured on almost all speech sounds but /ð/ and /n/, nasal turbulence was more restricted. Nasal turbulence was not observed on bilabials (/b, p, m/), dental fricatives, /w, r/ nor on /k/. All speech sounds could get potentially

Table 7: Qualitative analysis of occurrence of phonetic CPS characteristics per speech sound class

Phonetic CPS characteristics	Affected speech sounds
Nasal fricative	/s, ʃ/
Nasal emission	all but /ð, n/
Nasal turbulence	all but /k, b, p, m, w, r, ð, θ/
Nasal substitution	all but /ʃ/ and nasals
Glottal stop	all but /m, θ, z, ʒ, l/
Glottal reinforcement	all but /f, ð, θ/
Glottal fricative	all but /ʒ, h, r, ŋ/
Pharyngealisation	all but /m, n, p, b, f, ʒ, l, r/
Palatalisation	all but /m, w, r/
Backing	all but /g/
Double articulation	all but /θ, ð, v, z, ʃ, ʒ/
Non-pulmonic	all but /θ, s, ʒ, w, r/
Gliding	all but /h, w, r, k, n, ŋ/
Lowering	all but /θ, h/
Weak consonant	all but /θ, ʒ, h/
Devoiced	all voiced sounds but /r, n/
Linguolabial	/p, t, d, n, θ, ð, l/
Dentolabial	/p, d, n, ð, f, s, z, ʒ/
Percussive	/t, ʃ/
Interdental	/n, ð, f, s, z, ʒ/
Dentalised	/b, t, d, m, n, f, v, s, z, ʒ, l/
Lateralised	/ð, s, z, ʃ/

substituted by nasals, except postalveolar fricatives.
Glottal stops substituted pressure consonants, as well as /w, r, n/. While all stops were observed to be potentially substituted by a glottal stop, there was a tendency for voiceless fricatives to be more vulnerable to this process than voiced fricatives. All speech sounds but /f/ and dental fricatives were subject to glottal reinforcement. Almost all speech sounds but /ʒ, h, r, ŋ/ were observed to be potentially substituted by a glottal fricative.
Pharyngealisation was fairly restricted in the speech sounds it affected. It could not be found on nasals, liquids, bilabial plosives nor on the fricatives /ʒ, f/. In contrast, palatalisation was found on almost all speech sounds but /m, w, r/. Backing could affect all speech sounds. It was not observed on /g/, but on /k/ being retracted to uvular place

of articulation. Double articulation and non-pulmonic sounds were most likely to occur with stops or nasals. Only few fricatives (/f, s, h/) and the glide /w/ could be subject to double articulation as well. Non-pulmonic sounds were observed to accompany some fricatives (/ð, f, v, z, ʃ, h/) and /l/.
All pressure consonants but /k/ were affected by gliding. This phonetic CPS characteristic was also observed on /m, l/. Lowering affected all pressure consonants, except for /θ/. Almost all other speech sounds but /ŋ/ were also prone to that CPS characteristic. Weakening of consonants only affected pressure consonants. The only pressure consonants without reported weakening were /θ/ and /ʒ/. Devoicing was observed on all voiced sounds with the exception of /r, n/. Dental fricatives, alveolar stops and nasals, as well as /p/ and /l/ were found to be produced with linguolabial place of articulation. Bilabial and alveolar plosives, and nasals, as well as all fricatives (except for /ʃ, h/) were subject to dentalised production. Only the alveolar fricatives and /ð, ʃ/ were observed to be produced lateralised. Interdental production affected /n/ and all fricatives, except for /θ, f, ʒ/. Dentolabial production could affect plosives /p, d/, nasal /n/ and most fricatives (/ð, v, s, z, ʃ/). Only /ʃ/ and /t/ were found to be produced with additional percussive teeth (see table 7).

In summary, there were some phonetic CPS characteristics that were restricted in their usage to specific speech sounds and others that could be productive on almost all speech sounds with only few exceptions. Naturally, certain phonetic deviations only affected specific types of speech sounds by definition, e. g. devoiced is not productive on voiceless speech sounds. Above that, qualitative analysis showed that phonetic CPS characteristics that were expected to have a preference for certain speech sounds were, in fact, not necessarily restricted to these speech sounds, e. g. backing was not only found on alveolar or velar speech sounds but also on bilabials /p, b, m/ or postalveolar fricatives.

4.1.3 Proportional distribution of CPS characteristics

Intragroup differences: cohort At both ages 5 and 10, phonetic deviations made up the majority of the CPS characteristics in the cohort. Differences between percentage of phonological and phonetic characteristics in total were significant at age 5 and 10 (see table 8).

With regard to phonological characteristics, omissions ($) were more often found than substitutions in CPS at age 5 and 10 (see figure 5). Proportional distribution of

Table 8: Intragroup differences of phonological and phonetic CPS characteristics at age 5 and 10 in %

Age	Phonological	Phonetic	V	p
5	24.35 (8.29)	75.65 (8.29)	0	<.01
$5	10.68 (5.85)	89.32 (5.85)	0	<.01
10	20.39 (9.82)	79.56 (9.75)	0	<.01
$10	7.57 (6.31)	92.43 (6.31)	0	<.01

phonetic deviations within both groups was similar. In both groups, the percentages of phonetic characteristics were in ascending order for phonetic additions, phonetic omissions, distortions and phonetic substitutions. Differences between neighbouring categories in this ranking order were significant, except for the comparison between distortions and phonetic substitutions at age 5 (W=997.5, p=.30).

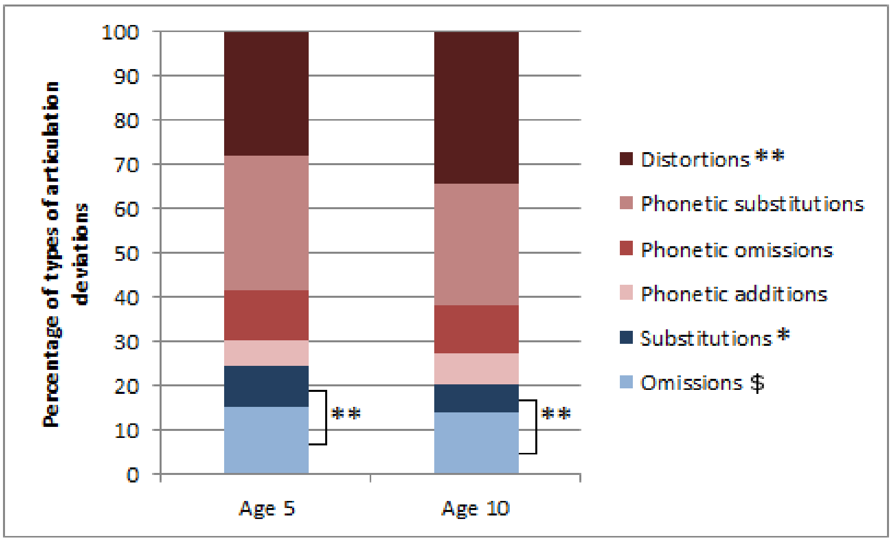

Figure 5: Mean percentage of types of CPS characteristics at 5 and 10 (*p<.05, **p<.01)

Intergroup differences: cohort When added up, the categories phonetic and phonological characteristics differed significantly in their percentages in paired comparisons. Phonological processes made up more of the overall CPS characteristics at age 5 than at age 10 (V=624, p=.03). Percentage of phonetic characteristics increased significantly from age 5 to 10 (V=280, p=.03) (see table 8 for mean values and standard deviation). This became even more apparent when omissions were disregarded in the analysis.

Regarding the proportional distribution of CPS characteristics at 5 and 10, there were only significant inter-group differences for substitutions and distortions. The percentage of substitutions decreased significantly from age 5 to 10 (V=621, p=.03). The percentage of distortions increased significantly from age 5 to age 10 (V=237, p<.01) (indicated in figure 5). The rest of the CPS features stayed relatively stable from age 5 to 10 with no significant results in Wilcoxon signed-rank tests.

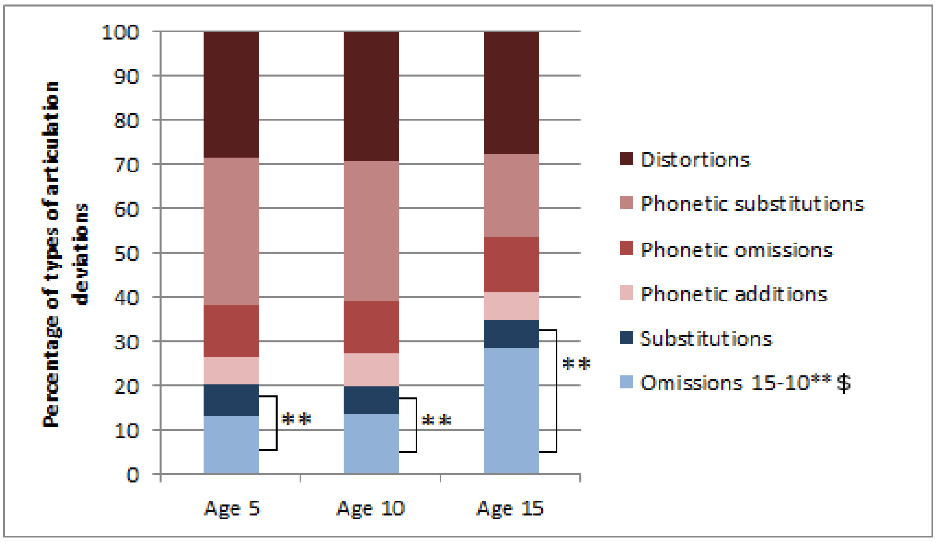

Figure 6: Mean percentage of types of CPS characteristics at 5, 10 and 15 (*p<.05, **p<.01)

Intragroup differences: sub-cohort Analysis of proportional distribution of phonological and phonetic characteristics of CPS within the sub-cohort rendered additional information on speech outcomes at age 15 for 14 of the children in the cohort.
Regarding the proportional distribution of phonological CPS characteristics within the three age groups, omissions ($) made up a significant higher percentage than substitutions at all ages. The distribution of phonetic deviations was described as above in the age groups 5 and 10, whereas at age 15 distortions made up a higher proportion of the CPS characteristics than phonetic substitutions. This difference was not significant (W=139.5, p=.06). The intra-group difference between distortions and phonetic substitutions at age 10 was not significant either (W=105, p=.77). As observed above, phonological characteristics made up a significant smaller proportion of CPS characteristics than phonetic deviations in all three age groups. This holds also true when omissions were disregarded in the analysis.

Intergroup differences: sub-cohort Intergroup comparisons showed that the percentage distributions of phonetic and phonological characteristics stayed relatively stable from age 5 to 10. At age 15, however, omissions ($) made up a significantly higher percentage of types of articulation deviations than they did 5 years earlier (V=6 , p<.01). Phonetic substitutions, on the other hand, decreased in their percentage at age 15 compared to age 10. This difference showed a tendency for significance (V=83, p=.057).

Table 9: Mean phonological and phonetic CPS characteristics at age 5, 10 and 15 in %

Age	Phonological	Phonetic
5	20.14 (5.65)	79.86 (5.65)
$5	8.01 (3.72)	91.99 (3.72)
10	19.94 (6.81)	80.06 (6.81)
$10	7.59 (5.22)	92.41 (5.22)
15	34.80 (19.15)	65.20 (19.15)
$15	9.12 (11.66)	90.88 (11.66)

When phonological and phonetic characteristics were summed up and compared between the age groups, proportional distribution at age 15 differed significantly from that at age 10. The overall percentage of phonological characteristics increased significantly at 15 compared to age 10 (V=96, p<.01) while, in turn, the overall percentage of phonetic characteristics decreased significantly. These results were only observed when omissions were counted as phonological processes at all ages. Results marked with $ in table 9 showed that when disregarding omissions in the analysis the proportional distribution of phonological and phonetic CPS characteristics stayed relatively stable over the years from age 5 to 15 for the 14 children in the sub-cohort.

In summary, at all three ages, phonetic characteristics of CPS formed a significantly higher proportion of the overall CPS characteristics than phonological processes. The proportional distribution of the CPS characteristics stayed relatively stable from age 5 to 10. At age 10, CP±L children produced a significantly smaller percentage of phonological substitutions and a higher proportion of distortions than 5 years earlier. At age 15, the percentage of phonological processes increased significantly compared to age 10, mainly due to the significant increase of the proportion of omissions ($) and decrease of the percentage of phonetic substitutions at that age. This result could not be found when omissions were disregarded in the analysis process.

4.2 Changes in speech performance

In the following section results of the automatic PCC measurements based on narrow transcripts of 20 CAPS-A sentences of CP±L children at 5, 10 and 15 are presented in order to investigate change in speech outcomes. There was information on PCC, PCC-A, PCC-R, as well as on PCC measures of different speech sound classes. The latter measures indicated how many targeted speech sounds of a specific speech sound class were articulated correctly.

4.2.1 Percentage of Consonants Correct

Table 10 gives the mean PCC values and their standard deviations of the age groups 5 and 10. All PCC-values of the age group 5 differed significantly (*p<.05) or highly significantly (**p<.01) from those measurements for the age group 10. On average, CP±L children at the age of 5 reached significantly lower values for the measures PCC, PCC-A, and PCC-R. Over the period of 5 years CP±L children improved the most in PCC, less in PCC-A and even less in PCC-R. When omissions were not included in the analysis as phonological processes, all PCC-measures at all ages increased (see marked values in table 10).

Table 10: Comparative analysis of mean PCC values in % (sd) of age groups 5 and 10 (*p<.05, **p<.01)

Measure	Age 5		Age 10		Improvement		Wilcoxon	
PCC	59.02	(13.46)	72.64	(10.17)	13.62	(13.40)	V=815	p<.01**
$ **PCC**	65.49	(11.15)	76.48	(8.77)	10.99	(11.49)	V=839	p<.01**
PCC-A	60.28	(13.28)	69.69	(11.48)	9.41	(13.71)	V=749.5	p<.01**
$**PCC-A**	72.17	(10.71)	83.51	(6.39)	11.34	(11.47)	V=857	p<.01**
PCC-R	75.03	(12.66)	80.80	(9.92)	5.77	(15.80)	V=640.5	p<.02*
$**PCC-R**	82.11	(12.39)	89.55	(5.42)	7.45	(13.08)	V=760	p=.01*

For 14 of the children who formed the cohort analysed in the current study, there was additional data at age 15. All PCC measures increased from 5 to 10, as observed above, and from 10 to 15. All three PCC measures reached significance level in pairwise Wilcoxon signed-rank tests between age groups 10 and 15. When omissions were not counted as speech errors, PCC-measures were higher at all ages (see table 11).

Table 11: Mean PCC values in % (sd) of age groups 5, 10 and 15 (*p<.1, **p<.05)

PCC value	Age 5		Age 10		Age 15		Wilcoxon 10 – 15
PCC	60.61	(13.83)	66.21	(9.14)	74.46	(9.91)	V=97 p<.01
$**PCC**	70.87	(12.96)	70.74	(7.96)	77.86	(8.51)	V=98 p<.01
PCC-A	62.36	(13.20)	61.70	(11.44)	66.88	(17.29)	V=8 p=.04
$**PCC-A**	78.22	(12.46)	66.89	(10.01)	71.32	(14.46)	V=86 p=.04
PCC-R	78.31	(9.64)	74.57	(12.04)	82.96	(7.53)	V=89 p=.02
$**PCC-R**	84.05	(8.34)	77.96	(10.51)	85.22	(6.69)	V=88 p=.02

4.2.2 PCC of speech sound classes

The PROPH segment included in CPro also informed about the percentage of correctly articulated representatives of each speech sound class. Speech analysis in CPro offered information on the correct realisation of stops, vibrants, nasals, fricatives, affricates, glides, liquids, clusters and cluster elements. Because of redundancy or lack of representatives in the data, the categories glides, cluster elements and vibrants were excluded from this analysis. There was only a total of four glides in the speech sample and all children managed to articulate them correctly at all ages tested. Cluster elements is a sub-category of clusters which was included in the analysis. There were no vibrants in the speech sample. In the following, results were presented with counting omissions as speech errors. All speech sound classes, liquids and clusters in particular, were affected by instances of omission ($). This observation held only true when omissions were included in the analysis.

Cohort Comparisons of percentage of speech sound classes correct between the group age 5 and 10 yielded highly significant (p<.01) results for all speech sound classes. CP±L children at 10 performed significantly better than at 5 in these measures (see figure 7). Furthermore, PCC analysis per speech sound class showed that CP±L performed better at producing certain speech sounds than others. The following performance pattern in descending order, which is also reflected in figure 7, became visible for both age groups 5 and 10: nasals, liquids, stops, fricatives, clusters, affricates. Pairwise statistical analysis of neighbouring categories of this performance pattern reached significance level for all pairings. One exception to this was found in the age 5 group. The difference between the neighbouring categories PCC fricatives and clusters was not significant (W=927, p=.69).

On average, fricatives (m=26.67 % (18.63 %)) improved the most from age 5 to age 10,

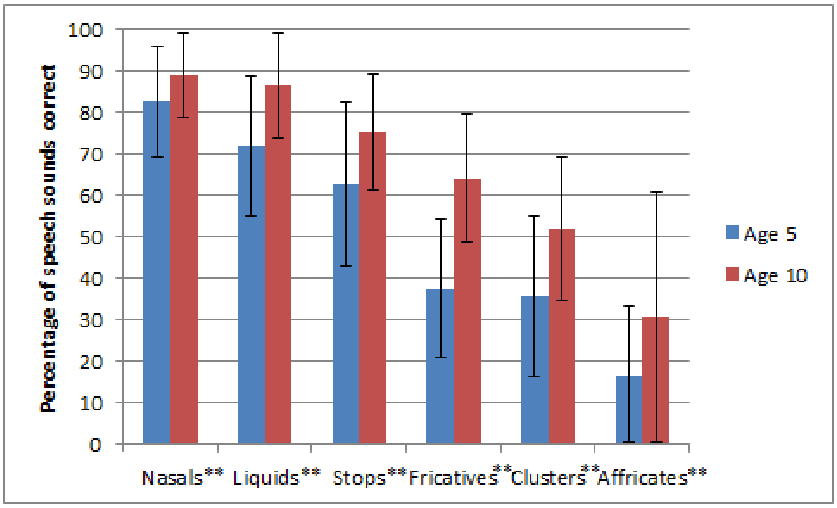

Figure 7: Mean percentage of speech sound classes correct at age 5 and 10 (**p<.01)

followed by improvement of PCC of affricates (m=21.50 % (27.11 %)). PCC measures of clusters increased by 16.29 % (24.96 %) and liquids by 14.41 % (18.39 %) on average from age 5 to 10. Compared to that, stops improved a little less from age 5 to 10 (m=12.64 % (20.11 %)). There was least improvement shown in the production of nasals (m=6.45 % (13.91 %)).

