Child Phonology as a Dynamic System

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Abstract

This study investigates the role of articulation, phonological systematicity and individual boldness in attempting challenging targets in phonological development. In particular, it examines the interaction of these factors and their link with variability. The purpose of the analysis is to provide an answer to the question whether child phonology could be better understood by adopting Dynamic Systems Theory, as it has been done in other natural sciences. Three longitudinal case studies of children acquiring English are presented. The results suggest that articulation, variability and individual differences in children's strategies of selecting words to attempt play an important part in the emergence of the phonological system. The evidence provided supports the view that the nature of the interaction between the above factors and the developing phonological systematicity and accuracy might the same as has been observed in other dynamic systems in the natural world. It is argued that further research in this direction, involving computer modeling, should be pursued as a promising direction in child phonology research.

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Author's Declaration

I declare that, except where explicit reference is made to the contribution of others, this dissertation is the result of my own work. No part of this thesis has been submitted for examination at any other institute, and no part of it has been previously published.

Marta Szreder-Ptasinska

INTRODUCTION

Phonological acquisition studies typically focus on a single factor out of many considered important for determining the course of language development. Many studies (e.g. Jakobson, 1941/1968; Smith, 1973; Stampe, 1979; Gnanadesikan, 2004; Łukaszewicz, 2007) constitute attempts to explain phonological acquisition in terms of rules or constraints that emerge in the mind, which determine child performance. Others choose to examine processes observed in child speech with main focus on the articulatory capabilities of the child (e.g. Studdert-Kennedy & Goodell, 1993; MacNeilage & Davis, 1990; Davis & MacNeilage, 1995; MacNeilage, 1998). Although it is apparent that both the cognitive structure and motor control develop simultaneously in the child, and that both necessarily affect the child's language production, researchers differ in what they consider to be the 'essence' of language, the 'core' which should be the domain of linguistic enquiry. It is seemingly assumed that studying a given 'essential' aspect of language separately from the others will allow us to understand the nature of language development, and only then should we attempt to explain how all the relevant factors act together in language acquisition. This study investigates the applicability of dynamic systems theory to phonological development. If successful, the theory would make it possible to view phonological development holistically, studying the emerging phonology as the result of interaction between all relevant factors. Furthermore, it would provide a novel theoretical approach in linguistics, with a potential to reveal new answers to some of the most difficult questions in the field.

The purpose of Chapter 1 is to present the factors that motivated the current study, in terms of both theoretical issues and as yet unanswered research questions. In section 1.1 I will outline what I consider to be the most intriguing theoretical problems in modern linguistics. I am convinced that no discussion of the current state of linguistic theory and research can omit the arguably most influential approach in the field, i.e. generative grammar, introduced by Chomsky in the mid 20th century. Since the time of the so called Chomskyan Revolution, which ended the behaviourist era in linguistics, this approach has produced a large amount of research, addressing some of the most fascinating questions about language. While often controversial, Chomsky's ideas have continued to inspire both popular and scientific audiences. For this reason, it is of crucial importance that the main concepts, developments and findings that constitute the legacy of the generative approach are referred to by any scientist wishing to propose a new approach. The reader is therefore asked to bear in mind that the discussion in this section is not intended to deny the achievements of the generative framework. Rather, it is an attempt to highlight the main problems which are not yet solved in the framework, to demonstrate how dynamic systems theory could contribute to better understanding of those as yet unexplained phenomena in language acquisition. At the same time, it is essential that there is continuity in the development of science, as all generations of linguists benefit from the work of those who came before them. Therefore many concepts from generative theory are compatible with the dynamic systems approach, and it was also my goal to emphasise those aspects in section 1.1. It is hoped that the discussion in that section will provide a solid theoretical grounding for the approach taken in this study, as well as giving credit to those who furthered our understanding of language to the point where we are able to think about new perspectives.

Section 1.2 is a bridge between theoretical considerations and the application of dynamic systems theory to phonological development. It provides a description of the main characteristics of dynamic systems, as well as their behaviour and development, as studied in natural sciences. In section 1.3, we discuss Articulatory Phonology, which is a phonological framework based on the assumptions of dynamic systems theory. Section 1.3.1 presents the research and findings in child phonology which were motivated by the theoretical assumptions of Articulatory Phonology. This line of research has mostly been focused on articulation, and has led to a revival of earlier motor approaches to language. The findings of research approaching phonological development from that angle and the problems with such an approach are discussed in section 1.4. We discuss evidence against a purely motor approach to language development, and consider why past research, which focused on the role of articulation and perception, has not so far been sufficient to explain phonological acquisition satisfactorily. At the same time, we highlight the findings in phonological development research that suggest child phonology develops according to the principles that guide the behaviour of dynamic systems. On the basis of this evidence, it is argued that dynamic systems theory should be applied to the study of the development of the cognitive linguistic system, and not solely to the development of articulation. Finally, in section 1.6 we outline the specific research objectives of the current study, designed to constitute a step in that direction.

On the most general level, Chapter 1 is intended to demonstrate that one of the things missing in the current phonological development research is a lack of solid examination of the link between competence and performance, phonetics and phonology, articulation and cognition, in the acquisition of language. While all of these factors are studied separately, their interaction in development is still to a large degree mysterious. This gap was the primary motivation for the current study. On the one hand, there is evidence that language develops as a coherent system in the mind, and that phonological development is not synonymous with motor development. A complex cognitive structure develops along with articulation, and that calls for explanation. However, poor articulation, variable production and individual tendencies all constitute an important part of every child's linguistic experience, and as such interact with the developing linguistic structure. The main premise of this thesis is that neither the motoric abilities nor the cognitive structure alone can account for language acquisition. It is their co-operation that leads to the emergence of language. In other words, it is postulated that rather than separating the two aspects of development, we should focus on how they interact, and how this interaction leads to the emergence of a complex linguistic system in the child. The results of three case studies (Chapters 3, 4 & 5) and the results of the comparisons and combined analysis of all three subjects (Chapter 6) demonstrate that the interaction between the two levels of the phonological system is observable and that it exhibits tendencies predicted by dynamic systems theory.

Chapter 7 summarises the findings and relates them to the discussion of dynamic systems presented in section 1.2, to show that the approach advocated here is a productive way of studying phonological development. The approach integrates all aspects of the child's linguistic experience as important determinants of each child's developmental path. It leads us to examine the link between different aspects of development, and provides new answers to theoretical questions. In addition, adopting Dynamic Systems Theory stresses the continuity between the development of phonological structure and the development of all other structure in nature. While it is too early to definitively demonstrate that this approach is correct, it is hoped that it will offer a new and inspiring way of conceptualising phonological development.

1. BACKGROUND

1.1 Grammar as the essence of language

An important theoretical assumption that often motivates focusing exclusively on linguistic structure is that of a distinction between what is truly linguistic (i.e. language-specific) and what constitutes issues in executing language production. This notion was introduced to modern linguistics by Chomsky, but is largely based on de Saussure's distinction between *langue* (Fr. 'language') and *parole* (Fr. 'speech') (de Saussure 1915/1959). For de Saussure, there is a fundamental difference between the structure of language as a system and each individual act of speech. While speech acts are made possible by the existence of *langue*, they are also influenced by factors external to linguistic structure (e.g. idiosyncracies of each individual speaker). Importantly, the relationship between the two is unidirectional, meaning that while language to a large extent determines acts of speech, the individual variation in speaking does not affect the structure of language. In de Saussure's view, the core linguistic structure is constant in this sense, and is preserved by society, which passes it on to children. It was this constant and systematic structure of language which interested de Saussure, and which he considered to be the object of linguistic inquiry.

In the generative framework, the distinction was reintroduced by Chomsky (1964, 1965), although in a slightly modified version. While Chomsky also distinguishes between the systematic structure of language and the individual acts of speech, he considers the structure to be speaker-internal rather than focusing on its social aspect. Competence (corresponding to *langue*) is not a set of rules maintained by society, but a system stored in the mind. These rules, however, are still independent of and immune to performance (i.e. *parole*), which can be affected by memory, articulation, context and other factors in speaking that are not controlled by grammar. This idea was later further supported by Fodor's (1983) hypothesis that the structure of human cognition is essentially modular, i.e. that different functions in the mind are encapsulated in separate modules, which do not interact with one another during processing (although the outcomes of processing in one module are, of course, available to be processed by other modules). The resulting assumption in the generative framework was therefore that grammar can and should be studied separately from other cognitive and articulatory factors which influence speaking. Competence was thus established as the essence of language.

Indeed, the distinction between langue and parole, and between competence and performance, carries a fundamental insight: there is visible systematicity in language which appears to be independent of the execution of individual speech acts. Acoustic analysis of the pronunciation of a single word by different speakers or at different occasions will quickly reveal large individual differences, and yet people generally do not have trouble understanding one another. Sounds are reduced and distorted in fluent speech, or if the speaker has a chewing gum in their mouth, but we intuitively understand that the underlying form is the same across very different linguistic instances. Moreover, as humans we were able to invent the alphabet, in which a single letter represents a generalisation across different acoustic 'versions' of what we consider to be the same sound. Chomsky and Halle (1968) introduced a new approach to phonology based on exactly that insight: there are underlying representations of the sounds of speech, which constitute phonological competence. There is a fundamental difference between phonology and phonetics, which is a reflection of the distinction between competence and performance.

The acquisition of linguistic competence

The generative framework introduced the first mentalist theory of language, interested in the linguistic structure in the mind of the speaker and making that structure the main focus of linguistics. However, its focus on internal competence, as opposed to language as a social construct, had an important consequence for the generative view of language acquisition.. As linguists were finding an increasing number of possible generalisations which could be made within and across languages (and which could constitute the core of the linguistic system), it was noticed that evidence for some of them is hard to find in actual speech. An example from phonology could be allophones which occur in complementary distribution, i.e. there is never evidence for them being two versions of the same phoneme. Inability to recognise them as such would, however, lead to inability to discover phonological rules. For example, treating /p^h/ and /p/ as two different consonants, would not allow the child to discover the rule of aspiration of stops in syllable onset. The assumption that grammar is based on economy, i.e. that grammatical rules need to be as general as possible, makes it essential for the child to be able to arrive at such generalisations to acquire native-like competence. Therefore, the idea that many rules cannot possibly be inferred from the input led Chomsky to formulate the hypothesis of an innate Language Acquisition Device (LAD, Chomsky 1964), which transforms the input into grammatical competence. LAD, later specified as Universal Grammar (UG), was the solution to the unlearnability problem. It was the innate linguistic competence which allows for language acquisition, and which contains all building blocks of language (e.g. the idea of a phoneme, or of onset and nucleus), as well as everything that is common to all languages (e.g. phonetic features, or CV syllable.) The child is thus supposed to be born with innate knowledge of linguistic structure, and all that is left to acquire are the rules and sounds that are particular to their target language.

However, as Pater (2002) points out, the first attempts at describing child phonology in terms of ordered sequential rules transforming the underlying phonemic representations into the output form (such as the ones postulated for adults), proved disappointing. In fact, only Smith's longitudinal case study of his son Amahl (Smith, 1973), the most famous and perhaps the most ambitious one of those, is still remembered today. Pater (2002) attributes this to two factors. Firstly, it was soon discovered that some processes observed in child speech (most notably consonant harmony) are rarely if ever attested in adult languages, and therefore cannot be explained by referring to UG (Menn 1976, Vihman 1980, Fikkert & Levelt, 2008). Secondly, derivational rules were blind to the output, while in child language there were often apparent rule conspiracies, aiming at deriving a similar output (e.g. cluster simplification) from different underlying forms (e.g. different clusters) (Menn 1980).

