CHAIN SHIFTS IN FIRST LANGUAGE ACQUISITION

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PREFACE

The idea for this thesis originated in the course *Phonological Acquisition* taught by René Kager. I read the article *On the characterization of a chain shift in normal and delayed phonological acquisition* by Daniel Dinnsen and Jessica Barlow (1998) and was intrigued by the phenomenon. After I started reading more on the subject, I became increasingly unhappy with the proposed analyses in the literature and decided to dive deeper into the matter. The result is this thesis.

I would like to thank René for his useful comments, critical questions and positive feedback. And I want to thank Ellen, Helga and Jaap for helping me recover my energy to write this thesis, Martin for his help with my English, and Roel for his everlasting support.

Fransien Walton
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1. INTRODUCTION

All normally developing children learn to speak their mother tongue perfectly. From an early stage of meaningless babbling they proceed through stages with increasing syntactic, semantic and phonological complexity until they have fully mastered their language. This is quite remarkable. The study of first language acquisition is important for linguistic theory, because the manner in which the child's language system develops can tell us more about language in general.

This thesis is concerned with children's phonological development. Children's early speech is impoverished relative to the target system. Typical first speech productions are meaningless *bababa*, *gagaga* and *dadada* sequences. From this stage children proceed to produce their first words, which consist of many errors relative to the target language. The speech errors can be substitutions of one sound for another, omission of (part of) an onset or a coda or omission of whole syllables. Examples of this can be found in the data of Smith (1973) who studied the phonological development of his son Amahl. At age 2;3[1] Amahl substitutes stops for target fricatives, producing [maut] for *mouse*, he sometimes deletes codas, e.g. [d̥idə] for *scissors*, and he deletes sounds from complex onsets and codas, e.g. [b̥ei] for *play* and [mik] for *milk*. With time children's speech productions become more complex and more in line with the target language. For example, at age 2;7 Amahl is first reported to produce *milk* as [milk], and in following stages he also produces *mouse*, *scissors* and *play* target-like.

Children's speech production data provide a window into the system of language. From their, often systematic, deviations from the target language we can infer how children acquire the phonology of their language. When we understand why children make certain speech errors and how they learn to overcome those errors we learn more about language in general. For example, all children start to produce stop consonants before fricatives regardless of the language they are acquiring. Moreover, in early speech target fricatives are often substituted by stops. The question is what causes this universal preference for stops. Within Optimality Theory the preference is explained by assuming that fricatives are universally more marked than stops, and that this markedness is encoded in the grammar.

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[1] Following convention age is notated in years and months. Age 2;3 means 2 years and 3 months.

Articulatory factors may also explain the preference, because stops are easier to articulate than fricatives (Perkell 1997, Vihman 1996). Another question is how children learn to overcome this preference and to produce fricatives. Is this a question of a developing grammar or developing articulatory abilities? Answers to those question tells us more about the system of language.

Children’s speech errors can thus be viewed as puzzles. Some attested errors can be readily explained within current linguistic theory, but for other error patterns there does not seem to be a straightforward explanation. Chain shifts constitute an example of error patterns that are not accounted for easily.

A common substitution pattern for both typically developing children and children with a phonological delay is the substitution of [f] for target /θ/. In this case the child pronounces both *thin* and *fin* as [fin]. Interestingly, in some cases this error pattern co-occurs with another error pattern: the substitution of [θ] for target /s/ (Dinnsen & Barlow 1998, Gierut & Champion 1999). In this case *sin* is realized as [θin]. These two error patterns can occur independently in different child’s systems, but they can also co-occur in the system of one child (Dinnsen & Barlow 1998, Dinnsen et al 2011). When these patterns co-occur the result is a chain shift as schematized in (1). Children who evidence this chain shift in their production substitute [θ] for target /s/, and substitute [f] for target /θ/, while /f/ is produced target-like.

(1) *Schematization of the s-θ-f chain shift*

$$\begin{tikzcd}
\text{/s/} \arrow[dr] & \text{/}\theta\text{/} \arrow[dr] & \text{/f/} \arrow[d] \\
& {[\theta]} & {[\text{f}]}
\end{tikzcd}$$

Subject 33 in the study of Dinnsen and Barlow (1998) exhibited a phonological disorder and evidenced the *s-θ-f* chain shift. In (2) a pretreatment speech sample of this subject is shown to further illustrate the chain shift.

(2) *Subject 33, age 5;4 (Dinnsen & Barlow, 1998:66)*

a. [f] for target /f/

[faɪjɚ]	‘fire’	[faɪv]	‘five’
[tafɪn]	‘coughing’	[buɾefʊ]	‘beautiful’
[naɪf]	‘knife’	[jif]	‘leaf’

b. [f] for target /θ/

[fʌm]	‘thumb’	[form]	‘thorn’
[tifi]	‘teeth (dimin.)’	[maʊfi]	‘mouth (dimin.)’
[bæf]	‘bath’	[tuf]	‘tooth’

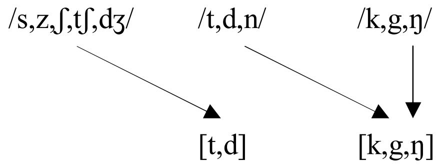
c. [θ] for target /s/

[θiʔ]	‘sink’	[θʌn]	‘sun’
[dɛθi]	‘dress (dimin.)’	[aɪθi]	‘icy’
[veɪθ]	‘vase’	[duθ]	‘juice’

Chain shifts constitute a fascinating phenomenon, because it is unclear why a child is able to produce a target sound, but only uses it as a substitute for another target sound. In this case, the child is able to produce [θ], but only produces it when substituting for /s/.

Another child chain shift reported in the literature is the *puzzle-puddle-pickle* problem. Smith (1973) studied the phonological development of his son Amahl and described two interacting error patterns that occurred between age 2;2 and 2;11. In this stage Amahl replaced target fricatives with stops, changing the word *puzzle* into [pʌdl̩]. At the same time he replaced target coronal stops with a velar before /l/, changing the word *puddle* into [pʌgl̩]. Velar stops were produced targetlike, that is, *pickle* was produced as [pɪkl]. So in this chain shift *puzzle* words become *puddle* words and *puddle* words become *pickle* words, while *pickle* words are produced target-like. Again one might wonder why *puzzle* does not change all the way to [pʌgl̩]. In (3) the *puzzle-puddle-pickle* problem is schematized and in (4) it is further illustrated by productions from Amahl.

(3) *Schematization of the puzzle-puddle-pickle problem*



(4) *Amahl, age 2;2-2;11 (Smith 1973)*

a. ***puzzle* words realized as *puddle* words**

[pʌdl̩]	‘puzzle’
[pɛntl̩]	‘pencil’
[wɪtl̩]	‘whistle’

b. ***puddle* words realized as *pickle* words**

[pʌgl̩]	‘puddle’
[bɔkl̩]	‘bottle’
[hæŋgl̩]	‘handle’

c. ***pickle* words realized target-like**

[pɪkl̩]	‘pickle’
[təːkl̩]	‘circle’

For both chain shifts a period of variability is reported following the chain shift stage. That is, there is no across-the-board elimination of all production errors (Dinnsen & Barlow 1998, Macken 1980). An important question is whether this variation occurs between words or within words, that is, is the chain shift resolved per lexical item or is there a period of free variation following the chain shift stage. Dinssen and Barlow (1998) claim that the *s-θ-f* chain shift is resolved per lexical item. However, a closer look at their data reveals that each lexical item only occurs once per speech sample. On the basis of their data it is not possible to decide whether the variation following the pure chain shift stage exists only between words or also within words.

Macken’s analysis of Smith’s data shows that there is an across-the-board elimination of the substitution of *puddle* for *puzzle* words and a period of variability for the substitution of *pickle* for *puddle* words (Macken 1980). In the stage of variability for *puddle* words the data only provides one *puddle* word that is produced more than once. This word shows intra-word variation, that is, *bottle* is produced as both [bɔkl̩] and [bɔtl̩] in this stage. Preceding this stage, 10 (out of 47) *puddle* words are already occasionally produced target-like. One of them, *cuddle*, is produced target-like at age 2;10 whereas it is produced as [kʌgl̩] five months later. None of the other words show intra-word variability. That is, after the word is produced target-like for the first time no substitution is seen anymore. There is thus no strong evidence for intra-word variability.

A similar pattern can be found in the data of one of the subjects in a study by Gierut & Champion (1999) for the *s-θ-f* chain shift. Gierut and Champion studied the data of two boys with a phonological delay elicited in a spontaneous picture naming task pre- and post-treatment. Both boys evidenced the *s-θ-f* chain shift and received treatment on /s/. Subject 74 shows an across-the-board elimination of all errors on /s/. In the three post-treatment samples (immediately post-treatment, two weeks later and two months later) all productions of /s/ are target-like (100%). Meanwhile his productions of /θ/ have not improved much, with only one or two target-like productions in each post-treatment sample (20.8%).

However, the other child in this study, subject 90, shows a very different pattern. His productions of /s/ do not improve significantly after treatment, although he shows some target-like productions (23.3%). The data also show two target-like productions of /s/ pre-treatment (20%). His productions of /θ/ show some more improvement, 3 target-like productions in each post-treatment speech sample (37.5%).

The interpretation of these data is not straightforward, because we see an across-the-board elimination of errors for /s/ for one child, but for the other there seems to be variability. For the error pattern with /θ/ a period of variability can be seen for both children. This variability seems to be between words, except for one word for each subject that shows variation in the post-treatment samples: subject 74 pronounces *bath* alternately as [bæf] and [bæθ] and subject 90 pronounces *thief* alternately as [θif], [fif] and [čif].

The *s-θ-f* chain shift has been reported to be resistant to treatment (Dinnsen & Barlow 1998, Gierut & Champion 1999). Dinnsen and Barlow (1998) report that five children with a phonological delay who evidenced the *s-θ-f* chain shift did not resolve their error patterns after conventional minimal pair treatment. However, only two of these five children received treatment on /s/ or /θ/. In a study by Gierut and Champion (1999) both children evidenced gains in production accuracy after treatment on /s/, but not all error patterns were resolved.

Morrisette and Gierut (2008) report about three children receiving minimal triplet treatment with non-word triplets starting with the sounds of the chain shift (s θ f). This treatment was able to resolve the chain shift effect for all three children. However, two of the children only evidenced the chain shift in word-initial position, which means that they already correctly produced /s/ and /θ/ in other positions.

The *puzzle-puddle-pickle* problem was listed as one of the puzzles in Smith's analysis of his son's data (Smith 1973:4). Both chain shifts remain puzzles for linguistic theory, because it is not clear how these chain shifts arise and subside in the child's system.

In general, substitution patterns can be caused by a number of factors. One sound can be substituted by another because of articulatory difficulties. If a child has trouble correctly producing a sound he might produce a different, but similar sound instead. For example, children who have trouble with the correct articulate of /s/ might produce [ʃ] instead. Perceptual problems can also be the cause of a substitution pattern. If a child does not hear the difference between two sounds he is likely to collapse these sounds in production as well. This results in an apparent substitution of one sound for the other. For example, if a child does not hear the difference between /b/ and /p/ he might consistently use [p] for both target sounds.

The child's grammar may also be responsible for a substitution pattern. A grammatical process may change one sound into another. For example, substitution of [t] for target /s/ can be explained by assuming a grammatical process that changes fricatives into stops. Alternatively, the child's grammar may lack a distinction between two sounds, because of a problem with the encoding of features in underlying representations. For example, if the child does hear the difference between /b/ and /p/, but somehow fails to encode the feature [voice] for /b/ in the representation of this sound, this will result in the production of [p] for both target /p/ and /b/.

It is unclear which of these processes is responsible for the chain shifts in first language acquisition. For the *s-θ-f* chain shift, the substitution of [f] for /θ/ cannot be due to articulatory difficulties, because the child is able to pronounce [θ]. Perceptual problems may play a role, but they cannot provide a full account of the chain shift. The child is clearly able to make a distinction between /s/ and /θ/, because the first is substituted by [θ] and the latter by [f]. And if the substitution pattern is the result of a grammatical mechanism, the question arises why [f] is not the substitute for both /s/ and /θ/. If there is a grammatical reason to change /θ/ to [f], why does this not hold when [θ] is a result of a substitution? The chain shifts thus pose a challenge to grammatical theories.

Questions that arise are: How can a chain shift be encoded in the grammar? And how can a child learn this grammar? Answers to these questions are not straightforward as will be seen in chapter 2. Jesney (2005:12) points out that there is no direct positive evidence for the chain shift effect in the target language. Still, child chain shifts do occur and are in need of an explanation. In the analysis the patterns of variation found for the chain shifts also need to be taken into account.

The main question of this thesis will be:
How can we best account for chain shifts in first language acquisition?

The best account is one that does not only capture the chain shift effect, but also provides a plausible theory of learnability. Within generative grammar the main focus has been on a grammatical explanation for child chain shifts. I will show that almost all grammatical accounts encounter learnability problems. Consequently I will argue that chain shifts in first language acquisition are due to two interacting error patterns, one caused by articulatory factors and the other by perceptual difficulties. In my view the chain shift patterns in children's speech are not a result of a grammatical process that needs to be learned by the child. Rather, the patterns surface in the speech productions as a direct result of misarticulation and misperception by the child. I argue that the chain shift patterns are not learned by the child, but are the result of independently motivated processes of articulation and perception that influence the child's speech output.

The rest of this thesis is structured as follows. In chapter 2 I will give an overview of the literature and discuss earlier proposals for child chain shifts within generative grammar. In chapter 3 I will present a new proposal and substantiate my claims with evidence. Chapter 4 will consist of a discussion of the proposed analyses for child chain shifts and I will finish with a conclusion in chapter 5.

2. PREVIOUS RESEARCH

In this chapter I will present an overview of the proposed analyses for child chain shifts within the field of generative grammar. The basic assumption of generative grammar is that all languages share certain grammatical principles that are innate. These principles are often referred to as Universal Grammar (UG). Evidence for this assumption is found in language typology and language acquisition. Typological studies show that, although there are obvious differences, languages actually share many properties. The idea is that the grammar of each language draws it options from a limited set: UG. From studies in language acquisition it becomes clear that children acquiring their first language follow similar developmental steps, regardless of the language they are learning. Moreover, children seem to be predisposed for learning language. The fact that children learn the grammar of their first language without apparent effort is an indication of innate grammatical knowledge.

UG can be viewed as a collection of processes that specify what is and is not possible in languages. In early generative grammar (Chomsky 1965) those processes were assumed to be rewrite rules that were ordered in a linear fashion. The problem with the theory was that there were no restrictions on possible rules and possible rule interactions, thus ‘filling’ UG with a limitless number of grammatical options. That posed a learnability problem, because it was unclear how a child could choose between the virtually infinite number of grammatical options. The theory of Principles and Parameters (Chomsky 1981) limited the number of options by postulating universal properties (principles) and a limited number of universal binary choices (parameters). Principles were assumed to hold for all languages, and the universal parameters were set to either ‘yes’ or ‘no’ in a given language.

However, it proved very difficult to formulate principles that hold true for all languages. With the advance towards Optimality Theory (OT) an important assumption of early generative grammar was abandoned. Inviolable rules were replaced by violable constraints. In OT UG is defined as a set of universal constraints whose ranking differs from language to language. Violation of a high-ranked constraint is more serious than violation of a low-ranked constraint and grammaticality is based on the ‘least serious’ violation.

In the following paragraphs I will discuss the previous research on child chain shifts. In paragraph 2.1 I will present two analyses from early generative grammar and in paragraph 2.2 I will discuss proposals within Optimality Theory.

2.1 EARLY GENERATIVE GRAMMAR

Early generative phonology is based on work by Chomsky and Halle (1968). In *The Sound Pattern of English* they present their theory of phonology. They postulate that segments are bundles of phonological features. For example, the segment /p/ is a bundle of the features [+consonantal, –approximant, –sonorant, –continuant, –nasal, –voice, +labial, –coronal, +anterior, –strident, –lateral, –dorsal]. The phonological features constitute a universally fixed set and natural classes of sounds can be defined in terms of the features. For example, stops constitute a natural class that can be defined with the features [–sonorant, –continuant], fricatives are [–sonorant, +continuant], nasals are [+sonorant, –continuant] and approximants are [+sonorant, +continuant].

Chomsky and Halle assume that all variants of a morpheme derive from a single underlying representation. The mapping from the underlying representation to the phonetic representation is carried out by rewrite rules. In (5) the general rule format is illustrated. This formula can be read as follows: A is realized B if it occurs between X and Y. A, B, X and Y may represent a segment or a null element. The rewrite rules are linearly ordered and may interact.

(5) *Rule format (Chomsky & Halle 1968:332)*

$A \rightarrow B \,/\, X \_\_ Y$

An example of a derivation with interacting rules is given in (6). Rule 1 changes A to B when it occurs between X and Y. Rule 2 deletes B when it occurs between X and Y. We assume the underlying representation XAY. If rule 1 is ordered before rule 2, A first changes to B by rule 1 and subsequently B is deleted by rule 2, resulting in the phonetic representation XY. This order is called a feeding order, because the result of the first rule ‘feeds’ the second rule, that is, rule 2 can only apply if rule 1 preceeds it, because it creates the correct environment for rule 2. In the counterfeeding order, rule 2 precedes rule 1. In this case rule 2 does not apply, because rule 2 only is active with the string XBY. Rule 1 does apply and replaces A with B, resulting in the phonetic representation XBY. Because rule 2 was ordered before rule 1 it cannot apply anymore, although the correct environment has now been created.

(6) *Rule interaction*

Rule 1: A → B / X __ Y
Rule 2: B → Ø / X __ Y

Feeding order

Underlying representation	/XAY/
Application of rule 1	/XBY/
Application of rule 2	/XY/
Phonetic representation	[XY]

Counterfeeding order

Underlying representation	/XAY/
Application of rule 2	---
Application of rule 1	/XBY/
Phonetic representation	[XBY]

The rewrite rules can be formulated in terms of individual sounds, but also in terms of features. For example, the rule in (7a) states that /s/ changes to [t] if it is followed by a /t/ and the rule in (7b) states that obstruents become voiced after voiced obstruents.

(7) *Rules*

a. s → t / __ t
b. [–sonorant] → [+voiced] / [–sonorant, +voiced] __

Smith (1973) made a significant contribution to the field of generative phonology. In *The Acquisition of Phonology* he provides an impressive overview and detailed analysis of the speech development of his son Amahl from age 2;2 to 3;9 who is acquiring English as a first language. He is also, to my knowledge, the first to report a chain shift in first language acquisition. In the following paragraph I will present his analysis of the *puzzle-puddle-pickle* problem.

2.1.1 SMITH (1973)

One of the ‘puzzles’ Smith encounters in the analysis of his son’s speech productions is the *puzzle-puddle-pickle* problem, where “the child appears unable to produce a particular sound or sequence in the correct place, but is perfectly capable of producing it as his interpretation of something else.” (Smith 1973:4).

Smith aims to show that the child’s phonological development is rule-governed and all changes in his output over time are the result of changes in rules applying to phonologically defined classes (Smith 1973:206). He claims that the child has the adult forms of words as underlying lexical representations. A collection of realisation rules act on these underlying representations resulting in the child’s output. Smith formulates these realisation rules as well as a crucial rule-ordering.

To account for the *puzzle-puddle-pickle* problem he formulates rules R3 and R24. R3 velarizes the alveolar stops /n/, /t/ and /d/ before a syllabic [l̩]. This rule is responsible for the change of *puddle* into [pʌgl̩]. R24 turns all non-sonorants into stops[2]. This rule is responsible for the change of *puzzle* into [pʌdl̩]. R3 must be ordered before R24, to prevent *puzzle* changing all the way to [pʌgl̩]. In other words, the rules must be ordered in a counterfeeding order, so that R24 does not feed R3. The rules and ordering are illustrated in (8).

(8) *Counterfeeding rules for the puzzle-puddle-pickle problem*

R3: /t, d, n/ → [k, g, ŋ]/…[l̩]

R24: [-sonorant] → [-continuant]/…

Underlying	/pʌzl̩/ ‘puzzle’	/pʌdl̩/ ‘puddle’	/pɪkl̩/ ‘pickle’
R3	---	/pʌgl̩/	---
R24	/pʌdl̩/	---	---
Phonetic	[pʌdl̩]	[pʌgl̩]	[pɪkl̩]

A similar rule-ordering can be constructed for the *s-θ-f* chain shift. The rules involved in the *s-θ-f* chain shift are Dentalization that changes underlying /s/ to [θ], and Labialization that

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[2] For ease of exposition this rule is formulated in its broadest terms. Smith (1973:90) proposes different reformulations for the different stages in Amahl’s development. For example, this rule already becomes optional for /f/ in the second stage in the data.

changes underlying /θ/ to [f]. When Labialization is ordered before Dentalization, /s/ changes to /θ/ after Labialization has occurred, so that the rule no longer applies. In (9) this rule-ordering is illustrated (taken from Dinnsen et al. 2011:2).

(9) *Counterfeeding rules for the s-θ-f chain shift*

Labialization: /θ/ → [f]/…
Dentalization: /s/ → [θ]/…

Underlying	/sʌm/ 'some'	/θʌm/ 'thumb'	/fʌn/ 'fun'
Labialization	---	/fʌm/	---
Dentalization	/θʌm/	---	---
Phonetic	[θʌm]	[fʌm]	[fʌn]

From age 2;11 (stage 21) Amahl does not change *puzzle* words into *puddle* words anymore. Rather *puzzle* words are produced target-like from this stage on. Smith (1979:92) accounts for this by changing R24 [3]. In stage 29 (age 3;9, the last stage in the data) the change from *puddle* to *pickle* words becomes optional. In this stage *sandal* is produced as [sæŋgl̩], *throttle* as [srɔkl̩], *bottle* as both [bɔkl̩] and [bɔtl̩] and *candle, handle, little, metal, puddle* are produced target-like. Smith accounts for this by making R3 optional in stage 29.

Smith's account of the *puzzle-puddle-pickle* problem with the proposed rules, rule change and rule-ordering seem to be able to capture the chain shift effect. It is, however, not at all clear how this system can be learned by the child and what motivates the child to 'invent' the proposed rules.

Smith (1973:206) claims that the realisation rules can be viewed as a result of universal constraints from which the child has to escape in order to learn his language. In his view changes in the realisation rules represent variable attempts of a child to overcome the universal characteristics of language in his progress towards learning his own language. However, he does not address how the child acquires these universal rules (whether they are innate or acquired early), nor does he address how it is that a child 'escapes' from these universal constraints. On which basis does a child decide to change or abandon the realisation rules? And how does the child learn the correct rule-ordering? Also, if these rules are based

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[3] The exact formulations of the rule are complex and not necessary for the discussion here.

on universal constraints, how can we account for the variation between children in their speech development?