Sub-cohort Analysis of the sub-cohort with additional information on speech outcomes at 15 did not give such a clear picture of differences between the age groups across speech sound classes. CP±L children at 15 reached higher percentages correct for all speech sound classes than at 10 and 5. This pattern only reached significance for fricatives (V=10, p<.01) and affricates (V=0, p<.01) (see figure 8).

Regarding the performance pattern investigated above the sub-cohort, unsurprisingly, showed the same pattern of speech sound classes that reached higher PCC values than others across the age groups of 5 and 10. Not all of the pairwise comparisons between neighbouring speech sound categories in this pattern reached significance level.

At age 10, PCC values for nasals and liquids were not significantly different (W=112, p=.53). This held also true for stops and fricatives in this age group (W=74, p=.28). Interestingly, at age 15 the pattern deviated slightly from that observed for the other two age groups: Affricates reached higher PCC values than clusters, in contrast to the pattern found at age 5 and 10 (W=94.5, p=.88). Statistical analysis showed that observed differences between performances for the respective speech sound classes at age 15 did not reach significance level, except for higher PCC values for fricatives than for affricates

(W=46, p=.03).

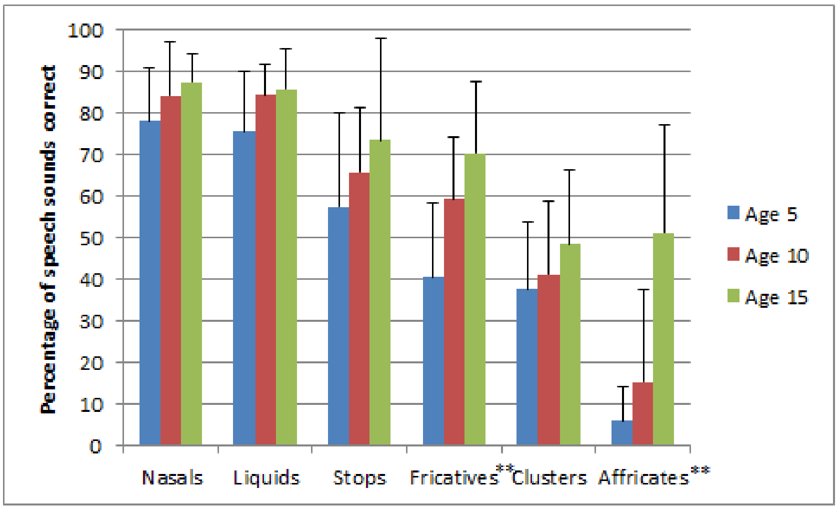

Figure 8: Mean percentage of speech sound classes correct at age 5, 10 and 15 (**p<.01

On average, PCC of affricates (m=35.9 % (24.4 %)) increased the most from age 10 to 15. Production of fricatives improved by 14.21 % (15.79 %) on average. Clusters (m=7.28 % (13.37 %)) and stops (m=4.61 % (19.32 %)) showed less high improvement rates. Nasals (m=3.26 % (13.14 %)) and liquids (m=0.73 % (11.62 %)) had the lowest numbers of mean improvement from age 10 to 15.

Summing up, CP±L children at age 5 and 10 differed significantly in all PCC measures analysed in the current study. All PCC measures increased from age 5 to 10. Both age groups show a performance pattern in their production of speech sounds. The speech sound classes reached higher PCC values in the descending order of nasals, liquids, stops, fricatives, clusters and affricates. At age 15, CP±L children showed improvement in all PCC measures compared to speech outcomes at 10. These differences reached significance level for all three PCC measures, as well as for the speech sound classes fricatives and affricates. The performance pattern of the speech sound classes was duplicated at age 15 with the exception of affricates showing a higher PCC than clusters.

4.3 Variance analysis

All dependent variables showed significance in MANOVA calculation of the cohort for the independent variable age. This reflected previous results on differences between the age groups 5 and 10 (see section 4.2). PCC-R and PCC-A depended by definition on

PCC. This is why additional MANOVA calculations on these measures were redundant. Only the variables cleft type, hearing issues at 10 and timing of PPS explained severity of speech impairment as main effects in some of the speech sound classes. There was no significant main effect for PCC (see table 12). Further investigations with PCC values not including omissions as speech errors did not add any gain to the analysis.

Table 12: Significant main effects for cohort MANOVA

PCC measure	Main effect	F	p
Stops	cleft type	4.99	.03
	hearing issues at 10	9.25	.01
Nasals	timing of PPS	4.20	.04

Table 13: Significant interactions for cohort MANOVA

PCC measure	Interaction	F	p
PCC	gender:cleft type	3.40	.046
	age:gender:timingPPS	6.22	.03
Stops	age:hearing10	6.20	.03
	age:dentition10	3.83	.04
	age:gender:timingPPS	16.13	$<.01$
Fricatives	gender:timingPPS	7.37	.02
Liquids	age:gender	6.06	.03
	age:hearing10	5.15	.04
	age:gender:timingPPS	6.73	.02
Clusters	age:gender:timingPPS	9.06	.01

There were considerably more significant interactions for the cohort MANOVA than significant main effects. Table 13 summarises these significant interactions which could be found in PCC, and the measures for correctly produced stops, fricatives, liquids, as well as clusters.

Due to the smaller number of participants in the sub-cohort the number of independent variables in MANOVA calculation was reduced to a maximum of four ($\sqrt{14} = 3.74$). The decision on which variables to include for the MANOVA on the data for 10 and 15 was based on previous results for each measure in the cohort.

None of the independent variables including age reached significance level for stops, clusters and liquids in the MANOVA for the sub-cohort. Reflecting the results from

paired comparisons with Wilcoxon signed-rank tests between speech performance of the age groups 10 and 15, the variable age reached significance level for affricates ($F(1)$=13.42, p<.01) and fricatives ($F(1)$=6.64, p=.03). For PCC ($F(1)$=4.57, p=.058) the variable age showed a tendency for significance.
Interaction of age and cleft type ($F(2)$=3.93, p=.046), interaction of age and timing of PPS ($F(2)$=4.09, p=.04), as well as interaction of cleft type and timing of PPS ($F(2)$=11.73, p<.01) reached significance level for nasals in the sub-cohort.

Post-hoc analysis of variance analysis Post-hoc analysis was performed via Tukey's Honestly Significant Difference (HSD) tests for MANOVAs of the cohort and the sub-cohort. Regarding the significant main effects identified in section 4.3 this test showed that differences in sub-groups of timing of PPS in the production of nasals did not reach significance level. Table 14 gives significant group differences following variance analysis for the main effects and interactions found in the cohort.

Table 14: Significant results of Tukey-test for age groups 5 and 10

PCC measure	Variable	Difference in %	p-value
	cleft		
Stops	uclp – cp	-10.79	.02
	hearing10		
Stops	y – n	-9.75	.04
	gender:cleft		
PCC	m:uclp – m:bclp	-20.89	.04
	age:gender		
Liquids	5:m – 10:f	-18.37	<.01
	10:m – 5:m	21.97	<.01
	age:dentition10		
Stops	5:n – 10:2	-25.37	.02
	5:n – 10:3	-23.99	.02
	10:n – 5:n	30.15	<.01
	age:hearing10		
Liquids	10:n – 5:n	12.35	.02
	5:y – 10:n	-23.11	.01
	10:y – 5:y	27.25	.02

PCC measure	Variable	Difference in %	p-value
Clusters	5:y – 10:n	-30.12	.04
	10:y – 5:y	36.84	.047
Stops	10:n – 5:n	13.45	.01
	5:y – 5:n	-17.74	.048
	5:y – 10:n	-31.20	<.01
	10:y – 5:y	29.43	.01
	age:gender:timingPPS		
Stops	10:m:11-13 – 5:f:<11	25.44	.04
	10:m:11-13 – 5:m:11-13	27.59	.04

The highest number of significant pairwise comparisons has been identified for stops. Both significant main effects explained severity of speech impairment in the measure for correctly produced stops. UCLP children performed less well than CP children in this parameter. Children with hearing issues at 10 showed lower PCC values for stops than children without hearing issues at 10. MANOVA calculation has shown that the interaction of dentition at 10 and age also explained variability in stops. 5-year old children without malocclusion at 10 performed less well in the production of stops than the same group at 10, and 10-year olds with malocclusion type III or II at 10.

Post-hoc analysis of variance analysis of the data for the sub-cohort only showed significant results for the speech sound class nasals. CP children with PPS timing before 11 months produced significant less correctly articulated nasals than the CP group with PPS performed between 11 and 13 months (d=33.21 %, $p<.01$) and BCLP children with this surgery performed before 11 months (d=26.14 %, $p=.03$).

Summary: Results Results of the current study have shown that phonological process usage decreased from age 5 to 10, and from age 10 to 15 when omissions were disregarded in the analysis. The most prominent phonological process at all ages was cluster reduction ($). Analysis of the proportional distribution of phonetic CPS characteristics revealed that palatalisation was the most prominent phonetic feature at age 5 and 10, while lowering was most prominent at age 15. Additional qualitative analysis of the different types of phonetic CPS characteristics showed that some of these features were restricted in their usage to specific speech sounds and others could be productive on almost all speech sounds with only few exceptions. This analysis could show that CPS characteristics that have been reported to have a preference for certain speech sounds can also appear on other phonemes. Backing, for instance, was not restricted to alveolars and velars but did also appear on bilabials or postalveolars.

Analysis of the combined proportional distribution of phonetic and phonological CPS characteristics showed that at all ages phonetic characteristics formed a significantly higher proportion of the CPS features. At age 10, the children in the cohort produced significantly less phonological substitutions but more distortions than at age 5. When omissions were disregarded in the analysis, only the decrease of the percentage of phonetic substitutions reached significance level at age 15. Regarding change in speech performance over the years from 5 to 15, CP±L children increased from age 5 to 10, and from 10 to 15 in all PCC measures. At age 5 and 10, children showed the following performance pattern in their production of speech sounds: Speech sound classes reached higher PCC values in the descending order of nasals, liquids, stops, fricatives, clusters and affricates. This performance pattern reappeared for the sub-cohort at age 15 with the exception of affricates showing a higher PCC than clusters. Variance analysis identified significant main effects for cleft type and hearing issues at 10 in explaining differences in the percentage of correctly produced stops, and for timing of PPS in explaining differences in the correct production of nasals in the cohort. Significant interactions with the variable age reflected previous findings about the improvement in performance from age 5, to 10 and 15.

5 Discussion

The current study of CPS was a longitudinal, retrospective analysis of phonetic and phonological characteristics in CP±L children from age 5 to 15. First, this dissertation aimed at describing the nature and extent of CPS characteristics with help of categorisations of CPS phenomena already established in the literature (e. g. Henningsson et al., 2008; Trost, 1981; Harding & Grunwell, 1996, 1998; Sell et al., 1999). Automatic analysis with CPro of the narrow transcripts of the data used in the current study allowed for reliable profiles of phonetic and phonological characteristics produced by every child. Second, comparative analysis of speech outcomes at different ages revealed whether speech performance of CP±L children changed throughout the ages 5 to 15. Finally, characteristics of CP±L children taken from their patient data were used as independent variables in multivariate variance analysis to potentially explain variability in speech performances.

5.1 Nature and extent of CPS characteristics

As expected, typical phonetic as well as phonological characteristics of CPS have been identified in the data analysed in this dissertation. Grouping the phonetic and phonological characteristics in categories of the same value, as executed in section 4.1, allowed for an assessment of the overall proportional extent of articulation features. This analysis has shown that phonetic characteristics made up the majority of all CPS characteristics at all ages 5, 10 and 15. This was even more imminent when omission were not counted as phonological processes. This result was to be expected based on previous findings on the phonological development of CP±L children (Chapman, 1993) and phonetic characteristics of CPS in different age groups (Persson, Elander et al., 2002).
With regard to significant differences between the age groups of the cohort, 10-year old CP±L children produced a significantly smaller percentage of phonological substitutions and a higher proportion of distortions than they did 5 years earlier. While phonological process usage of substitutions was significantly fading from age 5 onwards, those speech sounds that were now no longer substituted became vulnerable to cleft-related phonetic deviations, such as distortions. This meant that cleft-related errors prevailed in CPS at an age when phonological processes were fading.
These findings showed that recordings of children younger than age 5 were to be preferred for an analysis of CPS with a strong focus on phonological features. This also became apparent in light of the fact that most phonological processes were fading by the age of 5 in typical speakers (Grunwell, 1987; Smit et al., 1990). Most previous studies with a focus on the phonological development of CP±L children included recordings of 3-year old children in their cohort (e. g. Morris & Ozanne, 2003; Chapman, 1993; Chapman et al., 2008). If cleft ST was to strengthen its focus on phonological development, CAPS-A should be included in the regular 3 year audit form which is standard for CL±P children treated in Scotland (NHS, 2013). This additional data could then be analysed in retrospective studies and add valuable insight into the nature of the phonological development of CL±P children, especially since a number of previous studies has found differences in phonological development between cleft and non-cleft children (Estrem & Broen, 1989; Scherer, Williams & Proctor-Williams, 2008).
Depending on whether omissions were included in the analysis, results for the sub-cohort differed dramatically in the proportional distribution of CPS characteristics. When

omissions were not included proportions of phonetic and phonological characteristics stayed relatively similar over the years from age 5 to 15. Including omissions into the analysis led to an surprising increase of phonological processes at age 15, possibly due to the fact that these phonological processes are difficult to clearly separate from deletions in connected speech. It was also worth noticing that variance in these proportional distributions of different types of CPS characteristics increased with growing age. This finding could be indicative of increasing variability between CL±P children as they mature.

5.1.1 Phonological characteristics

This dissertation could confirm previous findings on the occurrence of common phonological processes in CP±L children (Chapman, 1993; Hodson et al., 1983). Due to the fact that phonological process usage of CP±L children was only rarely analysed in 5-year olds and older children (see section 2.3) the number of comparative studies for the following discussion was restricted.

Comparison to CPS studies Based on McReynolds and Elbert (1981) phonological processes were treated as productive in the current study when they showed at least 20 % process usage. Out of all phonological processes, only cluster reduction reached this minimum at all ages in the current study. In contrast, Chapman (1993) found liquid simplification (m=28.89 % (24.14 %)) to be the only process with at least 20 % process usage in 5-year old CP±L children, whereas cluster simplification reached 8.18 % (11.51 %) process usage on average in 5-year olds. The PROPH segment did not include the analysis of liquid simplification which was why comparative results were not available. In their study on CPS of 3-year olds Morris and Ozanne (2003) also found cluster reduction to be the most numerous process. Since cluster reduction is a subcategory of omissions, these findings depended on including these phonological processes in the data analysis.
Final consonant deletion ($) was used more than 10 % of all possible cases at age 5 in the cohort. Other phonological processes used in more than 10 % of all possible cases at age 5 were liquid deletion ($) and later stopping. There was no information available on comparative data for both of these processes due to differences in definitions. Findings by Morris and Ozanne (2003) confirmed high numbers for final consonant deletion above 10 % process usage at age 3. Chapman (1993) reported less frequent mean usage of this process at age 5 (m=3.24 % (5.66 %)). These findings for cluster reduction and final consonant deletion suggested that the children analysed in the current study behaved

more like 3-year old CP±L children regarding these two phonological processes. However, additional analysis of the PCC scores, in particular of PCC-R, showed that 5-year old CP±L children were not delayed in their speech development (see section 5.2.
Other phonological processes that decreased significantly from age 5 to 10 were velar fronting, palatal fronting and nasal assimilation. These processes were below 5 % process usage at the age of 5 and only rarely used (below 1 % process usage) at the age of 10. Nasal assimilation was reported with more than 10 % process usage in CP±L children with delayed expressive language skills at the age of 3 (Morris & Ozanne, 2003), while Chapman (1993) did not analyse nasal assimilation in her 5-year old cleft group.
Since this thesis did not control for expressive language skills, residual errors of the type nasal assimilation at age 5 could hint at a certain variability of language development in the group under investigation. Whether a CP±L child shows normal or delayed language development should thus be considered in the analysis of speech outcomes.

Comparison to normal phonological development According to Grunwell (1987) cluster reduction ($) should be in decline from 3;5 to the age 4. Lowe (2000) concluded that most children with NSA have overcome cluster reduction by the age of 6. Neither of those time points accounted for the high number of cluster reduction in CP±L children at the age of 10 or 15 in the cohort when omissions are included in the analysis.
With regard to reference data for NSA children, liquid deletion ($) and later stopping were variable at age 5. Final consonant deletion ($), on the other hand, should have been overcome by the age of 3;3 (Grunwell, 1987). Elision of a final consonant might not have been necessarily due to phonological processes. It could be assumed that final consonants were also elided due to insufficient intraoral pressure which would then classify as a phonetic CPS deviation (see section 2.3). Another possible explanation for the high number of final consonant deletions beyond normal age of process usage was that the transcriber might have failed to identify final consonants in some instances due to the relatively high noise level in some of the recordings.
Palatal fronting was variable from age 3;6 to 4;3, velar fronting should have been overcome by age 3;3, and nasal assimilation by age 3;0 (Grunwell, 1987). As these processes are below 5 % process usage at the age of 5 they could be interpreted as exceptional instances. Significant decrease of these processes from age 5 to 10 showed that this exceptional usage was not persistent until adolescence.

Findings about the extent and nature of the phonological features of CPS in this dissertation have stressed even more so that it would be advisable to use recordings of children younger than age 5 to investigate the nature of the phonological development of CP±L children (see above section 5.1).

5.1.2 Phonetic characteristics

As expected, phonetic CPS characteristics were prevalent in 5 and 10-year old children in the current study and persisted in some adolescents until the age of 15. This thesis has analysed proportional distribution of phonetic characteristics. This should be kept in mind while comparing its outcomes to studies which mostly rely on perceptual ratings of process usage (e. g. Persson, Lohmander & Elander, 2006; Karnell & Demark, 1986; Kirschner et al., 2000).

Palatalisation Palatalisation was one of the most prominent phonetic CPS deviations at age 5, 10 and 15 which has been shown to potentially affect all speech sounds except /w, m, r/. From age 10 to 15 the proportion of palatalisation of the overall phonetic CPS characteristics decreased without reaching significance level. Palatalisation was interpreted as an example of retraction (Henningsson et al., 2008). In her EPG experiments Gibbon (2004) has found that palatalisation was not restricted to the posterior region of the palate. Perceptually judged instances of palatalisation in CPS were often realisations of the target sound with increased tongue-palate contact involving the entire palate including alveolar ridge and the posterior region of the palate (Gibbon, 2004). According to the CAPS-A high frequency of palatalisation did not suggest that surgical interventions are necessary (John et al., 2006). Since it did not belong to the severe CPS characteristics that could indicate velopharyngeal surgery, high proportional percentages of palatalisation in this cohort were not of mayor concern. It is, however, worrying because palatalisation can be related to palatal fistula which may need surgical repair.