As a result, rules were eventually replaced by constraints, which allowed for rule conspiracies, and researchers became interested in the role of extra-grammatical, child-specific factors in phonological development, which could explain the differences between child and adult language. This latter objective was further facilitated by later theoretical developments in the generative framework, in particular by the Minimalist Program (MP, Chomsky, 1995; Hauser et al., 2002). MP set new goals for linguistic research, motivating investigation into the evolution of language. This meant a quest to reduce Universal Grammar to as few language-specific processes as necessary, to avoid redundancy, and to account for the evolution taking the relatively short time of the past seventy to one hundred thousand years (Boeckx, 2006; Hornstein, 2009). As a result of this shift, the generative framework now to a large extent supports the development of research aimed to determine the role of non-language-specific cognitive processes in language acquisition. Rules, even if they are abstract and generated by Universal Grammar, have to interact with general cognitive skills. These factors have to a large extent shaped the approach to competence and performance in the study of phonological development in the modern generative framework.

1.1.1 Competence and performance in child language

Fikkert and Levelt (2008) investigate the development of consonant harmony in phonological acquisition. As we have mentioned, consonant harmony is a phenomenon which is particularly problematic for an approach which assumes that there is continuity between child and adult grammars. In addition, as the authors point out, in the generative theory of acquisition, child language should linearly improve and steadily become closer to the adult language. However, consonant harmony is typically absent from early child words, and only appears after the child has gained some experience in speaking. Fikkert and Levelt thus postulate that extra-grammatical factors need to be acknowledged in the analysis. Indeed, the analysis of data from five children acquiring Dutch leads Fikkert and Levelt to claim that the innate grammar must be supplied with extra-grammatical elements in order to explain the observed patterns. Specifically, they postulate a constraint in early child grammar which allows for only one place of articulation for all consonants and vowels in any word. Since this constraint is unlikely to originate in the grammar (even though it constitutes a part of it), Fikkert and Levelt suggest that it may be motivated by either articulatory difficulties or processing load, which makes it impossible for the child to remember more than one place of articulation for each word. Furthermore, Fikkert and Levelt note that the later development of the constraints appears to correlate with the distribution of words in the input as well as in the child's own lexicon. In this way, they postulate a bidirectional relationship between grammatical and extra-grammatical factors, such that the latter lead to the emergence of new constraints in the grammar. However, such analysis raises an important question: if grammar emerges from the interaction of articulatory constraints, input and generalisations in the lexicon, then what *is* the role of grammar?

Inkelas and Rose (2008) suggest an answer to the question about the role and the importance of grammar, while acknowledging extra-grammatical factors in its development. They investigate the development of Positional Velar Fronting (PVF) and Positional Lateral Gliding (PLG) in one child acquiring English. Since PVF and PLG are also examples of processes that are not attested in adult languages, they too can be used to demonstrate the interaction between the two types of factors. On the basis of their analysis, Inkelas and Rose conclude that it is the differences between children's and adults' vocal tracts which explains the presence of the processes in child, but not in adult language. In particular, they propose that velar fronting is the result of children's initial lack of fine motor control of tongue movement. This is particularly evident in prosodically strong positions, in which children attempt an even stronger tongue movement to mirror adults' production of consonants in those positions. This added force, coupled with poor motor control, leads to PVF, which explains why many children show velar fronting in strong positions and not in weak positions, but never vice versa. Such an explanation thus relies solely on extra-grammatical factors, but Inkelas and Rose claim that there are reasons to believe that PVF is later extended to PLG, suggesting a role for grammar in the process. Given that PLG in the subject is based on the prosodic strength of the position, which is inconsistent with the adult realisation of laterals, Inkelas and Rose argue for the availability of this phonological pattern in the child's grammar (extended from PVF) as the reason for its emergence. They conclude that their findings provide evidence for the continuity of competence between children and adults, as inaccurate grammatical generalisations are made by children using the same building blocks, and the same principles in putting them together as are used by adults. In other words, although extra-grammatical differences make adult and child phonological processes have different outputs, the generalisations on which they are based and their phonetic motivation are the same.

This explanation can be interpreted as the modern formulation of the argument for the existence of continuous grammatical competence (UG), which has been present in the generative tradition for a long time: we need to postulate UG in order to account for the fact that all children acquiring a language eventually arrive at almost identical linguistic competence, even though the set of rules they all invariably learn is not present as such in the input. Moreover, in the process of acquisition they often make identical errors, and their inaccurate generalisations can be shown to be based on the same principles as underlie adult languages. There is, therefore, essential continuity in grammar throughout life.

1.1.2 The arguments for Universal Grammar

One can see that the long-standing generative tradition in linguistics, the first mentalist theory of language, is built on solid foundations. Through decades of research into the structure and functioning of language in the human mind the theory has led to the formulation of at least four strong arguments for the existence of innate grammatical structure, which can be summarised as follows:

1) *Competence is different from performance.* There is an apparent difference between the structure of language and individual instances of speech, pointing to the existence of a constant, systematic structure in the mind, which can be considered the 'essence' of language.
2) *The input is impoverished.* Children's success in acquiring all the rules of the language cannot be attributed to the input, which does not contain all the information necessary to discover the regularities of language.
3) *There is uniformity of outcome in acquisition.* All children acquiring one language eventually arrive at almost identical native-like competence, regardless of their individual experience with highly variable input.
4) *There is continuity of process in acquisition.* Child-specific phonological processes are based on the same principles as adult processes.

Given the strength of the above arguments, it is not surprising that generative theory is one of the most popular approaches to language acquisition today. However, in this study I propose that dynamic systems theory can provide answers to the above questions which do not rely on innate grammatical competence. I do so not in order to criticise the generative approach. Rather, I do so because I believe that UG is still only the best hypothesis we have been able to offer, and not a definitive answer. For this reason, it is crucial that we continue to ask the most puzzling questions, and that we try to look for alternative solutions. In order to be able to think about alternatives, we will now critically examine each of the four arguments above, to establish the assumptions on which they are based, and see how dynamic systems theory could change our understanding of those arguments.

Competence vs. performance

The problems of relating performance to competence and of establishing the process behind developmental changes are ones that have been faced by all fields of developmental research. Thelen and Smith (1994) present an analogy from locomotor development studies, which can be helpful in finding a solution for the difficulties encountered in cognitive development research.

The stages of locomotor development had been solidly established and extensively studied since the 1940's. It is apparent that all children follow a similar developmental path: newborns perform step-like movements with their legs when held erect, but this tendency disappears by the end of the second month of life. The movements then reappear in the second half of the first year, to finally turn into first independent steps around twelve months of age. Given how predictable the stages are, locomotor development used to be treated as a paradigmatic case of biological maturation guiding behavioural progress. According to McGraw (1945, as cited in Thelen & Smith, 1994), the stages were pre-programmed and unfolded with maturation of the brain (in a similar way to how Universal Grammar is expected to unfold). Therefore, there was a module for walking, the 'essence' of walking, on which the developmental process relied.

Esther Thelen and her colleagues (Thelen, 1982; Thelen & Fisher, 1984; Thelen, 1987) set out to test whether the stages could indeed be said to be due to maturation of the brain. What they found was that the stages of locomotor development were in fact dependent on many variables, and could be experimentally manipulated. First of all, the first decline in step-like movements in babies proved to be the result of weight gain. The babies who were quickly gaining weight were the fastest to lose the tendency to step when held erect. Moreover, attaching small weights to the legs of younger babies inhibited the tendency, while submerging older babies in warm water, thus reducing the weight, resulted in the return of the movements. Furthermore, all babies performed the very same step-like movements when lying down as opposed to being held erect.

Finally, babies were able to perform walking on a treadmill long before they could walk independently (at 4-6 months). In other words, all the mechanisms necessary for walking were essentially present throughout the first year of life. Interestingly, Thelen & Smith (1994) note that the fact of paying attention to the treadmill also seemed to have an effect on stepping. Young babies performed the movements without attending to the treadmill, while older babies did notice the treadmill and this apparently inhibited their actions.

There are two important consequences of these findings that are also relevant for our discussion of language development. First of all, if stepping is so context-sensitive, then it is impossible to claim that the observed stages in development are due to maturation. Apparently, the movements depend on factors independent of walking, such as weight, posture, attention etc. Therefore, it is possible that the development of other skills also does not have to rely on any specific maturational module. The other conclusion that follows from the studies of locomotor development is that postulating a single cause, an *essence* of a particular skill is pointless. Because even though the essential ability to perform step-like movements is present in babies from birth, they do not start walking until around twelve months later. If this is the case, then we simply cannot treat any skill as unidimensional, but rather as depending on the co-operation of various skills and conditions emerging at different time points.

In summary, we can see that one important problem with drawing the line between competence (the cognitive linguistic structure) and performance (the execution of each act of speech) is that it is impossible to talk about language development without acknowledging the fact that all other cognitive and motor functions are also developing in the child at the same time. This is a very important problem because it undermines the notion of competence as the focus of inquiry in acquisition studies. If infants have a full-blown grammatical structure but the *performance* issues make it impossible for them to use language like adults; if they do not know semantics, pragmatics, have immature articulation and memory, and cannot generate adult-like sentences, then innate competence cannot be treated as the essence of language acquisition. More importantly, in the case of walking the very existence of a core competence is undermined, since the non-walking-specific factors turn out to be sufficient to explain the development of that skill. This suggests that we cannot rely on the idea of competence before we are able to show that the extragrammatical factors are insufficient to explain language acquisition.

Poverty of the stimulus

The argument from *poverty of the stimulus* is the notion that the input to which children are exposed is much more limited than the linguistic capabilities they eventually acquire (Chomsky 1964, 1987). This argument is often presented as 'the logical problem of language acquisition', but it is worth noting that it is based on the assumption that the output must be proportional to the input (linearity). Chomsky argues that children are not exposed to a sufficient amount of linguistic evidence to explain the richness of the system that they acquire, and his proposal is that there must be some additional mechanism that would bridge the gap between the input and the acquired language competence. LAD, or later more specifically UG, is supposed to be that mechanism. However, it is worth pointing out that this conclusion only holds if we assume linearity. In the words of Mohanan (1992):

'The output of LAD contains principle P. Principle P could not have been inductively arrived at from the input. Therefore, it must have been innately specified as part of LAD. For this conclusion to be valid, we need to appeal to the hidden assumption that every organizational principle found in the output must be present either in the initial state (LAD) or in the input (data). That is to say, LAD is essentially entropic: the complexity of the output cannot exceed the sum total of the complexity of the input and the initial state.' (pp. 649 f.)

The *poverty of the stimulus* argument can only lead one to postulate innate grammatical structure if we believe that acquisition proceeds linearly. However, there are well-known systems in the natural world that do not behave in a linear way. These chaotic nonlinear systems are extremely sensitive to changes in the parameters that affect them. One notoriously nonlinear dynamic system is weather. The fact that the changes in weather cannot be predicted far in advance results from the fact that minimal factors can have disproportionately large influence on the system. This was termed *the butterfly effect*: the idea that the movement of a butterfly's wings in one hemisphere can result in a tornado in the other (Gleick, 1988). In nonlinear dynamic systems, a whole range of qualitative changes of the whole system may result from the influence of seemingly small factors.

Let us briefly consider in what sense language could be compared to weather in this respect. Firstly, we need to clarify that chaotic behaviour can be observed on different scales, although the mechanism remains the same. In the case of global variability, on a macro scale, weather has a wide range of different states, such as wind, thunderstorm, shower, tornado, etc. However, note that this variability is nonetheless constrained by the physical properties of the atmosphere and the rest of the universe. Despite seemingly wide variability, the weather system is capable of exhibiting only a finite set of states, which is a general property of chaotic dynamic systems. We are therefore dealing with a highly variable nonlinear system, a system which is chaotic, but not random and in fact highly constrained. There is a physical description of the changes in weather, and there are mathematical equations which capture its behaviour, but these equations are nonlinear. This means that the outcome is not the sum of the state of the weather and the values of the parameters acting upon it (e.g. the wings of the butterfly), but that the parameters coupled with the 'initial' state of the weather lead to the emergence of vast changes. As a final example here, consider a ball placed exactly on top of a steep hill between two valleys. A small movement will cause the ball to fall into one of the valleys. The small movement is not proportional to the rapid change of the ball's location.