Moreover, Smith's most convincing argument for postulation of adult-like underlying knowledge for the child, is that errors are resolved in an across-the-board fashion. An error, relative to the target system, is seen as the result of a rule in the child's system. When this rule is discarded, and the child's output resembles the adult's, the underlying knowledge of the child becomes evident. The resolution of errors in an across-the-board fashion is thus an argument in favour of adult-like underlying representations. However, in a re-analysis of Smith's data Macken (1980) shows that not all errors are eliminated in an across-the-board fashion. In the next paragraph her analysis will be presented.

2.1.2 MACKEN (1980)

Macken's (1980) reanalysis of Smith's data shows that whereas there is an across-the-board elimination for all production errors with *puzzle* words, this is not the case for *puddle* words. Of the 47 *puddle* words produced before stage 29, 10 words are produced once or more with a target /t/, /d/ or /n/, which constitutes 21.3% of the words. Interestingly no such exceptions are found for the *puzzle* words (before stage 20). Moreover, we have already seen that whereas *puzzle* words are suddenly produced target-like after stage 20, changing *puddle* words becomes optional, thus variable, at stage 29.

To account for this Macken, following Braine (1976), makes a distinction between perceptual-encoding rules that operate upstream of the lexical entry and output rules that operate downstream of the lexical entry. In her view, R3, that changes *puddle* into *pickle* words, should be viewed as a perceptual-encoding rule, whereas R24, that changes *puzzle* into *puddle* words, is an output rule. Her idea is that the lexical representation is the result of a codification of the filtering process effected by the perceptual encoding rules. The lexical representation subsequently serves as the input to the final set of rules, the output rules (Macken 1980:4).

Macken claims that the lexical representations for *puzzle* words are similar to the adult-surface form. The non-target productions (i.e. the change into *puddle* words) before stage 20 are the result of an output rule. At stage 20 this rule is discarded by the child and this explains the across-the-board elimination of production errors for *puzzle* words.

The lexical representations for *puddle* words are assumed to be non-adult-like as a result of misperception of the adult form. Evidence for a non-adult-like representation of these words comes from counter-examples to the across-the-board nature of change shown above. Interesting corroborating evidence is that in stage 29 (age 3;9), 3 (out of 8) *pickle* words are sometimes incorrectly produced as *puddle* words: *circle* is produced as [sə:tl̩], *pickle* as [pitl̩] and *winkle* as [wintl̩]. It seems that at this stage the child learns to make a distinction between *puddle* and *pickle* words, but sometimes makes an overgeneralization error, and interprets *pickle* words as *puddle* words. Before this stage the distinction between /dl/-/gl/, /tl/-/kl/ and /nl/-/ŋl/ seemed to have been neutralized at the level of the underlying representation.

Macken claims that the *puddle* words are stored with a velar stop and that /t/, /d/ and /n/ are misheard as the velars /k/, /g/ and /ŋ/ in the environment of a following velarized /l/. This contradicts with Smith's view who literally argues that these sounds are not misheard by the child. Smith (1973:150) states that Amahl "can easily identify such pairs as *riddle* and *wriggle* correctly", whereas Macken does not provide empirical evidence for her claim. However, Smith does not make clear how and when he tested Amahl's discrimination of the pair. Moreover, the word *riddle* does not occur in Amahl's speech data. Smith therefore is not able to show that Amahl perceives *riddle* correctly and at the same time produces it incorrectly.

A final point Macken makes is that R3 operates nearly a year longer than R24. She argues that it is reasonable to expect perceptual-encoding rules to be more difficult to change. In other words, it is harder for a child to change an underlying representation than an output rule. This might be the case, but interestingly she does not address what might be needed for a child to change either a perceptual-encoding or an output rule. This is an important question. Moreover, the perceptual-encoding rule is seen as a result of misperception[4], but for the output rule it is not clear how it came into being. Macken points to the fact that fricatives are more articulatory difficult than plosives, but does not make clear whether the output rule that changes /zl̩/ to [dl̩] is motivated by this articulatory difficulty.

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[4] Note that Macken incorporates perception into the grammar by formulating a perceptual-encoding rule.

In my view, the strength of Macken's proposal is that she accounts for the differences between the two error patterns within the chain shift. Although she does not make completely clear how a child 'learns' and 'unlearns' the rules involved – a well-known problem with rule-based accounts – I see it is a step forward from Smith's approach, because the substitution of *pickle* for *puddle* words finds a motivation in perception and is thus 'learned' through misperception.

In the following paragraphs I will present accounts of child chain shifts within the framework of Optimality Theory. Interestingly there are some important similarities between Smith's approach and most of the OT-accounts: the assumption of adult-like underlying representations and the idea that grammatical production processes are responsible for the chain shift effect. With the step to OT Macken's analysis of the two different processes that are involved in the *puzzle-puddle-pickle* problem seems to be disregarded. I will return to this in chapter 3. In the next paragraph I will provide a short introduction into Optimality Theory, before discussing the different proposals.

2.2 OPTIMALITY THEORY

2.2.1 INTRODUCTION TO OPTIMALITY THEORY

Optimality Theory was first introduced by Prince and Smolensky (1993). A theory of markedness lies at the base of OT. The assumption is that there are no universal principles that hold true for all languages. Rather there is a notion of universal markedness. For example, an open syllable (CV, V) is universally less marked than a closed syllable (CVC, VC) because all languages have open syllables, while only some have closed syllables. This theory of markedness is incorporated in OT in the form of markedness constraints that can be violated. For example, the universal markedness constraint against closed syllables is violated by many words in English.

The markedness constraints interact with faithfulness constraints. Faithfulness constraints ensure that lexical contrast is preserved. They are violated if features or segments in the lexical input are not preserved in the output of the grammar. For example, the English words *go* and *goat* would be pronounced the same, without a final consonant, if only markedness would play a role, since [gəʊ] is universally less marked than [gəʊt]. However, faithfulness makes sure that in English *goat* is pronounced faithfully, that is, with final [t]. The markedness and faithfulness constraints are assumed to be universal, but the ranking of the constraints is language-specific.

The grammar in OT consists of the Lexicon which contains lexical representations. These form the input to the Generator which generates a set of output candidates for a given input. These output candidates are evaluated by the Evaluator which is the set of ranked constraints. The Evaluator selects the optimal candidate. The grammar is thus an input-output mechanism. For each input, output candidates are generated which are evaluated by the constraint ranking which selects the optimal output. The constraints are universal, they are provided by UG, but the ranking of the constraints is language-specific. The grammars of different languages thus only differ in the constraint ranking. The constraints are output constraints, that is, they evaluate the output candidates. There are no constraints on the input. The principle of Richness of the Base states that no constraints hold at the level of underlying forms. This means that all inputs are possible in all languages.

I will illustrate the workings of OT with an example. In (10) two constraints and a constraint ranking are listed. The markedness constraint against closed syllables is ranked below the faithfulness constraint against deletion, illlustrated with " >> ". In other words, the faithfulness constraint dominates the markedness constraint.

(10) *Constraints and ranking*

Constraints

NO-CODA:	Markedness constraint against closed syllables
MAX-IO:	Faithfulness constraint indicating that input segments must have output correspondents

Ranking

MAX-IO >> NO-CODA

In tableau 1 can be seen how with these constraints and ranking [gəʊt] is the optimal output for input /gəʊt/. Each candidate violates a constraint, but the violation of MAX-IO by [gəʊ] is more serious, because it is ranked higher. The explanation mark illustrates that this candidate is ruled out. The candidate [gəʊt] violates NO-CODA, but is still the optimal candidate, which is indicated by the pointing hand.

For input /gəʊ/, in tableau 2, the situation is different. Output candidate [gəʊ] violates neither of the two constraints, while [gəʊt] violates the markedness constraint. In this case [gəʊ] is the optimal output. Note that these tableaux only have two candidates for ease of exposition. In reality many more candidates are generated and more constraints are involved in the evaluation.

TABLEAU 1

/gəʊt/	MAX-IO	NO-CODA
gəʊ	*!	
☞ gəʊt		*

TABLEAU 2

/gəʊ/	MAX-IO	NO-CODA
☞ gəʊ		
gəʊt		*!

All constraints are universal and innately present. In the initial state of the grammar the markedness constraints are assumed to outrank the faithfulness constraints, thus explaining the less marked speech of children relative to the adult system (Gnanadesikan 2004). For example, the stopping of target fricatives often found in child speech is explained by the high ranking of a markedness constraint banning fricatives. If a markedness constraint against fricatives is ranked above a faithfulness constraint for manner features, a stop will be the optimal output for a fricative in the input.

This is illustrated in tableau 3, given the constraints and ranking in (11). In an early stage in the child's grammar, [t] is the optimal output for input /s/, because [s] violates the high-ranked markedness constraint banning fricatives. The idea is that the child eventually reranks these two constraints such that ID[manner] is ranked above *FRICATIVE. Then [s] is the optimal output for input /s/, as can be seen in tableau 4. This is the case in adult English.

(11) *Constraints and ranking*

Constraints

*FRICATIVE: Markedness constraint against fricatives
ID[manner]: Faithfulness constraint indicating that corresponding segments must have identical manner features

Ranking

Early stage: *FRICATIVE >> ID[manner]
Later stage: ID[manner] >> *FRICATIVE

TABLEAU 3

/s/	*FRICATIVE	ID[manner]
s	*!	
☞ t		*

TABLEAU 4

/s/	ID[manner]	*FRICATIVE
☞ s		*
t	*!	

An important question is how the child moves from the initial constraint ranking to the target ranking. It is clear that constraints need to be reranked to achieve the adult grammar. Tesar and Smolensky (1993) have proposed the Constraint Demotion Algorithm (CDA) to capture the child's learning task. This algorithm works in the following way. It is assumed that the child faithfully perceives the sounds from the surrounding language input. The child, for example, hears the sound [s]. In his current grammar the optimal output for input /s/ is [t], but this is not consistent with the data the child hears. The constraint ranking in the early stage is thus not suitable anymore. Where [t] was first the 'winner', it should now be the 'loser', and the 'loser' [s] should become the 'winner'. The constraint *FRICATIVE favors the new 'loser', while ID[manner] favors the new 'winner'. The 'loser'-favoring constraint should then be demoted below the 'winner'-favoring constraint. So the child demotes *FRICATIVE immediately below ID[manner], resulting in the ranking in tableau 4, where [s] is the optimal output.

In many cases more constraints are involved so that the algorithm is more complex than sketched here. The main idea is that for a structure A to beat structure B as the optimal output, every constraint favoring B over A must be dominated by some constraint favoring A over B. The learning task than involves to demote every B-favoring constraint below some A-favoring constraint (McCarthy 2002:203). When more constraints are involved, the highest ranked constraint favoring the new 'loser', should be demoted immediately below the highest ranked constraint favoring the new 'winner'. This procedure is repeated until no more constraints need to be demoted. Tesar and Smolensky (1993) have shown that this algorithm can succesfully learn a constraint hierarchy of any complexity on the basis of input data.

Another proposal for a learning algorithm is done by Boersma (1997). He has proposed the Gradual Learning Algorithm (GLA), which in some respects is similar to the CDA. It also changes the constraint ranking on the basis of input data that conflict with the current constraint hierarchy. However, it differs crucially in other respects, because it assumes a continuous ranking scale instead of a categorical one and at every evaluation of the candidate set, a small noise component is temporarily added to the ranking value of each constraint, so that the grammar can produce variable outputs if some constraint rankings are close to each other (Boersma & Hayes 2001:46). In this way it can account for variation in child's speech productions. Moreover, in the GLA the reranking steps are executed as small differences on a scale, rather than as an entire demotion step. This makes the GLA more robust, since it is not disturbed by speech errors in the input data. For the CDA speech errors constitute a problem, because it is shown to work well as long as the input data are consistent. When presented with inconsistent data the CDA crashes.

Empirical tests with actual language data show that the proposed algorithms can learn constraint rankings when enough input data from the language to be learned are given (Boersma & Hayes 2001, Tesar & Smolensky 2000). This is a strong indication that OT-grammars are learnable for children. This is an important advantage of OT over earlier proposals within generative grammar.

It is argued that the only way in which a child's phonology differs from an adult's phonology is the constraint ranking. An important claim shared by many researchers within OT is that the constraints used in adult language are adequate to account for child phonology data as well, without the need to attribute more representational levels or more rules to the child's grammar (Gnanadesikan 2004:73). As we have seen, postulation of extra rules or different underlying representations were necessary in the proposals of Smith (1973) and Macken (1980), respectively.

Consequently, within OT most accounts of phenomena in child phonology concern the constraint ranking. As I have shown, a stopping pattern in children's productions can well be explained assuming a high-ranked markedness constraint banning fricatives. However, not all phenomena in children's speech data can be readily explained with a constraint ranking. Child chain shifts present a great challenge for a grammatical approach, as I will show in the following paragraphs.

2.2.2 CHAIN SHIFTS IN OPTIMALITY THEORY

It is not evident how to account for the child chain shifts with a constraint ranking. In general, opacity constitutes a problem within OT. Counter-feeding opacity (chain shifts) and counter-bleeding opacity (derived environment effects) cannot easily be accounted for without resulting to a rule-ordering. However, as we have seen there are no rules in OT and thus no rule-orderings. It is difficult to find a constraint ranking that yields the correct optimal outputs. With the basic constraints in (12) no ranking can be constructed that captures the *s-θ-f* chain shift. Note that I assume that /s/ is [coronal, +strident], /θ/ is [coronal] and /f/ is [labial].

(12) *Constraints*[5]

*s: strident fricatives are banned
*θ: interdental fricatives are banned
*f: labial fricatives are banned
IDENT[+strident]: correspondent segments in input and output have identical values for [+strident]
IDENTCORONAL: correspondent segments in input and output have identical values for [coronal]
IDENTLABIAL: correspondent segments in input and output have identical values for [labial]

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[5] The constraints in (12) are basic constraints that are proposed in the literature by various authors (e.g. Dinnsen 2008a).

It is clear that the markedness constraints *s and *θ need to be ranked high in the hierarchy to prevent target /s/ and /θ/ from surfacing faithfully. However, when *θ is ranked high, this also prevents target /s/ from surfacing as [θ]. What is needed is a faithfulness constraint, ranked above *θ, which is violated by output [f] for /s/, but not by output [f] for /θ/. Let's call this constraint F. With such a constraint and the ranking *s, F >> *θ the *s-θ-f* chain shift can be captured as is shown in tableaux 5 through 7.

TABLEAU 5

/s/	*s	F	*θ	*f	IDENT[+strident]	IDENTCORONAL	IDENTLABIAL
f		*!		*	*	*	*
☞ θ			*		*		
s	*!						

TABLEAU 6

/θ/	*s	F	*θ	*f	IDENT[+strident]	IDENTCORONAL	IDENTLABIAL
☞ f				*		*	*
θ			*!				
s	*!						

TABLEAU 7

/f/	*s	F	*θ	*f	IDENT[+strident]	IDENTCORONAL	IDENTLABIAL
☞ f				*			
θ			*!			*	*
s	*!					*	*

The big question is how to formulate the constraint F. Note that none of the faithfulness constraints in the tableaux can play the role of F: IDENT[+strident] violates both output [f] and [θ] for input /s/, and thus cannot decide between the two candidates; IDENTCORONAL and IDENTLABIAL are violated by output [f] for input /s/, but also by [f] for /θ/ and would thus yield the wrong result for input /θ/ when ranked above *θ. Neither is there another general faithfulness constraint that has the desired effect.

In the literature different realizations of 'constraint F' are proposed to account for child chain shifts. A well-known analysis for chain shifts uses local constraint conjunction, whereby two constraints are conjoined to form a complex constraint (Smolensky 1993). This locally conjoined constraint exactly plays the role of ‘constraint F’ as illustrated here. Morrisette and Gierut (2008) and Dinnsen, O’Connor and Gierut (2001) present local conjunction proposals to account for the *s-θ-f* chain shift and the *puzzle-puddle-pickle* problem, respectively. Jesney (2005, 2007) presents a different solution in her account of both the *s-θ-f* chain shift and the *puzzle-puddle-pickle* problem. She proposes a distinction between general and specific faithfulness constraints, where the latter takes the role of ‘constraint F’. Dinnsen et al. (2011) take a different approach to child chain shifts and make use of the framework of Optimality Theory with Candidate Chains (McCarthy 2007) to provide an analysis. Finally, Dinnsen and Barlow (2008) claim that the *s-θ-f* chain shift is due to underspecified underlying representations in the child’s system. In the following paragraphs I will discuss these analyses.

2.2.3 LOCAL CONSTRAINT CONJUNCTION

Local constraint conjunction is a mechanism in which two constraints are conjoined to form a single constraint. The locally conjoined constraint is violated if both of the component constraints are violated in the same domain, for example a segment. Local constraint conjunction was first proposed by Smolensky (1993) and the formal definition is given in (13).

(13) *Definition of Local Constraint Conjunction*

> The Local Conjunction of C_1 and C_2 in domain D, $[C_1 \& C_2]_D$, is violated when there is some domain of type D in which both C_1 and C_2 are violated.

The locally conjoined constraint does not replace the component constraints. Local conjunction thus results in three constraints: C_1, C_2 and the conjoined constraint. A conjoined constraint is assumed to be universally ranked above its components (Kager 1999:393).

Smolensky first introduced local constraint conjunction to decompose complex markedness constraints into the conjunction of two simple markedness constraints. Since then it has been used to account for synchronic chain shifts (Kirchner 1996, Moreton & Smolensky 2002), dissimilation (Alderete 1997, Itô & Mester 1998), word stress (Kager 1994, Crowhurst & Hewitt 1997), the Coda-Condition (Smolensky 1993), the Sonority Hierarchy (Smolensky

1995) and Vowel Harmony (Smolensky 1997, Bakovic 2000). It is a mechanism to avoid the "worst of the worst" (McCarthy 2002:18), because it singles out segments that violate multiple constraints. The local conjunction proposals for chain shifts are based on the intuition that these patterns stem from a drive to select output forms that avoid excessive deviation from the input (Kirchner 1996).

For the *s-θ-f* chain shift this "excessive deviation from the input" would be the substitution of [f] for /s/. The idea is that this substitution is avoided because /f/ and /s/ differ too much from each other, that is, they differ both in the feature [strident] and [coronal]. Output [f] for input /s/ violates both IDENT[+strident] and IDENTCORONAL whereas [θ] for /s/ only violates IDENT[+strident] and [f] for /θ/ only violates IDENTCORONAL. The local conjunction of IDENT[+strident] and IDENTCORONAL would prevent the step from /s/ to [f].

Morrisette and Gierut (2008) and Dinnsen, O'Connor and Gierut (2001) present local conjunction proposals to account for the *s-θ-f* chain shift and the *puzzle-puddle-pickle* problem, respectively. I will now discuss their proposals.

Morrisette and Gierut (2008) studied three preschool children with functional phonological delays, age 4;2, 3;9 and 4;8. These children evidenced the *s-θ-f* chain shift in their production and received minimal triplet treatment targeting the three phonemes that constitute the members of the chain shift /s θ f/. For two of the three children, the error pattern was restricted to the word-initial position. Morisette and Gierut collected three speech samples of each child using a spontaneous picture naming task: the first before treatment, the second immediately following treatment and the third two months posttreatment. For one child, LP127, they had an additional speech sample which was recorded three months prior to the pretreatment sample.

Studying the speech samples, Morrisette and Gierut found four stages that are illustrated in (14). The first stage, 3 months prior to pretreatment (only LP127), was the pure chain shift stage in which /s/ was substituted by [θ] and /θ/ was substituted by [f]. In the subsequent stage (pretreament) /θ/ was still substituted by [f], but /s/ was sometimes produced as [θ] and sometimes as dentalized [s̪]. This variation was found in the pretreatment sample of all three children. Dentalized [s̪] was reported to occur 60% of the time and [θ] 40% of the time for target /s/. In stage 3 (posttreatment) /s/ was produced as [s] and /θ/ was sometimes produced as [θ] and sometimes as [f]. In the fourth stage (two months posttreatment) both error patterns were resolved and /s/ was produced as [s] and /θ/ as [θ]. In all stages /f/ was produced target-like.

(14) *Four stages (Morrisette & Gierut 2008)*

Stage 1 /s/ as [θ]
/θ/ as [f]

Stage 2 /s/ as [s̪] and [θ]
/θ/ as [f]

Stage 3 /s/ as [s]
/θ/ as [θ] and [f]

Stage 4 /s/ as [s]
/θ/ as [θ]

Morrisette and Gierut were able to capture these four stages making use of local constraint conjunction and the idea of partial ordering. The constraints and the ranking for the four stages are listed in (15). I will go through each of these stages. Note that Morrisette and Gierut make the following assumptions: /θ/ is [coronal], /f/ is [labial], /s/ is [coronal, grooved].

(15) *Constraints and ranking (Morrisette & Gierut 2008)*

Constraints	
*s:	Grooved coronal fricatives are banned
*θ:	Interdental fricatives are banned
*f:	Labial fricatives are banned
ID[manner]:	Corresponding segments must have identical manner features
ID[grooved]:	Corresponding segments must have an identical [grooved] feature
ID[place]:	Corresponding segments must have identical place features
LC:	Local conjunction of ID[place] and ID[grooved]

Stage	**Ranking**
1	ID[manner], *s, LC >> *θ >> ID[grooved], ID[place], *f
2	ID[manner], LC >> {*s, ID[grooved]} >> *θ >> ID[place], *f
3	ID[manner], LC >> ID[grooved] >> *s >> {*θ, ID[place]} >> *f
4	ID[manner], LC >> ID[grooved] >> *s, ID[place] >> *θ, *f

The first stage is the pure chain shift stage, where /s/ is substituted by [θ] and /θ/ is substituted by [f]. In tableaux 8 and 9 this stage is illustrated. (Note that ID[manner] is left out of the tableaux because the outputs listed here do not violate this constraint.) The optimal output for /s/ is [θ], because [s] violates *s and [f] violates LC, which are both ranked on top of the hierarchy. The optimal output for /θ/ is [f], because [s] violates *s and [θ] violates *θ, both ranked higher than any constraint violated by [f].

TABLEAU 8

/s/	*s	LC	*θ	ID[grooved]	ID[place]	*f
f		*!		*	*	*
☞ θ			*	*		
s	*!					

TABLEAU 9

/θ/	*s	LC	*θ	ID[grooved]	ID[place]	*f
☞ f					*	*
θ			*!			
s	*!			*		

In the second stage [s̪] and [θ] are both produced for target /s/. (Note that Morrisette and Gierut assume that dentalized [s̪] is a correct production of target /s/ (note 3). I will return to this issue in chapter 3.) To account for the variable output for target /s/, Morrisette and Gierut assume a partial ordering. In stage 2 the constraints *s and ID[grooved] are partially ordered, where sometimes one constraint wins out, and sometimes the other. This is illustrated by the curly brackets in the constraint ranking in (15). In this stage /θ/ is still produced as [f]. In tableau 10 and 11 the different rankings are shown for input /s/, and in tableaux 12 and 13 for /θ/.