Lowering The proportion of lowering of the overall phonetic CPS characteristics increased from 5 to 10 and from 10 to 15. The difference in this measure between age groups 5 and 10 was significant. While other more severe CPS features decreased in their proportional distribution throughout the years, this less severe feature increased. This indicated that PCC measures were not alone in showing improvement in speech outcomes over the years but also the analysis of the proportional distribution of phonetic CPS features could uncover improving speech.

Besides that, lowering of pressure consonants did not necessarily need to be due to cleft-related issues. In connected speech, gestural weakening which is an undershoot of an articulatory target gesture in the sense of Lindblom (1963) was very common and increases with speaking rate (Barry, 1992; Byrd & Tan, 1996). Considering that CP±L speakers showed less cleft-related speech deviations with maturation (see section 5.2) the high mean proportion of lowering at age 15 (m=32.85 % (28.58 %)) could be explained by under-shoot. The high standard deviation of this measure showed that CP±L adolescents at 15 were highly variable in using this strategy to reduce articulatory effort.

Weakening Weakening of pressure consonants was related to VPI and insufficient intraoral pressure in CP±L speakers (Harding & Grunwell, 1998; Trost, 1981). This is why at high frequency, it was one of the CTCs that could indicate possible surgical interventions (John et al., 2006). Weakening increased significantly in the overall proportion of phonetic CPS characteristics from age 5 to 10. In contrast, other studies on CPS have found weakened pressure consonants only to persist in CP±L children until the age of 10 who were diagnosed with VPI at 5 years of age. Persson, Lohmander and Elander (2006) reported decrease in this measure from age 5 (moderately to severely reduced pressure) to age 10 (mildly reduced pressure). Thus, the fact that weakening prevailed in all age groups in the current study could not necessarily be traced back to cleft-related issues alone.
Similar to lowering of pressure consonants, weakening could be explained by gestural reduction. Van Son and Pols (1995) have found that consonant reduction in spontaneous speech is related to less articulatory effort. Lowering and weakening of pressure consonants could thus also be explained by gestural reduction and were not necessarily exclusively related to cleft-related issues. This could explain why the proportion of these phonetic characteristics increased significantly from 5 to 10, while other phonetic CPS features which could clearly be related to structural cleft issues decreased significantly in their proportional distribution during the same period.

Nasal air flow The proportions of nasal emission, nasal turbulence and nasal fricative of the overall phonetic CPS characteristics decreased significantly from age 5 to 10. Further significant decrease in proportional distribution has been identified for nasal emission from 10 to 15. Nasal emission and nasal turbulence were both subsumed under the heading of nasal airflow in the CAPS-A. Frequent usage, i. e. more than 10 % of the pressure consonants in the sample were affected, could lead to possible surgical

intervention strategies. In accord with Harding and Grunwell (1998) nasal fricatives were divided into active and passive nasal fricatives in the CAPS-A form[27]. If used frequently, they could also suggest further surgical interventions (John et al., 2006). Since neither nasal emission, nasal turbulence nor nasal fricatives have been associated with allophonic variation in normal speech they were clear indicators of CPS characteristics and the severity of these characteristics in children's speech outcomes. Significant proportional decrease of these measures thus indicated that CP±L children showed less clearly cleft-related issues in their speech at 10 than at 15.
Nasal emission has been found to occur more often in CPh children than in CPs children (Persson, Elander et al., 2002) which means that this phonetic characteristic was not only a clear indicator of CPS but also of the cleft type. Variance analysis for the proportional usage of nasal emission with the same model as in section 4.3 suggested that this finding also held true for the cohort analysed here. Although one should keep in mind that not process usage but proportional distribution of phonetic CPS features was analysed. Nasal emission made up a lower percentage of the overall phonetic characteristics in UCLP (d=12.30 %, p=.02) and CP groups (d=10.54 %, p=.047) than in BCLP children.

Backing In this dissertation, backing decreased significantly from 5 to 10 in its proportional distribution. Further decrease could be noted in the sub-cohort from age 10 to 15. In accord with Russell and Grunwell (1993) backing was interpreted as a phonetic CPS characteristic and not as an atypical phonological process. If a CP±L child was backing speech sounds to velar or uvular position frequently, this could lead to considering surgical interventions (John et al., 2006). Usually, backing has been mainly associated with alveolar or velar speech sounds (Harding & Grunwell, 1996). In the current study, analysis of speech outcomes of CP±L children has identified a broad range of speech sounds that could possibly be affected by this characteristic. All speech sounds but /g/ have been found to be potentially affected by backing. This also included speech sounds that were not thought to be particularly vulnerable in CPS, such as nasals.
Persson, Lohmander and Elander (2006) subsumed palatalisation and backing under the heading of retracted articulation. In the CP children analysed in their study there were no instances of retraction after the age of 3. Comparative analysis of the cleft groups from the current study showed that the proportional distribution of backing in CP children was in fact significantly smaller than in BCLP children (d=13.96 %, p<.01). This is why lack of retraction in Persson, Lohmander and Elander (2006) after the age of

27For reasons explained earlier this convention was not executed here (see section 2).

3 could be related to the cleft type investigated in their study.

Summing up, phonetic CPS characteristics in CP±L children which can also be due to gestural reduction, such as lowering and weakening of pressure consonants, increased significantly in their proportional distribution as they grew older, while other phonetic characteristics that are not found in normal speech, such as nasal airflow and backing, decreased in their proportion of phonetic CPS deviations. This phenomenon showed that CP±L children improved in their speech outcomes with maturation. When auditing CP±L children at age 10 or 15, it would be best not to interpret weakening of pressure consonants as a possible indicator for further surgical interventions, unless weakening appeared alongside other frequently used, clear indicators of VPI.

5.2 Changes in speech performance

This dissertation could confirm previous findings on the improvement of speech outcomes of children with repaired CP±L with maturation (Persson, Lohmander & Elander, 2006; Karnell & Demark, 1986; Van Demark & Morris, 1983; Pulkkinen et al., 2001).

5.2.1 Percentage of Consonants Correct

As expected, all PCC measures indicated significant improvement of speech performance from age 5 to 10 and from 10 to 15, regardless of whether omissions were included in data analysis. To the author's knowledge, four studies have used PCC measures to describe CPS. All of them investigated speech of 3-year old CP±L children (Morris & Ozanne, 2003; Willadsen, 2012; Raud Westberg, 2013; Chapman et al., 2008). Results of the analysis disregarding omissions could not be compared to previous studies because they based their analysis on the full set of phonological and phonetic characteristics. This is why these results were not discussed in this section.
The PCC scores for the age 5 group in the current study for total PCC (m=59.02 % (13.46 %)) and PCC-A (60.28 % (13.28 %)) were below those found in the 3-year old normally developed children (PCC=67.5 %) (Morris & Ozanne, 2003), the 3-year olds with recommended palatal repair at around 11 months (Chapman et al., 2008) (PCC=61.43 %), and the 3-year old UCLP group (PCC-A=68 %) (Raud Westberg, 2013).
Based on the fact that children improved in these measures with maturation (Austin & Shriberg, 1996) these lower scores in the age 5 group in the current study were unexpected. However, these results could also be due to differences in participant grouping and/or

data collection. Both methods of data acquisition in Raud Westberg (2013) and Morris and Ozanne (2003) were different from that used in this thesis. Morris and Ozanne (2003) used a spontaneous sample of 100 words as their data, while Raud Westberg (2013) analysed isolated target words which were either spontaneously uttered or imitated in a picture naming test. This dissertation did not focus on one cleft type in particular, as Raud Westberg (2013) did, nor did it control for expressive language skills as in Morris and Ozanne (2003). It also did not group its participants according to timing of PPS as done in Chapman et al. (2008).
In her study on timing of two-stage PPS Willadsen (2012) found that 3-year old CP±L children with hard palatal closure at around 12 months produced 82 % of all consonants correctly. In the same study, 3-year old CP±L children with hard palatal closure at around 36 months of age only showed a PCC score of 32 %. All 3-year olds were tested with a single word naming test in Willadsen's (2012) study. There was only one child in the cohort with two-stage PPS which was why this variable was not included in variance analysis. Willadsen's (2012) group of 3-year old children with early hard palate closure performed better in PCC than the normally developed 3-year olds in Morris and Ozanne (2003), the age-matched group with similar timing of PPS in Chapman et al. (2008) and the 5-year old CP±L children analysed in the current study which was probably due to the different levels of demand in speech elicitation.

Analysing CAPS-A data of CP±L children from the age of 5 to 15 with PCC measures has thus shown that these children continuously improve in their speech outcomes. This included phonetic as well as phonological characteristics of their speech. Unfortunately, PCC measures have been rarely used in CP±L studies, probably because they are based on demanding subphonemic transcription of connected, preferably spontaneous, speech.

Comparison to NSA reference data In order to further assess speech performance and improvement of CP±L children the results of the current study for the PCC measures were compared to reference data of children with normal speech acquisition (NSA) and children with speech delay (SD) found in Austin and Shriberg (1996). Due to lack of the entire data set of the reference data, the following comparative analysis could only be descriptive.
On average, CP±L children at the age of 5 performed poorer in all PCC categories than their age-matched NSA group (age 5;0 – 5;11). However, CP±L children at age 5 did not automatically qualify as having SD since they scored higher in mean PCC-R than

the NSA children. PCC-R was indicative of phonemic mastery and delayed phonological development (Shriberg, Lewis et al., 1997). As for all other PCC measures in the age 5 SD group, age-matched CP±L also showed poorer performance.
The group of the 10-year old CP±L children was compared to the reference group aged 9 to 11;11, and the 15-year old CP±L children was compared to the reference group at age 12 to 17;11. Both reference groups informed about the speech performance of NSA and RE children group RE-1 (see section 2.3). CP±L children at the ages of 10 and 15 scored lower in all PCC measures than their age-matched NSA and RE groups. This observations highlighted the need for a long-term approach in the ST treatment of CP±L children. It also justified why CP±L patients were assessed with the CAPS-A tool as 15-year old teenagers and referred to additional ST treatment, if deemed appropriate at this age.
CP±L children improved in their speech performance from 5 to 10 and from 10 to 15 more than their age-matched normally developed speakers. From age 5 to 10 NSA children showed a little less improvement in the three PCC measures (3.6 – 10.8 %) than CP±L children (5.77 % – 13.62 %) from age 5 to 10. Children with SD, on the other hand, showed vast improvement in PCC measures (11.6 % – 70.8 %) from age 5 to 10 which surpassed the improvement of the CP±L children in that same age range (5.77 % – 13.62 %). From age 10 to 15 CP±L children improved (5.18 % – 8.39 %), whereas the age-matched NSA children (0.4 % – 2.3 %) and RE children (0.1 % – 1.4 %) hardly improved.

Observations regarding the range of improvement from age 5 to 15 have shown that CP±L children neither behaved like children with NSA nor with SD. Furthermore, observations regarding differences in PCC scores from 5 to 15 between CP±L children and NSA or SD/RE children have shown that it is vital to monitor CP±L children until they reach adolescence. However, methods of eliciting CP±L children's speech at age 15 in the CAPS-A tool should be revised to assess this age group age-appropriately. Controlled elicitation of spontaneous speech could add to the open "Wh-questions" of the first part of the CAPS-A because in most cases children's answers were not readily intelligible for the transcriber (see section 3.2). This methodological approach could also be used for younger children if presented as a game. For instance, children could be asked to give directions on a map, describe pictures or geometrical shapes (Swerts & Collier, 1992).

5.2.2 PCC of speech sound classes

Since PCC improved significantly from age 5 to 10 and from 10 to 15 it was only to be expected that all PCC measures for the respective speech sound classes that comprised PCC improved as well from 5 to 15. Improvement from 5 to 10 was significant for all speech sound classes, while from age 10 to 15 it was only significant for fricatives and affricates. Throughout the years 5 and 10 the performance pattern of speech sound classes was consistent. The composition of this pattern was due to a combination of possible reasons, such as normal phonemic acquisition, cleft-related structural issues, as well as typical characteristics of CPS.

Although qualitative analysis showed that nasals were affected by almost all phonetic CPS characteristics they still reached the highest values in PCC. The production of nasals was not negatively affected by structural cleft-related issues since it required an open velopharyngeal port and CP±L children were at risk of having VPI. Since CP±L children reportedly faced issues producing consonants that require high intra-oral pressure (see section 2.3) the low pressure liquids (/l, r/) scored the second highest PCC at 5, 10 and 15. The other four speech sound classes, stops, fricatives, clusters and affricates, all contained high pressure consonants which made them more difficult to produce for children with repaired CP±L.

The descending order for the PCC measures stops, fricatives, clusters and affricates reflected, to a certain extent, the order in which these sounds were acquired (Dodd, Holm, Hua & Crosbie, 2003). Dodd et al. (2003) found that stops become part of the phonetic system of British English-speaking children between ages 3 and 3;5, as do fricatives /f, v, s, z, h/. In their sample, affricate /tʃ/ was acquired at around 4 years of age, while /dʒ/ followed a little later at 4;5 years of age. Acquisition of speech sounds cannot be regarded as a process that includes all speech sounds of one class at the same time because it highly depends on place of articulation. This is why dental fricatives were not acquired until the age of 7;0 and above (Dodd et al., 2003). This distinction could not be made in the analysis of PCC per speech sound class.

Bearing in mind that CP±L children produced a significantly higher proportion of phonetic deviations than phonological characteristics in CPS severely low (<50 %) PCC mean values for fricatives, clusters and affricates at age 5 and moderate-severe mean PCC for the same sound classes at age 10 (50 – 65 %) (Shriberg & Kwiatkowski, 1982) were mainly due to phonetic error types. Furthermore, poor performance in the production of clusters was also reflected in the analysis of phonological process usage with cluster reduction as the most prominent process at all ages. Affricates could be affected by several phonological processes, amongst those was later stopping which CPro counted on /v, z, ð, ʒ, tʃ, dʒ/. This process was one of the few which showed a high process usage of around 10 % at age 5 and 10. However, relating low PCC measures in affricates to this phonological process should better be done with caution considering that this process did not exclusively affect affricates.

Performance pattern The performance pattern observed in the age groups 5 and 10 was prevalent at age 15, with the exception of affricates reaching a higher PCC score than clusters. This finding could be related to the investigation of phonological processes. Cluster reduction increased from age 10 to age 15. Although this difference did not reach significance level, it could add to the finding that the performance pattern at age 15 was not consistent with that found 5 or 10 years earlier. One could argue that it is questionable whether performance patterns of speech sounds are to be expected in a teenage speaker at all since all speech sounds should be acquired by the age of 15 (Dodd et al., 2003). However, CP±L speakers did not show the same speech performance as their age-matched NSA groups in PCC measures, as explained above. This was also reflected in severely low PCC measures for clusters (<50 %) and moderate-severe scores for affricates (50 – 65 %) at age 15, as well as the fact that the overall performance pattern at this age was similar to that at age 5 and 10.
CP±L children at the age of 3 showed almost the identical performance pattern that was found in the current study for 5- and 10-year olds (Morris & Ozanne, 2003; Chapman et al., 2008). Both studies described PCC measures in the descending order of glides, nasals, plosives, fricatives, liquids/affricates and clusters. This pattern deviated with regard to the poor performance of liquids which could not be reported in the cohort analysed in this thesis. This deviation was possibly due to the fact that liquid /l/ is established as a phoneme in all word positions between the ages of 5 and 7 (Smit et al., 1990), and SSE /r/ is established after the age of 6 (Anthony, Bogle, Ingram & McIsaac, 1971). Since phonemic acquisition was not established at age 3, these speech sounds were ranked lower in the overall performance pattern found in the recordings of 3-year olds in Morris and Ozanne (2003) and Chapman et al. (2008), whereas in the current study liquid /l/ was already phonetically established at age 5, and the sonorant quality of both liquids added to the likelihood of correct production of these speech sounds in CP±L children.

5.3 Covariates of CPS characteristics

One of the main objectives of this dissertation was to identify possible factors that explain the speech performance of CP±L children at the ages of 5, 10 and 15. MANOVA of the PCC measures and six potential factors has yielded significant results for some of the PCC measures in the cohort and only few in the sub-cohort. There were only significant main effects for cleft type and hearing issues at 10 for PCC stops and for timing of PPS on the performance of nasals in the cohort. Besides that, mainly significant interactions have been found in MANOVA calculations which implied that sets of conditions are more likely to explain variability in the PCC measures than single conditions. Any significant interaction with the variable age reflected to a certain extent previous findings about the different performance of the age groups 5, 10 and 15. Any significant finding of the MANOVA which did not include age showed that variability was explained in CPS speech beyond the different age groups.

Cleft type Cleft type as a main effect explained severity in speech impairment of stops. UCLP children as a group scored significantly lower in the production of PCC stops than CP children. In addition, the interaction of cleft type and gender explained severity in speech impairment in the overall PCC. UCLP boys showed significantly poorer performance in PCC than BCLP boys. These findings suggested that the severity of the cleft had a significant influence on speech performance which was in agreement with Lynch et al. (1983), Persson, Elander et al. (2002) and Raud Westberg (2013).
Other findings disagreed with this view. In a study on CP and UCLP children Pulkkinen et al. (2001) found that neither gender nor cleft type explained the distribution of VPI characteristics. Such findings explained why it was common practice in some studies to disregard differences in cleft type and treat all CP±L children as an homogeneous cleft group (e. g. Chapman, 1993). While in the current study UCLP children performed significantly poorer in the production of stops than CP children who were considered to have a less severe cleft type (see section 1), there was no significant finding for the difference between BCLP and UCLP children. This result suggested that there was no direct correlation between the severity of the cleft and the severity of the speech impairment.
Taking all findings regarding this issue into consideration, it is recommended to control for cleft type in future research since in this dissertation interaction of gender and cleft type explained variability in PCC which was the main speech outcome measure for phonetic and phonological features in CPS.