With this in mind, consider now the phenomenon of categorical perception. The articulation-perception mapping is highly nonlinear, so that a small change in articulation can lead to large changes in perception. A slight difference in voice onset time (VOT) will have no effect in some areas of the voiced-voiceless spectrum, but will lead to the perception of a different category in others. Our ability to discriminate between two very different consonants, [p] and [b], is not motivated by a VOT difference of a particular range, but in that difference occurring at a particular point of the spectrum. Nevertheless, we would all agree that [p] and [b] are no less different than, for example, rain and snow.

If we want to apply chaos theory to development, we need to think of each child's acquisition as a parallel to each individual change of weather, which means we have to consider local variability. While the process is essentially the same, i.e. it progresses through instant qualitative changes in response to small parametric variation, the difference is that there is an end point: a progression towards a stable state. In the case of the weather, the stable state (e.g. rain) will last a much shorter time, because the factors acting upon the system will continue to push it towards a new transition. In the case of language, however, once the adult-like final state is achieved, the factors pushing the system out of this stable state are much less pronounced, because the input is now compatible with the output. This does not mean that language in an individual speaker does not evolve further. It does to a greater or lesser extent, e.g. if the speaker migrates to an area with a different accent, or to a different country. However, the strong input-output mismatch which stimulates more categorical changes in the developing language disappears. On the way from infancy to adult-like competence, development may proceed through a series of qualitative changes, which are not proportional to the stimulation received from the input, but adult-like competence leads to a large increase in the stability of the system. Such a conceptualisation can serve as a new perspective that could allow us to retain the insight of the poverty of the stimulus argument, but also provide an answer to the problem without resorting to innate grammatical structure, and with the added value of suggesting continuity between language, cognition, and the rest of the natural world.

Uniformity of outcome and continuity of process

We may recall that while most generative researchers now acknowledge the role of extra-grammatical factors in language acquisition, Inkelas and Rose (2008) provide an argument for why it is still essential to assume a language-specific factor being part of the process. This argument relies on the concept of continuity between child and adult grammars, even at the point where children 'invent' non-adult-like grammatical rules (such as PLG). Indeed, approaches which propose fundamental discontinuity of the process between child and adult language use and change have not been notably successful.

Perhaps the best-known proponent of such view is Tomasello (1992, 2002), who proposes that children at the early stages do not generalise across words and phrases, and instead store different linguistic structures on different levels of detail and abstraction (e.g. 'give X', but also more specific 'alldone'), and that they invent child-specific constructions which are not based on any adult structures (e.g. pivot constructions such as 'give X'). In time, children acquire the capability of generalising across their lexicon, and only then does their grammar begin to resemble adult grammars. Tomasello's key arguments come from his analysis of the verb structure acquisition of his daughter, which suggested that there was no transfer of skills from one verb to the next, meaning that each verb acquired its argument structure separately, regardless of how many similar verbs had already been acquired. However, Ninio (2003, 2006), in her reanalysis of Tomasello's data, was able to show that this was in fact not the case, and that the child's acquisition of verbs followed a regular learning curve, with each new type of verb facilitating the acquisition of other verbs of that type. In fact, many generative and cognitive linguists now agree that there is continuity of process in acquisition.

Let us now recall that the assumption of continuity of *structure*, which was formerly a part of the mainstream generative theory, is no longer endorsed in the Minimalist Program (Hornstein, 2009). UG is not supposed to contain all possible information about all the languages of the world (as used to be the case in the Principles & Parameters framework), but rather a single principle (or grammatical operation) unique to language. This principle is sufficient to lead to successful acquisition, given interaction with the input and, crucially, with other cognitive skills (Hornstein, 2009). In this sense, we are now perhaps closer to the often cited metaphor of imprinting in ducks (Chomsky, 1967; Lenneberg, 1967, Cook & Newson, 1996). The idea is that ducklings are born with an instinct to follow the first moving thing they encounter. Given that the environment of hatching ducklings is almost invariable, evolution did not provide them with a specialised mechanism for recognising the mother duck from a variety of moving objects. And although ducklings follow any moving object they see first, unless they are the victims of a researcher testing that theory (e.g. Lorenz, 1949, who first observed the phenomenon), for the great majority of them this simple, underspecified mechanism is sufficient to be safely taken care of by the mother duck. It thus appears that evolution, in guiding the development of dedicated, species-specific skills, can rely on the constancy of the environment and keep the innate component to a minimum.

Where generative and cognitive linguists might differ is of course the question of whether such a mechanism is linguistic in nature (e.g. if it is a specific grammatical operation, such as Merge or Label), or whether it lies in a more domain-general skill, which has been modified by evolution to suit the need of language learning (e.g. the structure of memory, attention to speech, babbling), but this question is beyond the scope of this study. Nonetheless, in his seminal work on the dynamic organisation of neurons, Gerald Edelman (Edelman, 1987) emphasises the importance of the history of each species and the evolutionary changes it has undergone in studying behaviour. We are not blank slates but the product of millions of years of evolution, and it is the interaction of who we are as a species and the environment that we live in that determines the development of our brains, our cognition, and our behaviour. Similarly, in any dynamical, self-organising system, what is of fundamental importance is the so-called initial state (not to be mistaken for the same term used in generative grammar to denote UG). In our previous examples of learning to walk and changes in weather, the nonlinear changes in behaviour of the system crucially depended not only on the value of parameters acting upon the system (e.g. weight of the infant in the first example, or wings of a butterfly in the second one), but also on the initial state of the system (the walking reflex, and the current distribution of e.g. clouds). It is the meeting of the two that results in the emergence of a new behaviour of the system.

To return to the question of the continuity of process and the uniformity of outcomes in language acquisition, by referring to evolution as a dynamic process on a macro scale, and language development as a dynamic process partially depending upon the characteristics of our species, and partially upon our interaction with the environment, we can address these questions with much more clarity. Regardless of the exact nature of the evolutionary skills we bring to the task of language acquisition, the fact is that we are all human beings with specifically human brains, with human skills, abilities and tendencies, and that we are brought up in a very constant environment of people taking care of us and surrounding us with language. This may be enough to account for why we all acquire language in a similar way and why the outcomes are so similar across people. At the same time, this perspective allows to account for variability, for the fact that we have our idiosyncratic pronunciations and grammatical constructions, and that only very rarely are some of us are not successful, whether because of genetic problems, or anomalous circumstances. Because infinite variability hidden under infinite similarity is the very essence of evolution.

1.2 Properties of Dynamic Systems[1]

We have argued that dynamic systems theory, part of chaos theory, offers a promising new perspective on several of the most difficult questions that have been raised in the study of language acquisition. Thelen and Smith (1994), taking the assumption that 'the acquisition of mental life is continuous with all biological growth of form and function' propose an approach to cognitive development based in nonlinear dynamics in which cognition is seen as a dynamic system (see also Smith & Thelen, 1993; Kelso, 1995; Herdina & Jessner, 2002). Such a dynamic approach to development could offer an integrated, across-domain account of developmental process (Lewis, 2000). However, before we focus on how the approach has been applied in phonology and on the promises it holds for the study phonological development, let us first present the basic properties of dynamic systems, as studied in physics and biology.

1.2.1 Open and nonequilibrium

Dynamic Systems Theory (DST) is concerned with the behaviour of systems which exhibit two crucial properties: they are *open* and *nonequilibrium.* What is meant by openness is that the systems are influenced by and exchange energy, information or matter with the environment. Thus, the environment is one of the determinants of the systems' behaviour. This property is typical for all living organisms, from the very basic level of metabolism (whereby every living creature takes in from its environment the ingredients necessary for survival to then return a different product) to the most metaphorical one, as in a popular opinion that a man is the product of his society.

Nevertheless, it is perhaps easy to overlook the fact that the interaction between living organisms and the environment is a constant, on-line process. For example, if we think of a man walking on a pavement, it may seem as if the action of walking was independent of the environment, a stable behaviour, coming entirely from within the organism. However, if we closely examine the way the action is performed on the said pavement as opposed to the same action in another setting, such as walking on sand on a beach, we notice that in fact the steps are very different, and adjusted to the properties of the particular surface (walking on broken glass would perhaps constitute an even more striking example). Moreover, Ashby (1960) notes that in people who develop symptoms of

[1] The general introduction to Dynamic Systems Theory presented below is based on Thelen & Smith (1994), Kelso (1995), Ashby (1960) and Abraham & Shaw (1993), unless specified otherwise.

Tabes dorsalis (a process of degeneration that affects sensory neurons, which carry incoming information to the brain), walking is severely disturbed, despite the motor impulses going out from the brain properly. Therefore, it is not sufficient for our imaginary man to have motor control over his legs to produce walking-like behaviour. He has to constantly adapt his actions to his surroundings.

However, Ashby also points out that one should be very careful about making a strict distinction between a system and its environment. Firstly, there are many scales on which the distinction could possibly be made, as every system is composed of many subsystems, which may constitute an environment for one another. Thus, the pavement may be considered the environment of the man, just as the legs may be seen as the environment of the nervous system which has to control them; the nervous system, in turn, is the environment of the sensory neurons, in our example so sadly affected by another system, namely *Tabes dorsalis*. Secondly, if a system interacts with the environment to produce new patterns of behaviour, then both the system and its environment create in fact another system, only on a larger scale. This is so because the interaction is bidirectional and the actions of the organism also affect its environment. In sum, the distinction between the system and its environment is difficult to make and is never fixed.

The second basic property of dynamic systems that we mentioned was that they are nonequilibrium, i.e. far from the state of thermodynamic equilibrium. This is related to the fact that they are open, as closed systems obey the second rule of thermodynamics and always tend to a state of entropic equilibrium, such that there is no flow of energy in the system. The fact that open systems do not obey that rule is only possible because the system-environment interaction is not only constant and reciprocal but also enables the system to function properly. Thus, a nonequilibrium system can reach stability without running down to a state of thermodynamic equilibrium thanks to the constant supply of energy from the environment. And the stability is crucial for the system to operate. As Pavlov (1927, as cited in Ashby 1960:65) put it:

'... Being a definite circumscribed material system, it [an animal] can only continue to exist so long as it is in continuous equilibrium with the forces external to it: so soon as the equilibrium is seriously disturbed the organism will cease to exist as the entity it was.'

Dynamic systems, therefore, cannot function independently of the environment. An open, nonequilibrium system needs to function in a context. As a result, the behaviour of such a system must be based on adaptability, i.e. constantly adjusting its actions to the surroundings (which is why a pattern of behaviour such as walking can only be stable if the performance of the action takes the surface into account). In sum, the basic characteristics of a dynamic system are that it interacts with the environment, that this interaction enables it to function, and at the same time that maintaining the function in a changing environment requires the behaviour of the system to be adaptive.

1.2.2 Complex in structure, complex in pattern

Another crucial property of dynamic systems is their complexity. This complexity can be observed on various levels, out of which perhaps the most obvious one is the *complexity of structure*. The system can be composed of innumerable subsystems and parts. A good and often mentioned example is the human brain, which operates with billions of neurons. But even when we think of a limb, the number of interacting parts (joints, muscles etc.), although not close to billions, is still enough to call the system complex.