In tableau 10 *s is ranked above ID[grooved] which results in [θ] as the optimal output for /s/, because [s] violates *s and [f] violates LC, which is ranked even higher. A variation on this ranking is shown in tableau 11, where ID[grooved] is ranked above *s. In this case the optimal output for /s/ is [s], because [θ] violates ID[grooved] and this constraints is now higher in the hierarchy. Output [f] is still ruled out, because it violates LC which is the highest ranked constraint. In tableau 12 the ranking results in [f] as the optimal output for /θ/, because

[f] only violates ID[place] and *f, which are ranked lowest in the hierarchy. The order of ID[grooved] and *s does not influence the result for input /θ/, as can be seen in tableau 13.

TABLEAU 10

/s/	LC	*s	ID[grooved]	*θ	ID[place]	*f
f	*!		*		*	*
☞ θ			*	*		
s		*!				

TABLEAU 11

/s/	LC	ID[grooved]	*s	*θ	ID[place]	*f
f	*!	*			*	*
θ		*!		*		
☞ s			*			

TABLEAU 12

/θ/	LC	*s	ID[grooved]	*θ	ID[place]	*f
☞ f					*	*
θ				*!		
s		*!	*			

TABLEAU 13

/θ/	LC	ID[grooved]	*s	*θ	ID[place]	*f
☞ f					*	*
θ				*!		
s		*!	*			

In the third stage /s/ is consistently produced as [s]. In tableau 14 it is shown that [s] is now the optimal output for /s/, because ID[grooved], which is violated by [θ], is ranked above *s. And [f] is ruled out because LC is still ranked highest. In this stage target /θ/ is sometimes produced as [f] and sometimes as [θ]. Again variable ranking is assumed for this variation. The constraints *θ and ID[place] are assumed to be partially ranked. The ranking in tableau 16 shows that when *θ is ranked above ID[place] the optimal output for /θ/ is [f], whereas in tableau 17 the ranking is reversed and consequently [θ] is the optimal output. The variable ranking in this stage does not influence the result for input /s/, as can be seen in tableau 15.

Tableau 14

/s/	LC	ID[grooved]	*s	*θ	ID[place]	*f
f	*!	*			*	*
θ		*!		*		
☞ s			*			

Tableau 15

/s/	LC	ID[grooved]	*s	ID[place]	*θ	*f
f	*!	*		*		*
θ		*!			*	
☞ s			*			

Tableau 16

/θ/	LC	ID[grooved]	*s	*θ	ID[place]	*f
☞ f					*	*
θ				*!		
s		*!	*			

Tableau 17

/θ/	LC	ID[grooved]	*s	ID[place]	*θ	*f
f				*!		*
☞ θ					*	
s		*!	*			

In the fourth and final stage the chain shift effect is resolved. Target /s/ is now produced as [s], and target /θ/ is produced as [θ]. The ranking in tableau 18 and 19 shows this result. Because *θ is now ranked lowest, there is no reason for /θ/ not to surface as [θ].

Tableau 18

/s/	LC	ID[grooved]	*s	ID[place]	*θ	*f
f	*!	*		*		*
θ		*!			*	
☞ s			*			

TABLEAU 19

/θ/	LC	ID[grooved]	*s	ID[place]	*θ	*f
f				*!		*
☞ θ					*	
s		*!	*			

Dinnsen, O'Connor and Gierut (2001) propose a similar account for the *puzzle-puddle-pickle* problem. In (16) the constraints and ranking they propose are listed. They distinguish three developmental stages: the early stage (the pure chain shift stage), the overgeneralization stage (in which some *pickle* words are produced as *puddle* words) and the adult stage.

(16) *Constraints and ranking (Dinnsen et al. 2001)*

Constraints

*FRIC: Avoid fricatives
*dl: Avoid coronals before liquid consonants
*gl: Avoid velar consonants before liquid consonants
ID[manner]: Corresponding segments must have identical manner features
ID[place]: Corresponding segments must have identical place features
LC: Local conjunction of ID[manner] and ID[place]

Stage	**Ranking**
Early	LC, *FRIC, *dl >> *gl >> ID[manner], ID[place]
Overgeneralization	LC >> ID[manner], *gl >> *dl, *FRIC, ID[place]
Adult	LC >> ID[manner] >> *dl, *FRIC, ID[place] >> *gl

In the early stage, the constraint *FRIC is ranked above ID[manner] to account for the stopping pattern (*puzzle* becomes *puddle*), and the constraint *dl is ranked above ID[place] to account for the velarization pattern (*puddle* becomes *pickle*). As we have seen for the *s-θ-f* chain shift, just these basic constraints cannot account for the chain shift effect. Dinnsen et al. therefore assume the constraint LC that consists of the local conjunction of ID[manner] and ID[place]. This constraint is violated by the output [pʌgl̩] for input /pʌzl̩/, because the change from /pʌzl̩/ to [pʌgl̩] violates both ID[manner] and ID[place].

With these constraints the chain shift effect can be captured as shown in tableaux 20 through 22. In tableau 20 it is shown that [pʌdl̩] is the optimal output for /pʌzl̩/ since [pʌgl̩] violates the high ranked LC constraint and [pʌzl̩] violates both high ranked markedness constraints. The optimal output for /pʌdl̩/, in tableau 21, is [pʌgl̩] because [pʌzl̩] violates both high ranked markedness constraints and [pʌdl̩] violates *dl. In tableau 22 it is shown that the optimal output for /pɪkl̩/ is [pɪkl̩] since [pɪsl̩] and [pɪtl̩] both violate one or more of the highest ranked constraints.

Tableau 20

/pʌzl̩/	LC	*Fric	*dl	*gl	ID[manner]	ID[place]
pʌzl̩		*	*!			
☞ pʌdl̩			*		*	
pʌgl̩	*			*!	*	*

Tableau 21

/pʌdl̩/	LC	*Fric	*dl	*gl	ID[manner]	ID[place]
pʌzl̩		*!	*		*	
pʌdl̩			*!			
☞ pʌgl̩				*		*

Tableau 22

/pɪkl̩/	LC	*Fric	*dl	*gl	ID[manner]	ID[place]
pɪsl̩	*!	*	*		*	*
pɪtl̩			*!			*
☞ pɪkl̩				*		

In the overgeneralization stage *puzzle* and *puddle* words are produced target-like, but some *pickle* words are pronounced as *puddle* words. Macken claimed that that is because the underlying representation for *puddle* and *pickle* words is equal and when the child starts to learn the correct underlying representation for *puddle* words, he sometimes makes overgeneralization errors which result in *pickle* words also being produced as *puddle* words. Dinnsen et al. (2001:514) do not want to assume underspecified underlying representations, because they claim that that is at odds with the principle of Richness of the Base. (In my view that is based on a misunderstanding that I will discuss in chapter 3.) They propose that a universal markedness constraint that becomes active and dominates ID[place] is responsible for the change of *pickle* to *puddle* words. The constraint they propose is *gl that bans velar consonants before liquid consonants.

In tableau 25 it is shown how the proposed ranking in (16) makes sure that [pɪtl̩] is the optimal output for *pickle*. The high ranking of *gl rules out [pɪkl̩], [pɪsl̩] is ruled out by the high ranking of LC and/or ID[manner]. Tableaux 23 and 24 show how with this ranking *puzzle* and *puddle* will be produced target-like.

TABLEAU 23

/pʌzl̩/	LC	ID[manner]	*gl	*FRIC	*dl	ID[place]
☞ pʌzl̩				*	*	
pʌdl̩		*!			*	
pʌgl̩	*!	*	*			*

TABLEAU 24

/pʌdl̩/	LC	ID[manner]	*gl	*FRIC	*dl	ID[place]
pʌzl̩		*!		*	*	
☞ pʌdl̩					*	
pʌgl̩			*!			*

TABLEAU 25

/pɪkl̩/	LC	ID[manner]	*gl	*FRIC	*dl	ID[place]
pɪsl̩	*!	*		*	*	*
☞ pɪtl̩					*	*
pɪkl̩			*!			

In the adult stage the constraint *gl is demoted below the other constraints in the hierarchy to make sure that all three words are produced target-like. This is illustrated in tableaux 26 through 28.

TABLEAU 26

/pʌzl̩/	LC	ID[manner]	*FRIC	*dl	ID[place]	*gl
☞ pʌzl̩			*	*		
pʌdl̩		*!		*		
pʌgl̩	*!	*			*	*

TABLEAU 27

/pʌdl̩/	LC	ID[manner]	*FRIC	*dl	ID[place]	*gl
pʌzl̩		*!	*	*		
☞ pʌdl̩				*		
pʌgl̩					*	*!

TABLEAU 28

/pɪkl̩/	LC	ID[manner]	*FRIC	*dl	ID[place]	*gl
pɪsl̩	*!	*	*	*	*	
pɪtl̩				*!	*	
☞ pɪkl̩						*

Dinnsen et al. (2001) pay a great deal of attention to the question how the child moves from one stage to another. They claim that their proposal for a constraint ranking, repeated in (17), is consistent with assumptions within OT about the course of acquisition and constraint demotion. In the early stage markedness constraints dominate faithfulness constraints, and in the following stage minimal demotion of markedness constraints is motivated by mismatches between the outputs of the child's system and those of the adult system.

(17) *Constraint ranking (Dinnsen et al. 2001)*

Stage	**Ranking**
Early	LC, *FRIC, *dl >> *gl >> ID[manner], ID[place]
Overgeneralization	LC >> ID[manner], *gl >> *dl, *FRIC, ID[place]
Adult	LC >> ID[manner] >> *dl, *FRIC, ID[place] >> *gl

According to the algorithm proposed by Tesar and Smolensky (1998), the child demotes the highest ranked constraint that the target-appropriate candidate violates when a mismatch is observed (Dinnsen et al. 2001:518). For example, *dl is demoted below *gl, when the child notices that its output of *puddle* words differs from the target output of *puddle* words.

It is interesting that Dinnsen et al. seem so concerned with the learnability of their proposed constraint rankings, but do not address the fact that LC, a faithfulness constraint, is at the top of the hierarchy all along. This is at odds with their assumption that children's initial state is to be characterized by the dominance of markedness constraints over faithfulness constraints (Dinnsen et al. 2001:515).

In general, learnability is a major problem for analyses with local constraint conjunction. Within OT the characteristics of children's early speech are assumed to reflect an initial state of relative unmarkedness or are learned from the observable primary linguistic data (Dinssen 2008a:121). However, the child receives no evidence for local conjunction in the input (Jesney 2007:190), nor is there a reason to assume that a locally conjoined constraint is at the top of the hierarchy in the initial state. Moreover, if for some reason we could assume that a locally conjoined constrained is at the top of the hierarchy in the initial state, one might wonder why not all children show chain shift effects in their productions. This is a serious problem for accounts based on local constraint conjunction, because although in itself the account seems to be able to capture the chain shift effect it is not at all clear how it could be learned by a child.

Note also that many locally conjoined constraints have been proposed in the literature to account for other phenomena (see references at the beginning of this paragraph). By allowing local conjunction there is an enormous increase of possible constraints and possible constraint rankings. As Jesney (2005:35) points out, the necessary conjoined constraint must either be present in the child's grammar as part of the initial state or is spontaneously posited by learners to bring their grammars closer to the target language. Both options are problematic. In the first case, the addition of conjoined constraints to the constraint system would seriously complicate both the learning task and the complexity of the grammar. In the second case, if the child has the option to freely conjoin constraints along with the option of reranking constraints, the learning task for the child becomes much more difficult. The child would have no way to determine whether to choose for constraint demotion or constraint conjunction at a certain stage in development.

Another question that can be raised is why no adult grammar is reported to have a chain shift effect similar to the *s-θ-f* chain shift or the *puzzle-puddle-pickle* problem. Chain shifts are reported for adult grammars (see Moreton & Smolensky 2002 for an overview), but the mappings s→θ→f and zl→dl→gl have not been attested in any adult language. If we want to assume that all constraints are universal, it is hard to think of a reason why the locally conjoined constraints that are responsible for these patterns would only be active in children's grammars.

The local conjunction analyses thus encounter some serious difficulties. In the next paragraph I will present Jesney's (2005, 2007) proposal for child chain shifts.

2.2.4 FAITHFULNESS TO INPUT PROMINENCE

Jesney (2005, 2007) provides an account for the *puzzle-puddle-pickle* problem and the *s-θ-f* chain shift. I will start with a discussion of the latter. Jesney looked at the *s-θ-f* chain shift in the production data of R.H., a typically developing child studied by Dinssen and Barlow (1998). In the data of this child there is a 'pure' chain shift stage, followed by an intermediate stage where the chain shift seems to be partly resolved: /s/ is still pronounced as [θ], but /θ/ is sometimes pronounced as [f] and sometimes as [θ].

Jesney (2007:191) formulates the *Faithfulness to Input Prominence Hypothesis* shown in (18).

(18) *Faithfulness to Input Prominence Hypothesis*

> Child chain shifts are driven by specific faithfulness constraints referencing *perceptually-prominent* input feature combinations. Input feature values can be preferentially preserved in the output, leading to chain shifts, just when they are subject to these constraints.

She goes on to argue that both typological and acquisition evidence suggests that the coronality of [+strident] segments is perceptually more distinct than the coronality of [–strident] segments. She finds support for this in the finding of Velleman (1998) that children confuse constrasts between [θ] and [f] more readily than contrasts between [s] and [f]. According to Jesney, these perceptually-driven biases are encoded in the grammar through specific faithfulness constraints that exists along with the set of general faithfulness constraints. Because the coronality of [+strident] segments is perceptually more distinct, a specific faithfulness constraint concerning [+strident] segments is part of the grammar. This constraint is shown in (19) together with the co-existing general faithfulness constraint (Jesney 2007:191).

(19) *Faithfulness constraints (Jesney 2007:191)*

Specific Faithfulness Constraint

IDENTCORONAL/[+strident] : a [coronal] feature of an input [+strident] segment is preserved by its output correspondent.

General Faithfulness Constraint

IDENTCORONAL : a [coronal] feature of an input segment is preserved by its output correspondent.

Note that this specific faithfulness constraint is similar to the positional faithfulness constraints as proposed by Lombardi (1999) and Beckman (1998). Positional faithfulness constraints are used to account for the observation that languages may maintain a distinction only in prominent positions and neutralize it elsewhere (Lombardi 1999:270). They call for preservation of contrast in specific psycholinguistically prioritised or perceptually prominent linguistic positions, such as initial syllables, stressed syllables, syllable onsets or root syllables (Beckman 1998:2). Jesney's specific faithfulness constraint does not concern a specific position, but a specific perceptually prominent segment, that is, a [+strident] segment.

Jesney (2007:198) points out that the specific faithfulness constraints are biased towards high ranking, just as is assumed for positional faithfulness constraints (Smith 2000). The *s-θ-f* chain shift can be captured by the constraints in (19) together with the constraints in (20).

(20) *Constraints (Jesney 2007:198)*

*θ:	Markedness constraint against non-strident coronal fricatives
*[+strident]:	Markedness constraint against [+strident] segments
IDENT[+strident]:	Faithfulness constraint for [+strident] segments

To obtain the chain shift effect the constraint *[+strident] must be ranked above IDENT[+strident] to ensure that underlying /s/ is not pronounced faithfully. And the constraint *θ must be ranked between the specific constraint IDENTCORONAL/[+strident] and the general constraint IDENTCORONAL to ensure that [f] is not the optimal output for all three inputs. The ranking is illustrated in (21). In tableaux 29 through 31 it is shown that this ranking provides the desired result.

(21) *Constraint ranking (Jesney 2007)*

Chain shift stage

*[+strident] >> IDENT[+strident]

IDENTCORONAL/[+strident] >> *θ >> IDENTCORONAL

TABLEAU 29

/s/	*[+strident]	IDENTCOR/[+strident]	IDENT[+strident]	*θ	IDENTCOR
f		*!	*		*
☞ θ			*	*	
s	*!				

TABLEAU 30

/θ/	*[+strident]	IDENTCOR/[+strident]	IDENT[+strident]	*θ	IDENTCOR
☞ f					*
θ				*!	
s	*!				

TABLEAU 31

/f/	*[+strident]	IDENTCOR/[+strident]	IDENT[+strident]	*θ	IDENTCOR
☞f					
θ				*!	*
s	*!				*

The chain shift is eventually overcome by a reranking of the constraints in which IDENT[+strident] outranks *[+strident] so that underlying /s/ is pronounced faithfully, and the constraint *θ is outranked by both the specific and general constraints IDENTCORONAL/[+strident] and IDENTCORONAL to ensure that /θ/ is pronounced faithfully (2007:197). Jesney proposes that in the intermediate stage *θ is already outranked by IDENTCORONAL/[+strident] and IDENTCORONAL, but *[+strident] still outranks IDENT[+strident]. The proposed rankings are listed in (22).

(22) *Rankings for s-θ-f chain shift (Jesney 2007)*

Initial state

*[+strident] >> IDENT[+strident]

*θ >> IDENTCORONAL/[+strident] >> IDENTCORONAL

Chain shift stage
*[+strident] >> IDENT[+strident]
IDENTCORONAL/[+strident] >> *θ >> IDENTCORONAL

Intermediate stage
*[+strident] >> IDENT[+strident]
IDENTCORONAL/[+strident] >> IDENTCORONAL >> *θ

Adult stage
IDENT[+strident] >> *[+strident]
IDENTCORONAL/[+strident] >> IDENTCORONAL >> *θ

As Jesney (2007:195) points out, the initial state of language acquisition is characterized by a ranking of markedness over all faithfulness. Therefore the markedness constraints *[+strident] and *θ are ranked above the faithfulness constraints. Moreover, she claims that specific faithfulness constraints are biased towards high ranking and co-exist with general versions of IDENT constraints (see e.g. Hayes 2004, Prince & Tesar 2004, Smith 2000, Tessier 2007). Therefore IDENTCORONAL/[+strident] is ranked above IDENTCORONAL in the initial state. With this initial state ranking the reranking of the constraints on the basis of positive target-language evidence is all that is needed in order for developmental chain shifts to emerge and subside (Jesney 2007:198).

The proposed initial state ranking results in a full neutralization. That is, target /s/, /θ/ and /f/ will all be produced as [f], as is shown in tableaux 32 through 34. However, in none of the data I have seen is this attested. Rather, the literature suggest that /s/ is never substituted by [f], regardless of the presence of a chain shift. Moreover, in a thorough study of the production data of 234 children with a phonological delay, Dinnsen et al. (2011) found that while labialization (/θ/ → f]) and dentalization (/s/ → [θ]) can occur independently or in a counter-feeding interaction, these processes are not attested in a feeding interaction. This means that some children showed labialization without dentalization, some children showed dentalization without labialization, some children showed a counter-feeding interaction (the *s-θ-f* chain shift), but none of the studied children showed a feeding interaction whereby all three fricatives are produced as [f]. Jesney's account thus seems to make a wrong prediction.

TABLEAU 32

/s/	*[+strident]	*θ	IDENTCOR/[+strident]	IDENT[+strident]	IDENTCOR
☞ f			*	*	*
θ		*!		*	
s	*!				

TABLEAU 33

/θ/	*[+strident]	*θ	IDENTCOR/[+strident]	IDENT[+strident]	IDENTCOR
☞ f					*
θ		*!			
s	*!				

TABLEAU 34

/f/	*[+strident]	*θ	IDENTCOR/[+strident]	IDENT[+strident]	IDENTCOR
☞ f					
θ		*!			*
s	*!				*

In the intermediate stage target /s/ is still pronounced as [θ], but /θ/ is sometimes pronounced as [f] and sometimes as [θ]. Tableaux 35 through 37 show the optimal outputs given the constraint ranking in the intermediate stage given in (5). As can be seen, the optimal output for /s/ is [θ], for /θ/ is [θ] and for /f/ it is [f].

TABLEAU 35

/s/	*[+strident]	IDENTCOR/[+strident]	IDENT[+strident]	IDENTCOR	*θ
f		*!	*	*	
☞ θ			*		*
s	*!				

TABLEAU 36

/θ/	*[+strident]	IDENTCOR/[+strident]	IDENT[+strident]	IDENTCOR	*θ
f				*!	
☞ θ					*
s	*!				

TABLEAU 37

/f/	*[+strident]	IDENTCOR/[+strident]	IDENT[+strident]	IDENTCOR	*θ
☞ f					
θ				*!	*
s	*!			*	

Subsequently, in the adult stage all three sounds are pronounced faithfully, as is shown in tableaux 38 through 40.

TABLEAU 38

/s/	IDENT[+strident]	IDENTCOR/[+strident]	*[+strident]	IDENTCOR	*θ
f	*!	*		*	
θ	*!				*
☞ s			*		

TABLEAU 39

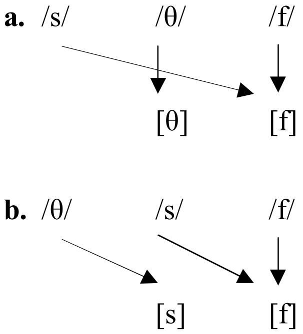
/θ/	IDENT[+strident]	IDENTCOR/[+strident]	*[+strident]	IDENTCOR	*θ
f				*!	
☞ θ					*
s			*!		

TABLEAU 40

/f/	IDENT[+strident]	IDENTCOR/[+strident]	*[+strident]	IDENTCOR	*θ
☞ f					
θ				*!	*
s			*!	*	

Jesney (2007:198) emphasizes how her account makes certain typological predictions. It follows from the posited relationship between the specific and general faithfulness constraint, that if, for example, the coronality of some but not all input segments is to be preserved in the output, it will be the coronality of [+strident] segments. This predicts that mappings such as in (23) are impossible. In these mappings the coronality of the [-strident] segment is preserved and the coronality of the [+strident] segment is lost, which rules against the proposal made by Jesney. Moreover she claims that a hypothetical constraint like IDENTCORONAL/[-strident] is ruled out, because only perceptually-prominent input feature combinations are reflected in specific faithfulness constraints.

(23) *Predicted impossible mappings (Jesney 2007:198)*



Jesney's account for the *puzzle-puddle-pickle* problem is similar to that of the *s-θ-f* chain shift. She uses the same constraints with addition of the constraint *tl, a markedness constraint barring adjacent [-continuant] coronal segments (Jesney 2007:189). Note that this constraint has the same function as *dl in earlier proposals. With the ranking shown in (24) Jesney captures the chain shift effect.