Hearing issues at 10 Hearing issues at the age of 10 also reached significance level as a main effect in the MANOVA for variability in PCC stops. The majority of the children with hearing issues at age 10 (80 %) already showed hearing issues at the age of 5 which meant that these children had chronic or recurring issues related to their hearing (see section 3.1). The current study has shown that if hearing issues persisted until the age of 10 in CP±L children, these children produced significantly fewer stops correctly than CP±L children without persistent hearing issues at this age.
In addition, the interaction of age and hearing issues at 10 explained severity of speech impairment in stops, clusters and liquids. Especially children at the age of 5 who showed persistent hearing issues at the age of 10 were vulnerable to perform poorly in the production of these speech sounds. They produced a significantly lower number of correct stops, liquids and clusters than both 10 year-old groups with and without hearing issues at 10. At the age of 5, children with persistent hearing issues at 10 could already be distinguished from their peers of the same age without later hearing issues at 10 in their poorer production of stops.
It could be assumed that mainly difficulties in the perception of voiceless plosives and clusters with voiceless consonants in the sample, such as /skr, stj, ms, st, ts/, have led to difficulties in the production of these speech sounds and low scores for children with hearing issues at 10. This was due to the fact that voiced speech sounds were less likely to be affected by hearing issues (Mody et al., 1999). Listener's identification of the correct voiceless plosive rely mainly on the acoustic properties of their bursts (Halle, Hughes & Radley, 1957). The acoustics of plosive bursts are similar to those of fricatives. It was, therefore, surprising that hearing issues at 10 did not explain variability in these speech sounds as well. As seen above, fricatives formed parts of the voiceless clusters used in the samples. Also, the correct production of liquids /l, r/ should not really be affected by hearing issues of any kind since they are sonorant.
In summary, these findings for the covariate hearing issues at 10 were inconclusive since they reflected only to some extent which speech sounds are usually most affected by hearing related issues (Mody et al., 1999). One should keep in mind, however, that the variable hearing issues at 10 was only defined by the simple factor levels existent and non-existent. There was lack of information on the nature and extent of the hearing issue, on possible hearing aids, on who analysed children's hearing status and with which method. Findings for this variable should therefore be treated with caution.

Timing of PPS As a main effect timing of PPS reached significance level in the production of nasals in the cohort. However, there was no significant difference between sub-groups of timing of PPS in the production of nasals. Higher PCC scores in CP±L children with PPS performed between months 11 and 13 than for children with PPS after 13 months of age only showed a tendency for significance (d=20.08 %, p=.09). This finding should be interpreted with caution since there was only one child with PPS performed after 13 months of age in the cohort. It did, however, suggest that timing of PPS between 11 and 13 months of age was to be preferred over later timing, as advocated by the authors Chapman et al. (2008), Hardin-Jones and Jones (2005) and Dorf and Curtin (1982).
Results of the MANOVA of the sub-cohort showed that timing of PPS interacted with cleft type in explaining severity of speech outcomes in nasals. CP children with PPS before 11 months performed poorer in the production of nasals than their reference group with PPS between 11 and 13 months and BCLP children with PPS before 11 months of age. This means that the most preferable timing of PPS could not be generalised for all cleft types. For CP children, repair of the palate between the age of 11 and 13 months was to be preferred over earlier repair with regard to the correct production of nasals, while for the other two cleft groups timing of PPS did not have a significant influence on the production of this speech sound class.
It was not quite clear why timing of PPS explained the severity of speech impairment in PCC nasals of all measures calculated here. As explained before and shown in the current study, nasals were not particularly vulnerable speech sounds in CPS. In their study Chapman et al. (2008) also found significantly higher scores for correctly produced nasals (and liquids) in CP±L children with early PPS around 11 months of age than in children with late PPS around 15 months, while they did not show significant differences in PCCs of pressure consonants nor in PCC total. Unfortunately, Chapman et al. (2008) did not offer an explanation for this finding. Their finding could, however, at any rate support the findings for the covariate timing of PPS in the current study and rule out a possible false positive result.
Further significant findings in the post-hoc analysis for the interaction of timing of PPS with age and gender for the production of clusters or stops only reflected the differences between the age groups 5 and 10 because there were no significant differences between boys and girls with different timing of PPS within the age groups.

Summing up, results of the current study seemed to be in alignment with previous studies with respect to favourable speech outcomes when PPS was performed between 11 and 13 months. Furthermore, based on results of post-hoc analysis general recommendations for timing of PPS for all cleft groups should not be made.

Gender Gender did not reach significance level for the PCC measures as a main effect but in interaction with other variables. The interaction of gender and age indicated that 5-year old boys performed significantly poorer than both girls and boys at age 10 in the production of liquids, while 5-year old girls did not share the same finding. They did not produce significantly less correct liquids at age 5 than the 10-year old groups. Post-hoc analysis furthermore indicated that there was a tendency for 5-year old girls to produce a significantly higher number of correct liquids than boys at age 5 (d=12.57, p=.08). This analysis suggested that the correct production of liquids was particularly vulnerable in 5-year old CP±L boys, regardless of their cleft type.

The majority of the studies on CPS aimed for equal numbers of boys and girls as their participants in order to have a balanced dataset. Furthermore, gender has proved to have an influence on age of phonemic acquisition (Smit et al., 1990). According to Smit et al. (1990) girls acquired phoneme /l/[28] one year before boys did, in initial word position (age 5) as well as final word position (age 6). Furthermore, there was no other phoneme according to (Smit et al., 1990) which differentiated boys and girls at the age of 5 than liquid /l/. These findings on differences in phonemic acquisition for boys and girls could explain why the covariate gender explained severity of speech impairment in liquids.

Dentition at 10 Occlusion type at the age of 10 did not explain variability as a main effect in the PCC measures. In interaction with age the variable dentition at 10 reached significance level for stops. Post-hoc analysis showed that CP±L children at the age of 5 with normal occlusion performed poorer at the production of stops than the same group at 10 and the 10-year old groups with malocclusion type II and III.

Bilabial speech sounds, including stops /b, p/, were at risk to be realised as approximants, i. e. they would be analysed as being lowered, in CP±L children with class II malocclusion (Moller, 1994). This fact could account for the finding that severity of speech impairment of stops was explained by occlusion type at 10. Besides that, (alveolar) fricatives would normally be expected to be the most vulnerable speech sound class to deviations in dentition (see section 2.2). Here, again, findings of the MANOVA were inconclusive regarding affected speech sound classes.

28SSE /r/ was acquired after the age of 6 in both genders (Anthony et al., 1971).

5.4 Implications for clinical practice and future research

Results of this study could inform clinical practice and give methodological recommendations for future investigations. CAPS-A was designed to mainly inform cleft SLTs about phonetic CPS characteristics. In order to analyse phonological CPS characteristics one would have to include phonological assessments based on word lists in the audit sessions. Thus, there would be no connected speech processes in the material that tests phonological development. Since this dissertation has found that there were only few traces of phonological processes in CP±L children at the age of 5, CAPS-A data should also be collected at the age of 3. This additional data would allow SLTs and ST research to focus on the phonological development of CP±L children.

SLTs need to be aware of different registers and associated speaking styles when assessing CPS. Neither coarticulation nor gestural reduction of consonants in CP±L speakers should be misinterpreted as cleft related speech errors. Thus, it is advisable to include different speech tasks in regular audit sessions, such as controlled elicitation of spontaneous speech or item naming tests in phonological development assessments. Speech tasks which elicit spontaneous speech would also be demanding enough for 15-year old speakers who might not feel challenged enough in the current set up of CAPS-A. Naturally, there is a trade-off in the choice of speech task between being age-appropriate for the participants and comparability across ages.

Phonetic characteristics of speech sounds rely heavily on the phonetic context of the respective speech sound (Laver, 1994). Unfortunately, phonetic context was not controlled because it was beyond the scope of this thesis. In future research, additional information on phonetic context could help differentiate coarticulation processes from typical CPS characteristics. In addition, this analysis, especially based on a sample of spontaneous speech, could investigate whether CP±L children make use of the same coarticulation strategies to reduce articulatory effort as their age-matched non-cleft peers.

5.5 Limits and future outlook

The limits of this dissertation lay within the nature of the data and the analysis tool. The GOS.SP.ASS. sentences were not designed for phonological analysis but for detailed phonetic analysis of CPS. Due to connected speech processes in all age groups investigated in the current study it was not possible to tease apart reduction processes and phonological processes, especially omissions, conclusively. Furthermore, PROPH tool was designed to assess phonological development based on word lists, and the tool could not differentiate

between phonological processes (omission and substitution) and instances of coarticulation (elision and assimilation). Therefore, results were also presented without including omissions, i. e. cluster reductions, liquid deletions and final consonant deletions.
Another difficulty in the data analysis lay within the fact that narrow transcription conducted in the current study was based on imitated sentences of children with repaired CP±L. The target sentences were known to the transcriber. This particular setting could lie ground for the phonemic restoration effect, i. e. although certain speech sounds were not articulated the transcriber might have restored them based on her language skills and her knowledge of the target sentences (Warren, 1970).
There was another drawback in the nature of the data acquired in CAPS-A. The test sentences had to be imitated since children at the age of 5 have not gained literacy yet. In order to keep the test conditions stable the audit sentences were also repeated at the ages of 10 and 15. This could result in unconscious imitation of the therapist's speech.
Lost patient data led to the reduction of the cohort and to the exclusion of the potentially informative variable type of PPS. In addition, the patient data was, in parts, imprecise which might have led to the inconclusive findings in the variance analysis mentioned above. Unfortunately, the noise level of the recordings was relatively high due to the fact that the internal microphone of the video camera was used for recording. For future recordings, it is advised to make use of an external, directed microphone which would allow for high quality recordings.
The database at the Dental Hospital in Glasgow is growing steadily. There is a wealth of information in this database and in similar ones in cleft care centres across Scotland and the UK. Further research could aim at a cross-centre approach, similar to that put forward by the Scandcleft (Lohmander, Willadsen et al., 2009) or Eurocleft projects (Grunwell et al., 2000; Shaw et al., 2001). This research could investigate differences in speech performance of CP±L speakers and in cleft care management across cleft care centres. Results of this research could assess the standard in cleft care and identify areas with potential of improvement in these centres.

6 Conclusion

This dissertation was a retrospective, longitudinal analysis of CPS from age 5 to 15 based on CAPS-A data collected in the Dental Hospital in Glasgow. The current study aimed at describing the nature and extent of phonetic and phonological characteristics of CPS, describing changes in speech performance from age 5 to 15, and identifying potential covariates that could explain severity of speech impairment. PCC measures based on narrow transcription of the CAPS-A sentences were used to describe speech performance at different ages. In addition, phonological process usage and the proportional distribution of phonetic and phonological processes informed about the nature and extent of CPS characteristics.

As expected, CP±L children used more phonetic than phonological characteristics of CPS at all ages, and they improved in their speech with growing age. Their improvement might be due to intervention strategies at the Dental Hospital of Glasgow. Variance analysis indicated that a combination of factors rather than single main factors explain severity in speech impairment. Stops seemed to be particularly indicative of the severity of differences between sub-groups of the cohort with different cleft types, hearing issues, and timing of PPS. These findings were, however, inconclusive. Hearing issues were expected to explain severity of speech impairment in fricatives above all other speech sound classes (Mody et al., 1999). Timing of PPS and cleft type were assumed to explain mainly severity of speech impairment in PCC (Persson, Lohmander & Elander, 2006; Chapman et al., 2008).

Findings of this dissertation could add to the work processes of cleft SLTs. It is recommended that recordings of younger children are added to the regular CAPS-A audits in order to assess phonological development successfully. Since CAPS-A does not assess phonological development it would be advisable to add phonological tests to the audit, especially in light of the fact that this analysis found phonological processes to be present at age 5. Furthermore, speech outcomes of adolescents with repaired CP±L should be interpreted and recorded with an age-appropriate approach. Controlled elicitation of spontaneous speech and specific phonological tests could add valuable insight into the speech performance of CP±L children.

References

Abdel-Aziz, M. (2013, January). Speech outcome after early repair of cleft soft palate using Furlow technique. *International Journal of Pediatric Otorhinolaryngology*, *77*(1), 85–88.

Aitken, A. J. (1984). Scottish accents and dialects. In P. Trudgill (Ed.), *Language in the British Isles* (Vol. 1). Cambridge: Cambridge University Press.

Albery, E. & Grunwell, P. (1993). Consonant articulation in different types of cleft lip and palate. In *Analysing cleft palate speech* (pp. 83–110). London: Whurr Publishers Ltd.

Amorosa, H., von Benda, U., Wagner, E. & Keck, A. (1985). Transcribing phonetic detail in the speech of unintelligible children: a comparison of procedures. *British Journal of Disorders of Communication*, *20*, 281–287.

Angle, E. H. (1899). Classification of malocclusion. *Dental Cosmos*, *41*, 248–264.

Anthony, A., Bogle, D., Ingram, T. T. S. & McIsaac, M. W. (1971). *The Edinburgh Articulation Test*. Edinburgh: E & S Livingstone.

Aumüller, G., Aust, G., Doll, A. & Engele, J. (2010). *Duale Reihe Anatomie*. Thieme Verlag.

Austin, D. & Shriberg, L. D. (1996). *Lifespan reference data for ten measures of articulation competence using the Speech Disorders Classification System (SDCS) (Tech. Rep. No. 3)*. Phonology Project, Waisman Center, University of Wisconsin-Madison.

Al-Awaji, N., Howard, S. & Wells, B. (2014). Speech production in Arabic-speaking children with repaired cleft palate. In *Poster presented at ICPLA 2014*. Stockholm.

Ball, M. J. (1995). *Phonetics for speech pathology*. London: Whurr Publisher Ltd.

Ball, M. J., Rahilly, J. & Tench, P. (1996). *The phonetic transcription of disordered speech*. San Diego, London: Singular Publishing Group Inc.

Baranian, B., Wells, B. & Harding-Bell, A. (2014). Cleft speech characteristics in speech production of Farsi-speaking children with repaired cleft palate. In *Poster presented at ICPLA 2014*. Stockholm.

Barry, M. C. (1992). Palatalisation, assimilation and gestural weakening in connected speech. *Speech Communication*, *11*, 393–400.

Bessell, A., Sell, D., Whiting, P., Roulstone, S., Albery, L., Persson, M., … Ness, A. R. (2013, January). Speech and language therapy interventions for children with cleft palate: a systematic review. *The Cleft Palate-Craniofacial Journal*, *50*(1), 1–17.

Boersma, P. & Weenink, D. (2014). Praat: doing phonetics by computer 5.3.76. Retrieved from http://www.praat.org/

Britton, L., Albery, L., Bowden, M., Harding-Bell, A., Phippen, G. & Sell, D. (2014). A cross-sectional cohort study of speech in five-year-olds with cleft palate ± lip to support development of national audit standards: benchmarking speech standards in the United Kingdom. *The Cleft Palate-Craniofacial Journal*, *51*(4), 431–451.

Burdi, A. R. (2006). Cleft lip and palate. Diagnosis and management. In S. Berkowitz (Ed.), (Chap. Developmental biology and morphogenesis of the face, lip and palate, Vol. 2, pp. 1–12). Berlin, Heidelberg: Springer-Verlag.

Byrd, D. & Tan, C. C. (1996). Saying consonant clusters quickly. *Journal of Phonetics*, *24*, 263–282.

Chapman, K. L. (1993). Phonologic processes in children with cleft palate. *The Cleft Palate-Craniofacial Journal*, *30*(1), 64–72.

Chapman, K. L., Hardin-Jones, M., Goldstein, J. A., Halter, K. A., Havlik, R. J. & Schulte, J. (2008, May). Timing of palatal surgery and speech outcome. *The Cleft Palate-Craniofacial Journal*, *45*(3), 297–308.

Copeland, M. (1990). The effects of very early palatal repair on speech. *British Journal of Plastic Surgery*, *43*, 676–682.

Dalston, R. M., Neiman, G. S. & Gonzalez-Landa, G. (1993). Nasometric sensitivity and specificity: a cross-dialect and cross-culture study. *The Cleft Palate-Craniofacial Journal*, *30*(3), 285–291.

Dixon, M. J., Marazita, M. L. & Murray, J. C. (2011, March). Cleft lip and palate: synthesizing genetic and environmental influences. *Nature Reviews Genetics*, *12*(3), 167–178.

Dodd, B., Holm, A., Hua, Z. & Crosbie, S. (2003). Phonological development: a normative study of British English-speaking children. *Clinical Linguistics and Phonetics*, *17*(8), 617–643.

Dorf, D. S. & Curtin, J. W. (1982). Early cleft palate repair and speech outcome. *Plastic and Reconstructive Surgery*, *70*(1), 74–81.

Doucet, J., Herlin, C., Bigorre, M., Bäumler, C., Subsol, G. & Captier, G. (2014). Mandibular effects of maxillary distraction osteogenesis in cleft lip and palate. *International Journal of Oral and Maxillofacial Surgery*, *43*(6), 702–707.

Duckworth, M., Allen, G. & Ball, M. J. (1990). Extensions to the International Phonetic Alphabet for the transcription of atypical speech. *Clinical Linguistics and Phonetics*, *4*, 273–280.

Estrem, T. & Broen, P. A. (1989). Early speech production of children with cleft palate. *Journal of Speech and Hearing Research*, *32*, 12–23.

Fairbanks, G. & Lintner, M. A. (1951). A study of minor organic deviations in functional disorders of articulation. *Journal of Speech and Hearing Disorders*, *16*, 253.

Fastl, H. & Zwicker, E. (2006). *Psychoacoustics. facts and models*. Springer-Verlag.

Gibbon, F. E. (2004). Abnormal patterns of tongue-palate contact in the speech of individuals with cleft palate. *Clinical Linguistics and Phonetics*, *18*(4-5), 285–311.

Gibbon, F. E., Smeaton-Ewins, P. & Crampin, L. (2005). Tongue-palate contact during selected vowels in children with cleft palate. *Folia Phoniatrica Logopedia*, *57*, 181–192.

Gordeeva, O. B. & Scobbie, J. M. (2013). A phonetic versatile contrast: pulmonic and glottalic voicelessness in Scottish English obstruents and voice quality. *Journal of the International Phonetic Association*, *43*, 249–271.

Greene, M. C. L. (1960). Speech analysis of 263 cleft palate cases. *Journal of Speech and Hearing Disorders*, *25*(1), 43–48.

Grundlach, K. K., Bradach, J., Filippow, D., Stahl-de Castrillon, F. & Lenz, J. H. (2013, January). Two-stage palatoplasty, is it still a valuable treatment protocol for patients with a cleft of lip, alveolus, and palate? *Journal of Cranio-Maxillo-Facial Surgery*, *41*(1), 62–70.

Grunwell, P. (1987). *Clinical phonology* (2nd ed.). Kent: Croom Helm.

Grunwell, P., Brondsted, K., Henningsson, G., Jansonius, K., Karling, J., Meijer, M., … Sell, D. (2000). A six-centre international study of the outcome of treatment in patients with clefts of the lip and palate: the results of a cross-linguistic investigation of cleft palate speech. [Abstract]. *Scandinavian Journal of Plastic and Reconstructive Surgery and Hand Surgery*, *34*(3), 219–229.

Halle, M., Hughes, G. W. & Radley, J.-P. A. (1957). Acoustic properties of stop consonants. *The Journal of the Acoustical Society of America*, *29*(107).