However, material complexity is not the only dimension of structure complexity in dynamic systems. The structure of these systems has many levels, which can be studied on many scales of time and granularity. Yet, their structure is *fractal*: on each level, the structure is the same. Larsen-Freeman (1997) notes that one can conceptualise this through the example of a tree. The overall shape of the tree is the same as the shape of its branches, and even the leaves: on both the micro and the macro scale, one can see the main trunk and the branches stemming out of it. Similarly, the dynamics of dynamic systems works the same on every level. The various levels interact in the same way that their components do. It should then not come as a surprise that the way parts of a system co-operate is also complex, resulting in *complexity of pattern*.

Various subsystems may participate in various tasks. There are no special muscles for reaching that would be separate from the ones for lifting things. Furthermore, advances in neuroscience have led researchers to the conclusion that not only the roles of muscles, but also the connections in the brain are not fixed: it seems that it is the overall pattern of response from the neural network that makes particular stimuli recognisable, not the response of particular neurons, since many neurons respond to various stimuli (Edelman, 1987).

In addition, the patterns are *multifunctional*: when one of the components or subsystems is disabled, others can compensate for its absence. This can be observed in the phenomenon called *motor equivalence* (Lashley, 1930). For example, people are able to hold a cup in various ways, depending on whether they need to hold two other cups with the same hand, whether the cup is filled with hot coffee, whether they need to point to some direction at the same time, and so on. Also, people can write their name holding the pen with their right or left hand, with their mouth or with their feet. It thus seems that patterns are not fixed, they are not specified as directions for particular components. Instead, the patterns are characterised by means of the task that they are to perform.

1.2.3 Dynamic and self-organising

As we have mentioned, dynamic systems are adaptable; they adapt to the environment to perform a task. To talk about adaptability is, in fact, to talk about constant change. The particular relationship between a system and its environment that we have discussed requires that the system be *dynamic* - meaning constantly changing, unfolding in time, permanently *becoming* rather than simply *being*. The next question now is how this change proceeds and how the system knows what type of change is going to be adaptive. The legs of our walking man surely are not informed about the said man's intention to walk: how are they to perform the action? Is there a control mechanism involved, which tells the various subsystems how to behave? The answer provided by Dynamic Systems Theory is that the dynamical change of a system is driven by the principle of self-organisation. Let us examine this notion in more detail.

In the words of Haken (1981), 'the interaction of subsystems gives rise to structuration.' That is to say, the very fact of the subsystems interacting results in pattern-formation, without the need for a control mechanism that would tell them how to act. There is also no need for feedback, as there is no 'central' mechanism in the system that would calculate the difference between the current and the needed state and perform computations in order to fix it. Instead, patterns emerge from *spontaneous* co-operation of subsystems. In other words, they are self-organising.

An important thing to mention at this point is that the way patterns emerge in dynamic systems is an example of *circular causality*. Indeed, if we exclude the notions of fixed input and output, then we must conclude that there is circular causality between the cause and the result. The structure of a pattern is defined by the action of the system's components, while the way the components behave is determined by the structure of the pattern.

A good example of self-organisation is provided in the experiment by Schmidt, Carello & Turvey (1990). In this experiment, two subjects were seated in chairs and told each to oscillate one of their legs according to the frequency of a metronome. Some pairs of people were told to do it symmetrically (*in-phase*), and others asymmetrically (*antiphase*). What was found was that as the pace increased, all pairs ended up in the in-phase co-ordination pattern. It does not seem plausible to claim that the in-phase pattern was somehow imposed on the two independent limbs so that they would start moving in a given way, as there was no mechanical link between the two subjects. Rather, through interaction, they spontaneously developed a pattern of co-ordination. This pattern, on the other hand, determined the timing of their movements. Importantly, none preceded the other: in this way there was a circular (instead of linear) causality between them.

An interesting aspect of this finding was that the system that emerged was one between two organisms, which demonstrates how order can spontaneously emerge when two otherwise independent components begin to interact. The fact that they do, without any central planning mechanism, not in response to the behaviour of one another but spontaneously, suggests that their behaviour is not entirely predictable. This leads us to the next important property of dynamic systems, namely *nonlinearity*.

1.2.4 Nonlinear

As we have discussed in section 1.1, the dynamic systems that we are concerned with are nonlinear. In mathematics, nonlinearity refers to equations which do not obey the *superposition principle*. The principle states that the input must be proportional to the output. Thus, if we take factor A, whose result on the system is x, and factor B, whose result on the system is y, then the two acting together will produce an outcome equal to the sum of the outcomes each of them would produce individually. If A=x and B=y, then (A+B)=(x+y). However, in a nonlinear system, the values of the factors are not additive. A small change in the value of a parameter can lead to extreme, and often unpredictable, changes in the system.

1.2.5 How does it work?

To understand how a given dynamic system works, we need to know its initial state, the external forces acting upon it, and the patterns of behaviour that emerge due to the interaction of those two forces. It needs to be emphasised that both the initial state and the external parameters are important here. The state of a given dynamic system before the external influence will to a great extent determine its outcome behaviour.

If we now take a dynamic system and imagine all possible modes of behaviour of that system, all possible patterns that it can exhibit, all of them together will constitute a given system's *phase space* (also called *state space*). Nevertheless, the patterns that can actually be observed will not be that many. There are areas in the phase space which the system is most likely to inhabit. The behaviour of the system will always be attracted to one of those stable patterns, and transition from this preferred pattern to a different area in the state space will be difficult. For this reason the patterns in question are called *attractors*.

While in these particular areas of the phase space the behaviour is stable, the system can and does undergo *phase transitions* (or *bifurcations* in mathematical terms), i.e. shifts to other patterns of behaviour. This is due to external influence. A change in the value of one of parameters in the environment, and more importantly, a change to some critical value, results in the emergence of a new attractor in the system's phase space. A parameter that has such influence on the system is called a *control parameter*. A phase transition is preceded by two types of warning signals: *critical slowing down* and *critical fluctuations*. Critical slowing down refers to the fact that a system on the verge of a phase transition will take a longer time to return to its preferred state when disturbed. Critical fluctuations mean that the behaviour of the system becomes increasingly variable. The values of the system's key variables (called *order parameter* or *collective variable*) undergo large fluctuations.

Let us illustrate the above concepts through an example from the classic study by Kelso, who tested the patterns of co-ordination of finger movements in human hands. We have already referred to the study by Schmidt et al. where a similar procedure was applied to co-ordination of leg movement between two subjects). Subjects in this study were asked to oscillate the index fingers in their two hands simultaneously, either in symmetric (in-phase) or anti-symmetric (antiphase) co-ordination. In principle, one might think there would be many other possible ways of co-ordinating the movement, but in fact, this proves difficult even for people who are trained to achieve relative independence of the two hands, such as pianists. Thus, despite the fact that the phase space includes other patterns of rhythmic organisation, the in-phase and anti-phase pattern are two attractors: two patterns of behaviour that the system will naturally assume.

The subjects oscillated their fingers according to a metronome. Interestingly, as the pace increased, they invariably ended up in the in-phase mode, regardless of the mode they started with. In other words, the speed served as the *control parameter*, which caused the system (the two oscillating fingers) in a stable antiphase mode to undergo a phase transition by creating a new attractor, namely the in-phase mode. However, during the transition there was a period of fingers oscillating in an irregular fashion, i.e. the above mentioned critical fluctuations. Moreover, once the phase transition occurred, the fingers did not move back into the antiphase mode once the metronome slowed down. Thus, at the same speed of the metronome, the fingers moved in the antiphase mode before the transition but in the in-phase mode afterwards. In other words, there were two states of the system for a single value of the control parameter, which depended on the direction of change. This is one of characteristic properties of dynamic systems that is called *hysteresis*. Most importantly, it shows that the behaviour of the system cannot be predicted solely from the parametric influence. The initial state, the intrinsic dynamics of the system, and the phase transitions it has gone through will determine how a given factor affects its behaviour.

Interestingly, the same pattern of behaviour has subsequently been shown to occur in horses when they shift gait. In fact, the in-phase limb co-ordination pattern that emerges when the pace of movement increases can even be shown for cockroaches. As we have noted before, different circumstances elicit changes in behaviour patterns, which is the key of adaptability.

In this section we have presented the key properties of dynamic systems and explained the key terms of Dynamic Systems Theory. The picture that emerges is that of complex systems, constantly changing in time, interacting with the environment as well as with one another, giving rise to a complex and fractal pattern structure. We have seen how the systems change in time under the influence of system-external parameters, but also that the changes are nonlinear, in that they cannot be predicted solely on the basis of the parameter, that the reaction of the system is not proportional to the influence, and finally, that this reaction is not guided by any control mechanism, but proceeds by means of self-organisation. We shall now return to language, to see how dynamic systems theory can be applied to language development.

1.2.6 Dynamic systems in development

What does it mean, then, to apply DST to phonological development? In essence, the approach views any structure as emergent from the interaction of components. Therefore, the study of development should seek to establish the structure of the system in question, focus on phase transitions that lead to the emergence of a new pattern of behaviour and the collective variable that is affected by the transition, and finally identify the control parameter responsible for the transition.

In addition, the behaviour of a dynamic system crucially depends not only on parametric variation but also on the intrinsic dynamics of the system. It is therefore necessary to focus on studying individuals, as a great deal of variability is to be expected across subjects, depending on their initial tendencies and skills. Moreover, the same value of the parameter can either push the system to a phase transition or have no effect, which means that a given change in behaviour is only possible when all the subsystems have developed to a particular state. Finally, circular causality leads to the assumption that the relationship between subsystems will be reciprocal, and that they will mutually constrain each other.

1.3 Dynamic Systems theory in phonology

In the previous section we mentioned motor equivalence, which is what accounts for the fact that we adjust our actions on-line to the requirements of a task. And so the same task may be performed by different parts of the body, or with different types of movement (cf. the example of holding a cup in different ways, depending on the circumstances). This is the foundation of the *task dynamics* model (Saltzman, 1986; Saltzman & Kelso, 1987): actions are defined by their goal, not by the particular types of movement or particular parts of the system that perform them.

That this should be the case for speech was first demonstrated by Kelso and his colleagues (Kelso et al. 1986), in an experiment on speech perturbation. The prediction was that if articulatory movements should follow from mechanical linking of articulators, i.e. if the movements are specified in terms of particular actions of particular components of the system, then sudden immobilisation of one of the components would disrupt speech production. If, on the other hand, components were flexible, and functionally linked, then other parts of the system should compensate for the disruption. Indeed, the latter proved to be the case. When a subject's jaw was suddenly halted in the middle of producing a bilabial closure, the lips immediately compensated for it to achieve the closure nonetheless. Similarly, when the jaw was halted in the same way, but during the production of an alveolar fricative, a compensatory action was observed for the tongue. As Kelso (1995) comments: 'the form of cooperation we observed in the speech ensemble was not rigid and stereotypic; rather, it was flexible, fast, and adapted precisely to accomplish the task.' (p. 41)

Articulatory Phonology is a framework originally proposed by Catherine Browman and Louis Goldstein (Browman & Goldstein 1986, 1992), which takes task dynamics to represent the way articulatory gestures are produced. The basic premise of the framework is that phonological representations do not employ abstract segments or features, but rather the actual articulatory gestures. These gestures are themselves self-organising dynamic systems (Browman & Goldstein, 1990; Browman & Goldstein, 1995; Goldstein et al. 2007). A gesture is viewed as 'one of the family of movement patterns that are functionally equivalent ways of achieving the same goal'. (Hawkins, 1992, p.13) Each of the constrictions necessary to produce a given gesture is a separate dynamic equation, e.g. for a voiced bilabial plosive, separate equations apply for lips and for glottis. The system works by means of a series of transformations, which first translate the abstract task (e.g. bilabial closure) into a physically defined tract variable (in this case lip aperture), and then transfer it onto particular *end effectors*, i.e. articulators (in this case lips and jaw) (Hawkins, 1992).