(24) *Rankings for puzzle-puddle-pickle problem (Jesney 2007)*

Initial state
*[+strident] >> Ident[+strident]
*tl >> IdentCoronal/[+strident] >> IdentCoronal

Chain shift stage
*[+strident] >> Ident[+strident]
IdentCoronal/[+strident] >> *tl >> IdentCoronal

Intermediate stage
Ident[+strident] >> *[+strident]
IdentCoronal/[+strident] >> *tl >> IdentCoronal

Adult stage
Ident[+strident] >> *[+strident]
IdentCoronal/[+strident] >> IdentCoronal >> *tl

In tableaux 41 through 43 it is shown how the proposed ranking for the chain shift stage captures the pattern. In tableau 41 we see that the optimal output for *puzzle* is [pʌdl̩] because [pʌzl̩] violates the high ranked *[+strident] and [pʌgl̩] violates the high ranked IDENTCOR/[+strident].

For *puddle*, in tableau 42, the optimal output is [pʌgl̩], because [pʌzl̩] and [pʌdl̩] both violate markedness constraints that are ranked about the faithfulness constraint IDENTCORONAL that is violated by [pʌgl̩]. In tableau 43 it is shown that [pɪkl̩] is the optimal output for *pickle*, because it violates none of the constraints.

TABLEAU 41

/pʌzl̩/	*[+strident]	IDENTCOR/[+strident]	*tl	IDENT[+strident]	IDENTCOR
pʌzl̩	*!				
☞ pʌdl̩			*	*	
pʌgl̩		*!		*	*

TABLEAU 42

/pʌdl̩/	*[+strident]	IDENTCOR/[+strident]	*tl	IDENT[+strident]	IDENTCOR
pʌzl̩	*!				
pʌdl̩			*!		
☞ pʌgl̩					*

TABLEAU 43

/pɪkl̩/	*[+strident]	IDENTCOR/[+strident]	*tl	IDENT[+strident]	IDENTCOR
pɪsl̩	*!				
pɪtl̩			*!		
☞ pɪkl̩					

The developmental steps are the same as for the *s-θ-f* chain shift, with the exception that in the intermediate stage of the *s-θ-f* chain shift *θ has been demoted, whereas in the intermediate stage of the *puzzle-puddle-pickle* problem *[+strident] is demoted (instead of *tl). This has to do with the different patterns in the data for R.H. who evidences the *s-θ-f* chain shift and Amahl who evidences the *puzzle-puddle-pickle* problem. In R.H.'s intermediate stage he starts to correctly produce /θ/, whereas he still substitutes [θ] for /s/. In

Amahl's intermediate stage he starts producing *puzzle* words correctly, whereas he still substitutes *pickle* words for *puddle* words. These different orders in resolution of the chain shift provide an interesting point, and I will come back to this in chapter 3. Jesney also assumes full neutralization for the *puzzle-puddle-pickle* problem in the initial state, that is, all words are produced as *pickle* words.

Jesney's account has some important advantages over the local constraint conjunction accounts. The proposed constraints and rankings seem to be more in line with general assumptions about learning. Jesney makes sure to provide arguments for the plausibility of the faithfulness to input prominence. Moreover, she shows the developmental steps in the chain shifts and how they can be learned. Unfortunately, the proposed constraint ranking for the initial state, before the *s-θ-f* chain shift, yields incorrect predictions.

I made an attempt to adapt Jesney's proposal to circumvent this problem. The substitution of [f] for target /s/ that is predicted in the initial state, is not attested in any data. However, what is attested is pervasive stopping of fricatives in the speech productions of young children (Smit 1993, Dinnsen et al. 2011). To capture the stopping pattern, Jesney's proposed constraint ranking can be complemented with the constraint IDENTCONTINUANT, a faithfulness constraint for the feature [continuant] and the constraint *FRICATIVE, a markedness constraint banning fricatives. In (25) I propose a new constraint ranking for the initial state.

(25) *Adapted constraint ranking*

Initial state (stopping)

*[+strident], *θ, *FRICATIVE >> IDENTCONTINUANT >> IDENTCORONAL/[+strident], IDENT[+strident] >> IDENTCORONAL

As can be seen in tableau 44 through 46 the proposed ranking for the initial state results in stopping of all three fricatives.[6] The optimal output for /s/ is [t], because the fricatives violate one or more of the high ranked markedness constraints. For the same reason, [t] is the optimal output for / θ/ and [p] is the optimal output for /f/.

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[6] For ease of exposition I chose to only include the stop that has the same (or almost the same) place of articulation and voicing as the input fricative in each tableau.

Tableau 44

/s/	*[+strident]	*θ	*Fric	IdentCont	IdentCor/[+str]	Ident[+strid]	IdentCor
f			*!		*	*	*
θ		*!	*			*	
s	*!		*				
☞ t				*		*	

Tableau 45

/θ/	*[+strident]	*θ	*Fric	IdentCont	IdentCor/[+str]	Ident[+strid]	IdentCor
f			*!				*
θ		*!	*				
s	*!		*				
☞ t				*			

Tableau 46

/f/	*[+strident]	*θ	*Fric	IdentCont	IdentCor/[+str]	Ident[+strid]	IdentCor
f			*!				
θ		*!	*				*
s	*!		*				*
☞ p				*			

The chain shift stage, the intermediate stage and the adult stage can subsequently be achieved through demotion of markedness constraints. The reranking in the subsequent stages is illustrated in (26).

(26) *Adapted constraint ranking*

Initial state (stopping)

*[+strident], *θ, *Fricative >> IdentContinuant >> IdentCoronal/[+strident], Ident[+strident] >> IdentCoronal

Chain shift stage (/s/ → [θ], /θ/ → [f], /f/ → [f])

*[+strident] >> IdentContinuant >> *Fricative, IdentCoronal/[+strident] >> Ident[+strident], *θ >> IdentCoronal

Intermediate stage (/s/ → [θ], /θ/ → [θ], /f/ → [f])
*[+strident] >> IDENTCONTINUANT >> *FRICATIVE, IDENTCORONAL/[+strident] >> IDENT[+strident] >> IDENTCORONAL >> *θ

Adult stage
IDENTCONTINUANT >> *FRICATIVE >> IDENTCORONAL/[+strident] >> IDENT[+strident] >> IDENTCORONAL, *[+strident] >> *θ

Note that if we assume minimal demotion, intermediate steps between the initial state and the chain shift stage are predicted to occur, because the reranking for the chain shift stage involves the demotion of both *FRICATIVE and *θ, and the latter is demoted more than one step. If the demotion of *FRICATIVE below IDENTCONTINUANT occurs before the demotion of *θ, this would result in a neutralization pattern where all three fricatives are produced as /f/. This is exactly the pattern we were trying to avoid with the adapted constraint ranking. Unfortunately, this constraint set also predicts a feeding pattern to be able to occur.

In (27) all possible output patterns for this constraint set are illustrated. With the programme OT Soft (Hayes et al. 2003) I was able to calculate the factorial typology of this set of constraints and candidates. The factorial typology is the set of output patterns that can be derived by ranking the constraints in all possible ways. It constitutes an important test for a constraint set, because the constraints, when freely ranked, should generate all and only the phenomena that are observed in the data (Prince & Smolensky 1993). For all the output patterns in (27) IDENTCORONAL/[+strident] is ranked above IDENTCORONAL[7]. Moreover, the constraint ranking for each output pattern can be achieved through demotion of constraints from the proposed initial state ranking (see (26)).

The output patterns in (27a) through (27h) are attested in children's speech data (see Dinnsen et al. 2011, Gierut 1996). I have no available data that show the patterns in (27i) and (27j), but there is no a priori reason to assume that these patterns would not be attested. This is different for the pattern in (27k). As I pointed out the pattern of neutralization was not attested in a study of the production data of 234 children by Dinnsen et al. (2011). Moreover, to my knowledge there are no studies that report a systematic substitution of [f] for target /s/ for children acquiring English. The absence of the pattern in Dinnsen et al.'s data therefore seems

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[7] Note that without this assumption the same set of output patterns is generated.

not to be the result of an accidental gap. The factorial typology thus shows that even with the proposed additional constraints, the constraint set would predict a pattern of neutralization to be able to occur. As I said, this prediction seems to be wrong.

(27) *Possible output patterns*

- **a.** /s/ → [θ], /θ/ → [f], /f/ → [f] *chain shift*
- **b.** /s/ → [θ], /θ/ → [θ], /f/ → [f] *only /s/ substituted by [θ]*
- **c.** /s/ → [s], /θ/ → [f], /f/ → [f] *only /θ/ substituted by [f]*
- **d.** /s/ → [s], /θ/ → [θ], /f/ → [f] *fully faithful productions*
- **e.** /s/ → [s], /θ/ → [s], /f/ → [f] *only /θ/ substituted by [s]*
- **f.** /s/ → [s], /θ/ → [t], /f/ → [p] */s/ is first fricative*
- **g.** /s/ → [t], /θ/ → [t], /f/ → [f] */f/ is first fricative*
- **h.** /s/ → [t], /θ/ → [t], /f/ → [p] *stopping*
- **i.** /s/ → [t], /θ/ → [f], /f/ → [f]
- **j.** /s/ → [s], /θ/ → [t], /f/ → [f]
- **k.** /s/ → [f], /θ/ → [f], /f/ → [f] *neutralization*

The adapted analysis is able to handle the fact that most children do not evidence a chain shift effect. From the proposed intial state ranking the child can proceed in different ways, depending on what constraints are demoted first. An important question is why some children would rerank their constraints in such a way that a chain shift effect arises, while for other children the reranking results in another pattern. To answer this question one would have to carefully study the children's input data and test the result of different sets of input data on learning algorithms. This is beyond the scope of this thesis.

What is important here is that with the addition of two constraints Jesney's analysis becomes more in line with children's early speech production data. The advantage of this solution is that the assumptions about ranking markedness over faithfulness and specific faithfulness over general faithfulness in the initial state need not be questioned. However, the proposed constraint set still makes a wrong prediction. Moreover, it still needs to be seen whether a chain shift stage is indeed preceded by a period of stopping of all fricatives in children's development. Longitudinal data of children's speech productions may show if this is the case.

Moreover, Jesney's account does not seem able to explain the difference between *puzzle* and *puddle* words. For the *puzzle-puddle-pickle* problem Macken (1980) showed that whereas incorrect productions of *puzzle* words were eliminated across the board in Amahl's data, productions of *puddle* words showed a period of variability in which some *puddle* words were produced target-like and some were still produced as *puzzle* words. Jesney cannot account for this difference. She would predict an across-the-board elimination of production errors for both *puzzle* and *puddle* words. And even if we would assume a learning algorithm like the GLA that accounts for variation in the grammar's output, it is not clear how this variation may occur with one type of words, but not with another type of words. In that case both *puzzle* and *puddle* words should show a period of variation.

Further, as with the local conjunction proposals, there seems to be no evidence that the assumed constraint is active in adult grammars. If IDENTCORONAL/[+strident] is a universal constraint, it would be expected to show up in some adult grammars as well. The plausibility of this account would strongly be supported with evidence from adult languages. At this point there is no independent evidence for the postulation of the constraint IDENTCORONAL/[+strident].

In conclusion, Jesney presents a strong account of chain shifts in first language acquisition that deals well with the issue of learnability. Jesney's proposed constraint ranking for the initial state results in a full neutralization of the three voiceless fricatives, which is not attested in children's production data in the literature. I proposed an adapted constraint ranking that would predict a stopping pattern in the initial state, but even with the proposed adaptation a neutralization pattern is predicted to occur in children's speech productions. Moreover, Jesney cannot account for all aspects of the chain shift data. She is not able to explain why for the *puzzle-puddle-pickle* problem errors on *puzzle* words are resolved across the board, whereas productions of *puddle* show a period of variability.

In the next paragraph I will present an approach to child chain shifts by Dinnsen et al. (2011) who make use of the framework of Optimality Theory with Candidate Chains.

2.2.5 OPTIMALITY THEORY WITH CANDIDATE CHAINS

Dinnsen, Green, Gierut and Morrisette (2011) propose an account for chain shifts using the framework of Optimality Theory with Candidate Chains (OT-CC) as proposed by McCarthy (2007). OT-CC is a synthesis of Optimality Theory with derivations and has been proposed to account for opacity effects in phonology (McCarthy 2007:3). In OT-CC a candidate includes not just a surface form but also a series of intermediate forms. A candidate is a chain of forms rather than a single form: a candidate chain. A candidate chain is an ordered *n*-tuple that connects the input with the output through a sequence of intermediate forms, each of which is minimally different from the forms that immediately precede and follow it. The last member of the chain is the output. Three conditions are posited on the well-formedness of candidate chains: (i) the first member of a chain must be fully faithful to the input; (ii) the successive forms in a chain must accumulate differences from the input gradually; (iii) the forms in a chain must be locally optimal (McCarthy 2007:60).

These conditions can be illustrated by candidate chains for input /s/ in (29). The chains in a, b and c are valid. They start with the fully faithful member /s/ and the successive forms each differ in one feature from the previous form. The chain in (29d) is invalid, because it does not start with the fully faithful form and thus violates the first well-formedness condition. The chain in (29e) is invalid because the step from [s] to [f] is not gradual, inasmuch as the two candidates differ in two features, violating the second well-formedness condition.

(29) *Candidate chains for input /s/*

a. [s]
b. [s] > [θ]
c. [s] > [θ] > [f]
d. *[θ] > [f]
e. *[s] > [f]

The violation of the third well-formedness condition depends on the constraint hierarchy of the language in question. This condition makes sure that every non-initial form in a chain is more harmonic than the previous form. Because the second well-formedness condition ensures that a form is less faithful than its predecessor, it must be less marked to conform to the third well-formedness condition, since a less faithful form can only be more harmonic if it is less marked (McCarthey 2007:62). I will return to that condition in the discussion of Dinnsen et al.’s (2011) account.

McCarthy (2007) also introduces a new type of constraint: the precedence constraint, notated as PREC. This constraint specifies the preferred order of faithfulness violations in a chain. For example, Dinnsen et al. (2011) make use of the constraint in (30) to rule out the candidate chain [s]>[θ]>[f].

(30) *Precedence constraint*

PREC(ID[coronal], ID[grooved]): Every violation of ID[grooved] must be preceded by a violation of ID[coronal], and it must not be followed by a violation of ID[coronal].

The candidate chain [s]>[θ] violates PREC(ID[coronal], ID[grooved]) because the violation of ID[grooved] with the step from [s] to [θ], is not preceded by a violation of ID[coronal]. This chain violates the precedence constraint once. The candidate chain [s]>[θ]>[f] violates PREC(ID[coronal], ID[grooved]) twice because the violation of ID[grooved] with the step from [s] to [θ], is not preceded by a violation of ID[coronal] *and* is followed by a violation of ID[coronal] with the step from [θ] to [f].

With this constraint and the constraint ranking in (31) Dinnsen et al. (2011) are able to capture the *s-θ-f* chain shift.

(31) *Constraint ranking (Dinnsen et al. 2011)*

***s-θ-f* chain shift**

*s >> ID[grooved], ID[continuant] >> PREC(ID[coronal], ID[grooved]) >> *θ >> ID[coronal]

In tableau 47 it is shown how the chain [s]>[θ], with output [θ], is the optimal candidate for input /s/. The chain [s]>[θ]>[f] violates the precedence constraint twice and is therefore ruled out. The chain [s] is ruled out, because the output of this chain, [s], violates high-ranked *s. The chain [θ]>[f] is the optimal candidate for input /θ/ in tableau 48. Neither of the candidate chains in this tableau violate the precedence constraint, but because *θ is ranked above ID[coronal] the chain [θ]>[f] is more optimal than the chain [θ].

TABLEAU 47

/s/	*s	ID[grooved]	ID[continuant]	PREC(ID[coronal], ID[grooved])	*θ	ID[coronal]
s	*!					
☞ s > θ		*		*	*	
s > θ > f		*		**!		*

TABLEAU 48

/θ/	*s	ID[grooved]	ID[continuant]	PREC(ID[coronal], ID[grooved])	*θ	ID[coronal]
θ					*!	
☞ θ > f						*

The challenge that Dinnsen et al. (2011) took upon them was to find a theoretical mechanism that can prevent multiple feature changes. In their study of the production data of 234 children with a phonological delay, they found that while labialization (/θ/ becomes [f]) and dentalization (/s/ becomes [θ]) can occur independently or in a counter-feeding interaction, these processes are not attested in a feeding interaction. Dinnsen et al. (2011:14) conclude that a change in both the place and manner features in the same segment is not tolerated, because /s/ is never substituted by [f]. OT-CC is a theoretical mechanism that is able to capture the *s-θ-f* chain shift as shown above. However, Dinnsen et al. also want to prevent the prediction of a feeding interaction. To achieve this they propose a modification to OT-CC.

McCarthy (2007:119) assumes that precedence constraints are initially ranked at the bottom of the hierarchy. Moreover, many OT-researchers assume that markedness constraints are ranked over faithfulness constraints in early stages of acquisition (e.g. Smolensky 1996). Given these assumptions the constraint ranking in an earlier stage (before the *s-θ-f* chain shift) would be as in (32b) where markedness constraints outrank faithfulness constraints. This ranking results in a feeding interaction as is shown in tableau 49 and 50.

In tableau 49 it is shown that the optimal output for input /s/ is [f], because [s] and [θ] violate the high ranked markedness constraints. Note that the candidate chain [s]>[θ] is excluded on other grounds as well: [θ] is not more harmonic than [s] given the constraint ranking in (32b), that is, [θ] is less faithful and not less marked. The chain thus violates the third well-formedness condition and is therefore not valid. With that constraint ranking the optimal output for input /θ/ also is [f], as can be seen in tableau 50.

(32) *Constraint ranking (Dinnsen et al. 2011)*

a. Counter-feeding interaction: *s-θ-f* chain shift

*s >> ID[grooved], ID[continuant] >> PREC(ID[coronal], ID[grooved]) >> *θ >> ID[coronal]

b. Feeding interaction: /s/, /θ/ and /f/ as [f]

*θ, *s >> ID[grooved], ID[continuant], ID[coronal] >> PREC(ID[coronal], ID[grooved])

c. Coronal stopping: /s/ and /θ/ as [t]

*θ, *s >> ID[grooved] >> PREC(ID[coronal], ID[grooved]), ID[coronal] >> ID[continuant]

TABLEAU 49

/s/	*s	*θ	ID[grooved]	ID[continuant]	ID[coronal]	PREC(ID[coronal], ID[grooved])
s	*!					
s > θ		*!	*			*
☞s > θ > f			*		*	**

TABLEAU 50

/θ/	*s	*θ	ID[grooved]	ID[continuant]	ID[coronal]	PREC(ID[coronal], ID[grooved])
θ		*!				*
☞ θ > f					*	**

OT-CC thus erroneously predicts a feeding interaction to be able to occur in earlier stages of acquisition. Dinnsen et al. (2011:17) propose a modification to OT-CC to circumvent this. They propose a fixed-ranking requirement between ID[continuant] and PREC(ID[coronal], ID[grooved]): ID[continuant] is ranked below the precedence constraint in the initial-state ranking. With this ranking, illustrated in (32c), there is no feeding interaction, rather stopping of coronal fricatives occurs. Dinnsen et al. (2011) point out that this modification is consistent with their findings. In their data stopping appears to be one of the preferred strategies for avoiding target coronal fricatives.

In tableau 51 it is shown that with that ranking [t] is the optimal output for input /s/. Note that the candidate chain [s]>[θ] is not included, because it violates the third well-formedness condition. Output [θ] is therefore ruled out on forehand. Output [s] is not optimal, because it violates the high-ranked *s. The candidate chains [s]>[t] and [s]>[f] both violate ID[grooved] and PREC(ID[coronal], ID[grooved]), but [s]>[f] also violates ID[coronal], which is ranked above ID[continuant]. The chain [s]>[t] violates ID[continuant], but since that constraint is ranked low it is still the optimal candidate.

The optimal candidate for input /θ/ is [t] as well, as can be seen in tableau 52. Candidate [θ] violates *θ and [θ]>[f] violates ID[coronal], which are both ranked above ID[continuant], the only constraint that is violated by [θ]>[t].

TABLEAU 51

/s/	*s	*θ	ID[grooved]	PREC(ID[coronal], ID[grooved])	ID[coronal]	ID[continuant]
s	*!					
☞ s > t			*	*		*
s > f			*	*	*!	

TABLEAU 52

/θ/	*s	*θ	ID[grooved]	PREC(ID[coronal], ID[grooved])	ID[coronal]	ID[continuant]
θ		*!				
☞ θ > t						*
θ > f					*!	

Dinnsen et al. (2011:18) propose that the fixed-ranking requirement between the precedence constraint and ID[continuant] is suspended once one of the markedness constraints against coronal fricatives has been demoted below PREC(ID[coronal], ID[grooved]). The constraint ranking for the chain shift stage, as illustrated in (32a), is then the result of “imperfect learning” by the child. Dinnsen et al. do point out that current error-driven learning algorithms do not provide for the kind of imperfect learning that they suggest. The question is thus, again, how the proposed ranking can be learned by a child. And it seems that Dinnsen et al. cannot provide an answer to that question.

More importantly, their proposal is not in line with McCarthy’s assumptions about OT-CC. He claims that learners will demote faithfulness and/or markedness constraints below a precedence constraint only when they encounter data that cannot be analyzed by permuting only faithfulness and markedness constraints (McCarthy 2007:119). This is clearly not the case with the *s-θ-f* chain shift, because the child receives no evidence for this pattern in its language input.

Another question is what reasons there are for the proposed modification to OT-CC other than providing an account for this particular chain shift. Interestingly, Dinnsen et al. (2011:20) claim that the fixed-ranking requirement between ID[continuant] and PREC(ID[coronal], ID[grooved]) is also crucial for their account of the *puzzle-puddle-pickle* problem. In (33) the proposed ranking for the *puzzle-puddle-pickle* problem is shown. The constraint VELARIZATION bans sequences of coronal stops followed by liquids.

(33) *Constraint ranking (Dinnsen et al. 2011)*
***Puzzle-puddle-pickle* problem**
*s, *θ >> ID[grooved] >> PREC(ID[coronal], ID[grooved]) >> VELARIZATION >> ID[coronal], ID[continuant]

With the ranking in (33) the *puzzle-puddle-pickle* problem can be captured, as is shown in tableau 53 and 54. In tableau 53 with input /zl̩/, candidate [zl̩] is ruled out because it violates high-ranked *s. Candidate chain [zl̩]>[dl̩] is more optimal than [zl̩]>[dl̩]>[gl̩], because the former violates the precedence constraint once, while the latter violates it twice. The optimal output for /zl̩/ thus is [dl̩].

In tableau 54 it is shown that [dl̩]>[gl̩] is more optimal than [dl̩] for input /dl̩/. Candidate chain [dl̩]>[gl̩] violates ID[coronal], but this constraint is ranked lower than VELARIZATION which is violated by [dl̩]. The optimal output for /dl̩/ thus is [gl̩].