Harding, A., Harland, K. & Razzell, K. (1997). *Cleft Audit Protocol for Speech (CAPS)*. Broomfield, Chelmsford, Essex: St. Andrews Plastic Surgery Centre.

Harding, A. & Grunwell, P. (1996). Characteristics of cleft palate speech. *European Journal of Disorders of Communication*, *31*, 331–357.

Harding, A. & Grunwell, P. (1998). Active versus passive cleft-type speech characteristics. *International Journal of Language and Communication Disorders*, *33*(3), 329–352.

Hardin-Jones, M. & Jones, D. L. (2005, January). Speech production of preschoolers with cleft palate. *The Cleft Palate-Craniofacial Journal*, *42*(1), 7–13.

Harland, K. (1996). An extended audit of complete boney unilateral cleft lip and palate patients aged 5-6 and 8-11: speech outcomes. In *Presented at the annual meeting of the Craniofacial Society of Great Britain and Ireland*. Egham, Surrey.

Henningsson, G., Kuehn, D. P., Sell, D., Sweeney, T., Trost-Cardamone, J. E. & Tara L. Whitehill, P. (2008). Universal parameters for reporting speech outcomes in individuals with cleft palate. *The Cleft Palate-Craniofacial Journal*, *45*(1), 1–17.

Hess, D. (1959). Pitch, intensity, and cleft palate voice quality. *Journal of Speech, Language, and Hearing Research*, *2*, 113–125.

Hodson, B. W., Chin, L., Redmond, B. & Simpson, R. (1983, February). Phonological evaluation and remediation of speech deviations of a child with a repaired cleft palate. *Journal of Speech and Hearing Disorders*, *48*, 93–98.

Howard, S. & Heselwood, B. (2002). Learning and teaching phonetic transcription for clinical purposes. *Clinical Linguistics and Phonetics*, *16*(5), 371–401.

Howard, S. & Heselwood, B. (2011). Instrumental and perceptual phonetic analyses: the case for two-tier transcriptions. *Clinical Linguistics and Phonetics*, *25*(11-12), 940–948.

Howard, S. & Lohmander, A. (2012). *Cleft palate speech: assessment and intervention*. New York: John Wiley and Sons.

Ingram, D. (1991). Toward a theory of phonological acquisition. In J. F. Miller (Ed.), *Research on child language disorders* (pp. 55–72). Austin: Pro-Ed.

International Phonetic Association. (1999). *Handbook of the International Phonetic Association: a guide to the use of the International Phonetic Alphabet*. Cambridge: Cambridge University Press.

IPA. (2005). The International Phonetic Alphabet. Retrieved from https://www.langsci.ucl.ac.uk/ipa/IPA_chart_%28C%292005.pdf.

John, A., Sell, D., Sweeney, T., Harding-Bell, A., Williams, A. & Orth, F. (2006, May). The Cleft Audit Protocol for Speech-Augmented: a validated and reliable measure for auditing cleft speech. *The Cleft Palate-Craniofacial Journal*, *43*(3), 272–288.

Jurafsky, D., Bell, A., Fosler-Lussiert, E., Girand, C. & Raymond, W. (1998). Reduction of English function words in Switchboard. In *In proceedings of icslp-98*. Sydney, Australia.

Karling, J., Larson, O. & Henningsson, G. (1993). Oronasal fistulas in cleft palate patients and their influence on speech. *Scandinavian Journal of Plastic and Reconstructive Surgery*, *27*(3), 193–201.

Karnell, M. P. & Demark, D. R. V. (1986). Longitudinal speech performance in patients with cleft palate: comparisons based on secondary management. *The Cleft Palate Journal*, *23*, 278–288.

Kerswill, P. (2003). Dialect level and geographical diffusion in British English. In D. Britain & J. Cheshire (Eds.), *Social dialectology: in honour of Peter Trudgill* (pp. 223–243). Amsterdam: John Benjamins Publishing.

Khan, L. M. & Lewis, N. (1986). *Khan-Lewis Phonological Analysis*. Circle Pines: AGS Publishing.

Kirschner, R. E., Randall, P., Wang, P., Jawad, A. F., Duran, M. & Huang, K. (2000). Cleft palate repair at 3 to 7 months of age. *Plastic and Reconstructive Surgery*, *105*(6), 2127–2132.

Klatt, D. H. (1975). Voice onset time, frication, and aspiration in word-initial consonant clusters. *Journal of Speech, Language, and Hearing Research*, *18*, 686–706.

Kohli, S. S. & Kohli, V. S. (2012). A comprehensive review of the genetic basis of cleft lip and palate. *Journal of Oral and Maxillofacial Surgery*, *16*(1), 64–72.

Konst, E. M., Rietveld, T., Peters, H. F. & Prahl-Andersen, B. (2003, January). Phonological development of toddlers with unilateral cleft lip and palate who were treated with and without infant orthopedics: a randomized clinical trial. *The Cleft Palate-Craniofacial Journal*, *40*(1), 32–39.

Kuehn, D. P. & Moller, K. T. (2000). Speech and language issues in the cleft palate population: the state of the art. *The Cleft Palate-Craniofacial Journal*, *37*(4), 348–383.

Kuehn, D. P. & Moon, J. B. (1998, February). Velopharyngeal closure force and levator veli palatini activation levels in varying phonetic contexts. *Journal of Speech, Language, and Hearing Research*, *41*, 51–62.

Kummer, A. W. (2007). *Cleft palate and craniofacial anomalies. Effects on speech and resonance*. Thomson Delmar Learning.

Kummer, A. W., Briggs, M. & Lee, L. (2003). The relationship between the characteristics of speech and velopharyngeal gap size. *The Cleft Palate-Craniofacial Journal*, *40*(6), 590–596.

Laver, J. (1994). *Principles of phonetics*. Oxford: Cambridge University Press.

Lawson, R. (2009). *Sociolinguistic constructions of identity among adolescent males in Glasgow* (Doctoral dissertation, University of Glasgow, Glasgow).

Lewis, K. E., Watterson & Quint, T. (2000). The effect of vowels on nasalance scores. *The Cleft Palate-Craniofacial Journal*, *37*(6), 584–589.

Lilja, J. (2009, October). Alveolar bone grafting. *Indian Journal of Plastic Surgery*, *42*((Suppl.)), 110–115.

Lindblom, B. (1963). Spectrographic study of vowel reduction. *Journal of the Acoustical Society of America*, *35*, 1773–1781.

Little, J., Cardy, A., Arslan, M. T., Gilmour, M. & Mossey, P. A. (2004). Smoking and orofacial clefts: a United Kingdom-based case-control study. *The Cleft Palate-Craniofacial Journal*, *41*(4), 381–386.

Lohmander, A. & Olsson, M. (2004, January). Methodology for perceptual assessment of speech in patients with cleft palate: a critical review of the literature. *The Cleft Palate-Craniofacial Journal*, *41*(1), 64–70.

Lohmander, A., Willadsen, E., Persson, C., Henningsson, G., Bowden, M. & Hutters, B. (2009). Methodology for speech assessment in the Scandcleft project – an international randomized clinical trial on palatal surgery: experiences from a pilot study. *The Cleft Palate-Craniofacial Journal*, *46*(4), 347–362.

Long, S. H., Fey, M. E. & Channel, R. (2003). Computerized Profiling 9.7.0 (CPro).

Lorente, C., Cordier, S., Goujard, J., Aymi, S., Bianchi, F., Calzolari, E., … Knill-Jones, R. (2000). Tobacco and alcohol use during pregnancy and risk of oral clefts. *American Journal of Public Health*, *90*(3), 415–419.

Lowe, R. J. (2000). *ALPHA (assessment link between phonology and articulation phonology)*. Mifflinville: ALPHA Speech & language resources.

Lynch, J. I., Fox, D. R. & Brookshire, B. L. (1983, August). Phonological proficiency of two cleft palate toddlers with school-age follow-up. *Journal of Speech and Hearing Disorders*, *48*(3), 274–285.

Macafee, C. (1983). *Glasgow*. John Benjamins Publishing.

McCarthy, O. & Stuart-Smith, J. (2013). Ejectives in Scottish English: a social perspective. *Journal of the International Phonetic Association*, *43*, 273–298.

McCartney, E. (2012). Voice and speech function. In A. Majnemer (Ed.), *Measures for children with developmental disabilities* (Chap. Body structures and functions, Vol. 1, *194 - 195*, pp. 181–191). Clinics in developmental medicine. London: Mac Keith Press.

McGurk, H. & MacDonald, J. (1976, December). Hearing lips and seeing voices [Abstract]. *Nature*, *264*, 746–748.

McReynolds, L. & Elbert, M. (1981). Criteria for phonological process analysis. *Journal of Speech and Hearing Disorders*, *48*, 274–285.

McWilliams, B. J., Morris, H. L. & Shelton, R. L. (1990). *Cleft palate speech*. B. C. Decker.

Meyer-Marcotty, P., Kochel, J., H., B., Linz, C., Klammert, U. & Stellzig-Eisenhauer, A. (2011). Face perception in patients with unilateral cleft lip and palate and patients with severe class III malocclusion compared to controls. *Journal of Cranio-Maxillo-Facial Surgery*, *39*(3), 158–163.

Mody, M., Schwartz, R. G., Gravel, J. S. & Ruben, R. J. (1999, October). Speech perception and verbal memory in children with and without histories of otitis media. *Journal of Speech, Language, and Hearing Research*, *42*(5), 1069–1079.

Moller, K. T. (1994). Dental-occlusal and other oral conditions and speech. In J. E. Bernthal & N. W. Bankson (Eds.), *Child phonology: characteristics, assessment, and intervention with special populations*. New York: Thieme Verlag.

Morris, H. L. & Ozanne, A. (2003, September). Phonetic, phonological, and language skills of children with a cleft palate. *The Cleft Palate-Craniofacial Journal*, *40*(5), 460–470.

Morris, H. L., Spriestersbach, D. C. & Darley, F. L. (1961). An articulation test for assessing competency of velopharyngeal closure. *Journal of Speech and Hearing Research*, 4–48.

NHS. (2013, July). *Overall care pathway for child born with a cleft palate or cleft lip and palate*.

Oller, D. K. & Ramsdell, H. L. (2006, December). A weighted reliability measure for phonetic transcription. *Journal of Speech, Language, and Hearing Research*, *49*, 1391–1411.

Pearman, K. (2000). Ear problems in children with cleft palates. Retrieved from http://www.clapa.com/documents/earproblemsinchildren_withcleftpalates.pdf.

Persson, C., Elander, A., Lohmander-Agerskov, A. & Soederpalm, E. (2002). Speech outcomes in isolated cleft palate: impact of cleft extent and additional malformations. *The Cleft Palate-Craniofacial Journal*, *39*(4), 397–408.

Persson, C., Lohmander, A. & Elander, A. (2006, May). Speech in children with an isolated cleft palate: a longitudinal perspective. *The Cleft Palate-Craniofacial Journal*, *43*(3), 295–309.

Pradel, W., Senf, D., Mai, R., Ludicke, G., Eckelt, U. & Lauer, G. (2009, December). One-stage palate repair improves speech outcome and early maxillary growth in patients with cleft lip and palate. *Journal of Physiology and Pharmacology*, *60*(8), 37–41.

PRDS. (1980). Progress report. Phonetic representation of disordered speech. *British Journal of Disorders of Communication*, *15*(1), 215–220.

Pruthi, T., Espy-Wilson, C. Y. & Story, B. H. (2007, June). Simulation and analysis of nasalized vowels based on magnetic resonance imaging data. *Journal of the Acoustical Society of America*, *121*(6), 3858–3873.

Puho, E. H., Szunyogh, M., Metneki, J. & Czeizel, A. E. (2007, March). Drug treatment during pregnancy and isolated orofacial clefts in Hungary. *The Cleft Palate-Craniofacial Journal*, *44*(2), 194–202.

Pulkkinen, J., Haapanen, M. L., Paaso, M., Laitinen, J. & Ranta, R. (2001). Velopharyngeal function from the age of three to eight years in cleft palate patients. *Folia Phoniatrica Logopedia*, *53*(2), 93–98.

R Development Core Team. (2014). R: a language and environment for statistical computing. Retrieved from www.r-project.org.

Raphael, L. J., Borden, G. J. & Harris, K. S. (2006). *Speech science primer: physiology, acoustics, and perception of speech* (P. Sabatini & A. M. Klingler, Eds.). Baltimore: Lippincott William & Wilkins.

Raud Westberg, L. (2013). *Speech in 3-year-old children with unilateral cleft lip and palate: impact of method for palatal repair and early intervention* (Master's thesis, Karolinska Instituet).

Rivkin, C. J., Keith, O., Crawford, P. J. M. & Hathorn, I. (2000, February). Dental care for the patient with a cleft lip and palate. Part 2: the mixed dentition stage through to adolescence and young adulthood. *British Dental Journal*, *188*(3), 131–134.

Ross, R. B. (1987). Treatment variables affecting facial growth in complete unilateral cleft lip and palate. *The Cleft Palate Journal*, *24*, 5–77.

Russell, J. & Grunwell, P. (1993). Speech development in children with cleft lip and palate. In *Analysing cleft palate speech*. London: Whurr Publisher Ltd.

Russell, J., Kiddy, H. C. & Mercer, N. S. (2014). The use of symnose for quantitative assessment of lip symmetry following repair of complete bilateral cleft lip and palate. *Journal of Cranio-Maxillo-Facial Surgery*, *42*, 454–459.

Sandy, J. R., Williams, A., Mildinhall, S., Murphy, T., Bearn, D., Shaw, W. C., ... Murray, J. J. (1998). The Clinical Standards Advisory Group (CSAG) cleft lip and palate study. *British Journal of Orthodontics*, *25*, 21–30.

Scherer, N. J., Oravkinova, Z. & McBee, M. T. (2013, June). Longitudinal comparison of early speech and language milestones in children with cleft palate: a comparison of US and Slovak children. *Clinical Linguistics and Phonetics*, *27*(6-7), 404–418.

Scherer, N. J., Williams, A. L. & Proctor-Williams, K. (2008). Early and later vocalization skills in children with and without cleft palate. *International Journal of Pediatric Otorhinolaryngology*, *72*, 827–840.

Schutte, B. C. & Murray, J. C. (1999). The many faces and factors of orofacial clefts. *Human Molecular Genetics*, *8*(10), 1853–1859.

Scobbie, J. M., Gordeeva, O. B. & Matthews, B. (2006). Acquisition of Scottish English phonology: an overview. *QMUC Speech Science Research Centre Working Paper*, *7*, 3–30.

Scobbie, J. M., Hewlett, N. & Turk, A. E. (1999). Standard English in Edinburgh and Glasgow: the Scottish vowel length rule revealed. In P. Foulkes & G. Docherty (Eds.), *Urban voices: accent studies in the British Isles* (pp. 230–245). London: Arnold.

Sell, D., Harding, A. & Grunwell, P. (1994). A screening assessment of cleft palate speech (Great Ormond Street Speech Assessment). *European Journal of Disorders of Communication*, *29*, 1–15.

Sell, D., Harding, A. & Grunwell, P. (1999). GOSP.SP.ASS.'98: an assessment for speech disorders associated with cleft palate and/or velopharyngeal dysfunction (revised). *Journal of Language and Communication Disorders*, *34*(1), 17–33.

Serrurier, A. & Badin, P. (2008, April). A three-dimensional articulatory model of the velum and nasopharyngeal wall based on MRI and CT data. *Journal of the Acoustical Society of America*, *123*(4), 2335–2355.

Shaw, W. C., Semb, G., Nelson, P., Brattstroe, V., Mulsted, K., Prahl-Andersen, B. & Gundlach, K. K. (2001). The Eurocleft project 1996-2000: overview. *Journal of Cranio-Maxillo-Facial Surgery*, *29*, 131–140.

Shriberg, L. D. (1993, February). Four new speech and prosody-voice measures for genetics research and other studies in developmental phonological disorders. *Journal of Speech and Hearing Research*, *36*, 105–140.

Shriberg, L. D., Austin, D., Lewis, B. A., McSweeny, J. L. & Wilson, D. L. (1997, August). The Percentage of Consonants Correct (PCC) metric: extensions and reliability data. *Journal of Speech, Language, and Hearing Research*, *40*, 708–722.

Shriberg, L. D. & Kwiatkowski, J. (1982). Phonological disorders III: a procedure for assessing severity of involvement. *Journal of Speech and Hearing Disorders*, *47*, 236–270.

Shriberg, L. D., Lewis, B. A., McSweeny, J. L. & Wilson, D. (1997). The Speech Disorders Classification System (SDCS): extensions and lifespan reference data. *Journal of Speech, Language, and Hearing Research*, *40*, 723–740.

Shriberg, L. D. & Lof, G. L. (1991). Reliability studies in broad and narrow phonetic transcription [Abstract]. *Clinical Linguistics and Phonetics*, *5*(3), 225–279.

Slifka, J. (2006). Some physiological correlates to regular and irregular phonation at the end of an utterance. *Journal of Voice*, *20*(2), 171–186.

Smit, A. B., Hand, L., Freilinger, J. J., Bernthal, J. E. & Bird, A. (1990). The Iowa Articulation Norms Project and its Nebraska replication. *Journal of Speech and Hearing Disorders*, *55*(4), 779–798.

Strauss, R. P. & Broder, H. (1993). Children with cleft lip/palate and mental retardation: a subpopulation of cleft-craniofacial team patients. *The Cleft Palate-Craniofacial Journal*, *30*(6), 548–556.

Stuart-Smith, J. (2003). Phonology of modern urban Scots. In J. Corbett, J. D. McClure & S.-S. Jane (Eds.), *The Edinburgh companion to Scots* (pp. 110–137). Edinburgh: Edinburgh University Press.

Swerts, M. & Collier, R. (1992). On the controlled elicitation of spontaneous speech. *Speech Communication*, *11*, 463–468.

Thorp, E. B., Virnik, B. T. & Stepp, C. E. (2013, October). Comparison of nasal acceleration and nasalance across vowels. *Journal of Speech, Language, and Hearing Research*, *56*, 1476–1484.

Timmons, M. J., Wyatt, R. & Murphy, T. (2001). Speech after repair of isolated cleft palate and cleft lip and palate. *British Journal of Plastic Surgery*, *54*, 377–384.

Trost, J. E. (1981). Articulatory additions to the classical description of the speech of persons with cleft palate. *The Cleft Palate Journal*, *18*(3), 193–203.

Van Demark, D. R., Hardin, M. A. & Morris, H. L. (1988). Assessment of velopharyngeal competence: a long-term process. *The Cleft Palate Journal*, *25*(4), 362–373.