Articulatory Phonology thus offers a Dynamic Systems approach to phonology, according to which phonological representations are gestures, which are defined as dynamic systems: they are flexible, self-organising and multifunctional. They are multifunctional, in that different combinations of different types of constrictions are performed by the same small set of components (i.e. articulators). They are flexible, in that every gesture can be performed in various ways (from subtle differences in voice onset time, to large distortions due to, for example, chewing gum). Finally, they are self-organising, in that the activity of the components is adjusted on-line to the requirements of the constriction to be achieved.

Furthermore, Browman and Goldstein (1995) argue that articulatory processes are a sub-system of phonological organisation. Under this account, phonetics (in this case, articulation) and phonology are in fact two levels of the same system. On the articulatory (micro) level, the degrees of freedom for articulators include all the configurations and types of constriction that the human vocal tract is capable of producing. On the cognitive (macro) level, the degrees of freedom are constrained by the defined set of contrasts that a given language employs, which serve to distinguish between lexical items.

1.4 Articulatory approaches to language acquisition

Browman and Goldstein (1989) offer a way of thinking about how phonological acquisition can be seen in the gestural framework. In essence, articulatory gestures are thought to emerge as non-linguistic actions, and to then be gradually differentiated, and finally refined until their precision and the patterns of their coordination are adult-like. At the same time, the gestures would gradually become harnessed as units of phonological contrast, leading to the emergence of language-specific phonology. Phonological development would thus proceed by gradual mastery of articulatory actions and their co-ordination.

Much research has been done investigating the development of articulatory gestures in children. Although babbling resembles other rhythmic patterns, e.g. chewing, Moore & Ruark (1996) and Ruark & Moore (1997) found that in two-year-olds and in 15-month-olds mandibular muscle activation patterns were different for linguistic and non-linguistic tasks. This means that children develop task-specific patterns of jaw, lip and tongue movement very early in development. The Articulatory Phonology hypothesis that linguistic gestures are adapted to the requirements of language production in ontogeny thus requires further investigation.

However, several researchers have observed that early speech gestures appear to gradually progress towards differentiation, which would confirm the second part of Browman and Goldstein's hypothesis. Davis and MacNeilage (1990, 1995, 1995; MacNeilage, 1998) observed that babbling emerges as the motoric activity of rhythmic jaw movement, with little or no activity from the lips or tongue. This claim is supported by the findings of Green et al. (2000). In this study the authors also investigated the jaw and lip movement patterns in older children. They found that while one-year-olds mainly exhibited ballistic jaw movement, as previously noted by Davis and MacNeilage, two-year-olds were also consistently producing lip movement, although both upper and lower lip moved as a single unit. Among six-year-olds, the coordination of jaw and lips was similar to that of adults. Green and his colleagues conclude that it is likely that the development of gestures proceeds through increasing differentiation and then refinement of gestures, from basic jaw movement, to differentiation between lips and jaw, to coordination of all articulators.

It appears that approaching the development of articulatory and phonetic capabilities of the child in terms of mastering the motor control required for producing speech sounds (i.e. differentiating and refining individual gestures) has been a fruitful direction in developmental research. It is beyond doubt that articulatory control plays a large part in a child's phonological development. As Green et al. (2000) point out, acknowledging the trajectory of articulatory development can help us explain common phonological phenomena in children. Certain sounds and certain patterns of coordination cannot be produced by the child from the beginning. For example, ballistic jaw movement in the beginnings of speech can explain many children's tendency to produce CVCV shapes more often than others. Studdert-Kennedy and Goodell (1995), adopting an Articulatory Phonology approach, examined the production of an eighteen-month-old child, and found that the child's errors were best described in terms of problems with gestural co-ordination. On the one hand, the errors involved paradigmatic confusions between gestures. For example, the word *elephant* was produced as [a'mbɪn], [a'mɪn], [a'fɪn] and [a'pɪn], showing variable constriction degrees for the medial labial. On the other hand, the child employed articulatory routines, such as consonant harmony and labial-alveolar melody, which demonstrated preferred syntagmatic relations between gestures, i.e. emerging patterns of gestural coordination.

However, a drawback of the Articulatory Phonology and related approaches is that they tend to focus solely on articulation. Although Browman and Goldstein discuss the two levels of granularity, phonetic and phonological, their focus on gestures appears to obscure the cognitive level of phonological development. While the studies discussed above demonstrate the dynamics of development on the micro, phonetic level, they do not investigate the simultaneous emergence of the cognitive linguistic structure. Rather, they bear close resemblance to the Motor Theory of Speech Perception (Liberman et al., 1967), which assumes that speech is perceived through one's own articulatory actions. This would imply that linguistic representations are in fact motor representations of one's own production. While the more recent gestural approaches differ from Liberman's theory in that they assume an emergent link between articulatory and auditory representations, they nonetheless often neglect the role of any higher-order phonological representations.

We discussed the problems inherent in focusing solely on linguistic structure in the mind, i.e. 'competence', and we argued that such an approach ignores the fact that 'performance' skills, including articulation, are developing in the child at the same time. By the same token, focusing solely on articulatory skills obscures the fact that each act of speech and each instance of listening to speech is processed in the child's mind, leading not only to changes in perception, but also to the emergence of a complex cognitive architecture. If the interaction of systems gives rise to structuration, then we cannot ignore either of the two components, and the changes that this interaction brings in each of them. Below we discuss the evidence for phonological systematicity, and we examine the specific problems that strictly articulatory approaches encounter in explaining it.

1.4.1 Early phonological systematicity

Vihman and Velleman (2000) discuss the issue of articulation vs. phonology in development. They argue that phonology is more than patterns of coordination emergent from the interaction between articulation and perception. Another aspect that has to be taken into account, and that mediates between the two, is each child's own generalisations across both the input and the output forms they experience. Vihman and Velleman see these generalisations as each child's individual solutions to the mismatch between the input and their own production. Therefore, while the conflict between the two is a result of the child's articulatory and perceptual limitations, the generalisations that these two types of constraints motivate are a separate, individual aspect of phonological development. There are signs of systematicity in children's production that clearly show the emerging phonological architecture.

After the child moves beyond the first words stage, one can see a gradual emergence of phonological patterns that constrain the child's production in a way that cannot be attributed solely to articulation. One particularly common type of such early patterns is *word templates.* The phenomenon was first brought to the attention of researchers in the 1970's (Waterson, 1971; Priestly, 1977; Macken, 1979) and since then it has been thoroughly studied. It has been observed that after the initial period of relatively accurate production (if articulatory limitations are disregarded), many children begin favouring word forms with a particular structure, which leads to regression in accuracy. Vihman and Velleman argue that this so called U-shaped curve in development is not compatible with approaches relying solely on motor control, which would be expected to improve with age.

Vihman and Velleman discuss two main aspects of word templates, which reflect two types of systematicity in early phonological development. Firstly, children who use word templates attempt forms of the structure that they are able to produce. Such a process, termed 'selection' by Vihman and Velleman, should not be considered a conscious strategy of the child (contra Menn 1971) but is likely to result from increased perceptual salience of the word shapes produced by the child. The second type of phonological systematicity is revealed by words whose structure is modified to fit the child's preferred pattern ('adaptation'). However, this process is unlikely to result from incorrect perception of targets, which has been repeatedly shown to develop ahead of production (Swingley, 2003; Swingley & Aslin, 2000; 2002). Therefore, how these patterns emerge remains an open question. Below, we will discuss research focused on explaining the emergence of phonological systematicity in children.

1.4.2 A motor account of systematicity

As we have mentioned, modern motor approaches attribute the emergence of target-like phonology to the interaction between articulatory and auditory percepts. It has been proposed that the gradual progress in coordination between different gestures, as well as the acquisition of language-specific constraints on that coordination, results from a feedback loop between the child's articulatory actions and their perception of the adult input. Guenther (1995) and Callan et al (2000) develop computational models of the child's gestures and their coordination, and the way in which they arrive at the target language-specific organisation. These models include feedback between speech production and auditory perception, as well the changing capabilities of the child in producing speech sounds. In this way, they are able to model phonological development by relying on the principles of task-specific dynamic organisation.

The role of the child's own production on the perception of input had previously been established by Vihman and her colleagues for the period of transition from babble to words in children. Vihman (1993) proposed an *articulatory filter* as the mechanism aiding early phonological development. According to Vihman, sounds produced by the child also become more salient to the child in the input, which in turn results in these sounds being attempted more often. The perception-action loop in the transition from babble to first words was then demonstrated experimentally by DePaolis et al. (2011), who showed that the sounds produced by children affect the sounds they attend to. Specifically, children who showed mastery of a given consonant attended to passages containing this consonant. Interestingly, children who had mastered more than one consonant showed the opposite tendency, attending more to passages containing consonants not yet mastered. This effect was also present in the study by Vihman and Nakai (2003), where children who had more extensive practice in a given sound (over 200 instances), also preferred to listen to passages containing other sounds. It would thus seem that what the child is able to produce interacts with what they perceive in a complex and constantly evolving way. A control parameter for the shift in children's attention to particular consonants that has been proposed is the Vocal Motor Scheme (VMS, McCune & Vihman, 1987), i.e. a well-practiced, stable consonant used frequently in babbling. McCune and Vihman (2001) demonstrated that the age of developing two VMS strongly predicted the age of the onset of word use - an effect later replicated by Keren-Portnoy et al. (2005; 2009) and Majorano et al. (submitted).

Westermann and Miranda (2004) present a model of how this connection between production and perception could develop in the mind. We will discuss their proposal in detail, as it specifically addresses the Articulatory Filter hypothesis and the VMS effects, as well as incorporating the hypothesis of mirror neurons, which has often been proposed as neurological evidence for motor speech representations. Westermann and Miranda's model is mainly based on the Hebbian theory of learning. In Hebbian learning, if activation of one cell excites activation in another cell, after a sufficient number of instances of repeated coactivation, the connection becomes strengthened and more stable. In this way, the two become associated, providing a basis for learning. In Westermann and Miranda's model, repeated coactivation between items in the auditory and the motor maps in the brain leads to the development of a strong sensorimotor coupling. As a result, perceived sounds activate the motor response, so that they can be reproduced. Since the motor response is based on the child's own production, as constrained by articulatory limitations, the imitation of the sound will not necessarily be faithful to target. However, perceived sounds that cannot yet be produced also trigger some activation in the motor units through the connected auditory units. In time, through continuous remapping of the connections, resulting from extended exposure to speech and changes in the vocal tract, the child production gradually achieves increasing resemblance to the ambient language. The implied element in this model are mirror neurons, which could be treated as a form of representation emergent from the perception-action link. Mirror neurons are motor neurons observed in monkeys, which fire whenever the action is perceived. Such representations would therefore be strictly limited to the link between action and perception, without any mediating process of organisation necessary.

Westermann and Miranda's model can thus account for bidirectional interaction between production and perception. Firstly, it can explain how the child's production is shaped by the ambient language. Therefore, it can account for the well-established finding that children's consonants and vowels move towards the target language already in babble (Boysson-Bardies et al., 1989; Boysson-Bardies & Vihman, 1991). Secondly, the model can also explain the VMS effects in the transition from babble to words, whereby the child's own production highlights the same sounds in their perception of the input. Finally, the same type of learning could be responsible for children's systematicity in attempting words that match their articulatory patterns ('selection'). However, there are two drawbacks to the model. First of all, like most motor approaches, it predicts steady progress towards target-like production. Improving motor skills and prolonged exposure to the ambient language should result in linear improvement in performance. Since nothing mediates between the motor and the auditory representation, and there is also no higher-order process that would integrate them into a single unit, there is no candidate for a process that could lead to a mismap between auditory and articulatory units in development, of a type that is observed in ('adapted') word templates. This is related to the second problem with the model, namely the very idea of representations that it assumes, i.e. mirror neurons.