TABLEAU 53

/zl̩/	*s	*θ	ID[grooved]	PREC(ID[coronal], ID[grooved])	VELAR	ID[coronal]	ID[continuant]
zl̩	*!						
☞ zl̩ > dl̩			*	*	*		*
zl̩ > dl̩ > gl̩			*	**!		*	*

TABLEAU 54

/dl̩/	*s	*θ	ID[grooved]	PREC(ID[coronal], ID[grooved])	VELAR	ID[coronal]	ID[continuant]
dl̩					*!		
☞ dl̩ > gl̩						*	

The ranking of ID[continuant] below the precedence constraint is crucial to ensure the stopping of target /zl̩/ rather than substitution by another fricative. Output [ðl̩] would violate *θ , a constraint banning interdental fricatives. And [zl̩]>[ðl̩] would already be ruled out as a candidate in OT-CC because it violates the third well-formedness condition: [ðl̩] is not more optimal than [zl̩] given this constraint ranking. However, the low-ranking of ID[continuant] must ensure that [vl̩] does not surface as optimal output for /zl̩/. A high-ranked markedness constraint against labial fricatives cannot be assumed, because Smith (1973) shows that the *puzzle-puddle-pickle* problem continues to exist in Amahl's data long after /f/ is produced target-like. A constraint against labial fricatives must thus be ranked below ID[continuant] for independent reasons.

Both chain shifts thus provide a reason to rank ID[continuant] below the precedence constraint. However, the solution seems to be adhoc. A modification of the theory solely to account for child chain shifts is not desirable. The question is whether the modification is warranted without independent evidence to support it.

In conclusion, Dinnsen et al.'s account encounters serious learnability issues and the assumptions for modification of OT-CC are at least questionable. In the next paragraph I will present an analysis by Dinnsen and Barlow (1998).

2.2.6 UNDERSPECIFIED UNDERLYING REPRESENTATIONS

Most analyses of child chain shifts within Optimality Theory focus on a purely grammatical account. That is, constraints and constraint ranking are held responsible for the chain shift effect, as in the above proposals. However, Dinnsen and Barlow (1998) propose that the substitution patterns are a result of underspecified underlying representations. They claim that children's substitution patterns are caused by the fact that two or more sounds have the same underlying specification, while they are contrastive in the target system. The idea is that underspecified features are filled in by default resulting in a merger of the two sounds.

An example of this is the common production error that young children make where fricatives are replaced by stops. The idea is that stops and fricatives are underspecified for the feature manner and the unmarked [-continuant] is filled in by default (Dinssen & Barlow 1998: 72). Note that the stopping pattern is explained differently by most OT researchers. The standard assumption, as I showed in paragraph 2.2.1, is that a high-ranked markedness constraint banning fricatives can explain the substitution by stops. In that case the underlying representations are assumed to be fully specified. In general, the appeal to underspecification is disfavoured since the introduction of OT. The focus has been on output constraints and OT provides a powerful grammar that is able to account for many phenomena without the need to resort to underspecification. Moreover, many researchers assume that underspecification is at odds with the principle of Richness of the Base. I will return to a discussion of this principle in paragraph 3.3.

To account for the *s-θ-f* chain shift, Dinnsen and Barlow assume that the underlying representations for /f/, /θ/ and /s/ are underspecified. The underlying representations are only specified for a few features, as shown in (34).

(34) *Underlying representations*

Target /f/ = /F/ [+continuant]
Target /θ/ = /F/ [+continuant]
Target /s/ = /S/ [+continuant, coronal]

Target /f/ and /θ/ have the same underlying features. The default feature for place is assumed to be [labial] which results in surfacing of /f/ and /θ/ as [f]. Dinnsen and Barlow (1998:73) acknowledge that [coronal] is generally assumed to be the default feature for place in fully developed systems, but claim there is evidence that this might be different for developing phonological systems. The evidence consists of the fact that many children at some stage limit their fricative productions to either labials or coronals. If children only produce labial fricatives this might be because [labial] is the default place feature. Dinnsen and Barlow (1998:88) go on to speculate that the *s-θ-f* chain shift might only emerge in children's systems where the default place feature is [labial] instead of [coronal]. So for children evidencing the *s-θ-f* chain shift the feature [labial] is not specified and filled in by default.

When a child does not have fully specified representations, as is proposed by Dinnsen and Barlow, this can be because he has not accurately perceived all the features (misperception), because he has a problem with encoding the perceived features or because there are limitations on his underlying representations. The authors do not make clear which is the case. However, it seems far-fetched to assume that some children misperceive the feature [labial] whereas other children misperceive the feature [coronal]. The underspecified representations thus must be caused by a problem with encoding of perceived features or by restrictions on representations. The latter is problematic because it is at odds with the principle of Richness of the Base, which states that no restrictions can be placed on the input. (I will come back to a discussion of this principle in paragraph 3.3.) For now it is important to point out that Dinnsen and Barlow do not seem to take a position on the issue at hand.

Together with the assumed underspecified representations, Dinnsen and Barlow use the constraints and ranking in (35) to obtain the chain shift effect.

(35) *Constraints and ranking (Dinnsen & Barlow 1998:85)*

Constraints

MAX[FEATURE]	Every feature in the input segment must occur in the corresponding output segment
DEP[+strident]	The presence of [+strident] in the output must correspond to the presence of [+strident] in the input
DEP[-strident]	The presence of [-strident] in the output must correspond to the presence of [-strident] in the input
DEP[coronal]	The presence of [coronal] in the output must correspond to the presence of [coronal] in the input
DEP[labial]	The presence of [labial] in the output must correspond to the presence of [labial] in the input

Ranking

DEP[+strident], MAX[FEATURE] >> DEP[-strident] >> DEP[coronal] >> DEP[labial]

In tableau 55 and 56 it is shown how [f] is the optimal output for underlying /F/, the underlying representation for target /f/ and /θ/ and that [θ] is the optimal output for underlying /S/.

TABLEAU 55

/F/	DEP[+strident]	MAX[FEATURE]	DEP[-strident]	DEP[coronal]	DEP[labial]
☞ f					*
θ			*!	*	
s	*!			*	

TABLEAU 56

/S/	DEP[+strident]	MAX[FEATURE]	DEP[-strident]	DEP[coronal]	DEP[labial]
f		*!			*
☞ θ			*		
s	*!				

Dinnsen and Barlow (1998:77) claim that the chain shift is resolved per lexical item. The underlying representation of each lexical item needs to be changed in order for the chain shift effect to resolve. They claim that the few target-appropriate realizations of /θ/ that occurred in the data of their subjects post-treatment are the result of the specification of the feature [coronal] in just those words, whereas other words with target /θ/ were still underspecified. The few target-appropriate realizations of /s/ would be the result of specification of [+strident] in just those lexical items. The authors go on to speculate that the task of restructuring input representations might be more difficult for children than to rerank constraints. This might account for the resistance to treatment that they report for the *s-θ-f* chain shift. Also they make a suggestion that the chain shift does not emerge in children's systems whose first and only fricative is a coronal, and not a labial.

Since the purely grammatical accounts of children's chain shifts all seem to encounter problems, it may indeed be needed to resort to other options such as underspecified underlying representations. Dinnsen and Barlow provide an account that explains the error pattern and the period of variability for the *s-θ-f* chain shift. Their account also raises questions. For example, it is not clear how the child eventually learns the fully specified representation of a sound. Does the child suddenly perceive the difference between /f/ and /θ/

correctly, or was the perception accurate all along and is it a question of encoding? Dinnsen and Barlow touch upon these questions, but do not provide a model for acquisition. As I pointed out, they do not even make clear what causes the representations to be underspecified. Different answers to those questions would result in different predictions that can be tested. It is also not clear why the feature [coronal] is underspecified in the representation of /θ/, but not in the representation of /s/.

Dinnsen and Barlow also suggest that the *s-θ-f* chain shift only arises in children's systems whose first fricative is a labial, whereas it does not arise when the first fricative is a coronal. What they do not make clear is what influences the 'choice' of the first produced fricative in children. Why would some children first produce a coronal fricative and others a labial fricative? Moreover, they do not adress the fact that most children that produce /f/ as their first fricative do not evidence a chain shift effect (see Dinnsen et al. 2011). A difference in the underlying representations or the constraint ranking would have to be assumed to explain that most children do not exhibit the *s-θ-f* chain shift.

The lack of explicitness in the proposal by Dinnsen and Barlow makes it difficult to test empirically. Moreover, the issue of learnability is repeatedly shown to be the most difficult in accounting for the chain shift patterns and is in need of an answer.

2.3 CONCLUSION

Within generative grammar many analyses have been proposed to account for chain shifts in first language acquisition. The early generative accounts of the *puzzle-puddle-pickle* problem by Smith (1973) and Macken (1980) are able to capture the chain shift effect. Smith's proposal consists of rewrite rules that are ordered in a counterfeeding order, but his analysis does not take into account the difference in elimination of errors on *puzzle* and *puddle* words. Macken showed that errors with *puzzle* words are eliminated across-the-board, whereas the production of *puddle* words shows a period of variation. She claims that the chain shift effect is the result of two different types of rules: *puzzle* words change to *puddle* words through an output rule, while the change of *puddle* words to *pickle* words is due to a perceptual-encoding rule. For both accounts it is not clear how the child learns the rules that are involved. No plausible theory of learnability is provided.

Optimality Theory has an important advantage regarding learnability when compared to other frameworks within generative grammar. Tests with algorithms have shown that OT-grammars can be learned (Tesar & Smolensky 2000, Boersma & Hayes 2001). Nonetheless, child chain shifts pose a difficult challenge for OT. The apparent counterfeeding interaction is impossible to capture in a constraint ranking without resorting to more controversial constraints.

Analyses that make use of local constraint conjunction are proposed by Morrisette and Gierut (2008) for the *s-θ-f* chain shift and by Dinnsen et al. (2001) for the *puzzle-puddle-pickle* problem. The proposed locally conjoined constraints are able to prevent the substitution of [f] for /s/ and *pickle* for *puddle* words, but pose a learnability problem. Since there is no evidence from the surrounding language input for the chain shift patterns, there is no way that a child can learn the locally conjoined constraint. Moreover, if we would assume that locally conjoined constraints are innately present at the top of the constraint hierarchy all children would have to show the result of this in their speech productions. In either case, whether locally conjoined constraints are learned or innate, they seriously complicate the child's learning task.

Jesney (2005, 2007) tries to solve the issue of learnability by assuming a more plausible constraint. The specific faithfulness constraint IDENTCORONAL/[+strident] is violated if the coronal feature of [+strident] segment is changed. She provides an account for the *s-θ-f* chain shift and the *puzzle-puddle-pickle* problem and is able to capture both chain shifts in a constraint ranking. Moreover, she shows the developmental steps in the children's productions and how they can be learned by the child. Unfortunately she makes a wrong prediction for the initial state, before the *s-θ-f* chain shift. She predicts that in this stage all three fricatives are produced as [f], but this pattern is not attested in any data. I have proposed an adapted constraint ranking that would predict a stopping pattern of the fricatives in the initial state. But even with the adapted constraint set a neutralization is predicted to occur in children's speech. Jesney also cannot account for Macken's observation that errors on *puzzle* and *puddle* words are resolved in a different manner. Jesney predicts that errors with both types of words are eliminated across-the-board, but this is not the case.

Dinnsen et al. (2011) make use of the framework of OT with Candidate Chains to account for the *s-θ-f* chain shift and the *puzzle-puddle-pickle* problem. However, their account encounters serious learnability problems. Moreover, they suggest a modification to OT-CC that is rather adhoc. Dinnsen and Barlow (1998) take a different approach and claim that the *s-θ-f* chain shift is due to underspecified underlying representations. Their account is able to capture the chain shift pattern, but it is unclear what causes the underspecification and why, for example, the feature [coronal] is underspecified in the representation of one sound but not in that of another.

In conclusion, none of the above discussed proposals gives an unproblematic account of the phenomenon. While some accounts are able to capture the chain shift effect, the issue of learnability keeps returning. Jesney's account is the most promising, because it provides a plausible theory of learnability. However, as we have seen, it makes certain predictions that are not in line with the actual data.

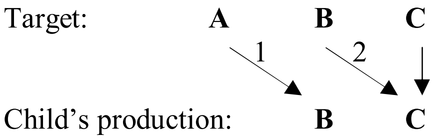
It is interesting to note that Macken's (1980) insights in the *puzzle-puddle-pickle* problem are overlooked in the later accounts within OT. None of the analyses takes into account the differences between the two error patterns that Macken pointed out. She showed that the errors on *puzzle* words are eliminated across-the-board, whereas errors on *puddle* words show a period of variability. Moreover, she emphasized the fact that the two error patterns are resolved at a different point in time. In the next chapter I will present an alternative account for child chain shifts that will incorporate her important observations.

3. A NEW PROPOSAL

In the previous chapter we saw that it is very difficult to provide a grammatical account without learnability problems for chain shifts in first language acquisition. In this chapter I will argue that the chain shift effect is not due to grammatical processes. I claim that child chain shifts are due to two independent processes outside of the grammar. In my view a chain shift arises when two different error patterns interact. I will argue that these two error patterns each have a different cause: articulatory and perceptual difficulties. My view thus contrasts with most previous literature that has focused on a grammatical explanation.

In (36) I give a schematization of the chain shift effect. Arrow 1 illustrates the substitution of [θ] for /s/ in the *s-θ-f* chain shift and *puddle* for *puzzle* words in the *puzzle-puddle-pickle* problem, and arrow 2 illustrates the substitution of [f] for /θ/ and *puddle* for *pickle* words, respectively.

(36) *Schematization of the chain shift effect*



I want to argue that the substitution of sound B for target A (arrow 1) is due to articulatory difficulties. Children evidencing the *s-θ-f* chain shift have trouble with the correct articulation of /s/ and produce [θ] instead, and children evidencing the *puzzle-puddle-pickle* problem have trouble with the articulation of /z/ and produce [d] instead[8]. The same holds for the substitution of [t, d] for /s, ʃ, tʃ, dʒ/ in the *puzzle-puddle-pickle* problem.

The substitution of C for B (arrow 2) is due to a different cause. My claim is that children have trouble with the correct perception of target B and misperceive this sound as C. Because the child fails to perceive the difference between B and C, the difference is not encoded in the child's underlying representation. For the *s-θ-f* chain shift that means that the child misperceives /θ/ as /f/ and consequently has the same underlying representation for /θ/ and /f/. For the *puzzle-puddle-pickle* problem that means that the child misperceives /dl̩/ as /gl̩/ and

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[8] Smith's (1973) data of his son Amahl suggest that the stopping of /z/ is not confined to the environment preceding [l̩].

consequently has the same underlying representation for /dl̩/ and /gl̩/. The same holds for /tl̩/ which is misperceived as /kl̩/ and /nl̩/ which is misperceived as /ŋl̩/.

My claims can be summarized as follows:

1. The chain shift effect is due to two independent processes;
2. Sound A is produced as sound B, because of articulatory difficulties with sound A;
3. Sound B and C have the same underlying representation due to misperception of sound B.

Note that my account follows Macken (1980) in assuming that /t/, /d/ and /n/ are misheard as the velars /k/, /g/ and /ŋ/ in the environment of a following /l/ in the *puzzle-puddle-pickle* problem. Moreover, my proposal is based on Macken's idea that two different and independent processes are causing the chain shift effect. However, I argue that the error patterns are caused by processes outside of the grammar, whereas Macken formulates grammatical rules to account for the *puzzle-puddle-pickle* problem. She explains the first part of the chain shift with an output rule that operates on the lexical representation, that is, at the level of the grammar, whereas I assume it is caused by articulatory difficulties. And she formulates a perceptual-encoding rule to account for the second error pattern, while I would argue that perception is not part of the grammar. Moreover, there is a great advantage I have as compared to Macken. Since 1980 a large amount of speech and perception data of young children have become available, material which I can use to substantiate my claims.

There are a number of predictions that follow from my proposal. Because I claim that the chain shift effect is due to two independent processes, I predict that the error patterns can exist independently of each other in a child's system. Moreover, when the error patterns co-occur I predict that they may differ in their timing. One pattern may be resolved before the other and vice versa. I claim that the first error pattern is due to articulatory difficulties with sound A, which means that I assume that the production of sound B for sound A is the result of a failure to correctly articulate sound A, rather than a substitution of B for A. I therefore predict that an acoustic difference is detectable between the production of sound B for target A and the target-like production of sound B. From my third claim it follows that children will fail to discriminate between the second and third sound in the chain shift. And I predict that at the stage where children start to correctly perceive sound B and reorganize their underlying representations, confusion may occur regarding the underlying representations not only of sound B, but also of sound C. A final prediction is that the first error pattern will show an across-the-board elimination, because I assume that articulatory difficulties with a sound are resolved across-the-board, and the second error pattern will show a period of variability, inasmuch as the underlying representation of each word needs to be changed after it is correctly perceived by the child.

While I claim that the chain shift effect is due to processes outside of the grammar, I do not doubt the existence of a grammar. I assume an OT-grammar and assume that perception and production are processes that are active outside of that grammar. I also assume that children's underlying representations are fully specified, except in the case where children do not correctly perceive all features of a sound, as I claim is the case for sound B in the child chain shifts.

In the rest of this chapter I will provide evidence for my claims. In paragraph 3.1 I will discuss evidence for the claim that two independent processes are involved in the chain shift effect. In paragraph 3.2 I will substantiate my claim about articulatory difficulties in the first part of the chain shift. Before discussing evidence that misperception plays a role in the second part of the chain shift in paragraph 3.4 I will present an overview of the research on children's underlying representations and a discussion of the argument of Richness of the Base in 3.3. In 3.5 I will revisit the predictions and summarize the evidence discussed. And I will finish this chapter with a conclusion in 3.6.

Before going on I want to point out, that while I keep using the terms 'chain shift' and 'substitution' for clarity's sake, my proposal implies that neither of these words are suitable for the cases at hand. I claim that there is no pattern of phonological substitution, because, for example, for the *s-θ-f* chain shift it is not the case that /s/ is substituted by another sound, rather the produced [θ] is the result of a misarticulation of /s/. Neither is the production of [f] for target /θ/ a case of substitution, because the child does not make a distinction between the two sounds. If two sounds are represented as the same, one cannot be substituted for the other. The term 'chain shift' is at odds with my proposal as well, because I claim that two independent processes are responsible for the attested pattern. In my view there is no chain of events leading to the 'chain shift effect'. Rather there are interacting error patterns (term used by Gierut & Champion 1999), that result in something that could superficially be called a chain shift.

3.1 INDEPENDENT PROCESSES

I claim that the chain shift effect is caused by two independent processes. There are in fact several indications that two independent processes are involved.

The available data show that the two error patterns are not resolved at the same time. Smith (1973) shows that his son Amahl stops changing *puzzle* into *puddle* words at age 2;11, while the change of *puddle* into *puggle* words persist until age 3;9 and becomes optional at that stage. For the *s-θ-f* chain shift, Morrisette and Gierut (2008) show that three children with a phonological delay resolve the error pattern with /s/ immediately post-treatment, while the error pattern with /θ/ is resolved only in the following speech sample, two months post-treatment. A similar picture is found for subject 74 in the study by Gierut and Champion (1999). That child evidences the *s-θ-f* chain shift and shows an across-the-board elimination of all errors on /s/ immediately post-treatment, while errors on /θ/ are not yet resolved in the last speech sample two months post-treatment.

Interestingly, the other order, where the second part of the chain shift is resolved before the first, is also attested. In the same study by Gierut and Champion subject 90 starts showing correct productions of target /θ/ before /s/ is produced target-like. R.H., a typically developing child studied by Dinssen and Barlow (1998) also shows this pattern. In the data of this child there is a chain shift stage, followed by an intermediate stage where the chain shift seems to be partly resolved: /s/ is still pronounced as [θ], but /θ/ is sometimes pronounced as [f] and sometimes as [θ]. Thus not only do the error patterns follow different timelines, there also does not seem to be a crucial ordering.

Moreover, Macken (1980) shows, in a reanalysis of the *puzzle-puddle-pickle* data of Amahl, that there is an across-the-board elimination of errors on *puzzle* words, while errors on *puddle* words show a period of variability. I assume that this follows from the different processes that cause the errors. Articulatory errors are resolved across-the-board, while perceptual errors are resolved per lexical item, because the underlying representation of each word needs to be changed given the new information the child receives when perception becomes correct.

Further evidence comes from a study by Velleman (1988) on children’s production and perception of voiceless fricatives. Velleman studied 12 children acquiring English between age 3;2 and 5;6. From each child speech samples were collected that consisted of free conversation, spontaneous, elicited and imitative picture- and toy-naming and elicited imitation of meaningless fricative-vowel syllables. Perception data were collected in a real-word picture-pointing task. The production and perception data were compared and an acoustic analysis was made of the production data.

The results show a strong correlation between the perception and production of /θ/. Children who scored low on perception of /θ/ scored low on production and vice versa and children who scored high on perception of /θ/ scored high on production and vice versa. This correlation was not found for /s/. Perception scores for /s/ were high for most of the children, but there was less of a tendency for high perception scores to be accompanied by high productions scores. These results indicate that perception does play an important role in the correct production of target /θ/ but not of target /s/.

Acoustic analyses of the production data reveal that the children's productions of [f] for /θ/ do not differ from their productions of [f] for target /f/. Velleman interprets this as a lack of acoustic evidence that the children are attempting to produce the adult contrast. The same holds for the substitution of [s] for /θ/: the production of [s] for target /θ/ does not differ acoustically from the [s] for target /s/. Interestingly, acoustic differences were found between [θ] for target /s/ and [θ] for target /θ/. [θ]'s for target /s/ were found to differ from [θ]'s for target /θ/ on overall spectral shape, high peaks, overal high cutoffs, and 50% high cutoffs. This means that there was a consistent difference between production of [θ]'s that were substitutions of /s/ and [θ]'s that were target productions of /θ/. This difference was not perceivable by adult listeners and is known as covert contrast (Macken and Barton 1980, Scobbie et al. 2000). Velleman concludes that the children who substitute [θ] for target /s/ are attempting to produce the adult contrast between /θ/ and /s/, but fail to do so because of articulatory difficulties. Her overall conclusion is that in general substitutions for /s/ tend to have a motoric basis, whereas substitutions for /θ/ are due to a non-adult phonemic representation.

This study provides direct evidence for my proposal for the *s-θ-f* chain shift, because it presents empirical evidence that different processes are involved in substitutions for /θ/ than in substitutions for /s/. Moreover, the results show a link between perceptual and production difficulties for /θ/ and provide evidence that the child is not attempting to produce the adult contrast between /f/ and /θ/. My claim that the substitution for /s/ is due to articulatory difficulties is supported by the fact that the acoustic analyses reveal that the children seem to fail at their attempt to produce the contrast.

My claim that two different processes are involved in the chain shift effect is thus supported by the fact that the error patterns are not resolved at the same time, that the order can vary, and that the elimination of errors may follow a different route. Moreover, Velleman (1988) has shown that in general children's substitutions for target /θ/ behave differently than substitutions for target /s/.