Van Demark, D. R. & Morris, H. L. (1983). Stability of velopharyngeal competence. *The Cleft Palate Journal*, *20*, 18–22.

Van Son, R. J. J. H. & Pols, L. C. W. (1995). Acoustic consonant reduction: a comparison. In *Proceedings of the Institute of Phonetic Sciences* (pp. 83–91). Amsterdam.

Vettore, M. V. & Sousa Campos, A. E. (2011, September). Malocclusion characteristics of patients with cleft lip and/or palate. *European Journal of Orthodontics*, *33*(3), 311–217.

Warren, D. W. (1986). Compensatory speech behaviours in individuals with cleft palate: a regulation/control phenomenon. *The Cleft Palate Journal*, *23*(4), 251–260.

Warren, R. E. (1970, January). Perceptual restoration of missing speech sounds. *Science*, *167*(3917), 392–393.

Willadsen, E. (2012, September). Influence of timing of hard palate repair in a two-stage procedure on early speech development in Danish children with cleft palate. *The Cleft Palate-Craniofacial Journal*, *49*(5), 574–595.

Working Group IPDTOC. (2011, January). Prevalence at birth of cleft lip with or without cleft palate: data from the International Perinatal Database of Typical Oral Clefts (IPDTOC). *The Cleft Palate-Craniofacial Journal*, *48*(1), 66–81.

Wright, M. (2007). Clicks as markers of new sequences in English conversations. In *ICPhS XVI* (pp. 1069–1072). Saarbrücken.

Review of Cleft Lip and Palate Surgical Service in Scotland. (2006, May). NHS Scotland.

National Managed Clinical Network for Cleft Lip, Cleft Palate or Cleft Lip & Palate. (2011, February). NHS Scotland.

CLEFTSiS National Managed Clinical Network Audit Timetable 2013/2014. (2013, September). CLEFTSiS.

Zajac, D. J. & Milholland, S. (2014). Abrupt laryngeal engagement during stop plosive-vowel transitions in children with repaired cleft palate and adequate velopharyngeal closure: aerodynamic and sound pressure level evidence. *The Cleft Palate-Craniofacial Journal*, *51*(1), 98–104.

Appendix I: Target transcription

Mary came home early.	/mɛri kem hom ɛrli/
The puppy is playing with a rope.	/ðə pʌpe ɪz pleɪŋ wɪθ ə rop/
Bob is a baby boy.	/bɔb iz ə bebe bɔe/
The phone fell off the shelf.	/ðə fon fɛl ɔf ðə ʃɛlf/
Dave is driving a van.	/dev ɪz drʌivɪŋ ə van/
This hand is cleaner than the other.	/ðɪs hand ɪz klinər ðən ðɪ ʌðər/
Neil saw a robin in a nest.	/nil sɔ ə rɔbɪn ɪn ə nɛst/
A ball is like a balloon.	/ə bɔl ɪz lʌik ə bəlʉn/
Tim is putting a hat on.	/tɪm ɪz pʉtɪŋ ə hat ɔn/
Daddy mended a door.	/dade mɛndəd ə dɔr/
I saw Sam sitting on a bus.	/ʌi sɔ sam sɪtɪŋ ɔn ə bʌs/
The zebra was at the zoo.	/ðə zɛbrə wəz ət ðə zʉ/
Sean is washing a dirty dish.	/ʃɔn ɪz wɔʃɪŋ ə dɛrte dɪʃ/
Charlie's watching a football match.	/tʃalɪz wɔtʃɪŋ ə fʉpbɔlmɛtʃ/
John's got a magic badge.	/dʒnz gɔt ə madʒɪk bɛdʒ/
The bell's ringing	/ðə bɛlz rɪŋɪŋ/
Karen is making a cake.	/karən ɪz mekɪŋ ə kek/
Gary's got a bag of Lego.	/garɪz gɔt ə bag əv lɛgo/
Hannah hurt her hand.	/hanə hɛrt ər hand/
Stuart's hamster scrambled up his sleeve.	/stjʉərts hamstər skrɛmbld ʌp ɪz sliv/

Appendix II: Tables

Table 16: PCC-values for nonsyndromic and syndromic CL±P children in % (sd) (*p<.05)

PCC-value	Cleft groups				Statistics	
Age 5	syndromic n(4)		nonsyndr. n(42)		*W*	*p*
PCC	48.85	(10.67)	59.02	(13.46)	40	.09
PCC-A	50.45	(10.99)	60.28	(13.28)	42	.11
PCC-R	71.55	(12.44)	75.03	(12.66)	70	.60
Age 10	syndromic n(4)		nonsyndr. n(42)		*W*	*p*
PCC	58.98	(7.65)	72.64	(10.17)	25.5	.02*
PCC-A	52.23	(15.17)	69.69	(11.48)	23	.02*
PCC-R	69.15	(10.55)	80.80	(9.92)	32	.04*
Age 15	syndromic n(1)		nonsyndr. n(14)		*W*	*p*
PCC	53.8		72.64	(9.91)	0	.13
PCC-A	52.6		66.88	(17.29)	2	.30
PCC-R	60.6		82.96	(7.53)	0	.13

Table 17: PCC-values for CL±P children with and without learning needs in % (sd) (*p<.05)

PCC-value	Cleft groups				Statistics	
Age 5	learning needs n(3)		no learning needs n(39)		*W*	*p*
PCC	55.42	(12.36)	58.47	(13.67)	86	.57
PCC-A	56.78	(12.92)	59.75	(13.46)	88	.63
PCC-R	73.96	(12.84)	74.82	(12.67)	94	.78
Age 10	learning needs n(3)		no learning needs n(39)		*W*	*p*
PCC	62.78	(12.17)	72.50	(10.11)	51.5	.07
PCC-A	54.54	(18.88)	69.84	(10.88)	48	.06
PCC-R	74.08	(10.35)	80.49	(10.31)	64	.18
Age 15	learning needs n(2)		no learning needs n(12)		*W*	*p*
PCC	64.90	(6.65)	76.06	(9.63)	4	.20
PCC-A	62.45	(6.01)	67.62	(18.60)	6	.31
PCC-R	75.85	(0.77)	84.15	(7.50)	4	.17

Table 18: PCC-values for CL±P children with and without PRS in % (sd) (*p<.05)

PCC-value	Cleft groups				Statistics	
Age 5	PRS n(3)		no PRS n(39)		*W*	*p*
PCC	68.43	(12.30)	57.80	(13.28)	90	.23
PCC-A	68.73	(12.31)	59.05	(13.28)	87	.30
PCC-R	79.57	(11.01)	74.74	(12.63)	81.5	.41
Age 10	PRS n(3)		no PRS n(39)		*W*	*p*
PCC	72.77	(6.22)	70.91	(10.65)	67	.87
PCC-A	76.00	(8.36)	67.31	(12.77)	86	.31
PCC-R	83.10	(10.03)	79.17	(10.30)	76.5	.55
Age 15	PRS n(1)		no PRS n(13)		*W*	*p*
PCC	90.70		73.22	(9.10)	13	.14
PCC-A	90.70		65.04	(16.52)	13	.14
PCC-R	90.30		82.40	(7.53)	11	.32

Table 19: Excerpt from PCC reference data in % (Austin & Shriberg, 1996)

Age	PCC measure	NSA		SD	
5;0 – 5;11	PCC	87.1	(7.7)	63.7	(10.6)
	PCC-A	93.2	(4.2)	68.4	(11.4)
	PCC-R	94.0	(4.2)	70.7	(10.5)
9;0 – 11;11				RE I	
	PCC	97.2	(3.0)	93.6	(3.0)
	PCC-A	97.3	(3.0)	97.0	(1.9)
	PCC-R	97.6	(2.9)	97.6	(1.4)
12;0 – 17;11				RE I	
	PCC	98.1	(2.2)	94.0	(2.6)
	PCC-A	98.2	(2.1)	96.7	(2.4)
	PCC-R	98.5	(1.9)	97.1	(2.1)

Appendix III: CAPS-A form

Cleft Audit Protocol for Speech - Augmented

Please rate all items. Omissions are ambiguous. Circle number '8' only if it is not possible to make a judgement.

Name:		Date:	Audit No:
Date of Birth:	Age:	Centre:	
Male/Female	First Language:	Therapist:	
Type of Cleft/Structure:			
Background information (e.g. current URTI, Voice disorder)			

Insufficient speech sample to audit the case:		8
1 Intelligibility/Distinctiveness of speech		
Rating	Description	
0	Normal.	8
1	Different from other children's speech, but not enough to cause comment.	
2	Different enough to provoke comment, but possible to understand most speech.	
3	Only just intelligible to strangers.	
4	Impossible to understand.	
2 Voice		
Rating	Voice Characteristics	
0	Absent	8
1	Distinctive or abnormal voice quality	
3 Resonance		
3a Hypernasality		
Rating	Description	
0	Absent	8
1	Borderline - minimal	
2	Mild - evident on close vowels e.g. zoo, three, six /ũ, ĩ, ɪ̃/	
3	Moderate - evident on open and close vowels	
4	Severe - evident on vowels and voiced consonants	
3b Hyponasality		
Rating	Description	
0	Absent	8
1	Mild – partial denasalization of nasal consonants and adjacent vowels	
2	Marked - denasalization of nasal consonants /m̃, ñ, ŋ̃/ and adjacent vowels	
4 Nasal Airflow		
4a Audible Nasal Emission		
Rating	Description	
0	Absent on pressure consonants	8
1	Occasional: pressure consonants affected <10% of the sample	
2	Frequent: pressure consonants affected >10% of the sample (judged as highly pervasive or highly distinctive)	
4b Nasal Turbulence		
Rating	Description	
0	Absent on pressure consonants	8
1	Occasional: pressure consonants affected <10% of the sample	
2	Frequent: pressure consonants affected >10% of the sample (judged as highly pervasive or highly distinctive)	
5 Grimace		
Rating	Grimace	
0	Absent	8
1	Grimace behaviour – sufficient to distract the listener	

Version 11 November 2009

6 Consonant Production																					
6a Consonant Production																					
Realization	Labial			Dental			Alveolar						Post Alveolar			Velar			Gtl	/s/Clstr
Initial Realization																				
Correct Target	m	p	b	f	v	ð	n	l	t	d	s	z	ʃ	tʃ	ʤ	ŋ	k	g	h	st skr sl
Final Realization																				
6b Observations of spontaneous speech: note any distinctive characteristics in speech/sound imitation																				

7 Cleft Type Characteristics (CTCs) Summary				
7a Cleft Type Characteristics (CTCs) Rate individual CTCs		Absent 0	1 or 2 consonants affected	3 or more consonants affected
Anterior Oral CTCs		NB. Transcribe consonants affected		
1	Dentalization/ inter-dentalization e.g. [t̪] [t̪͆]			
2	Lateralization / lateral e.g. [ls] [ɬ] or [sˡ tˡ]			
3	Palatalization / palatal e.g. [tʲ] [ç ɟ]			
Posterior Oral CTCs				
4	Double articulation e.g. [t͡k] [p͡k]			
5	Backed to velar/uvular e.g. /t d s n l/ => [k g x ŋ] [q G χ N]			
Non-Oral CTCs				
6	Pharyngeal articulation e.g. [ħ ʕ]			
7	Glottal articulation e.g. [ʔ], [h ɦ]			
8	Active nasal fricatives e.g. [m̥̃] [ñ̥] [ŋ̊̃]			
9	Double articulation e.g. [b͡ʔ] [d͡ʔ]			
Passive CTCs				
10	Weak and or nasalized consonants e.g. [b˺, b̃, d˺, d̃]			
11	Nasal realization of plosives e.g. b=>[m], d =>[n], and/or suspected passive nasal fricative e.g. f => [(f͡)m̥], [(f͡)ɱ̊] or s / ʃ => [(s͡)n̥ (x͡)ŋ̊]			
12	Gliding of fricatives/ affricates / f v / => [w], /s z ʃ / => [j]			

7b Non-cleft speech immaturities / errors	Absent	Present	Describe/ Transcribe examples
Rating	0	1	e.g. fronting, stopping, gliding, cluster reduction

7c Evidence of influencing factors: general comments on child's speech and language, hearing etc.

8 Perceived Need		
Speech and Language Therapy required for cleft speech problems at some point	Yes	No

Appendix IV: Definitions of phonological processes (CPro)

Definitions of Phonological Processes (as used in Computerized Profiling 9.7.0)

Reduplication	A multi-syllable production different from the target where the syllables are phonetically identical, e.g., [bɑbɑ] for "bottle," [nʌnʌ] for "tummy," etc. The target form must be multisyllabic.
Velar Assimilation	The substitution of a velar consonant in a word containing a velar target sound, e.g., [gʌk] for "duck", [gægən] for "wagon", [gæjum] for "vacuum".
Nasal Assimilation	The substitution of a nasal consonant in a word containing another nasal, whether correctly produced or substituted for another phone, e.g., [nʌn] for "sun", [mæmiz] for "matches", [neŋ] for "snake".
Velar Fronting	The substitution of an alveolar stop or nasal for a velar stop or nasal in either singleton or cluster context, e.g., k→t, g→d, ŋ→n, k→d, g→t, ŋ→d, ŋ→t, kr→tr, kr→tw. Note that the substitution of other anterior consonants (alveolar fricatives, bilabial stops, etc.) are not analyzed as Velar Fronting.
Early Stopping	The substitution of a homorganic or near-homorganic stop for the fricatives /f, θ, s, ʃ/ in either singleton or cluster context, e.g., f→p, f→b, θ→t, θ→d, s→d, s→t, ʃ→t, ʃ→d, fr→pr, fr→pw, ʃr→tr.
Final Consonant Deletion	The omission of a final consonant singleton or cluster except for nasal and liquid singletons. Word-final glottal stop substitutions (e.g., [sɑʔ] for sock" are not analyzed as Final Consonant Deletion but are included under Other Substitutions. Deletion of word final liquids is analyzed as Liquid Deletion. Deletion of word final nasals is analyzed as Other Deletions (Brief process analysis) or Deletion of Nasals (Extended process analysis).
Context-sensitive Voicing	The substitution of a consonant singleton by its voiced or voiceless cognate, i.e., p→b, b→p, t→d, d→t, k→g, g→k, θ→ð, ð→θ, f→v, v→f, s→z, z→s, ʃ→ʒ, ʒ→ʃ, ʧ→ʤ, ʤ→ʧ
Cluster Reduction	The replacement of a consonant cluster by a consonant singleton or by a cluster containing fewer consonants, e.g., bl→b, sw→s, spl→pw, etc.
Gliding	The substitution of a glide for a liquid singleton, i.e., r→w, l→w, r→j, l→j.
Palatal Fronting	The substitution of an alveolar fricative or affricate for a palatal fricative or affricate, e.g., ʃ→s, tʃ→z, ʒ→s, dʒ→z, dʒ→dz.
Later Stopping	The substitution of a homorganic stop for the fricatives [v, ð, z, ʒ] or the substitution of a stop for an affricate in either singleton or cluster context, e.g., v→b, v→p, z→t, z→d, ʒ→d, ʒ→t, ð→d, ð→t, tʃ→d, tʃ→t, dʒ→d, dʒ→t, vd→bd.
Fricative Simplification	The substitution of a labiodental or alveolar fricative for an interdental fricative with no change in voicing, i.e., θ→f, θ→s, ð→v, ð→z.
Cluster Simplification	The substitution of a glide for a liquid in C[r], C[l], CC[r], and CC[l] clusters, e.g., bl→bw, tr→tw, spl→spw.
Deaffrication	The substitution of a palatal fricative for an affricate, i.e., tʃ→ʃ, tʃ→ʒ, dʒ→ʃ, dʒ→ʒ.
Liquid Deletion	Liquids /l/ and /r/ are deleted or replaced by a back vowel, e.g., ræbɪt→æbɪt, kɛrət→kɛøət, däl→däo. In final position, this process may also be referred to as Vocalization or Vowelization.
Backing of Alveolars	The substitution of velar consonants for alveolar consonants, e.g., t→k, d→g, n→ŋ, s→k, z→g. Velar Assimilation may be operative in certain instances.
Glottal Substitution	The substitution of a glottal stop [ʔ] or a glottal fricative [h] for another consonant singleton, e.g., d→h, s→ʔ, sp→h, sk→ʔ.
Sound Additions	A word normally initiated with a vowel is instead initiated with a consonant, e.g., æpəl→bæpəl, or a word terminating with a vowel is terminated with a consonant, e.g., pɪlo→pɪlos. The process cannot occur in medial position.
Gliding of Fricatives	The substitution of glides /w, j/ or the liquid /l/ for fricative singletons, e.g., f→w, s→l, s→j.
Stopping of Liquids	The substitution of /d/ for the liquid singletons /l, r/.

Glottal Substitution for Stops	The substitution of a glottal stop /ʔ/ or a glottal fricative /h/ for a singleton stop consonant.
Glottal Substitution for Fricatives/ Affricates	The substitution of a glottal stop /ʔ/ or a glottal fricative /h/ for a singleton fricative or affricate consonant.
Glottal Substitution for Liquids/Glides/Nasals	The substitution of a glottal stop /ʔ/ or a glottal fricative /h/ for a singleton liquid, glide, or nasal consonant.
Deletion of Stops	The deletion of a singleton stop consonant.
Deletion of Fricatives	The deletion of a singleton fricative consonant.
Deletion of Affricates	The deletion of a singleton affricate consonant.
Deletion of Glides	The deletion of a singleton glide consonant.
Deletion of Nasals	The deletion of a singleton nasal consonant.
Deletion of /s/ clusters	The deletion of all segments in a cluster containing /s/.
Deletion of /r/ clusters	The deletion of all segments in a cluster containing /r/.
Deletion of /l/ clusters	The deletion of all segments in a cluster containing /l/.
Deletion of nasal clusters	The deletion of all segments in a cluster containing /m, n, ŋ/.
Fronting of velar clusters	The substitution of an alveolar stop for a velar stop in a cluster context, e.g., gr→dw.
Lateralization of sibilants	Lateral emission in the production of sibilants /s, z, ts, dz, ʃ, ʒ, tʃ, dʒ/, in either singleton or cluster context, indicated by a diacritic for lateralization, e.g., z_u “zoo”, s_pun “spoon”.
Epenthesis	Insertion of a schwa vowel between segments in an initial or medial cluster, indicated by a diacritic for lengthening, e.g., s:pun “spoon”.
Flapping	Substitution of a flap for an alveolar stop in medial position.
Other Substitutions	All other substitution patterns not accounted for by the foregoing process analysis, e.g., s→n (when assimilation is not involved).
Other Deletions	All other deletion patterns not accounted for by the foregoing process analysis, e.g., initial consonant deletion.
Syllable Structure Changes	Syllable loss or addition between the target and transcription forms. Loss of initial unstressed (weak) syllables is normal and continues through Stage II. Other patterns of syllable loss and addition occur in dialectal variation.