Mirror neurons are a group of neurons discovered in monkeys (di Pellegrino et al., 1992; Gallese et al., 1996), which respond to both performed and observed goal-directed movement. Since these neurons are not activated before the onset of the monkey's action, and also do not result any covert muscle activity when the action is observed, they were hypothesised to form a basis for action understanding (di Pellegrino et al., 1992). However, an equivalent of these neurons in humans has not yet been unequivocally identified (Hickok, 2008), and their relevance for action understanding in monkeys or humans in general, and for language development in particular has often been questioned (Stamenov, 2002; Hurford, 2004; Hickok, 2008). As pointed out by Hickok (2008), even though a lesion in the 'mirror-neuron' brain region in monkeys has a negative effect on action performance, it does not disrupt action perception. Therefore, even in monkeys, the role of mirror neurons in understanding (i.e. representing) actions would be questionable. Furthermore, Stamenov (2002) provides a detailed list of properties of mirror neurons which make them unlikely to suffice as an explanation of the development of language in phylogeny or ontogeny. In particular, mirror neurons do not rely on intersubjectivity, do not facilitate sharing of experience, and they are limited to the here and now, not supporting propositional representations that can be recalled in the absence of the perceived action. Stamenov (2002), Hurford (2004) and Hickok (2008) all reach similar conclusions, stating that if we want to explain action understanding and language development in humans by referring to mirror neurons, it would mean that the human mirror neurons are nothing like the ones discovered in the monkey. In the light of that evidence, it seems unlikely that mirror neurons provide reliable support for motor approaches to language. Cognitive representations therefore still require investigation.

1.4.3 Towards a holistic dynamic systems account of systematicity

In contrast to motor accounts, Vihman et al. (2009) proposes an account of the emergence of templates based on exemplar theory of cognition, referring to ideas of Pierrehumbert (2003) (cf. Bybee, 2001 for a similar approach). In her exemplar model of phonology, Pierrehumbert identifies two main classes of processes contributing to the organisation of the phonological system. The first type are bottom-up processes, which enable grouping together the experienced exemplars by means of detecting similarities between them. In this way, categories emerge from dense groupings of similar items. The other types of processes are those that act top-down, i.e. enable categorisation of novel exemplars on the basis of the previously established classes. Based on this premise, Vihman attributes the emergence of templates to the onset of top-down processes acting upon categories based on the child's own production. Under this approach, dense categories based on the relative weight of the child's own forms (which are frequently experienced and strengthened by proprioceptive feedback) serve as 'magnets' for all new exemplars, which become modified in memory and production. Note that what distinguishes this approach from the motor approaches is the emphasis on the process of modification resulting from the organisation of the system, rather than from mismapping between perception and production. In other words, here, templates are early cognitive categories which constitute the *cause* of mismapping, while in motor approaches they would be its result.

The connection between perception and production, the circular nature of this connection, as well as the individual paths of development observed (different children will develop a different VMS) also support the idea that this linguistic organisation develops in children as a dynamic system. Vihman et al. (2009) integrate the findings from the two early stages of phonological development (i.e. babble to words transition and the emergence of templates), and offer a Dynamic Systems account of phonological acquisition. They present the stages in terms of phase shifts, resulting from the interaction of the child's input and output forms. Another piece of evidence which supports their view of templates as emergent from dynamic organisation of the early phonological system comes from the study by Vihman and Velleman (1989). The authors closely examined the emergence of word templates in a longitudinal case study of one child and found that there was an increase in variability of given structures before they became adapted as templates. This suggests that the coordination patterns that the child produces could be the building blocks of the child's phonological competence, which develops through a series of periods of individual systematicity surrounded by periods of variability.

In summary, there is extensive evidence that phonetic development can be studied as a dynamic system. Research within the Articulatory Phonology framework suggests that early articulatory and phonetic development is a process of emergence of task-specific, dynamically organised gestures, which interacts bidirectionally with the child's perception of the ambient language. Therefore, there are reasons to believe that the dynamics of development may be the same on both phonetic and phonological levels, supporting the ideas of Browman and Goldstein. Research by Vihman and colleagues implies that the same dynamic principles guide the development of phonological systematicity, which is guided by the interaction of perception and production and mediated by the emergence of child-specific systematicity. Nonetheless, the study of word templates as the higher level of dynamic phonological organisation is still in a very early phase.

Firstly, at the time of writing this dissertation, I am not aware of any studies, other than Vihman and Velleman (1989), which would examine variability as a function of developing systematicity. Investigating variability in this context is essential if we want to claim that word templates are a stable phase that emerges in development due to a dynamic transition. Given that the findings of Vihman and Velleman (1989) were based on only one subject, this idea remains to be further investigated. Secondly, while the development of articulation has been extensively studied, studies demonstrating the relationship between the child's own articulatory preferences and their later word templates are missing. It is important that we do not leave this relationship as a plausible theoretical concept, but that we look for evidence in its support. This study was thus designed to investigate the relationship between the two levels of the phonological system: the articulatory and the cognitive, to examine whether and how the higher level organisation acts to constrain the output, while also being formed by the output. Instead of focusing on the relationship between production and perception, as has often been done in the past, this study focuses on the relationship between production and early phonological systematicity.

1.5 Research objectives

It is hoped that this study might help to further establish the dynamic systems approach to child phonology as a promising direction in research. This goal is further motivated by the theoretical considerations discussed in section 1.1. If language can be shown to function as a dynamic system, then this new approach could provide genuinely novel solutions to the questions that have been a matter of heated debate in the field for the past fifty years. For this reason, this study is intended to constitute a small step on the way to changes in our thinking about language, and as such to contribute to the development of both theoretical and applied linguistics.

The above discussed findings in child phonology, i.e. the task-oriented development of articulation, the bi-directional interaction between production and perception, as well as the observed stages of phonological systematicity, suggest that child phonology may develop as a dynamic system. In this study, we examine longitudinal data from three children, in order to provide evidence that phonological development is best conceptualised as a process of transitions of a self-organising system that involves interaction between articulation and cognitive structure, as apparent in systematic whole-word generalisations.

However, the reader should bear in mind that this study is only a small step on the way to a definitive demonstration that language behaves according to the principles of DST. Such a demonstration would necessarily require a computer model and precise mathematical equations describing the dynamics of the proposed interaction between articulation and systematicity. It is beyond the scope of this study to develop such a model, since the approach first needs solid observational evidence that would confirm its applicability to phonological acquisition. This study is therefore intended as a proof of concept. In the theoretical sense, if successful, it could provide a theoretical alternative to Universal Grammar, but nonetheless possibly still remain on a comparable level of abstractness. This ambitious goal is hoped to be achieved by the research objectives outlined below.

Articulatory basis of substitution processes

The first objective of this study is to investigate whether child phonology operates on words assembled from articulatory gestures, as previously argued in Articulatory Phonology approaches. If so, then substitution processes found in child speech should be articulatorily motivated. In particular, it is expected that consonantal substitutions will not be systematic, and that they will not result in categorical changes of segments. In other words, we predict that consonants will vary with regard to one or two phonetic features, such as amount of closure (e.g. [b]-[w]), voicing (e.g. [t]-[d]), affrication (e.g. [t]-[tɕ]) and palatalisation (e.g. [t]-[tʲ]), but that they will not be substituted by segments which do not share most phonetic features with the target (e.g. [b]-[j]). In addition, we predict that these modifications will vary across words and across targets, and across tokens, showing that substitutions are due to on-line issues with production. Such a result would show lack of phonological motivation of those early processes and it would allow us to establish articulation as a factor in the development of phonology, rather than only a result of phonological generalisations. However, the methodological apparatus of Articulatory Phonology is not employed, as defining particular phase relations between gestures goes beyond the scope of this study.

Reciprocity between articulation and phonology

We have argued that articulation should be viewed as an important factor in the development of phonology, rather than as a performance issue that is independent of phonology. As noted earlier, the structure of dynamic systems implies reciprocity between different sub-parts of a system. As applied to phonology, it is postulated that there is bi-directional interaction between articulation and phonology, such that phonological processes are motivated by articulatory constraints, while articulation is constrained by the system of contrasts and interdependencies that a language employs. We can therefore hypothesise that in development, the articulatory constraints due to immature motor control of the child will result in child-specific phonological constraints, which in turn will further affect articulation. The first research objective of this study is to examine systematic modifications to words made by children, and to compare them to those same children's earlier production. The prediction is that each child's patterns will be rooted in that child's former articulatory preferences and routines, showing reciprocity between the two levels of phonological organisation.

Phase transitions

If child phonology is a dynamic system, then development proceeds through several stages of reorganisation of the system, which are triggered by a change of value in a control parameter acting upon that system. Therefore, periods of systematic modifications to words in children's production are taken to represent temporarily stable states which emerge and then disappear, and which in time lead to the system increasingly resembling adult phonology. It is thus expected that periods of systematicity in children's production will be preceded and followed by increased variability. If this variability can be found in articulation, then this will provide further evidence regarding reciprocity between phonology and articulation, and indicate that the two constitute components of a larger system. Furthermore, it should be possible to identify the control parameter that is responsible for the particular instance of reorganisation.

Nonlinearity and individuality

Dynamic systems develop in a nonlinear and individual way. Firstly, a control parameter can trigger reorganisation in a system that is not proportional to its influence. Secondly, it can only do that if the system is in a particular state. In phonological development, that implies that children's accuracy, as well as systematicity, will not show a linear improvement over time, but rather go through stages of regression due to phase transitions. In addition, a large amount of individual variation is expected across children. Which factors will prove crucial for the development of a child's phonological organisation will depend on the initial state of the child and their experience in production. Among other factors, this experience should be partly shaped by the child's personal tendencies in choosing words to attempt. It is expected that differences in what children choose to say will result in different patterns of phonological development.

While much work has been done on individual differences, and they have often been used as part of the explanation for processes found in child language (Farwell, 1985; Ferguson, 1986) they are often approached as systematic binary features (Nelson, 1973; Bates, Bretherton & Snyder, 1988; Bates, Dale & Thal, 1995). For example, Bates and her colleagues, in an attempt to account for individual differences, propose a way of classifying children into two types of learners: a more 'analytic' type and a more 'holistic' type. It appears that such a classification, instead of emphasising the importance of individual variation, results in just another tool of analysis which draws our attention away from what is truly individual in each particular child and from the uniqueness of each child's language experience. In this study, apart from individual qualitative analysis of each particular subject, the tendency to attempt challenging targets was selected as one individual strategy which could potentially affect the trajectory of phonological development. The interaction between this individual and extra-grammatical factor and other variables will be investigated in order to examine the potential of such factors to explain the path of phonological development.

In summary, this study advocates the view that it is the interaction of articulatory and cognitive processes that is of fundamental importance to the emergence of the phonological system. Dynamic Systems Theory is adopted as the framework that can incorporate individual differences, variability and articulation into the study of child phonology. The aim of the study is to investigate phonological development holistically, as a result of a combination of a variety of factors, and individually, as a process determined by each child's experience.

2. METHOD

2.1 Data

The data for this study come from longitudinal recordings of three children, two girls and one boy, pseudonyms Alison, Rebecca and Jude. All children were monolingual, acquiring English, and their parents were native speakers of English. Two of the children, Rebecca and Jude, were living in Wales, and Alison was from Yorkshire. Rebecca's mother was Scottish. The mothers therefore spoke Scottish, Welsh and Yorkshire dialects of English, and the accuracy of child forms was evaluated according to the phonetic realisation of the target in the respective maternal dialect. However, none of the differences in phonological strategies and templates of the three children could easily be attributed to the dialectal differences between their mothers, and therefore they are not considered relevant for the interpretation of the results of this study, or discussed in detail.