3.2 ARTICULATORY DIFFICULTIES

As we have seen, within Optimality Theory there is a strong tendency to opt for a grammatical explanation of the deviations in children's speech. Grammatical processes are held responsible for children's substitution patterns. I, on the other hand, claim that articulatory difficulties are responsible for the substitutions of [θ] for /s/ in the *s-θ-f* chain shift.

A problem with a grammatical account for the substitution of [θ] for /s/ is that /θ/ is more marked than /s/. In the UCLA Phonological Segment Inventory Database (UPSID) (see Maddieson 1984) where data from 317 language are gathered the most frequent fricative is /s/, occurring in 266 of the 317 languages[9], while /θ/ only occurs in 18 of the languages. Moreover, of the languages that contain fricatives 88.5 percent has /s/, and /s/ is the only fricative for 31 of the 37 languages that have just one fricative. Therefore /s/ can be assumed to be the least marked fricative.

It is unclear on what grounds an unmarked segment, such as /s/, would be substituted by a more marked segment. Moreton and Smolensky (2002:4) point out that within Optimality Theory inputs change only to become less marked, which means that in a chain shift with a mapping x→y→z, x should be more marked than y, and y should be more marked than z. This is not the case in the *s-θ-f* chain shift, because /s/ is less marked than /θ/ and /f/. The constraint *s cannot be ranked over *θ in the initial ranking, since /θ/ is more marked. The

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[9] Note that /s/ indicates both dental and alveolar /s/ here.

reranking of *s over *θ should then be the result of evidence from the input the child receives. However, given the English language input, there does not seem to be a reason to demote *s below *θ. A non-grammatical account of substitution of [θ] for /s/ is therefore to be preferred for the *s-θ-f* chain shift and for this substitution pattern in general.

Moreover, /s/ is a difficult sound to articulate[10]. Developmental norms show that /s/ appears rather late in children's inventories (Forrest et al. 1995) and Ferguson (1978:94) regards misarticulation of /s/ as one of the most common "speech defects" in English. Gibbon (1999) points out that formation of the midsagittal groove in the tongue that creates a passage for air to hit the back of the teeth, which is needed to produce [s], is motorically difficult. As discussed above, Velleman's study provides evidence that in general substitutions of [θ] for /s/ tend to have a motoric basis, because children who substitute [θ] for /s/ are found to actually produce an acoustic contrast between target /s/ and target /θ/. This covert contrast is not picked up when speech samples are transcribed by human researchers, but acoustic analyses show significant differences between [θ] for target /s/ and [θ] for target /θ/ (1988:232).

The data from Morisette and Gierut (2008) give another indication that misarticulation of /s/ is causing the error pattern. In their study of three children with a phonological delay, they show that /s/ is substituted by [θ] and dentalized [s̪]. Dentalized [s̪] can be seen as a step from [s] in the direction of [θ]. In the pretreatment sample dentalized [s̪] was reported to occur 60% of the time and [θ] 40% of the time for target /s/. I see this as a strong indication that the children are attempting to produce [s], but fail to do so because [s] is hard to articulate. Some attempts result in [θ] and some in [s̪], until the child learns to pronounce [s] correctly. In an analysis of errors on consonant singletons in the Iowa-Nebraska Articulation Norms Project, Smit (1993:543) shows that dentalization is by far the most common error for target /s/. Dentalization errors are reported at an average rate between 15 and 30% between age 2;0 and 5;6 and continue at a rate of about 10% even for children at age 9;0, the oldest group studied. Smit (1993:544) also labels these errors as distortions, rather than phonological substitutions.

Snow (1963) reports that productions of /s/ are still distorted 16 percent of the time by children between 6;5 and 8;7. She tested 438 children in a picture-naming task. Of the

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[10] Note that /s/ is the least marked fricative, although it is difficult to articulate. One might expect a sound to be more marked when it is articulatory difficult, but at least in this case that does not hold.

productions for /s/ 78 percent was correct. The 22 percent errors consisted of mild distortions, severe distortions, omissions and substitutions. An interesting finding is that of the total errors with /s/ 74 percent are distortions and only 25 percent are substitutions. The percentages differ greatly with those for /θ/: substitutions make up 85 percent of the total amount of errors for /θ/ and distortion only 9 percent. It thus seems that even at this age children have trouble with the correct articulation of /s/.

Another indication that [θ] for target /s/ is due to articulatory factors, is the fact that lisping results in [θ]-like productions for target /s/ even for children acquiring a language that does not have /θ/ in its phonemic inventory. For example in Dutch, a language lacking the phoneme /θ/, lisping is a common phenomenon that is even reported to persist into young adulthood with a rate of 23% (Van Borsel et al. 2007). The error pattern whereby /s/ is pronounced as [θ], and sometimes [s̪], can thus well be explained by articulatory factors.

For the *puzzle-puddle-pickle* problem the situation is somewhat different. The substitution of [t, d] for /s, z, ʃ, tʃ, dʒ/ is a step from a more marked to a less marked segment, since stops are less marked than fricatives. Stops occur in the inventory of all known languages, while fricatives occur in approximately 93 percent of the languages (Maddieson 1984). This means that when a language contains one or more fricatives, it also contains stops. A grammatical account of this substitution pattern therefore does not encounter the same problems as for the *s-θ-f* chain shift. A ranking of *s over *t in the initial state, which may result in the substitution of [t] for /s/, conforms to optimality theoretic assumptions. Still I want to argue that also for this chain shift the first part (*puzzle-* to *puddle-*words) is due to articulatory difficulties with /s, z, ʃ, tʃ, dʒ/ and not to phonological processes.

Richtsmeier (2010:12) points out that the so-called substitutions in the *puzzle-puddle-pickle* problems “are by no means indisputable cases of substitutions”. He claims that the “apparently substituted” [d] may have articulatory and acoustic markings of the target /z/. Unfortunately neither Richtsmeier nor I are in the possession of reliable phonetic data to test this claim.

In the first part of this paragraph I have established that /s/ is hard to articulate. Gibbon (1999) claims that children lack the fine motor coordination required to produce the groove that is needed to articulate /s/. The result of a flatter articulation would essentially be a stop.

Stopping can thus be assumed as a different outcome of the attempt of the child to correctly articulate /s/. The same holds for /z/ which is reported by Smit (1993) to be produced both as [d] or dentalized [z̪] by children acquiring English.

However, if I am to assume that stopping of /s, z, ʃ, tʃ, dʒ/ is due to articulatory factors in the *puzzle-puddle-pickle* problem, I have to consider the larger issue of stopping in general. Smith's (1973) data indicate that Amahl does not only stop fricatives in *puzzle* words, but also in words where the fricatives are not followed by an /l/. The change of *puzzle* to *puddle* words thus seems to be the result of a general stopping pattern in Amahl's productions.

Within Optimality Theory stopping is considered to be a phonological process, whereby (more marked) fricatives are substituted by (less marked) stops. At this point I do not have enough evidence to provide a strong alternative to the grammatical account. Vihman (1996) suggests that an articulatory account of stopping is available because fricatives are more difficult to produce than stops. As Perkell (1997:351) points out the formation of a precisely-configured constriction for some fricatives is more complex than the simple, complete occlusion of a stop. Articulatory factors might also explain why stops emerge in children's early productions before fricatives. But, as Richtsmeier (2010:3) points out, an account of stopping based on articulatory concerns is incomplete, because of a lack of detailed studies of acoustic data.

Acoustic analyses of stopping patterns in child's speech, might or might not support my view. If an acoustic difference can be found between the production of [t, d] for target /s, z/ and the production of [t, d] for target /t, d/, this would provide support for my view that articulatory difficulties underlie the stopping pattern. Tyler (1995) studied three children that evidenced a stopping pattern. One of these children produced a durational acoustic difference between target fricatives and stops. Further research has to show whether more children are producing a covert contrast when they seem to be producing a stop for a target fricative.

If no further evidence for stopping as an articulatory process can be found, I could adapt my proposal for the *puzzle-puddle-pickle* problem. I would still assume that two independent processes are causing the chain shift, but in that case I would assume the phonological process of stopping to be responsible for the first part of the *puzzle-puddle-pickle* problem. That explanation does have not my preference, because I would like to provide a unified account for chain shifts in first language acquisition, but it would be compatible with my most important claim that the chain shift effect is due to two independent processes.

3.3 UNDERLYING REPRESENTATIONS

Before presenting evidence for my claim that the error pattern in the second part of the chain shift is due to misperception, I will give a summary of the discussion on children's underlying representations within current linguistic theory.

The standard assumption in early generative accounts, such as Smith (1973) and in current OT accounts, is that children's underlying representations are adult-like and thus fully specified for all features. The absence of certain phonological contrasts in a child's productions is explained by grammatical rules (e.g. Smith 1973) or constraint rankings (within OT). One of the reasons that children's underlying representations are assumed to be fully specified even in absence of evidence from production, is that perception has been found to be ahead of production in many cases.

Some children produce the word *fish* as [fis] instead of [fɪʃ], but reject the pronunciation when uttered by an adult (Berko & Brown 1960). This anecdotal evidence shows that their perception is ahead of their production. Many speech perception studies have provided experimental evidence supporting that claim. Perception experiments have shown that infants as young as one month can discriminate virtually all phonological contrasts on which they have been tested (e.g. Eimas et al. 1971, Eimas 1975, Eimas & Miller 1980, Miller & Morse 1976, Jusczyk 1977). In those studies children are exposed to a repeated stimulus, for example the syllable [ba], which is then changed to a similar but different stimulus, for example [da]. The child's attention to the stimulus is usually measured by sucking rate in very young infants and by gaze and head turns in infants older than four months. A difference in sucking rate or gaze when the second stimuli is introduced is regarded as indication that the infant notices the difference between the two sounds. Whereas adults have trouble distinguishing non-native contrasts, children seem to start out as universal listeners.

Children's discrimination abilities subsequently become language-specific in the course of their first year of life (e.g. Best et al. 1995, 1988, Kuhl et al. 1992, Polka & Werker 1994, Werker & Lalonde 1988, Werker and Tees 1984). So at a very young age, long before they are producing those contrasts, children are able to perceive small differences between sounds. A study by Juszcyk and Aslin (1995) shows that 7.5 month-old American infants are able to recognize word forms to which they have been familiarized and behave differently when the words are slightly mispronounced (e.g. *feet* produced as *zeet, dog* as *bog*). The picture that emerges is that of children who are born as perfect universal perceivers and through exposure to their own language their correct perception is reduced to just the native contrasts.

Interestingly, Sundara et al. (2008:233) point out that many studies have focussed on the question *how many* infants discriminate a contrast. However, recent studies that index *how well* infants discriminate a contrast show that perceptual performance on some native phonetic distinctions increases with age, pointing to a facilitative effect of language. Kuhl et al. (2006) tested 32 American infants and 32 Japanese infants on the contrast between /ra/ and /la/ in a head-turn task. The /ra/-/la/ constrast is phonemic in English, but not in Japanese. At 6 to 8 months of age the American and Japanese infants are equivalent in their discrimination, performing at approximately 65 percent correct. At 10 to 12 months of age the performance of the American infants increased to 74 percent correct, while the Japanese infants showed a decrease to 60 percent correct. This experiment shows that 6-to-8 months old infants' discrimination between /ra/ and /la/ is above chance, but far from perfect and that the ability to discriminate a contrast improves over time if the contrast is present in the target language.

A study by Tsao et al. (2006) yields similar results. American and Taiwanese infants were tested on a phonemic pair that is present in Mandarin Chinese, but not in English. At the age of 6 to 8 months the American and Taiwanese infants performed similarly, while at the age of 10 to 12 months the correct discrimination had increased for the Taiwanese whereas it had decreased for the American infants. Children's perceptual abilities thus seem to develop further in time.

Moreover, some contrasts seem to be harder to perceive than others. Some studies report that contrasts between fricatives resist discrimination. The contrasts between [sa]-[za], [fa]-[θa] and [fi]-[θi] were not discriminated by young infants in experiments by Eilers & Minifie (1975), Eilers (1977) and Eilers et al. (1977) but other studies have reported that infants of 2 to 3 months are able to discriminate between [fa]-[θa] (Jusczyk et al. 1979, Levitt et al. 1988). Holmberg et al. (1977) points out that their 6-month-old subjects were able to discriminate between /f/ and /θ/ in a head-turn task, but that they required on average about twice as many trials to distinguish /f/ and /θ/ as they needed for the comparable contrast between /s/ and /ʃ/.

Word learning studies further complicate the picture. Werker et al. (2002) showed that 14-month old English-learning Canadian children could not distinguish newly learned words that contrast minimally, such as *bih* and *dih*. The same children were able to distinguish these words in a pure discrimination task. Werker et al. (2002) explain this by assuming that the task of word learning is so demanding that phonetic detail is temporary unavailable to the child. This argument is known as the resource limitation hypothesis. A study by Fennel and Werker (2003) shows that 14-month old children are able to distinguish well-known words that differ minimally in contrast to words that they have just learned. The resource limitation hypothesis can thus account for the apparent inconsistency between the fine phonetic abilities in speech perception studies and the mistakes made in early word learning.

Using a different task, Swingley and Aslin (2002) showed that 14- and 15-month old infants do notice small differences in words. In this experiment where 50 infants between age 14;4 and 15;3 were tested, the subject looked at a screen with two pictures and heard the question *Where's the* ...? The word in the question (e.g. *dog*) was either correctly pronounced or mispronounced. Two kinds of mispronunciation were tested: close (e.g. *tog* for *dog*) and distant (e.g. *mog* for *dog*). The infants were videotaped and the infants' gaze direction was coded afterwards. The results showed that the correctly pronounced items were significantly easier to recognize for the infants. The mispronunciation effect was equally strong for close and distant mispronunciations. This indicates that infants of 14 and 15 months old do have detailed lexical representations of words.

Fikkert (2010) challenges this assumption and presents evidence that 14-month old children learning Dutch do not notice the difference between *bin* and *din* in a word-recognition task, but do notice the difference between *bon* and *don*. The difference between *bin-din* and *bon-don* in the word-recognition task cannot be explained by a different processing load and a pure discrimination task shows that the children are able to distinguish between both *bin* and *din* and *bon* and *don*. Fikkert proposes a representational account to explain these results. She assumes that the feature coronal is underspecified, but not the feature labial, and that at the early stage of development only the place specification feature of the vowel matters. She makes a distinction between perceived features (both coronal and labial are perceived by the child) and stored features (only labial is stored in the child's lexical representations) and claims that children's perceptual abilities may be accurate, while mapping the perceived features to stored lexical items is a different matter. The words *bin* and *din* have a coronal vowel and because that feature is underspecified, there is no mismatch with the perceived labial consonant /b/ in *bin*. However, the vowel /o/ is labial, which is not underspecified, and therefore a mismatch occurs with the perceived coronal consonant /d/ in *don*.

So far, no consensus has been reached as to whether children's underlying representations are adult-like or not and the experimental results do not clearly point in one direction. However, it seems clear that although infant's perceptual abilities in general are very good, they are not perfect. Moreover, in experiments where children need to recognize or learn words their perceptual abilities are not as good as in pure discrimination tasks.

Another argument for adult-like underlying representations is provided by Gnanadesikan (2004:84). She studied the speech of her 2-year-old daughter Gitanjali who was acquiring English. Gitanjali substitutes a dummy syllable *fi-* for word-initial unstressed syllables: *umbrella* is pronounced as [fi-bɛyə], *Rebecca* as [fi-bɛkə], *spaghetti* as [fi-gɛɾi], *adviser* as [fi-vayzə]. The segments of the initial unstressed syllable are deleted, but a syllable does appear, which implies that the child's inputs contain syllable structure. Moreover, Gnanadesikan shows that although the segments of the initial syllable do not surface, they are present in the underlying representation of the child. This becomes apparent with words like *koala*. Insertion of *fi-* in this word would be expected to result in [fi-ɑlɑ], but Gitanjali produces [fi-kɑlɑ]. Gnanadesikan argues that [fi-ɑlɑ] is ruled out because it violates a high-ranked markedness constraint in the child's grammar which demands that every syllable has an onset. The child is able to use the onset consonant of the removed initial syllable as onset for the stressed syllable. Words like *balloon, police* and *below* show the same pattern: they are pronounced as [fi-bun], [fi-pis] and [fi-bo], respectively. In these cases the stressed syllable cannot start with a liquid, because that would violate a markedness constraint against liquid onsets active in the child's grammar. Therefore the child inserts the deleted word-initial consonant in the second syllable. These examples show that the segments of the initial syllable are available for the child, even when they are not produced.

A final argument that has often been put forward to assume adult-like underlying representations is a more conceptual one. The argument is that the postulation of non-adult-like underlying representations violates the principle of Richness of the Base. For example, Dinnsen, Green, Gierut and Morrisette (2010:514) want to avoid posing restrictions on the underlying representations of the child to account for the *puzzle-puddle-pickle* problem, because they claim that that would be at odds with Richness of the Base. I will argue that this idea stems from a misunderstanding.

Richness of the Base (ROTB) is an important principle within Optimality Theory stating that no constraints hold at the level of underlying forms, or in other words, that lexical representations in any language are free to contain any kind of phonological contrast (Kager 1999:19). It follows that there are no language-particular restrictions on the input and neither underspecification nor anything else can be required of inputs. ROTB can be seen as a natural consequence of the central hypothesis in Optimality Theory that explanation can be achieved through output constraints alone and that languages differ only in constraint ranking (McCarthy 2002:70, Ito et al. 1995:588).

The ROTB principle is sometimes misunderstood to mean that the set of input representations is the same for all languages (e.g. Dinnsen et al. 2001:504). All languages indeed share the same set of potential inputs, but each language has its own vocabulary and thus its own set of input representations which is a subset of the set of potential inputs (McCarthy 2002:77). The set of input representations is the language-specific lexicon. For example for English there is no lexical representation in the lexicon beginning with /ŋ/. That is not because there are restrictions on word-initial /ŋ/ on the level of the representation, but because no words in English start with /ŋ/, so that there is no reason to represent word-initial /ŋ/ underlyingly. (Note that there are restrictions on word-initial /ŋ/ on the level of the grammar. A hypothetical input /ŋɑw/ would be mapped to /nɑw/ by the English grammar.) The misunderstanding lies at the base of the assumption of some OT-researchers that children's input representations must be adult-like. If all input representations must be the same for all languages, they must, by extension, be the same for all children, as Dinnsen et al. (2001:504) are assuming.

From ROTB it follows that no restrictions can be put on underlying representations, but that does not mean that the underlying representations of the child cannot be influenced by other factors. As Itô, Mester and Padgett (1995:593) point out, there may well be learnability factors restricting the choice of the underlying form. For example, if children have trouble mapping perceived features to representations, as Fikkert (2010) claims, their representations will differ from the adult representations without violating the principle of ROTB. The mapping of features is an independent process that can influence the underlying representations, but does not pose restrictions on them. In the same manner misperception could influence the child's representation, as I will argue in the following paragraph.

As I said, I think the argument of ROTB to reject non-adult-like representations is based on a misunderstanding. It is not in conflict with ROTB to assume that independent processes may influence the underlying representations of the child. In the next paragraph I will show there is ample evidence for the claim that the second error pattern in the chain shifts is due to perceptual error.

3.4 MISPERCEPTION

To establish an adult-like underlying representation a child needs to correctly perceive a segment and correctly encode the features of that segment in the underlying representation. A non-adult-like underlying representation can therefore be caused either by misperception or by incorrect encoding. Fikkert (2010) argues for the latter option to account for underspecification of the feature coronal in the child's underlying representation: children do perceive the feature correctly, but fail to map it correctly to the representation. Misperception, on the other hand, has not often been used as an explanation for non-adult-like underlying representations, because research has shown that children actually can perceive very accurately (see the previous paragraph). However, I argue that both in the *s-θ-f* chain shift and the *puzzle-puddle-pickle* problem the second error pattern is caused by misperception by the child. In this paragraph I will present evidence for that claim.

To account for the second part of the *s-θ-f* chain shift I claim that the child misperceives /θ/ as [f] and consequently has the same underlying representation for /θ/ and /f/. Although children are in general very good perceivers, the difference between /θ/ and /f/ is perceptually confusable. This is true even for adult listeners (Dinnsen & Barlow 1998:62, Vihman 1982:252). Miller and Nicely (1955:347) point out that the distinctions between /f/ and /θ/ are among the most difficult for listeners to hear and claim that it seems likely that in most natural situations the differentiation between the two sounds depends more on verbal context and on visual observation of the talker's lips than it does on acoustic difference. Moreover, /θ/ is among the last sounds to be mastered by the child (Smit et al. 1990) and it is frequently reported that children have difficulty in production and distinctive use of /θ/ (Gierut 1996:402).

There is much experimental evidence showing that children acquiring English have difficulty perceiving the distinction between /f/ and /θ/. Eilers and Oller (1976) conducted a discrimination task with ten children between age 1;10 and 2;2. The children were presented with two toy objects, one of which was familiar to the child (e.g. *cow*) and one unfamiliar toy which was give an unfamiliar label (e.g. *paw*). After establishing that the child knew the labels, the experimenter would tell the child where a piece of candy was (e.g. *It's under the cow*) The child would respond by choosing one of the two items. In the experiment none of the children discriminated between [fish] and [θish], although they did discriminate other contrast pairs. Production data showed that the children did not produce the contrast between /f/ and /θ/ either.

In another discrimination experiment, Graham and House (1971) tested thirty girls from age 3 to 4;6. The auditory stimuli were all of the form /hɘ'Cɑdɘ/ where C was the test sound. The girls were presented with paired stimuli and had to judge whether they were the same or different. The error rate for the /f/-/θ/ pair was 79 percent, which means that in 79 percent of the cases the children rated /f/ and /θ/ as the same sound. That percentage was by far the highest. The average error rate was 14 percent and only 11 out of 120 contrast pairs yielded an error rate higher than 20 percent. A pilot study by Tikofsky and McInish (1968) with four seven-year-olds showed that even at that age children have trouble perceiving the difference between /f/ and /θ/. The experiment was similar to that of Graham and House. Of the total number of responses only 2 percent was in error, which can be explained by the fact that the children were much older. However, for the pair /f/-/θ/ the percentage was much higher: 25 out of a total of 36 responses for that pair were in error, a rate of 70 percent.

The experiments provide strong evidence for the difficulties children have with the perception of /θ/. Other evidence comes from the before mentioned study of Velleman who showed a strong correlation between the production and perception of /θ/. She showed that of 12 children between age 3;2 and 5;6, those who substitute [f] for target /θ/ do not perceive the difference between the two sounds. A free classification task with 30 children between age 3;1 and 5;10 conducted by Gierut (1996) yielded the same results. McGregor and Schwartz

(1992) showed that perceptual error can even co-exist with target-like productions of /θ/. They studied a boy, age 4;6, who correctly used [θ] in his productions for target /θ/, but also used [θ] as a substitute for all voiceless fricatives and affricates in all word positions. In a perception task the boy performed at or below chance on his discrimination judgments of /f/-/θ/ in all word positions.