Appendix V: Example of PROPH output

PROPH Profile

Filename: 020597-1
020597-10 05-06-2014
Word List: C:\CP\GOSPASS2.WDL gospass2

Diacritics

`	aspirated	<	fronted	(	rounded
>	backed	+	juncture	=	unaspirated
$	denasalized	_	lateralized	!	uncertain
^	dentalized	:	lengthened	ǀ	unreleased
-	derhotacized	*	nasal emission	)	unrounded
.	devoiced	~	nasalized	/	voiced
#	frictionalized	'	palatalized	&	weakened
°	word-final sound produced only when next word has initial vowel				

	Gloss	Target	Transcription	Code
1	at	at	at	
2	baby	bebI	beb>I	
3	badge	bad┐	bad┐'	
4	bag	bag	bag	
5	ball	bôl	vôl	
6	balloon	bÓlun	bÓlu	
7	bells	b¯lz	b¯lz	
8	bobis	bôbIz	bôbIz	
9	boy	boI	boI	
10	bus	b´s	b´s	
11	cake	kek	kek	
12	came	kem	kem	
13	charlies	tʃarliz	tʃarliz	
14	cleaner	klinÕ	klinÕ	
15	daddy	dadI	dadI	
16	daves	devIz	devIz.	
17	dirty	dIrtI	dIrtI	
18	dish	dI¶	dI¶	
19	door	dor	d>or	
20	driving	draIvI³	d>laIvI³	

21	early	¯rli	¯rli		
22	fell	f¯l	f¯l		
23	football	fut+bôl	fut+bôl		
25	garys	gariz	gariz		
26	got	gôt	gôt		
27	got	gôt	gôt		
28	hamster	hamstÕ	ha~msÕ		
29	hand	hand	hand		
30	handis	handIz	ha~ndIz		
31	hannah	hanÓ	ha~nÓ		
32	hat	hat	hat		
33	her	Ó	Ó		
34	his	hIz	Iz		
35	home	hom	hom		
36	hurt	h´rt	h´rt		
37	in	In	In		
38	is	Iz	Iz		
39	is	Iz	I~z		
40	is	Iz	Iz		
41	is	Iz	I~z		
42	johns	d┐ônz	d┐ônz		
43	karen	k¯rÓn	k¯rn		
44	lego	l¯go	l¯g#o		
45	like	laIk	laIk		
46	made	med	med>		
47	magic	mad┐Ik	mad┐I		
48	making	mekI³	mek³		
49	mary	m¯ri	m¯ri		
50	match	matƒ	matƒ*		
51	neil	nil	nim		
52	nest	n¯st	n¯st>		
53	of	Óv	Óv		
54	off	ôv	ôv.		
55	on	ôn	ô~n		
56	on	ôn	ôn		
57	other	´ÙÕ	´ÙÕ		
58	phone	fon	fon		
59	playing	ple+I³	p>le+I³		
61	puppyz	p´pIz	p´pIz		
62	putting	putI³	put³		
63	ringing	rI³I³	rI~³I³		
64	robin	rôbIn	rôb>In		
65	rope	rop	rop		
66	sam	sam	sam		
67	saw	sô	sô		
68	saw	sô	sô		
70	sean	¶ôn	¶'ôn		
71	shelf	¶¯lf	¶¯lf		
72	sitting	sItI³	s<It*I³		
73	sleeve	sliv	sliv		
74	stuarts	stjuÓts	stuÓs		
75	than	ÙÓn	dÓn		
76	the	ÙÓ	ÙÓ		
77	the	ÙÓ	ÙÓ		
78	the	ÙÓ	ÙÓ		
79	the	ÙÓ	ÙÓ		
80	the	ÙÓ	ÙÓ		
81	the	ÙÓ	Ó		

82	the	Ùi	di
83	this	ÙIs	dIs
84	tim	tIm	t>Im
85	up	´p	´p>
86	van	van	van
87	was	wôz	wôz
88	washing	wô¶I³	wô¶'I³
89	watching	wôtƒI³	wôƒ'I³
90	with	wIÚ	wIÚ
91	zebra	z¯brÓ	z¯brÓ
92	zoo	zu	zu

Problems (possible syllable structure simplifications)

1	scrambled	rk#amb>Ól

Code	count
p Problem	1

Total Word Types	78
Total Word Tokens	90
Type-Token Ratio	0.87

Variability Analysis

Number of repeated words, showing same error	0
Number of repeated words, all produced correctly	2
Number of repeated words, showing different errors	0
Number of repeated words, one or more produced correctly	3
Number of repeated words	5
Variability index	0.00

Homonymy Analysis

Number of homonymous forms	0
Number of phonetic forms	82
Ratio of homonymous forms	-----
Proportion of homonymous forms	0.00
Number of homonymous types	0
Number of lexical types	78
Ratio of homonymous types	-----
Proportion of homonymous types	0.00

Independent Analyses

Inventory of Word Shapes

C	0	0.0%	
V	2	2.2%	Syllable Structure Level
CV	10	11.1%	(Paul & Jennings, 1992)
VC	12	13.3%	Level 1 = 2

CVC	28	31.1%	Level 2 = 26
CnV	0	0.0%	Level 3 = 62
CnVC	2	2.2%	SSL = 2.67
VCn	0	0.0%	
C(n)VCn	8	8.9%	
2-syllable	28	31.1%	
3-syllable	0	0.0%	
4-syllable	0	0.0%	
5-syllable	0	0.0%	
6+-syllable	0	0.0%	

Inventory of Stress Patterns

S	53	58.9%
Ss	7	7.8%
Sw	20	22.2%
w	9	10.0%
wS	1	1.1%

Stress Pattern Types 5 Stress Pattern Tokens 90

Inventory of Vowel Phones

Back Series	u	4	o	5	ô	15	ô~	1		
Front Series	i	8	I	24	I~	3	e	7	¯	8
Central Series	a	12	a~	3	Ó	13	´	4		
Diphthongs	aI	2	oI	1	uÓ	1				
Rhotic Series	Õ	3	Ir	1	ar	1	¯r	1	´r	1

Vowel Types 21 Vowel Tokens 118

Inventory of Consonant Phones

Initial

Singletons (listed by place of articulation)

Stops	p	2	b	9	t>	1	d	7	d>	1	k	3
	g	3										
Vibrants												
Nasals	m	5	n	2								
Fricatives	f	3	v	2	Ù	5	s	3	s<	1	z	2
	¶	1	¶'	1	h	7						
Affricates	tƒ	1	d┐	1								
Glides	w	4										
Liquids	l	2	r	3								
Clusters	kl	1	st	1	sl	1	d>l	1	p>l	1	rk#	1

Medial

Singletons (listed by place of articulation)

Stops	p	1	b	1	b>	2	t	2	t*	1	d	1

	k	1	g#	1								
Vibrants												
Nasals	n	2	³	1								
Fricatives	v	2	Ù	1	¶'	1						
Affricates	d┐	1										
Glides												
Liquids	l	3	r	3								
Clusters	br	1	mb>	1	ms	1	nd	1	ƒ'	1		

Final												
Singletons (listed by place of articulation)												
Stops	p	1	p>	1	t	6	d>	1	k	2	g	1
Vibrants												
Nasals	m	5	n	9	³	8						
Fricatives	v	2	v.	1	Ú	1	s	3	z	11	z.	1
	¶	1										
Affricates	tƒ*	1	d┐'	1								
Glides												
Liquids	l	4	r	1								
Clusters	st>	1	lf	1	lz	1	nd	1	nz	1		

	Consonant Types	Consonant Tokens
Initial		
singletons	23	69
clusters	6	6
Medial		
singletons	16	24
clusters	5	5
Final		
singletons	20	61
clusters	4	4
All Positions		
singletons	21	154
clusters	15	15
all phones	36	170

Relational Analyses

Word Shape Target Analysis			
Matches	95.6%	86	
Monosyllabic	62.2%	56	94.9% of all monosyllabic shapes
V		1	
CV		10	
VC		11	
CVC		28	
CnVC		1	
C(n)VCn		5	
Multisyllabic	33.3%	30	96.8% of all multisyllabic shapes
2-syllable		30	
Mismatches	4.4%	4	
Monosyllabic	3.3%	3	5.1% of all monosyllabic shapes

CV-->V		1	
CVC-->VC		1	
C(n)VCn-->CnVC		1	
Multisyllabic	1.1%	1	3.2% of all multisyllabic shapes
2-syllable-->C(n)VCn		1	

Stress Pattern Target Analysis

Matches	96.7%	87	90.3% of all multisyllabic words
S		50	
Ss		7	
Sw		20	
w		9	
wS		1	
Mismatches	3.3%	3	9.7% of all multisyllabic words
Sw-->S		3	

Vowel Target Analysis

Back Series	
u (+)	4
U	-
o (+)	5
ô (+)	15
ô──»ô~	1
@	-
ä	-
Front Series	
i (+)	8
I (+)	24
I──»I~	3
I──»Ý	2
e (+)	7
¯ (+)	8
æ	-
Central Series	
a (+)	11
a──»a~	3
}	-
Ó (+)	12
Ó──»Ý	1
´ (+)	4
Diphthongs	
aI (+)	2
oI (+)	1
aU	-
eI	-
uÓ (+)	1
Rhotic Series	
3	-
Õ (+)	3
Ir (+)	1
ar (+)	1
¯r (+)	1

´r (+)			1

Percentage of Vowels Correct: 109/119 = 91.6%
Percentage of Vowels Correct Ignoring Diacritics: 116/119 = 97.5%

Consonant Target Analysis

	C-	-C-	-C
Stops			
p (+)	2	1	1
p——»p>	0	0	1
b (+)	9	1	0
b——»b>	0	2	0
b——»v	1	0	0
t (+)	0	2	6
t——»t*	0	1	0
t——»t>	1	0	0
d (+)	4	1	0
d——»d>	1	0	1
k (+)	3	1	2
k——»Ý	0	0	1
g (+)	3	0	1
g——»g#	0	1	0
Vibrants			
Ô	-	-	-
Ò	-	-	-
R	-	-	-
Nasals			
m (+)	5	0	4
n (+)	2	2	9
n——»Ý	0	0	1
ñ	-	-	-
³ (+)	0	1	8
Fricatives			
Þ	-	-	-
ß	-	-	-
f (+)	3	0	0
v (+)	1	2	2
v——»v.	0	0	1
Ú (+)	0	0	1
Ù (+)	5	1	0
Ù——»d	3	0	0
Ù——»Ý	1	0	0
s (+)	3	0	2
s——»s<	1	0	0
z (+)	2	0	11
z——»z.	0	0	1
¶ (+)	1	0	1
¶——»¶'	1	1	0
Z	-	-	-
x	-	-	-
þ	-	-	-
h (+)	7	0	0
h——»Ý	1	0	0

	C-	-C-	-C
Affricates			
tʃ (+)	1	0	0
tʃ——»tʃ*	0	0	1
tʃ——»ʃ'	0	1	0
d┐ (+)	1	1	0
d┐——»d┐'	0	0	1
Glides			
w (+)	4	0	0
j	-	-	-
Liquids			
l (+)	2	3	3
l——»m	0	0	1
r (+)	3	3	1
Clusters			
br (+)	0	1	0
dr——»d>l	1	0	0
pl——»p>l	1	0	0
kl (+)	1	0	0
st——»st>	0	0	1
sl (+)	1	0	0
ts——»s	0	0	1
nd (+)	0	1	1
nz (+)	0	0	1
lf (+)	0	0	1
lz (+)	0	0	1
mst——»ms	0	1	0
stj——»st	1	0	0

Percentage Consonants Correct

	Correct	Total	% Occurrence	% Correct
Stops	37	47	27.5%	78.7%
Vibrants	0	0	0.0%	----
Nasals	31	32	18.7%	96.9%
Fricatives	42	52	30.4%	80.8%
Affricates	3	6	3.5%	50.0%
Glides	4	4	2.3%	100.0%
Liquids	15	16	9.4%	93.8%
[Clusters	8	14	8.2%	57.1%]
Cluster Elements	23	30	----	76.7%
PCC	155	187		82.9%
Early 8	59	70		84.3%
Middle 8	41	52		78.8%
Late 8	55	65		84.6%
PCC-Revised	171	187		91.4%
PCC-Adjusted	155	187		82.9%

Severity Adjective (Shriberg & Kwiatkowski, 1982)	Inapplicable
Articulation Competence Index (Shriberg, 1993)	67.3
Phonological Mean Length of Utterance (Ingram & Ingram, 2001)	5.01
Maximum possible PMLU	5.48
Proportion of Whole Word Proximity (Ingram & Ingram, 2001)	91.48

Error Breakdown

Substitutions	8	25.8%
Omissions		
singletons	4	12.9%
entire cluster	0	0.0%
cluster element	1	3.2%
Distortions	16	51.6%
Additions	2	6.5%
Total Errors	31	

Phonological Process Analysis

Process Description	Gloss	Transcription

- Reduplication

Stage I common 0;9-2;1 variable 2;2-2;6

(A multi-syllable production different from the target where the syllables

│are phonetically identical, e.g., [baba] for «bottle», [n´n´] for «tummy».   │
│The target form must be multisyllabic.)

├──Total──
──────┤
│   Occ 0   Opp 29   0% Process Usage   41% Other Errors   59% Correct   │
ã═══
═════Á
│- Velar Assimilation

│Stages I-II   common 0;9-2;4   variable 2;5-3;0

│(The substitution of a velar consonant in a word containing a velar target   │
│sound, e.g., [g´k] for «duck», [gægÓn] for «wagon», [gæjum] for «vacuum».   │
├──Total──
──────┤
│   Occ 0   Opp 19   0% Process Usage   32% Other Errors   68% Correct   │
ã═══
═════Á
│- Nasal Assimilation

│Stages I-II   common 0;9-2;4   variable 2;5-3;0

│(The substitution of a nasal consonant in a word containing another nasal,   │
│whether correctly produced or substituted for another phone, e.g., [n´n]

│for «sun», [mæmiz] for «matches», [ne³] for «snake».

│   l──»m   51 neil   nim

├──Total──
──────┤
│   Occ 1   Opp 34   3% Process Usage   44% Other Errors   53% Correct   │
ã═══
═════Á
│- Velar Fronting

│Stages I-III common 0;9-2;6   variable 2;7-3;3

│The substitution of an alveolar stop for a velar stop in either singleton or │
│cluster context, e.g., k──»t, g──»d, ³──»n, k──»d, g──»t, ³──»d, kr--»tr,   │
│kr--»tw.

├──Initial──
──────┤
│   Occ 0   Opp 7   0% Process Usage   0% Other Errors 100% Correct   │
├──Medial───
──────┤

```
│      Occ  0   Opp  3    0% Process Usage   33% Other Errors   67%
Correct    │
├──Final──────────────────────────────────────────────────────────────────
───────┤
│      Occ  0   Opp 12    0% Process Usage    8% Other Errors   92%
Correct    │
├──Total──────────────────────────────────────────────────────────────────
───────┤
│      Occ  0   Opp 22    0% Process Usage    9% Other Errors   91%
Correct    │
ã═════════════════════════════════════════════════════════════════════════
═════Á
│- Early Stopping (f,s,¶,Ú)
│
│Stages I-III  common  0;9-2;5  variable 2;6-3;0
│
│The substitution of a homorganic or near-homorganic stop for the
fricatives  │
│/f, Ú, s, ¶/ in either singleton or cluster context, e.g., f──»p, f──»b,
│
│Ú──»t, Ú──»p, s──»d, s──»t, ¶──»t, ¶──»d, fr--»pr, fr--»pw, ¶r──»tr.
│
├──Initial────────────────────────────────────────────────────────────────
───────┤
│      Occ  0   Opp  9    0% Process Usage   22% Other Errors   78%
Correct    │
├──Medial─────────────────────────────────────────────────────────────────
───────┤
│      Occ  0   Opp  1    0% Process Usage  100% Other Errors    0%
Correct    │
├──Final──────────────────────────────────────────────────────────────────
───────┤
│      Occ  0   Opp  4    0% Process Usage    0% Other Errors  100%
Correct    │
├──Total──────────────────────────────────────────────────────────────────
───────┤
│      Occ  0   Opp 14    0% Process Usage   21% Other Errors   79%
Correct    │
ã═════════════════════════════════════════════════════════════════════════
═════Á
│- Final Consonant Deletion
│
│Stages I-IV   common 0;9-2;9   variable 2;10-3;3
│
│The omission of a final consonant singleton or cluster except for nasal
and   │
│liquid singletons.
│
│      k──»Ý                    47 magic               mad┐I
│
├──Total──────────────────────────────────────────────────────────────────
───────┤
│      Occ  1   Opp 40    3% Process Usage   20% Other Errors   78%
Correct    │
ã═════════════════════════════════════════════════════════════════════════
═════Á
│- Context-Sensitive Voicing (singletons)
│
```

│Stages I-IV   common 0;9-2;3   variable 2;4-3;0

│The substitution of a consonant singleton by its voiced or voiceless cognate,│
│e.g., p──»b, b──»p, t──»d, d──»t, f──»v, z──»s.
│
├──Initial──┤
│   Occ 0   Opp 47   0% Process Usage   19% Other Errors   81% Correct   │
├──Medial───┤
│   Occ 0   Opp 16   0% Process Usage   38% Other Errors   63% Correct   │
├──Final──┤
│   Occ 0   Opp 34   0% Process Usage   21% Other Errors   79% Correct   │
├──Total──┤
│   Occ 0   Opp 97   0% Process Usage   23% Other Errors   77% Correct   │
ã═══Á
│- Cluster Reduction

Stages I-IV   common 0;9-3;3   variable 3;4-3;9

The replacement of a consonant cluster by a consonant singleton or by a

cluster containing fewer consonants, e.g., bl──»b, sw──»s, spl──»pw.
│
├──Initial──┤
│   stj──»st   74 stuarts   stuÓs
│
│   Occ 1   Opp 5   20% Process Usage   40% Other Errors   40% Correct   │
├──Medial───┤
│   mst──»ms   28 hamster   ha~msÕ
│
│   Occ 1   Opp 3   33% Process Usage   0% Other Errors   67% Correct   │
├──Final──┤
│   ts──»s   74 stuarts   stuÓs
│
│   Occ 1   Opp 6   17% Process Usage   17% Other Errors   67% Correct   │
├──Total──┤
│   Occ 3   Opp 14   21% Process Usage   21% Other Errors   57% Correct   │
ã═══Á
│- Gliding
│

```
│Stages I-VII  common 0;9-2;11  variable 3;0-5;0+
│
│The substitution of a glide for a liquid singleton, i.e., r──»w, l──»w,
│
│r──»j, l──»j.
│
├──Initial────────────────────────────────────────────────────────────────
─────┤
│      Occ  0   Opp  5    0% Process Usage    0% Other Errors  100%
Correct    │
├──Medial─────────────────────────────────────────────────────────────────
─────┤
│      Occ  0   Opp  6    0% Process Usage    0% Other Errors  100%
Correct    │
├──Final──────────────────────────────────────────────────────────────────
─────┤
│      Occ  0   Opp  5    0% Process Usage   20% Other Errors   80%
Correct    │
├──Total──────────────────────────────────────────────────────────────────
─────┤
│      Occ  0   Opp 16    0% Process Usage    6% Other Errors   94%
Correct    │
ã═════════════════════════════════════════════════════════════════════════
═════Á
│- Palatal Fronting (¶,Z,tƒ,d┐)
│
│Stages IV-V   common 2;9-3;5   variable 3;6-4;3
│
│The substitution of an alveolar fricative for a palatal fricative or
│
│affricate, e.g., ¶──»s, tƒ──»z, Z──»s, d┐──»z.  Note that the
substitution    │
│of an alveolar stop for a palatal phoneme is analyzed as Stopping.
│
├──Initial────────────────────────────────────────────────────────────────
─────┤
│      Occ  0   Opp  4    0% Process Usage   25% Other Errors   75%
Correct    │
├──Medial─────────────────────────────────────────────────────────────────
─────┤
│      Occ  0   Opp  3    0% Process Usage   67% Other Errors   33%
Correct    │
├──Final──────────────────────────────────────────────────────────────────
─────┤
│      Occ  0   Opp  3    0% Process Usage   67% Other Errors   33%
Correct    │
├──Total──────────────────────────────────────────────────────────────────
─────┤
│      Occ  0   Opp 10    0% Process Usage   50% Other Errors   50%
Correct    │
ã═════════════════════════════════════════════════════════════════════════
═════Á
│- Later Stopping (v,Ù,z,Z,tƒ,d┐)
│
│Stages IV-VII common 0;9-4;8   variable 2;6-5;0+
│
│The substitution of a homorganic stop for the fricatives /v, Ù, z, Z/ or
│
```

the substitution of a stop for an affricate in either singleton or cluster
context, e.g., v—»b, Ù—»d, z—»t, Z—»d, tʃ—»d, d┐—»d, vd—»bd.