The data come from a larger study by Vihman et al. (in prep). In the current study, the children were selected on the basis of the availability of at least seven consecutive sessions, beginning at the 25 word point for each child. The 25 word point, that is the first session in which the child produced at least 25 identifiable spontaneous words, was selected as the first session included in the analysis. The threshold of 25 words is often used in child phonology studies (Vihman & Velleman, 2002; Vihman et al., in prep), to represent the developmental point where children are still at an early stage of word learning, but they are also beyond the very first words, which often overlap with the final stages of babbling. Since templates are typically not observed in the very first words, the 25-word point was selected as the first data point. This procedure also has the advantage of matching children according to their progress in producing words, rather than according to age. All children were also at the one word stage (MLU=1.0) in the first session.

There were seven 30-minute sessions for each of the children, with approximately a month in between. Although it would be advantageous to obtain data with high density, it follows from the theory of dynamic systems that the observable dynamics

should be the same on any level of granularity. Therefore, while this sampling might have obscured faster-developing small changes in production, the observed trajectory of development was expected to reflect the overall dynamics of the system. It was decided that monthly recordings, which are commonly used in phonological acquisition studies, would be sufficient at this early stage of application of DST to child phonology.
Table 1 presents the ages of the children at the time of the sessions, along with the number of recorded types and tokens.

Session Number	Jude			Rebecca			Alison		
	Age	Types	Tokens	Age	Types	Tokens	Age	Types	Tokens
1	1;3.11	41	188	1;6.28	34	78	1;4.24	38	163
2	1;3.29	39	152	1;7.19	62	215	1;5.23	39	204
3	1;5.10	62	196	1;8.12	71	264	1;7.0	110	253
4	1;6.22	72	218	1;9.21	58	165	1;7.24	49	247
5	1;8.2	72	174	1;11.1	80	226	1;9.5	79	441
6	1;9.20	94	222	2;0.23	74	180	1;10.7	83	411
7	1;11.2	98	269	2;1.20	101	189	1;11.06	95	533

Table 1: Ages of subjects and number of types and tokens recorded in each session.

Although only spontaneous words were considered when identifying the 25 word point, both spontaneous and imitated child utterances were included in the rest of analyses. The only utterances that were excluded were words which did not have an identifiable target, as well as onomatopoeia without a stable adult target (e.g. 'pig sound'). Individual words were also extracted from multiword utterances, excluding function words and words which underwent reduction or coarticulatory processes.

For each session, two word lists were compiled. One single variant, which included only the most adult-like child form for each target, and one multi variant, which included all child forms which differed in consonants and syllable shape. For example, if the child said /mæmɪ/, /mʌmɪ/ and /maβɪ/ for *mummy*, the single variant list would only include /mʌmɪ/, as the most accurate one, and the multi variant list would include /mʌmɪ/ and /maβɪ/, because the consonants are rendered differently, but it would not include / mæmɪ/, as differing from /mʌmɪ/ only in the quality of the first vowel. Vowels were excluded from the analysis due to being highly variable in young children and difficult to transcribe accurately.

The single and multi variant lists then served as the basis for the rest of analyses. Four variables were identified as relevant for the study:

(1) accuracy, understood as motoric development leading to eventual articulatory precision and progress in co-ordination of articulatory gestures;
(2) systematicity, understood as top-down processes of generalisation across different word forms;
(3) variability, understood as lack of systematicity in output constraints or in the realisation of these constraints;
(4) boldness, understood as the child's individual inclination to attempt consonants that are challenging for children at the early stages of development.

In addition to the above four variables, a qualitative analysis of each child's progress was performed.

2.2 Qualitative analysis

Two aspects of child word production were analysed qualitatively. Firstly, the development of word shapes was followed across sessions on the basis of the single variant word lists. In particular, the analysis focused on production of variegated syllables within disyllabic words (C1VC2V) and on the production of codas in both mono- and disyllabic words. The analyses involved detailed examination of child forms sorted by the complexity of targets.

The second aspect of the developing word production that was analysed was the skill in producing particular consonants. Both the single and the multi variant word lists were analysed in terms of the processes that affected consonants, to allow for across-session comparison of how the child's production was developing. The words were examined for the presence of systematic segment substitutions (as reported in literature, e.g. Templin, 1957; Grunwell, 1995; Dodd et al., 2003), so that the source of modifications could be established. The variability/stability of the processes was also assessed.

The purpose of the qualitative analysis was to answer the question of whether the observed modifications to the syllable structure of words and to individual consonants could be explained by production issues related to articulatory co-ordination. Producing variegated syllable onsets and codas constitute the first important challenges to the child after the transition from babble to words. To be able to produce words, the child must learn to co-ordinate different onsets of syllables (as opposed to repeating the same syllable, which is most often the case in babble), as well as to produce closed syllables (which do not typically occur in babble). Furthermore, arriving at stability and precision in producing individual consonants is another difficult task for the child at the early stages of word production. These skills were challenging to all three subjects, albeit to a varying degree, and a detailed analysis of how they developed in each of the children is presented in Chapters 3-5.

2.3 Accuracy

The measure of accuracy used was Percentage of Consonants Correct (PCC, Shriberg & Kwiatkowski, 1982). This analysis was based on single variant word lists. Every consonant produced by the child was compared with the target and the percentage of accurate consonants was calculated for each session. Unlike in the original method, where the percentage is calculated on the basis of 100 words, all words in every session were included, as most sessions did not exceed 100 words. Only consonantal errors were counted (as opposed to syllable shape errors), regardless of whether the consonant was misplaced in the child form. Furthermore, cases of substitution were only considered inaccurate if they were phonemic, i.e. when the substituted consonant was also present in the target language. Thus, if the child produced *fish* as /ç/, the final consonant was marked as correct, even though it was not entirely precise, and even though the rest of the word was missing. In addition, dark /ɫ/ vocalisation was not marked as inaccurate, following the assumption that the transcription of vowels cannot always be reliable.

It must be noted that such procedure is likely to overestimate children's accuracy. The fact that only the most accurate child forms are analysed, and that non-phonemic errors and word position errors are not counted means that it is relatively easy to obtain a high score. It was assumed that owing to this type of analysis the trajectory of development of accuracy would not be affected by comparisons with adult language that are too demanding for children at the very early stages. The purpose of this analysis was thus to reliably assess children's progress in producing individual consonants. In addition, subjects' consonant inventories in the first and the last session were analysed, to provide further information regarding the children's articulatory skills. Target-like production in at least two different words was needed for a consonant to be considered as acquired (although at this early stage, it would be more precise to say that it was in the process of being acquired). The number of consonants produced accurately at least in two targets within a given session was then compared to the number of all consonants of English, disregarding the voicing distinction (therefore, e.g. [p] and [b] were treated as a single consonant). The glottal fricative [h] was excluded, due to the fact that it was rare among targets, as well as because it is often omitted in the adult language. The size of the consonant inventory was then calculated as a percentage of accurate consonants among all target consonants (excluding [h] and the voicing distinction resulted in 15 target consonants).

2.4 Systematicity

The measure of word shape systematicity in this study was adapted with slight modifications from Vihman et al. (in prep.). The purpose of this analysis was to obtain a measure of how similar the child's words were to one another. In order to ensure that systematicity was not overestimated, only the single variant word lists were included. All words were divided into categories depending on the syllable shape of the word. Most shape categories were defined purely in terms of syllable structure, without specifying the particular consonants or vowels (i.e. CV, CVV, CVC, CVCV, VCV, VCVC, CVCVC). However, if any of the three children showed a clear preference for what type of consonant or vowel was used in a given position in the word (i.e. having at least three words modified for this purpose in any session), that was added as a specified category to the analysis of all subjects. For example, because Rebecca strongly favoured final fricatives in session 3, a CVfr category was added.

Next, the child forms in each session were assigned to the word shape categories and examined with regard to whether their shape matched the target (i.e. they were 'selected') or was modified to fit the preferred shape (i.e. they were 'adapted').. Errors that did not affect syllable structure were ignored. For example, if *car* was produced as [ga:], the inaccurate voicing of the onset stop was ignored and the word was considered to be an accurate ('selected') member of the category CV. The only exception were substitutions which resulted in one of the specific word shapes, e.g. the CVfr shape discussed in the previous paragraph. For example, *dog* produced as [doχ] was taken to represent an instance of syllable shape modification aiming at a CVfr shape, rather than a segmental substitution, on the basis of the fact that this syllable shape was often preferred by one or more children. This child form was therefore treated as 'adapted'.

A slight modification to the original way of calculating the score in this study was introduced in quantifying 'selection'. In the original procedure, any category that made up for over 10% of the child forms was considered to be selected by the child. In this study, the 10% cut-off point was replaced with the frequency of the categories in attempted targets of the children. Child-attempted targets were coded for word shape, which resulted in an estimate of how frequently a given shape appears. This was done for two reasons.

Firstly, by calculating target frequency it was possible to assess more accurately whether the child has a genuine preference for a particular word shape or whether their production reflects the frequency of that shape in what targets are available in the ambient language. For example, some categories constituted over 10% of targets, which made it impossible to establish whether a child who produces 10% of a given word shape does so because of a genuine preference, or whether they reproduce the target frequency. Secondly, calculating target frequency allowed to identify cases of selection which did not exceed 10%. For example, some word shapes (e.g. V[glide/glottal]V) proved to be extremely rare in targets, and yet appeared much more frequently in child speech, even though their frequency did not exceed 10%.

This modification was considered particularly important for the cases where the child did not adapt any targets to fit the preferred pattern, but selected a large proportion of similar targets. Comparison with target frequency assured that the preference did not come from a particular bias in targets which are typically available to children acquiring English. Calculating the frequency on the basis of targets, rather than on the basis of adult English, ensured that the measure was based on the actual intake of children. At the same time, comparing word shapes of particular children with frequency in targets of other children, as well as other sessions, ensured that the measure was not biased by any particular child's selection strategy.

The final step of the analysis was assigning points to each of the words, on the basis of whether they were selected or adapted, and whether the category as a whole exceeded target frequency. For categories that did not exceed target frequency by more than 5%, each selected word was assigned 1 point, and each adapted word 2 points. For categories that exceeded target frequency by more than 5%, i.e. appeared to be favoured by the child, selected words were assigned 2 points and adapted words 3 points. The total number of points, divided by the number of words gave the template score (T score) for each session, which was used as a measure of word shape systematicity. Table 2 presents an example of the procedure.

CVʔ < target frequency		**Pts**	**C1VC1 > target frequency**		**Pts**
Target	Child form		Target	Child form	
that	*daʔh*	*1*	*mum*	*məm̥ˑ*	*2*
car	*kaʔ*	*2*	*catch*	*kʰʊaʔkʰ*	*3*
			duck	*kʰakʰ*	*3*

Table 2. An example of the T score procedure. 'Adapted' words are marked in red.

The 5% over target frequency cut-off point was established through qualitative analysis, which revealed that this value allowed for the most accurate description of the data. In particular, exceeding target frequency by under 5% was common across children and categories, while production exceeding target frequency by over 5% usually appeared in sessions where a given category dominated the child's repertoire significantly above this value.

The 1-3 scale of points assigned to the words was adapted from the original procedure, where it is meant to reflect the difference between selection (1pt), adaptation (2pts) and the combination of the two, i.e. adapting words to a category that is also selected (3pts). However, it must be noted that it does not allow for a clear distinction between selection and adaptation. For example, a high T score could indicate that the child is selecting a large number of similar words to produce (without making any modifications to targets), or that the child has several categories of shapes they can produce and they adapt all other words to fit those shapes (but the pool of shapes nonetheless remains diverse). The rationale here is that the score is meant to reflect the overall systematicity, understood as the child's phonological organisation being based on the shape similarities across words, regardless of how that systematicity is reflected (i.e. by selection or adaptation). As such, it was used in this study as a general measure of phonological systematicity, and it was only intended to indicate whether the child's modifications to words were random or organised. It was assumed that individual differences between different strategies that the T score is not sensitive to will be revealed by qualitative analysis. The comparative results of the T score analysis with emphasis on the selection-adaptation distinction are discussed in detail in Chapter 6.