It thus seems well-established that children make perceptual errors with /θ/. This fact explains well why children produce [f] for target /θ/. Apparently the difference between [f] and [θ] is so subtle that children need more time to perceive it correctly in word forms. One may wonder how it can be that infants are able to discriminate between /f/ and /θ/ whereas older children have trouble with correct perception of /θ/. I would argue that attention to perception is reduced when children are starting to learn words, as has been suggested by Werker and colleagues (2002). Note also that experiments have shown that even for infants the contrast between /f/ and /θ/ is more difficult than other contrasts. The study by Holmberg et al. (1977) mentioned before showed that 6-month-old infants do detect the difference between /f/ and /θ/ in a head-turn task, but that they require on average twice as many trials than for other contrasts. And Eilers et al. (1977) reported that infants of 3 months and 6 to 8 months were not able to discriminate between /fa/ and /θa/ (cf. Jusczyk et al. 1979, Levitt et al. 1988). So even for infants this contrast is difficult.

Remarkably, similar experimental evidence is available for the *puzzle-puddle-pickle* problem. I claim that /tl̩, dl̩, nl̩/ are misheard as [kl̩, gl̩, ŋl̩] by children evidencing the *puzzle-puddle-pickle* problem. An interesting experiment by Hallé and Best (2007) shows that English speaking adults confuse initial /tl/ and /dl/ clusters with /kl/ and /gl/, respectively. The experiment was set up to test the perception of word-initial /tl, dl, kl, gl/-clusters of fourteen native speakers of American English. While the clusters /tl/ and /dl/ are word-medially legal in English, they are illegal in word-initial position. Control items were legal /tr, dr, kr, gr/-clusters. In a discrimination task the mean percentage for correct discrimination was 66 percent for /dl/-/gl/ and 61 percent for /tl/-/kl/, while for /dr/-/gr/ and /tr/-/kr/ the percentages were 95 and 96 percent, respectively. Moreover, a categorization task showed, that while the mean percentage of correct responses was 99.7 percent for /kl/ and /gl/, it was only 58 percent for /dl/ and 14 percent for /tl/. The cluster /dl/ was on average categorized as /gl/ 39 percent of the time and /tl/ as /kl/ 86 percent of the time. Important to note is that while /tl/

was categorized as /kl/, and /dl/ as /gl/, the miscategorization did not operate in the opposite direction: /kl/ and /gl/ were not miscategorized as /tl/ and /dl/.

The results show that even adult English speakers have trouble correctly percieving /tl/ and /dl/ and have a tendency to interpret those clusters as /kl/ and /gl/, respectively. While the experiment was concerned with illegal word-initial clusters, I want to claim that the results and the misperception in the *puzzle-puddle-pickle* problem can be attributed to the same process of dental-to-velar perceptual assimilation (Hallé & Best 2007). Perception studies thus provide strong evidence for my claim that misperception is the cause of the second part of the chain shift effect.

Other evidence that the second error pattern is due to non-adult-like underlying representations comes from Macken's (1980) reanalysis of Smith's data. At age 3;9 Amahl starts showing variation in the production of *puddle* words. Some *puddle* words are produced target-like, while others are still substituted with *pickle* words. In the same stage three *pickle* words are sometimes incorrectly produced as *puddle* words: *circle* is produced as [səːtl̩], *pickle* as [pitl̩] and *winkle* as [wintl̩]. That is noteworthy because up to that point *pickle* words were produced target-like by Amahl.

It seems that at that stage Amahl learns to make a distinction between *puddle* and *pickle* words, but sometimes makes an overgeneralization error, and interprets *pickle* words as *puddle* words. That is best explained by assuming that the distinction between /dl/-/gl/, /tl/-/kl/ and /nl/-/ŋl/ was neutralized at the level of the underlying representation. At that stage Amahl is reorganizing his lexical representations and makes some overgeneralization errors. As Fikkert (2010:5) points out, there is no evidence in the data for a general rule changing velars to coronals. The *puddle*-like productions for *pickle* words can thus only be explained as a confusion regarding the underlying representation.

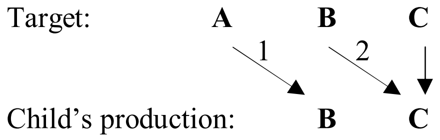
Another indication from the data that perception plays a role in the error pattern, is that Amahl produces the word *gently* as [dɛŋkliː] and [dzɛŋkliː] while he produces *slightly* as [laidiː] and [łaitliː]. The fact that the error pattern is present in his productions for *gently*, but not for *slightly* can be assumed to be due to the fact that Amahl knows the word *slight* and thus knows that there is a /t/ in *slightly*[11]. For the /t/ in *gently* he does not have such independent evidence and he mishears this /t/ as /k/.

In conclusion, the experimental evidence strongly supports my view that the second part of the chain shifts is caused by perceptual error by the child. Perception experiments with children who evidence a chain shift effect could further support this.

3.5 PREDICTIONS REVISITED

In this paragraph I will discuss the evidence for the predictions that I listed in the beginning of this chapter. For clarity's sake I repeat the schematization of the chain shift effect and my claims here in (37) and (38).

(37) *Schematization of the chain shift effect*



(38) *My claims*

1. The chain shift effect is due to two independent processes;
2. Sound A is produced as sound B, because of articulatory difficulties with sound A;
3. Sound B and C have the same underlying representation due to misperception of sound B.

With the first claim I predict that the error patterns can exist independently of each other, that is, one error pattern may occur in the productions of a given child while the other is absent. Moreover, I predict that when the processes do co-occur in a child's system they can differ in their timing. One pattern may be resolved before the other and vice versa. Both of the predictions seem to be borne out by the data. In paragraph 3.1 I discussed data that show that the error patterns are not resolved at the same time. And in an analysis of the production data of 234 children with a phonological delay, Dinnsen et al. (2011) show that the error pattern where target /s/ is produced as [θ] and the error pattern where there /θ/ is produced as [f] can

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[11] Note that the word *slight* does not occur in Smith's data of Amahl, but Smith (1973:173) presumes that it would be pronounced with a final /t/.

co-occur (yielding the *s-θ-f* chain shift), but that each error pattern can also occur independently in the child's system.

From my second claim it follows that an acoustic difference, a covert contrast, should be detectable between the production of [θ] for target /s/ and the target-like production of /θ/ for the *s-θ-f* chain shift. This prediction is impossible to test, because children evidencing the *s-θ-f* chain shift do not produce /θ/ target-like. However, for the *puzzle-puddle-pickle* problem the presence of such a covert contrast can be tested, because the children evidencing that chain shift do have target-like productions of /t/ and /d/ (just not in front of a /l/). I predict that an acoustic difference will be found between the production of [t] for target /s, ʃ, tʃ/ and for target /t/, and between the production of [d] for target /z, dʒ/ and for target /d/ for children evidencing the *puzzle-puddle-pickle* problem. Future research may show if this prediction can be borne out.

The prediction from my third claim is that children fail to discriminate between the second and third sound in the chain shift. In a perception study, children evidencing the *s-θ-f* chain shift would fail to discriminate between [θ] and [f]. And children evidencing the *puzzle-puddle-pickle* problem would fail to discriminate between [dl̩] and [gl̩], between [tl̩] and [kl̩] and between [nl̩] and [ŋl̩]. The failure to discriminate will gradually disappear with time. I assume that at some point a child starts to correctly perceive the sound in some words and with time that generalizes to all words. So a child evidencing the *s-θ-f* chain shift might show correct perception of /θ/ in some words, but not in others. I would expect a gradual decrease of words that are perceived correctly that is correlated with the correct production of those words for a given child. For example, a child starts to perceive the sound correctly in some frequent words and subsequently starts to produce those words correctly (where perception probably is ahead of production), while it does not perceive the sound correctly in other words, and thus does not yet produce those words correctly. To my knowledge perception studies of children evidencing a chain shift have not yet been reported in the literature, so future research will have to show whether the prediction can hold.

Note that Smith (1973:150) claims that the substitution of *pickle* for *puddle* words in the Amahl's speech cannot be due to misperception of *puddle* words, because Amahl "can easily identify such pairs as *riddle* and *wriggle* correctly". However, Smith does not make clear how and when he tested Amahl's discrimination of this pair. Moreover, in Amahl's production data the word *riddle* does not occur. Therefore we do not know how Amahl would produce this word. Perhaps *riddle* was one of the first *puddle*-like words that Amahl perceived and subsequently produced correctly.

Another prediction concerning my third claim is that at the stage where children start to correctly perceive the difference between the two sounds and consequently change their underlying representations, confusion may occur regarding the underlying representations of not only sound B (/θ/ for the *s-θ-f* chain shift and /tl̩, dl̩, nl̩/ for the *puzzle-puddle-pickle* problem), but also sound C (/f/ for the *s-θ-f* chain shift and /kl̩, gl̩, ŋl̩/ for the *puzzle-puddle-pickle* problem). As shown in the previous paragraph, the confusion is evident in Smith's (1973) data from Amahl, because he produces some *pickle* words as *puddle* words in this stage. For the *s-θ-f* chain shift I have not seen such data. Eilers and Oller (1976:328) do report that children who substitute [f] for /θ/ may go through a short transition period in which [θ] is substituted for /f/. Further research might show that pattern for children evidencing the *s-θ-f* chain shift as well. Note however, that absence of the pattern would not falsify my claim.

The final prediction that follows from the combination of my three claims is that the first error pattern shows an across-the-board elimination, while the second shows a period of variability and is resolved per lexical item. I expect that articulatory errors are resolved across-the-board, while perceptual errors are resolved per lexical item, because the underlying representation of each word needs to be changed given the new information the child receives when perception becomes correct. The data from the *puzzle-puddle-pickle* problem support that, because errors on *puzzle* words are eliminated across-the-board and errors on *puddle* words show a period of variability. The data for the *s-θ-f* chain shift do not provide a clear picture concerning that point. Further research is needed, especially with regard to the question whether the variability with the second error pattern is within or between words.

Note that some within-word variability for *puddle* words and words with /θ/ would still be consistent with my claims. It is very well possible that children need some time to figure out the correct underlying representation for a word. Braine (1976:496) also points out that "a restructuring might be followed by a brief period of doubt about what the proper pronunciation really is." For the *puzzle-puddle-pickle* problem we saw that there is a period where *pickle* words are sometimes produced as *puddle* words, which is best explained as a stage of confusion at the level of the underlying representation. Such confusion might also occur for *puddle* words or for words with /θ/.

Lastly, I want to address a production pattern that is not predicted by my account. Morisette and Gierut (2008) report that two children evidence the *s-θ-f* chain shift only in word-initial position. They report this fact in a footnote and claim that word-medial and -final productions of /s/ and /θ/ surface correctly. This pattern is not predicted by my analysis and it is not immediately clear how it could be explained. Interestingly, Morisette and Gierut do not account for it either in their local conjunction analysis of the chain shift. However, in general grammatical accounts have a better chance at explaining substitutions that occur in certain positions but not in others. Positional faithfulness constraints (Beckman 1998, Lombardi 1999) can be used to account for the preservation of a distinction in prominent positions while it is neutralized elsewhere. Because the word-initial chain shift pattern is only reported for these two children and because Morisette and Gierut (2008) cannot provide the data of the children's productions for further analysis, I decide to leave this 'puzzle' unresolved.

3.6 CONCLUSION

I have proposed that child chain shifts are due to two independent processes in the child's system, both outside the grammar. Articulatory and perceptual difficulties are responsible for the first and second part of the chain shifts, respectively. My proposal differs from most earlier analyses within generative grammar, because I do not assume that grammatical processes are causing the chain shift effect.

In fact, in my view child chain shifts are literally speaking not chain shifts. The 'chain shift effect' is due to two independent processes that may or may not co-occur in the child's system. If a child both has articulatory difficulties with /s/ and has trouble correctly perceiving /θ/ the result may be something that could superficially be called the *s-θ-f* chain shift. It might seem that the child substitutes [θ] for target /s/ and [f] for target /θ/. In reality the child is attempting to produce [s] for target /s/ and does not recognize the difference between /f/ and /θ/. In neither case can we speak of a true substitution.

In this chapter I have discussed experimental results that show that in general children may have trouble correctly articulating the first sound of both the *s-θ-f* chain shift and the *puzzle-puddle-pickle* problem. And I have presented evidence that both /θ/ (for the *s-θ-f* chain shift) and /tl̩/ and /dl̩/ (for the *puzzle-puddle-pickle* problem) are hard to perceive correctly for children and adult listeners. Further research is needed to make clear whether children evidencing a chain shift indeed show these problems.

An important difference between my proposal and nearly all earlier proposals for child chain shifts is that I have decided to take a look outside of the grammar to explain a pattern in children's speech productions. In the next chapter I will present a discussion of the fact that many proposals within generative linguistics focus solely on the explanatory value of the grammar and thereby disregard other factors that play a role in children's speech development.

4. DISCUSSION

Within generative linguistics the main focus is on linguistic competence, while less or no attention is paid to performance factors. Chomsky (1965:4) formulates *competence* as the speaker-hearer's knowledge of his language and *performance* as the actual use of language in concrete situations. The task for the linguist, in his view, is to determine from the performance data the underlying system of rules that has been mastered by the speaker-hearer (ibidem). The formulation of this underlying system of rules, or in OT: constraints and constraint rankings, has been the main focus of studies within generative linguistics.

This narrow focus on linguistic competence has led to a disregard of performance factors. However, competence can only be studied through performance data. As Chomsky (1965:4) already points out, only in an idealized situation with a speaker who is unaffected by memory limitations, distractions, errors and shifts of attention can performance data be regarded as a direct reflection of a speaker's linguistic competence. This ideal situation never occurs. The problem is that many researchers in practice do regard production data as a direct reflection of competence. In that way not only performance factors are ignored, but also a wrong picture of a speaker's linguistic competence may emerge if performance factors are attributed to a speaker's competence.

Smolensky (1996:720) claims that the gap between children's competence and performance is not dramatically greater than for adults and that the limitations in child's outputs are to be explained by a grammar. In my view, a grammar is not sufficient to account for all aspects of children's speech productions, because their productions are strongly influenced by their perceptual and articulatory abilities. And those abilities differ significantly from adult's. In the previous chapter I have shown that children's perceptual abilities develop over time. The same holds for articulatory abilities. Locke (2004:182) claims that speech control functions must develop and that if speech is like other motor skills in this respect, development occurs in response to experience and maturation. And Fletcher (1973) points out that the infant's tongue is ill-equipped for complex movement due to the immaturity of the intrinsic muscles. I therefore argue that the gap between children's competence and performance is greater than for adults. Studies of child phonology should take this into account.

Hale and Reiss (1995, 1998) argue that it is crucial to make a distinction between the output of an individual's grammar (competence) and the output of his body (performance). They provide a schematization of the different levels that are involved in speech production, here shown in (39).

(39) *Schematization (Hale & Reiss 1995:3)*

$$\begin{tikzcd}
\text{Underlying representation:} & X \arrow[d, "\text{OT Phonology}"] \\
\text{Output of grammar:} & Y \arrow[d, "\text{Production System \& Context}"] \\
\text{Output of body:} & Z
\end{tikzcd}$$

In their view the OT phonology represents a mapping between the underlying representation X and the output of the grammar Y, and the production system of the speaker converts the mental representation Y into an acoustic output Z. Hale and Reiss (1995:4) argue that Y and Z can never be the same, because Y is a mental representation, whereas Z is an acoustic event. Still, many researchers regard, at least in practice, the output of the body Z as equal to the output of the grammar Y. This is a problem for the study of adult phonology, but an even bigger problem for the study of child phonology.

As is clear by now, I claim that chain shifts in first language acquisition are due to a combination of misarticulation and misperception, processes that I assume to take place outside of the grammar. I assume a model like that of Hale and Reiss (1995, 1998) in which a substitution can be due to a neutralization of two sounds at the level of the underlying representation, at the level of the output of the grammar or at the level of the output of the body. I argue that the first error pattern in the chain shifts is a neutralization[12] at the level of the output of the body, due to misarticulation of the first sound. The second error pattern is a neutralization at the level of the underlying representation, due to misperception of the second

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[12] The term neutralization may be confusing because for the *s-θ-f* chain shift there is no neutralization of /s/ and /θ/ at any level, because /θ/ is not produced target-like in the chain shift. The point I want to make is that target /s/ has been changed to [θ] at the level of the output of the body and not at the level of the underlying representation or at the level of the output of the grammar. The same holds for *puzzle* words in the *puzzle-puddle-pickle* problem. The *puzzle* words have only changed to *puddle* words at the level of the output of the body.

sound. This is illustrated in (40) for the *s-θ-f* chain shift and in (41) for the *puzzle-puddle-pickle* problem.

(40) *Illustration of the s-θ-f chain shift*

Target:	‘s’	‘θ’	‘f’
Underlying representation:	s	f	f
	↓	↓	↓
Output of grammar:	s	f	f
	↓	↓	↓
Output of body:	θ	f	f

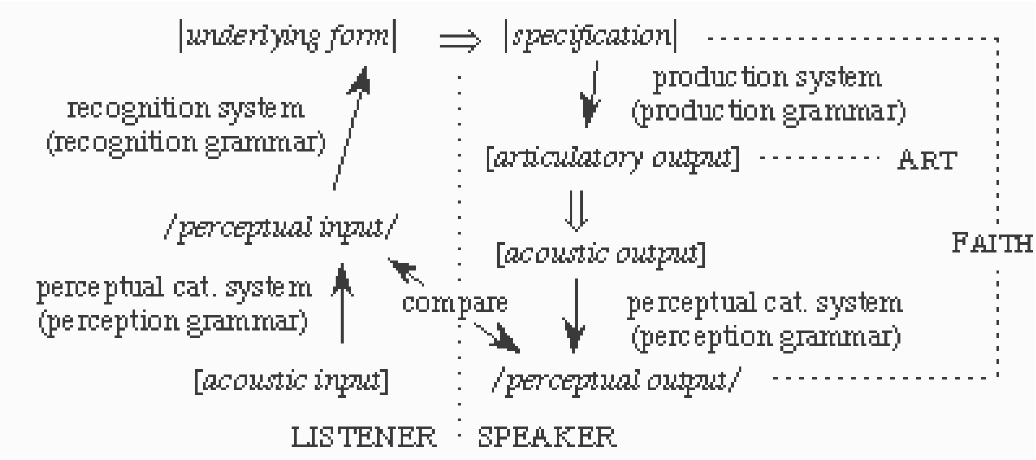
(41) *Illustration of the puzzle-puddle-pickle problem*

Target:	‘zl’	‘dl’	‘gl’
Underlying representation:	zl	gl	gl
	↓	↓	↓
Output of grammar:	zl	gl	gl
	↓	↓	↓
Output of body:	dl	gl	gl

My proposal differs from earlier analyses of child chain shifts within the framework of OT, because I do not assume that the grammar is responsible for the chain shift patterns. Within OT there is a strong tendency to assume a priori that a neutralization between two target sound is due to the grammar, that is, a certain constraint ranking. The powerful OT grammar is capable of accounting for many neutralizations (or substitutions, as they are regarded) and the central hypothesis of OT is that explanation can be achieved through output constraints alone (McCarthy 2002:70, Ito et al. 1995:588). With my account the explanatory burden is taken away from the output constraints. This might seem at odds with optimality theoretic assumptions, but the fact that in OT the grammar is reduced to output constraints, does not mean that the child’s system is reduced to these constraints. Processes of articulation and perception do play a role in children's phonological development. Although in practice they are ignored by many OT researchers, none of them would go as far as to deny their existence.

Boersma (1998, 1999, 2000) advocates a different approach regarding the role of the grammar and processes of perception and articulation. He claims that the grammar must directly reflect an interaction between the articulatory and perceptual principles of effective and efficient communication (Boersma 2000:465)[13]. In his theory of Functional Phonology the processes of articulation and perception are incorporated in the grammar in the form of articulatory and perceptual constraints. As a consequence, there is no distinction between competence and performance components of the language system. In (41) a schematization of the grammar as proposed by Boersma is shown.

(41) *Grammar model of Functional Phonology (Boersma 2000:466)*



The right-hand side of the figure models the speaker and the left-hand side the listener. The *specification*, in the top-right corner, is the input for the *production grammar* that maps underlying forms to phonetic forms. The *production grammar* is the grammar that is modelled in most theories of phonology. The *articulatory output* of this grammar is a set of timed articulatory gestures. The subsequent *acoustic output* is the automatic auditory result of the *articulatory output*. The *perception grammar* maps this output to a phonological surface structure, the *perceptual output*. In the down-left corner the *acoustic input*, the auditory signal received by the listener, is mapped to the *perceptual input* by the *perception grammar*. The

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[13] Within the framework of OT the functional hypothesis has also been pursued by other authors, such as Flemming (1995), Jun (1995), Steriade (1995, 1996), Hayes (1996) and Kirchner (1998). I will limit my discussion to the work by Boersma.

perceptual input is the input as perceived by the listener. The *recognition grammar* maps the *perceptual input* to an *underlying form*. The *underlying form* is the same as the *specification*.

The three grammars in Boersma's model are optimality theoretic constraint grammars. In the *production grammar* gestural constraints (ART) evaluate aspects of articulatory effort and faithfulness constraints (FAITH) evaluate aspects of perceptual similarity between the *specification* and the *perceptual output*. The *perception grammar* determines how a listener converts the raw acoustic input to a more perceptual representation with categorization and abstraction constraints. This grammar is used for the *acoustic input* of other speakers as well as the speakers's own *acoustic output.* Faithfulness constraints in the *recognition grammar* evaluate aspects of perceptual similarity between the perceptual input and the underlying form. A fourth processing system is the *comparison module*. This module compares the *perceptual output*, the learner's own output forms and the *perceptual input*, the adult surface forms as perceived by the listener. A gradual learning algorithm will take action if the two forms differ.

Unlike Hale and Reiss (1995, 1997), Boersma incorporates the processes of articulation and perception into the grammar. The articulatory constraints in the production grammar evaluate the minimization of articulatory effort, whereas the faithfulness constraints evaluate the minimization of perceptual confusion. Articulatory constraints are ranked by effort. That is, constraints against articulations that require more effort are universally ranked higher than constraints against easier gestures. Faithfulness constraints are ranked by perceptual contrast. That is, constraints that require the faithfulness of strongly distinctive features are ranked higher than constraints for weakly distinctive features.