Initial

Ù—»d	75	than	dÓn
	82	the	di
	83	this	dIs

Occ 3 Opp 14 21% Process Usage 7% Other Errors 71% Correct

Medial

Occ 0 Opp 5 0% Process Usage 20% Other Errors 80% Correct

Final

Occ 0 Opp 17 0% Process Usage 24% Other Errors 76% Correct

Total

Occ 3 Opp 36 8% Process Usage 17% Other Errors 75% Correct

- Fricative Simplification (Ú,Ù)

Stages IV-VII common 2;6-3;6 variable 3;7-4;6

The substitution of a labiodental or alveolar fricative for an interdental fricative with no change in voicing, i.e., Ú—»f, Ú—»s, Ù—»v, Ù—»z.

Initial

Occ 0 Opp 9 0% Process Usage 44% Other Errors 56% Correct

Medial

Occ 0 Opp 1 0% Process Usage 0% Other Errors 100% Correct

Final

Occ 0 Opp 1 0% Process Usage 0% Other Errors 100% Correct

Total

Occ 0 Opp 11 0% Process Usage 36% Other Errors 64% Correct

- Cluster Simplification (C/l/,C/r/)

Stages V-VI variable 3;6-4;0

│The substitution of a glide for a liquid in C[r], C[l], CC[r], and CC[l]
│
│clusters, e.g., bl──»bw, br--»bj, tr──»tw, spl──»spw.
│
├──Initial──
──────┤
│   Occ 0   Opp 4   0% Process Usage   50% Other Errors   50%
Correct   │
├──Medial───
──────┤
│   Occ 0   Opp 1   0% Process Usage   0% Other Errors 100%
Correct   │
├──Final──
──────┤
│   Occ 0   Opp 0 ---- Process Usage ---- Other Errors ----
Correct   │
├──Total──
──────┤
│   Occ 0   Opp 5   0% Process Usage   40% Other Errors   60%
Correct   │
ã═══
═════Á
│- Deaffrication
│
│Stages V-VI variable 3;2-4;8
│
│The substitution of a palatal fricative for an affricate, e.g., tʃ──»¶,
│
│d┐──»Z.
│
├──Initial──
──────┤
│   Occ 0   Opp 2   0% Process Usage   0% Other Errors 100%
Correct   │
├──Medial───
──────┤
│   Occ 0   Opp 2   0% Process Usage   50% Other Errors   50%
Correct   │
├──Final──
──────┤
│   Occ 0   Opp 2   0% Process Usage 100% Other Errors   0%
Correct   │
├──Total──
──────┤
│   Occ 0   Opp 6   0% Process Usage   50% Other Errors   50%
Correct   │
ã═══
═════Á
│- Liquid Deletion
│
│Atypical in initial and medial position, variable 2;0-5;0+ in final
position │
│Liquids /l/ and /r/ are deleted or replaced by a back vowel, e.g.,
│
│ræbIt──»æbIt, k¯rÓt──»k¯ÝÓt, däl──»däo. In final position, this process
may │
│also be referred to as Vocalization or Vowelization.
│

```
├──Initial──────────────────────────────────────────────────────────────
───────┤
|       Occ  0    Opp  5    0% Process Usage    0% Other Errors  100%
Correct    |
├──Medial───────────────────────────────────────────────────────────────
───────┤
|       Occ  0    Opp  6    0% Process Usage    0% Other Errors  100%
Correct    |
├──Final────────────────────────────────────────────────────────────────
───────┤
|       Occ  0    Opp  5    0% Process Usage   20% Other Errors   80%
Correct    |
├──Total────────────────────────────────────────────────────────────────
───────┤
|       Occ  0    Opp 16    0% Process Usage    6% Other Errors   94%
Correct    |
ã═══════════════════════════════════════════════════════════════════════
═════Á
|- Backing of Alveolars

 Atypical process

|The substitution of velar consonants for alveolar consonants, e.g.,
t──»k,    |
|d──»g, n──»³, s──»k, z──»g.  Velar Assimilation may be operative in
certain   |
|instances.
|
├──Initial──────────────────────────────────────────────────────────────
───────┤
|       Occ  0    Opp 12    0% Process Usage   25% Other Errors   75%
Correct    |
├──Medial───────────────────────────────────────────────────────────────
───────┤
|       Occ  0    Opp  4    0% Process Usage   25% Other Errors   75%
Correct    |
├──Final────────────────────────────────────────────────────────────────
───────┤
|       Occ  0    Opp 21    0% Process Usage   10% Other Errors   90%
Correct    |
├──Total────────────────────────────────────────────────────────────────
───────┤
|       Occ  0    Opp 37    0% Process Usage   16% Other Errors   84%
Correct    |
ã═══════════════════════════════════════════════════════════════════════
═════Á
|- Glottal Substitution

 Atypical process

|The substitution of a glottal stop /?/ or a glottal fricative /h/ for
another|
|consonant singleton or cluster, e.g., d──»h, s──»?, sp──»h, sk──»?.
|
├──Initial──────────────────────────────────────────────────────────────
───────┤
|       Occ  0    Opp 67    0% Process Usage   16% Other Errors   84%
Correct    |
```

├──Medial──
──────┤
│   Occ 0   Opp 27   0% Process Usage   22% Other Errors   78%
Correct   │
├──Final───
──────┤
│   Occ 0   Opp 67   0% Process Usage   16% Other Errors   84%
Correct   │
├──Total───
──────┤
│   Occ 0   Opp161   0% Process Usage   17% Other Errors   83%
Correct   │
ã══
═════Á
│- Sound Additions

Atypical process

│A word normally initiated with a vowel is instead initiated with a
consonant,│
│e.g., æpÓl──»bæpÓl, or a word terminating with a vowel is terminated
with a │
│consonant, e.g., pIlo--pIlos. The process cannot occur in medial
position. │
├──Initial───
──────┤
│   Occ 0   Opp 0 ---- Process Usage ---- Other Errors ----
Correct   │
├──Medial──
──────┤
│   Occ 0   Opp 0 ---- Process Usage ---- Other Errors ----
Correct   │
├──Final───
──────┤
│   Occ 0   Opp 0 ---- Process Usage ---- Other Errors ----
Correct   │
├──Total───
──────┤
│   Occ 0   Opp 0 ---- Process Usage ---- Other Errors ----
Correct   │
ã══
═════Á
│# Other Substitutions & Distortions

├──Initial───
──────┤

b──»v	5 ball	vôl
t──»t>	84 tim	t>Im
d──»d>	19 door	d>or
s──»s<	72 sitting	s<It*I³
¶──»¶'	70 sean	¶'ôn
dr──»d>l	20 driving	d>laIvI³

```
│      pl──»p>l                 59 playing            p>le+I³
│
├──Medial────────────────────────────────────────────────────────────
─────┤
│      b──»b>                    2 baby               beb>I
│
│      b──»b>                   64 robin              rôb>In
│
│      t──»t*                   72 sitting            s<It*I³
│
│      g──»g#                   44 lego               l¯g#o
│
│      ¶──»¶'                   88 washing            wô¶'I³
│
│      tʃ──»ʃ'                  89 watching           wôʃ'I³
│
├──Final─────────────────────────────────────────────────────────────
─────┤
│      p──»p>                   85 up                 ´p>
│
│      d──»d>                   46 made               med>
│
│      v──»v.                   54 off                ôv.
│
│      z──»z.                   16 daves              devIz.
│
│      tʃ──»tʃ*                 50 match              matʃ*
│
│      d┐──»d┐'                  3 badge              bad┐'
│
│      st──»st>                 52 nest               n¯st>
│
├──Total─────────────────────────────────────────────────────────────
─────┤
│      Occ 20   Opp --  ---- Process Usage    0% Other Errors  ----
Correct   │
ã════════════════════════════════════════════════════════════════════
═════Á
│# Other Deletions
│
├──Initial───────────────────────────────────────────────────────────
─────┤
│      Ù──»Ý                    81 the                Ó
│
│      h──»Ý                    34 his                Iz
│
├──Medial────────────────────────────────────────────────────────────
─────┤
├──Final─────────────────────────────────────────────────────────────
─────┤
│      n──»Ý                     6 balloon            bÓlu
│
├──Total─────────────────────────────────────────────────────────────
─────┤
│      Occ  3   Opp --  ---- Process Usage    0% Other Errors  ----
Correct   │
ã════════════════════════════════════════════════════════════════════
═════Á
```

¨ Syllable Structure Changes - Deletions

Sw-->S	39 putting	putV³
	72 karen	k¯rVn
	74 making	mekV³

Occ 3 Multisyllabic Opp 31 Monosyllabic Opp 59 10% Usage

ã

Á

Syllable Structure Changes - Additions

Occ 0 Multisyllabic Opp 31 Monosyllabic Opp 59 0% Usage

Appendix VI: Letter of favourable opinion by NHS Rec

Part of the research infrastructure for Wales funded by the National Institute for Social Care and Health Research, Welsh Government.
Yn rhan o seilwaith ymchwil Cymru a ariennir gan y Sefydliad Cenedlaethol ar gyfer Ymchwil Gofal Cymdeithasol ac Iechyd, Llywodraeth Cymru

NISCHR
Gwasanaeth Moeseg Ymchwil | RES | Research Ethics Service

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E-mail : sue.byng@wales.nhs.uk
Website : www.nres.nhs.uk

Dr Wendy Cohen
School of Psychological Sciences and Health
University of Strathclyde
Graham Hills Building
Glasgow
G1 1QE

26 February 2014

Dear Dr Cohen

Study title:	**Speech factors predicting change in children with repaired cleft palate**
REC reference:	**14/WA/0079**
Protocol number:	**uec14/07**
IRAS project ID:	**149868**

The Proportionate Review Sub-committee of the Dyfed Powys Research Ethics Committee reviewed the above application on 26 February 2014.

We plan to publish your research summary wording for the above study on the NRES website, together with your contact details, unless you expressly withhold permission to do so. Publication will be no earlier than three months from the date of this favourable opinion letter. Should you wish to provide a substitute contact point, require further information, or wish to withhold permission to publish, please contact the Co-ordinator Mrs Sue Byng, sue.byng@wales.nhs.uk.

Ethical opinion

On behalf of the Committee, the sub-committee gave a favourable ethical opinion of the above research on the basis described in the application form, protocol and supporting documentation, subject to the conditions specified below.

Ethical review of research sites

The favourable opinion applies to all NHS sites taking part in the study, subject to management permission being obtained from the NHS/HSC R&D office prior to the start of the study (see "Conditions of the favourable opinion" below).

Conditions of the favourable opinion

The favourable opinion is subject to the following conditions being met prior to the start of the study.

Management permission or approval must be obtained from each host organisation prior to the start of the study at the site concerned.

Management permission ("R&D approval") should be sought from all NHS organisations involved in the study in accordance with NHS research governance arrangements.

Guidance on applying for NHS permission for research is available in the Integrated Research Application System or at http://www.rdforum.nhs.uk.

Where a NHS organisation's role in the study is limited to identifying and referring potential participants to research sites ("participant identification centre"), guidance should be sought from the R&D office on the information it requires to give permission for this activity.

For non-NHS sites, site management permission should be obtained in accordance with the procedures of the relevant host organisation.

Sponsors are not required to notify the Committee of approvals from host organisations.

Registration of Clinical Trials

All clinical trials (defined as the first four categories on the IRAS filter page) must be registered on a publically accessible database within 6 weeks of recruitment of the first participant (for medical device studies, within the timeline determined by the current registration and publication trees).

There is no requirement to separately notify the REC but you should do so at the earliest opportunity e.g when submitting an amendment. We will audit the registration details as part of the annual progress reporting process.

To ensure transparency in research, we strongly recommend that all research is registered but for non clinical trials this is not currently mandatory.

If a sponsor wishes to contest the need for registration they should contact Catherine Blewett (catherineblewett@nhs.net), the HRA does not, however, expect exceptions to be made. Guidance on where to register is provided within IRAS.

You should notify the REC in writing once all conditions have been met (except for site approvals from host organisations) and provide copies of any revised documentation with updated version numbers. The REC will acknowledge receipt and provide a final list of the approved documentation for the study, which can be made available to host organisations to facilitate their permission for the study. Failure to provide the final versions to the REC may cause delay in obtaining permissions.

It is the responsibility of the sponsor to ensure that all the conditions are complied with before the start of the study or its initiation at a particular site (as applicable).

Approved documents

The documents reviewed and approved were:

Document	*Version*	*Date*
Evidence of insurance or indemnity		12 February 2014
CV: Dr Wendy Cohen		06 February 2014
CV: Dr Anja Lowit		14 February 2014
CV: Erica Schulz		13 February 2014
NHS GGC Consent Form		
Protocol	1	07 February 2014
REC application	1	13 February 2014

Membership of the Proportionate Review Sub-Committee

The members of the Sub-Committee who took part in the review are listed on the attached sheet.

Statement of compliance

The Committee is constituted in accordance with the Governance Arrangements for Research Ethics Committees and complies fully with the Standard Operating Procedures for Research Ethics Committees in the UK.

After ethical review

Reporting requirements

The attached document "After ethical review – guidance for researchers" gives detailed guidance on reporting requirements for studies with a favourable opinion, including:

- Notifying substantial amendments
- Adding new sites and investigators
- Notification of serious breaches of the protocol
- Progress and safety reports
- Notifying the end of the study

The NRES website also provides guidance on these topics, which is updated in the light of changes in reporting requirements or procedures.

Feedback

You are invited to give your view of the service that you have received from the National Research Ethics Service and the application procedure. If you wish to make your views known please use the feedback form available on the website.
information is available at National Research Ethics Service website > After Review

14/WA/0079	Please quote this number on all correspondence

We are pleased to welcome researchers and R & D staff at our NRES committee members' training days – see details at http://www.hra.nhs.uk/hra-training/

With the Committee's best wishes for the success of this project.

Yours sincerely

Sue Byg

pp **Mr Derek Lassetter**
Vice-Chair

Enclosures:	*List of names and professions of members who took part in the review*
	"After ethical review – guidance for researchers"
Copy to:	*Joanne McGarry, NHS Greater Glasgow and Clyde* *Helen Baigrie, University of Strathclyde* *Erica Schulz*

Dyfed Powys Research Ethics Committee

Attendance at PRS Sub-Committee of the REC meeting on 26 February 2014

Committee Members:

Name	*Profession*	*Present*	*Notes*
Mrs Sarah Jones	Clinical Trials Nurse	Yes	
Mr Derek Lassetter	Lay member / Vice-Chair	Yes	
Mrs Rosemary Whittemore	Lay member	Yes	

Also in attendance:

Name	*Position (or reason for attending)*
Mrs Sue Byng	REC Coordinator

List of acronyms

ABG
: alveolar bone graft

BCLP
: bilateral cleft lip and palate

CAPS
: Cleft Audit Protocol for Speech

CAPS-A
: Cleft Audit Protocol for Speech – Augmented

CL
: cleft lip

CL±P
: cleft lip and/or palate

CLEFTSiS
: Clinical Network for Cleft Service in Scotland

CLP
: cleft lip and palate

CP
: cleft palate

CP±L
: cleft palate with or without cleft lip

CPh
: cleft hard and soft palate

CPro
: Computerised Profiling 9.7.0

CPS
: cleft palate speech

CPs
: cleft soft palate

CSAG
: Clinical Standards Advisory Group

CTC
: cleft type characteristics

ENT
: ear, nose and throat specialist

EPG
: electropalatography

extIPA
: extended International Phonetic Alphabet Symbols for Disordered Speech

GOS.SP.ASS.
: Great Ormond Street Speech Assessment

HSD
: Honestly Significant Difference

IPA
: International Phonetic Alphabet

IPAT
: Iowa Pressure Articulation Test

KLPA
: Khan-Lewis Process Analysis

MANOVA
: multivariate analysis of variance

NHS
: National Health Service

NSA
: normal speech acquisition

PCC
: Percentage of Consonants Correct

PCC-A
: Percentage of Consonants Correct – Adjusted

PCC-R
: Percentage of Consonants Correct – Revised

PIC
: pre-foramen incisor cleft

PPS
: primary palate surgery

PROPH
: profile of phonology

PRS
: Pierre Robin sequence

RE
: Residual-Error

SD
: speech delay

SLT
: speech and language therapist

SSBE
: Southern Standard British English

SSE
: Standard Scottish English

SSS
: secondary speech surgery

ST

speech and language therapy

TIC

trans-foramen incisor cleft

UCLP

unilateral cleft lip and palate

VPI

velopharyngeal insufficiency