The constraints are grounded in the learner's articulatory and perceptual abilities. Therefore no innate knowledge needs to be postulated. Boersma (2000:520) claims that UG "contains no substance". In his view the grammar starts out empty and subsequently is filled with articulatory and faithfulness constraints that follow from children's perceptual organization of the language input (including their own productions) and their developing articulatory abilities. Importantly, no crucial distinction between competence and performance can be made in Boersma's model. For example, if a child has not yet acquired the articulatory implementation of /s/ an articulatory constraint of the form *[sibilant] will be ranked high in his production grammar. The performance factor thus cannot be separated from the child's competence.

An example[14] to illustrate the difference between the different models of grammar is provided by Boersma (1999:11) and is illustrated in (42). If a person suddenly looses his medial teeth his pronuncation of /s/ will change. The sibilant noise of /s/ is most often produced by a tongue-grooving gesture that directs a jet of air along the ridges of the medial teeth. If the teeth have fallen out the perceptual result of this gesture will be a non-sibilant fricative, which might be perceived as [θ]. In a standard generative derivational model in the style of Smith (1973) this would be described as the addition of a rule that maps underlying /s/ to [θ]. In (42a) the model of standard generative grammar before and after tooth loss is illustrated.

(42) *Three models of tooth loss (Boersma 1999:11)*

a. Smith's model

$$\begin{tikzcd}
\text{Before} & \text{After} \\
/s/ \arrow[d, "\textit{grammar}"] & /s/ \arrow[d, "\textit{grammar}"] \\
{[s]} & {[\theta]} \\
\rightarrow \text{sound} & \rightarrow \text{sound}
\end{tikzcd}$$

b. Hale and Reiss's model

$$\begin{tikzcd}
\text{Before} & \text{After} \\
/s/ \arrow[d, "\textit{grammar}"] & /s/ \arrow[d, "\textit{grammar}"] \\
/s/ \arrow[d, "\textit{body}"] & /s/ \arrow[d, "\textit{body}"] \\
{[s]} & {[\theta]} \\
\rightarrow \text{sound} & \rightarrow \text{sound}
\end{tikzcd}$$

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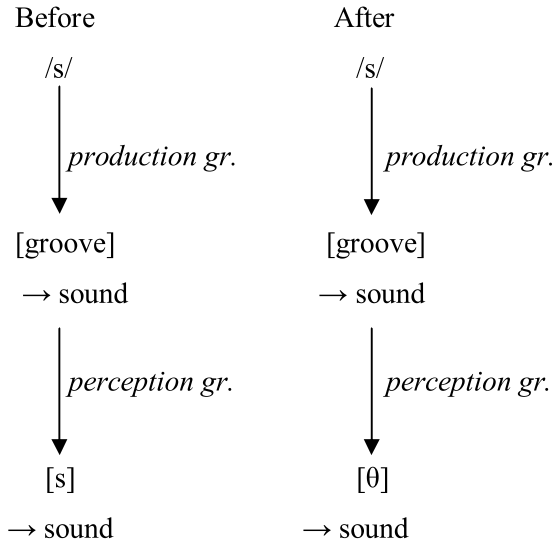
[14] Boersma's example is a reaction to a message that Charles Reiss sent to the Optimality List on April 27, 1998. Reiss wrote: "My reading of the generative linguistics literature is that it is about knowledge states, not behavior. If I don't start flossing, all my teeth may fall out – my pronuncation will change, but my phonology won't." (Cited in Boersma 1999:11).

c. Boersma's model



The description in Smith's model clearly cannot be correct, because a grammar does not change suddenly in reaction to a clear performance problem. In the model by Hale and Reiss (1995, 1998) the grammar precedes the performance system. In (42b) it is shown that the changed pronunciation is the result of the 'body' rather than the 'grammar'. Because the physical properties of the speaker have changed the output of the 'body' is different.

Boersma's model, illustrated in (42c), provides an alternative description. In his model the grammar does not immediately change either as a result of teeth loss. The articulatory output of the production grammar is formulated as a set of timed articulatory gestures. The gestures remain the same, because the grammar has not changed, but the acoustic output that is the direct result of the gestures is different. The acoustic output is mapped to the perceptual output by the perception grammar. The perception grammar has not changed either, but the perceptual output is different, because the input (the acoustic output) to the grammar is different. Note that the production grammar eventually will change under influence of the comparison module that will signal that the perceptual output of the speaker differs from the perceptual input of other speakers. The production grammar will be adapted so that the speaker will be able to produce a more [s]-like sound even without his front teeth.

It is beyond the scope of this thesis to go into exact details of how Boersma's grammar works, but I want to make clear that performance factors can be incorporated into the grammar. The strict division between competence and performance in Hale and Reiss' model can be questioned. In Boersma's view the performance factors that I hold responsible for the child chain shifts cannot be distinguished from children's competence. Interestingly, Boersma (2000:493) briefly discusses how the *puzzle-puddle-pickle* problem could be explained within Functional Phonology. For example, Boersma considers the ranking of an articulatory constraint *z above *dl as universal, because [z] is harder to articulate than [d]. These constraints and their ranking are thus a direct consequence of the speaker's articulatory abilities. He also formulates the faithfulness constraints *REPLACE(z,g), *REPLACE(z,d) and *REPLACE(d,g). The first is violated when /z/ is replaced by [g], the second when /z/ is replaced by [d] and the third when /d/ is replaced by [g]. Boersma assumes that *REPLACE(z,g) is universally ranked above the other two constraints, because the perceptual distance between /z/ and /g/ (different place and manner) is larger than between /z/ and /d/ (same place) and between /d/ and /g/ (same manner).

Note that the universality that Boersma assumes is not the result of an innate constraint ranking, but of articulatory and perceptual abilities that are the same for every typically developing person. In Boersma's model the processes of articulation and perception that are responsible for the chain shift pattern are represented in the grammar. In his view not only child chain shifts can be explained by articulatory and perceptual factors. Rather all language production is explained by these factors.

It is an interesting question why the processes of perception and articulation have been disregarded in so many OT accounts for phonological acquisition. It seems to me to be a matter of focus. Since the main focus was on output constraints, and since standard OT provides a very powerful grammar, other processes were simply overlooked. The claim that articulatory difficulties may influence the child's speech output, is not at odds with optimality theoretic assumptions. Still there have been no accounts that have used articulatory factors to account for chain shift patterns in first language acquisition. Macken (1980) does refer to articulatory factors in her pre-OT account of the *puzzle-puddle-pickle* problem, but she does not make clear whether the rule she formulates in her analysis is indeed motivated by articulatory difficulty. In the previous chapter I have provided evidence for the claim that the first error pattern in both the *s-θ-f* chain shift and the *puzzle-puddle-pickle* problem is due to articulatory factors.

The misinterpretation of the principle of Richness of the Base, has led to a reluctance to consider the status of underlying representations in the child's system. Many OT-researchers assume a priori that the child's underlying representations are fully specified and adult-like, but in the previous chapter I have shown that it is not at odds with the principle of Richness of the Base to argue that underlying representations may be underspecified due to misperception. Macken (1980) and Dinnsen and Barlow (1998) do make use of underspecification of underlying representations in their accounts. Macken claims that the second error pattern in the *puzzle-puddle-pickle* problem is due to misperception of /dl̩/, which the child erroneously hears as [gl̩]. Dinnsen and Barlow (1998) account for the *s-θ-f* chain shift by assuming that all three sounds are underspecified underlyingly. However, they do not make clear what causes this underspecification. In the previous chapter I have provided evidence for the claim that the second error pattern in both chain shifts is due to misperception of the second sound.

It is clear that further research is needed to strengthen my claims, but the main virtue of my proposal may be that I show that processes outside of the grammar can explain patterns in child's speech productions. Within OT the grammar is held responsible for many phenomena that could also be explained with processes outside the grammar. The grammar is not only powerful, but also greedy. Actually, it is more in line with Occam's razor to assume a priori that patterns in the speech output are caused by perceptual and articulatory factors. Especially in the case of child chain shifts, where extra constraints need to be assumed to provide a plausible grammatical account. It is more minimal to attribute the chain shift patterns to perceptual and articulatory factors that are independently motivated, than to assume additional grammatical machinery.

Jesney (2005, 2007) provides the strongest grammatical account, but her analysis is based on the postulation of an extra constraint. The proposed specific faithfulness constraint IDENTCORONAL/[+strident] is assumed to exist along with the general faithfulness constraint. Jesney makes sure to provide arguments for the plausibility of this constraint and the learnability of the proposed constraint rankings and is able to account for most aspects of the data. I showed that with a small adaptation of her proposed ranking for the initial state her analysis is even more in line with children's early production data, although a neutralization pattern of all voiceless fricatives is still wrongly predicted to occur. However, following Occam's razor, if a phenomenon can be explained with or without the postulation of extra machinery, all else being equal, one should choose for the latter. Importantly, Jesney does not provide independent evidence for the specific faithfulness constraint. If this or a similar constraint turns out to be crucial to account for other phenomena in child or adult speech productions, the situation is different.

At this point there is no reason for the postulation of IDENTCORONAL/[+strident] other than to account for child chain shifts. Given this fact my account should be preferred, because no extra constraint needs to be assumed. I have provided independent evidence for the articulatory problems children evidence with the first sound of both chain shifts and the perceptual difficulties children have with the second sound of both chain shifts. Moreover, my account has the additional benefit that it explains the difference between the elimination of errors *puzzle* and *puddle* words, the first of which is reported to occur across-the-board whereas for the latter a period of variable production is shown (Macken 1980). Also, Jesney's (2005, 2007) account predicts a neutralization of all three voiceless fricatives to be able to occur, but this is not attested in any data.

The situation is somewhat different for the proposals that make use of local conjunction of constraints to account for child chain shifts (Morrisette & Gierut 2008, Dinnsen et al. 2001). Local constraint conjunction has been used to account for a number of phenomena in adult language as well. Independent evidence thus is available for this type of constraint. However, while local constraint conjunction is controversial even for adult language, it is very clear that it poses a strong learnability problem when it is used to account for child language phenomena. Evidence for the particular chain shift patterns is lacking from the language input that children receive. Children therefore cannot learn the chain shift on the basis of input data. Moreover, if we assume that locally conjoined constraints are innately present at the top of the constraint hierarchy we predict that all children go through a chain shift stage. This clearly is not the case.

Despite the obvious learnability problems that local constraint conjunction faces, it is widely known as 'the' account for chain shifts in first language acquisition. In my view, local constraint conjunction is an inadequate explanation for child language phenomena, because the issue of learnability cannot be solved. My analysis does solve the learnability issue, because I claim that the chain shift patterns are not learned. Rather they are a direct consequence of a child's articulatory and perceptual abilities. For example, if a child cannot correctly articulate [s] the result is something that sounds like [θ]. The child does not learn a mapping from /s/ to [θ], rather it cannot help but produce a [θ]-like sound. Of course, a process of learning is involved, because the child eventually learns to correctly articulate [s]. However, this process is evidenced by all children acquiring English (or another language containing /s/) and cannot be considered problematic.

In general, I want to argue that even if extra-grammatical processes are not the first thing an OT researcher will consider when accounting for children's production data, they should not be overlooked entirely, as has been the case in most accounts for child chain shifts. Let me point out that my aim is not to argue against OT. My claims are compatible with OT assumptions such as Richness of the Base. I just want to argue for a broader view. Children's productions cannot be fully explained by a standard OT grammar. As Smit (1993:534) points out, phonological processes do not encompass all possible errors made in children's speech. The fact that all grammatical accounts of child chain shifts encounter problems, has actually provided a chance to look beyond the grammar. Or, as Boersma (1998) suggests, to incorporate the processes of articulation and perception into the grammar.

In 1980, more than a decade before the introduction of OT, Lise Menn formulates the wish for a formal device that can represent children's articulation limitations:

> The child's 'tonguetiedness', that overwhelming reality which Stampe and Jakobson both tried to capture with their respective formal structures, could be handled more felicitously if one represented the heavy articulation limitations of the child by the formal device of output constraints […]. The child's gradual mastery of articulation then is formalized as a relaxation of those constraints. (Menn 1980:35-36)

I want to argue that in OT the articulatory limitations of children are not adequately represented in the output constraints. Only in a grammar such as Boersma's (1998) where the constraints directly reflect the articulatory and perceptual abilities of the child can the articulatory limitations truly be considered to be represented. The fact that /s/ is a difficult sound to articulate (Gibbon 1999), but at the same time is assumed to be the least marked fricative within OT, indicates that the grammar in this case does not 'represent' the articulatory factors. I therefore argue that we should either assume a standard OT grammar with a role for independent articulation and perception processes (Hale and Reiss' model) or a grammar in which these processes are incorporated (Boersma's model). I have assumed the first.

I have been able to show that chain shifts in first language acquisition can be very well explained as the result of independent articulatory and perceptual processes outside of the grammar. Instead of a greedy grammar that is the starting point of most analyses within classical OT, I am arguing for greedy performance . Boersma (1998) provides an inbetween position in which competence and performance work in tandem. I have chosen here to assume a model where competence and performance are separated, because it is assumed (implicitly) by most analyses within OT. However, it is questionable if a strict division between competence and performance can hold. I will leave this discussion to others.

My performance analysis of child chain shifts may be generalized to other patterns in children's speech productions. If the 'substitution' patterns in child chain shifts are caused by factors outside of the grammar, this may be true for other error patterns as well. For example, the well-known process of stopping of fricatives in children's speech is explained in OT as the result of the grammar. A markedness constraint banning fricatives is assumed to be ranked above a faithfulness constraints for fricatives, and thus a stop is a more optimal output for the underlying fricative. Dinnsen and Barlow (1998:72), on the other hand, assume that stops and fricatives are neutralized at the level of the underlying representation, because the feature [continuant] is underspecified in the child's system. The unmarked [-continuant] is filled in by default, and in this way, an underlying fricative becomes [-continuant] and is thus produced as a stop. Another option is that the child makes an attempt to produce a fricative, but because this is articulatory more difficult (Perkell 1997:351), he actually produces a sound that is much more like a stop.

In this way, the three options that follow from Hale and Reiss' model in (39) can be considered for each production error that is found in child speech. If two sounds are neutralized in a child's productions, this may be because they are neutralized at the level of the underlying representation, at the level of the output of the grammar or at the level of the output of the body. It is not straightforward how to find out what causes a particular error. An important question is which empirical evidence can be used to answer this question.

To find out whether a neutralization exists at the level of the underlying representation children's speech perception can be tested. Speech perception studies can show whether children are able to perceive the difference between two particular sounds. Velleman (1988) shows that children who substitute [f] for target /θ/ do not perceive the difference between the two sounds, which is a strong indication that for these children /f/ and /θ/ are neutralized at the level of the underlying representation. It is hard to conceive how a child could encode a difference between two sounds, when he does not perceive this difference.

Evidence for neutralization at the level of the output of the body comes from studies on covert contrast. A covert contrast is a contrast between two sounds that is not readily perceivable by an adult listener, but does show up in an acoustic analysis. Macken and Barton (1980) were the first to report a covert contrast in their study of the acquisition of the voicing contrast in American English word-initial stops. They found imperceptible distinctions in Voice Onset Time between target voiceless and target voiced stops in the speech of typically developing children. While it seemed that the children were not producing a contrast between voiceless and voiced stops, the acoustic analysis revealed that in fact they were. Subsequent studies have shown covert contrasts for voicing, velar fronting, alveolar backing, glide and liquid homophony, stopping, dentalisation of /s/, cluster reduction, onset deletion, coda deletion, and weak syllable deletion (see Scobbie 1998 for an overview).

Strictly speaking a covert contrast is not a neutralization at the level of the output of the body, because since there is a measurable contrast we cannot speak of a neutralization. However, from the point of view of the analyst we can speak of a neutralization of two sounds in the child's speech, because the analyst does not perceive the difference between the two sounds. When we assume a model like that of Hale and Reiss, we can interpret the studies of covert contrast as empirical evidence that we must make a distinction between grammatical and motor factors. A standard OT grammar cannot explain why a child would produce imperceptible but consequent contrasts between two sounds. Smolensky's (1996:720) claim that the limitations in child's outputs can be fully explained by a grammar does not hold, unless motor factors are incorporated in the grammar as in the functional grammar model proposed by Boersma (1998).

Some errors in children's speech cannot be straightforwardly explained with perceptual and/or articulatory factors. An example is the substitution pattern that is reported by Gnanadesikan (2004). Her 2-year-old daugther Gitanjali substitutes a dummy syllable *fi-* for word-initial unstressed syllables. As a result, *umbrella* is pronounced as [fi-bɛyə], *Rebecca* as [fi-bɛkə], *spaghetti* as [fi-gɛɾi] and *adviser* as [fi-vayzə]. Moreover, if the second syllable lacks an onset or starts with a liquid, the onset of the deleted syllable is copied onto the second syllable. As a result, *balloon* is pronounced as [fi-bun] instead of [fi-lun], *police* as [fi-pis], *below* as [fi-bo] and *koala* as [fi-kɑlɑ]. This substitution pattern is best explained as the result of a grammatical process. Misperception cannot explain the pattern, because it is very unlikely that the child perceives for example *umbrella* as [fi-bɛyə] and *balloon* as [fi-bun]. Misarticulation cannot explain the pattern either. It is not clear how articulatory factors could account for the systematic copying of the onset of the first syllable in words like *balloon* and *koala*. In this case a grammatical explanation is more minimal, because a grammatical account is available to explain the pattern (see Gnanadesikan 2004:84), and neither perceptual nor articulatory factors can provide a plausible explanation.

The issue whether a child's speech error should be attributed to perceptual, grammatical or articulatory factors is not only a theoretical problem. Many studies on children's speech errors describe the productions of children with a phonological delay. These children are behind in their phonological development compared to typically developing children of their own age, but are developing typically in other respects. Many of these children receive treatment to enhance their phonological development. With a correct theoretical understanding of their speech errors, the treatment might be improved.

As I pointed out in the Introduction the *s-θ-f* chain shift has been reported to be resistant to treatment. The only treatment that proved to be succesful in fully eliminating both error patterns, was a treatment that targeted all three sounds of the chain shift (Morrisette & Gierut 2008). This is interesting, because many studies have reported that treatment on one sound can generalize to other sounds (Dinnsen 2008b, Forrest et al. 1997). This seems not to be the case for the *s-θ-f* chain shift. Treatment on /s/ does not result in an elimination of both error patterns (Dinssen & Barlow 1998, Gierut & Champion 1999). Since I assume that the chain shift effect is due to two independent processes I would not expect treatment on /s/ to enhance the child's productions of /θ/. That is, if through treatment the child's articulation of /s/ improves, I would not expect this to influence the correct perception of /θ/. The fact that only treatment on all three sounds is able to eliminate both error patterns therefore supports my analysis.

One would expect a generalization of treatment effect, when the speech errors are due to the child's grammar. For example, if a child stops all fricatives and this stopping pattern is the result of the child's constraint ranking (e.g. a high ranking of *FRICATIVE), treatment on one fricative might result in a reranking of constraints (e.g. demotion of *FRICATIVE). The result of the treatment might then be that not only the treated fricative, but all fricatives are produced as fricatives, instead of stops. In this way, reports on treatment effects can actually shed light on the nature of the child's errors. However, it is in the interest of the child to assess the nature of his errors beforehand, so that he is able to receive the best treatment. Articulatory, perceptual and grammatical errors might each call for different treatment strategies. Therefore further research on the nature of children's speech errors also serves a practical goal.

Further research may also answer the question if chain shift patterns are found in other developing languages. To my knowledge there are no reports of child chain shifts in languages other than English. I would expect chain shift patterns to occur in places where articulatory and perceptual difficulties meet. In theory the English *puzzle-puddle-pickle* problem could have a Dutch equivalent: the *puzzel-poedel-pukkel* problem (Dutch words for 'puzzle', 'poodle', and 'pimple'). Analyses of speech data of children acquiring Dutch, may or may not show the pattern. In this thesis 'chain shifts in first language acquisition' refers to the two known chain shifts: the *puzzle-puddle-pickle* problem and the *s-θ-f* chain shift. In this respect, it is also interesting to note that the widely discussed *puzzle-puddle-pickle* problem has only been reported in the speech data of Smith's (1973) son Amahl. Further research may show if the pattern is attested more widely.

5. CONCLUSION

In this thesis I have shown that chain shift patterns in first language acquisition can be best accounted for as the result of two independent processes outside of the grammar. Articulation and perception processes can explain the patterns in the *puzzle-puddle-pickle* problem and the *s-θ-f* chain shift. The first error pattern, [θ] for /s/ and *puddle* for *puzzle* words, is due to articulatory difficulties children encounter with /s/ and /z/. The second error pattern, [f] for /θ/ and *puddle* for *pickle* words, is due to misperception of /θ/ and /dl/.

Most earlier analyses within generative linguistics have placed the explanatory burden on the grammar. Especially within OT the grammar is powerful and greedy. I advocate a greedy performance approach. In my view, if a phenomenon can be explained through articulatory and/or perceptual factors that are independently motivated, this explanation should be preferred over a grammatical approach that adheres to extra rules or constraints. This is in line with Occam's razor. In chapter 3 I have provided independent evidence for the articulatory and perceptual difficulties children experience with the first and second sound of the chain shifts, respectively.

Moreover, my analysis best accounts for the patterns of variation and change in the production data of children evidencing a chain shift[15]. It explains the difference in elimination of error patterns that is reported for the *puzzle-puddle-pickle* problem (Macken 1980). None of the analyses within Optimality Theory can account for this. It also explains that the error patterns can exist independently or co-occur (Dinnsen et al. 2011) and that when the patterns co-occur they may freely vary in their timing (see data of Gierut & Champion 1999, Dinnsen & Barlow 1998).

None of the presented grammatical accounts is unproblematic. While all accounts are able to capture the chain shift effect, all but one encounter serious learnability issues. A good account should explain how the chain shift patterns arise and subside in the child's system. With a purely grammatical approach this proves to be very difficult. Only Jesney's (2005, 2007) analysis of the chain shifts provides a plausible theory of learnability. However, her account wrongly predicts a stage in which all three voiceless fricatives are produced as [f]. This stage

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[15] Except for the pattern Morrisette and Gierut (2008) reported of two children evidencing the the *s-θ-f* chain shift only in word-initial position. Note however that none of the discussed accounts explains this pattern.

is not attested in any child production data. Moreover, Jesney cannot account for the difference in elimination of error patterns for the *puzzle-puddle-pickle* problem. Most importantly, Jesney's analysis requires the postulation of an additional specific faithfulness constraint for which no independent evidence is provided.

In conclusion, my analysis is more minimal in the sense of Occam's razor and it can better account for the attested patterns in the data. The issue of learnability is solved, because in my view the chain shift patterns are not learned. Rather they are a direct consequence of a child's articulatory and perceptual abilities. Further research is needed to determine whether children evidencing a chain shift indeed display the articulatory and perceptual difficulties that I predict.

In my view, the merit of my investigation is that I have made clear that the processes of articulation and perception play a crucial role in children's speech production and should not be disregarded.

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