2.5 Variability

Overall variability was calculated as a ratio of the number of word types which had at least two different phonetic forms to the total number of word types that were produced more than once. All available phonetic detail of consonants was considered when qualifying forms as different, including voicing. For example, /tadɪ/ and /dadɪ/ for *daddy* would be counted as two different forms (as customary in studies of English, voiceless unaspirated stops were transcribed as [d], and aspirated stops as [t]). In addition, variability in syllable shape was also included. Vowel quality was disregarded, but the difference between a single vowel and a diphthong was marked (e.g. /dadɪ/ and /dadɪə/ were considered different).

The reason for using only words which appeared in more than one token in a given session was to avoid underestimating variability by including words that could not be variable by the sole virtue of having only been uttered once. In this way, the effect of the type/token ratio in a given session was minimalised, since only multitoken words were analysed. For example, if a child produced 100 words in a given session, but only ten of them were attempted several times, and five of those with different phonetic outcomes, the variability measure would still be relatively high at 5/10 (=50%). Therefore, despite a relatively small overall percentage of variable words (5 out of 100) resulting from sampling, variability could be established only among the relevant words. In addition, a type of binary score was used, such that words were either considered stable (uttered more than once, but only in one phonetic form), or variable (uttered more than once, in more than one form), and the scale of variability of individual words was therefore not assessed. This was also done in order to minimalise frequency bias, which could lead to words attempted more often receiving a higher variability score. For example, if a child produced twenty tokens of one word, with fifteen different phonetic variants, this word would count the same as for a child who produced one word three times, with only two different phonetic variants. While not suitable for comparing variability across words, variability measured in this way was intended to provide information regarding the overall stability of word forms in the child's system.

2.6 Boldness

The last variable in the study was boldness. This was intended to represent the child's individual approach to consonants which have been shown to be typically acquired at later stages of language development than the children in this study. These consonants include fricatives ([ʃ], [ʒ]), affricates ([tʃ], [dʒ]) and liquids ([l], [ɹ]). Indeed, none of the children had mastered these consonants before the beginning of the study. The single variant word lists were examined and the number of fricatives, affricates and liquids was counted, and then compared to the total number of consonants attempted by the child. The indication of the child's boldness in attempting challenging consonants was thus the percentage of those consonants among all consonants the child attempted in a given session. It was expected that there would be an observable interaction between how many difficult sounds a child attempts and how accurate, variable and systematic their words are. Furthermore, examining boldness was hoped to reveal the child's individual approach to learning. It has been argued that children often employ avoidance strategies in acquisition.

Boldness was thus meant to help to distinguish between actual skill in producing consonants and avoidance strategies that dictate which consonants are to be attempted.

2.7 Questions

The chapters that follow present the results of the above analyses. First, the qualitative analysis of each child along with a brief discussion of the development of all variables for that child are presented in Chapters 3-5. Then, the trajectories of all measured variables are compared across children in Chapter 6. The discussion of results is therefore focused around the four issues outlined at the end of Chapter 1, which can be summarised as follows:

(1) Is there evidence that segment-based processes are articulatory in essence and follow from on-line difficulties?
(2) Can the emergence of phonological systematicity (top-down) be traced back to earlier articulatory processes (bottom-up)?
(3) Do the periods of systematicity evolve through phase transitions, surrounded by periods of increased articulatory variability?
(4) Is development non-linear and is it related to individual tendencies in production?

The detailed analysis of accuracy, systematicity, variability and boldness is intended to provide answers to the four research questions which could help us determine whether child phonology can be treated as dynamic system.

3. ALISON

3.1 25-word point

3.1.1 Consonant inventory

Alison first produced more than 25 spontaneous words in one session at the age of 1;3.21. In that session, 38 different words were recorded, and it is the first session included in the analysis. The child began with a limited inventory of accurate consonants, which consisted of only 5 segments out of the 15 English consonants included in the analysis (33%). Table 3 presents Alison's consonant inventory.

Table 3														
	Bilabial		**Labio-dental**		**Dental**		**Alveolar**		**Post-alveolar**		**Palatal**		**Velar**
Plosive	p	b					t	d					k
Nasal	m						n						ŋ
Trill													
Tap/Flap													
Fricative			f	v	θ	ð	s	z	ʃ	ʒ			
Affricate									tʃ	dʒ			
Glide	w										j		
Liquid							l	ɹ					

Table 3: The consonant inventory of English, with consonants present in Alison's repertoire in session 1 highlighted in grey.

A velar stop only occurred once in this session. Furthermore, although Alison did not produce affricates, liquids and fricatives consistently, there was one occurrence of /tʃ/ (*choo-choo* [tʃɪ^{h}tʃəu]). In addition, the child produced one non-target final fricative /ɸ/ (*push* [pəɸ], *woof* [ɔɸ]). Nevertheless, the fricative /ɸ/ was substituted for two different target consonants, and the affricate /tʃ/ in most other tokens of *choo-choo* was reduced to stop (e.g. [dʊduː]). The fact that these consonants were produced very inconsistently and very rarely suggests that Alison was only beginning to learn them, and they cannot yet be considered fully acquired.

The consonants that Alison produced most frequently were voiced labials /b/ (9 words) and /m/ (5 words). In general, she appeared to prefer voiced (i.e. voiceless unaspirated) consonants, as even stops that were inaccurate were usually voiced (e.g. *truck* [gʌʔ], *stop* [ʔbɑʔ]). She also produced many glottal stops, particularly in coda position.

3.1.2 Word shape inventory

The constraints on word and syllable shape that could be observed for Alison in session 1 are those related to babble: lack of codas and frequent use of consonant harmony. These constraints often, although not always, resulted in modification of targets that made them match the preferred shapes. Thirty-two percent of all child forms were the result of such an adaptation.

CVCV

Almost all disyllabic words that Alison produced had the same consonant repeated in both syllable onsets. Out of 15 CVCV child forms, 8 have the same consonant repeated in the target, 6 are adapted by Alison to that form, and only 1 is produced with a different C2. Table 4 presents all CVCV child forms from session 1 (doggy /tudəː/ and help please /wəʔpʰjəʊ/ are treated as harmony despite the differences in voicing and/or type of closure, as the substituted consonants share more features with the other consonant in the word than with the target).

Table 4					
C1VC1V (select)		**C1VC1V (adapt)**		**C1VC2V**	
baby	bɛʰʔbɒː	*doggy*	tudəː	*help please*	wəʔ pʰjəʊ
bubbles	bʊboʊ	*grandma*	mʊmaɪ		
bye bye	baʔbʊʔ	*milk please*	mɛʰ muː		
choo choo	tʃɪʰtʃəu̥	*more please*	nmɛʰəməː		
doodles	deɪʔdu	*thank you*	daʔdɔʰ		
mummy	mæmə	*yes please*	mɛʰʔmə		
night night	nɪʰʔnaʰː				
quack quack	gæʔgaʊ̥				

Table 4: Alison’s CVCV child forms in session 1.

As a side note, it is perhaps worth noting that four of the targets in table 3 are not in fact single words but expressions with the word *please* (*milk please*, *more please*, *yes please* and *help please*). However, the fact that the word *please* did not appear on its own in this session, and the fact that most of these utterances are affected by consonant harmony suggest that the child treated them as one unit. This interpretation is further supported if we consider the fact that the child was explicitly taught to produce these combinations by the mother, which meant they were usually imitated. The short dialogue below is representative of many that were recorded:

CHI: [m:ɛ]

MOT: More, good girl.

MOT: Say 'more please'.

CHI: [nmɛʰəmə:]

Therefore, *please* was usually added by means of reduplication at the request of the mother. Although the vowel was often different than in the original word, it was never a high vowel that could have come from the target *please*, confirming that these utterances were learned as chunks. These reduplicated holistic utterances might have led to consonant harmony being further entrenched.

Coda

Alison did not produce codas in disyllabic words (all of those were omitted in child forms), but she had developed her individual way of dealing with codas in monosyllabic words. She mostly attempted monosyllabic targets with voiceless stop coda, and in great majority of cases these were replaced with a glottal stop.

The glottal stopping of codas was often adult-like, if the target was an alveolar stop. In the two words that were not adult-like, an alveolar stop from onset appeared to have been metathesised with the labial and velar coda, and then glottalised (*truck* [gʌʔ], *stop* [ʔbɑʔ]). It thus appeared that Alison only used final glottal stop accurately, i.e. for voiceless alveolar stops, although that sometimes required modifying the words for the stop to appear in coda. Further evidence for the child's accurate use of glottal stopping comes from the words in which the coda was retained in at least one token, none of which had an alveolar stop in either onset or coda in the child form. Most of these had a labial consonant (stop, fricative or glide) in both onset and coda. Table 5 presents mono- and disyllabic targets with coda.

Table 5							
coda		**coda deletion CVC**		**coda deletion CVCVC**		**coda glottal stopping**	
map	dːæb̚			*bubbles*	bʊboʊ	*boat*	bɔːʔ
pop	pɛp̚			*doodles*	deɪʔdu	*boot*	buʔ
push	pəɸ			*help please*	wəʔ pʰjəʊ	*night*	ʔnɪʔ
woof	ɔɸ			*milk please*	mɛʰ muː	*stop*	ʔbɑʔ
				more please	nmɛʰəməː	*truck*	gʌʔ
				night night	nɪʰʔnaʰː		
				quack quack	gæʔgaʊ̥		
				yes please	mɛʰʔmə		

Table 5: Alison’s child forms for targets with coda in session 1.

3.1.3 Consonantal variability and accuracy

Despite having only a small number of consonants at her disposal, Alison did not frequently mispronounce target consonants, but rather focused on targets that contained sounds she was able to produce. In this session, the only regularly appearing segmental substitution (i.e. occurring in at least 10% of child forms) was gliding and vocalisation of liquids (e.g. *ball* [bəʊ], *bubbles* [bʊboʊ]). However, the child’s consonantal accuracy was affected by whole word processes, such as consonant harmony and coda omission.

As a result, the accuracy of onset position was relatively high (73%), since most onsets were selected to fit Alison’s skills in producing consonants, and thus they did not undergo many modifications. The accuracy of codas was lower, due to many codas being omitted. However, since many glottal and several supraglottal codas were produced, it was still on a moderate level (57%). The lowest accuracy was recorded in medial position. The widespread use of consonant harmony resulted in the accuracy of this position being as low as 33%. Therefore, despite few segmental substitutions, the whole word processes made the overall accuracy relatively low, at 57%.

In session 1, Alison produced 163 tokens, i.e. four times more than targets. The words which appeared in more than one token exhibited high variability, with 70% of them varying across tokens with regard to consonants and syllable shapes. There were several processes that were most often the cause of variability of consonants. The first type of variation included processes that could be considered simple mispronunciations of particular consonants. In Alison’s data, the most common source of variability appeared to be lack of co-ordination between articulatory features. This was true particularly for the labial nasal /m/, which often appeared with an added consonant resulting from the nasalisation not being co-ordinated with lip movement (e.g. *mummy* [mæmə], [mæmwə];

more [mɛ:], [mnɛ:]). Furthermore, there was variability in codas, which were variably glottalised (e.g. *boat* [bɔ:ʔ], [bəʊpʰ]). These articulatory processes were present in 70% words that appeared more than once in the data, as the child's articulatory skills at this early stage were not yet stable enough to make it easy to pronounce words in the exact same way several times. However, almost no variation in voicing was recorded (most consonants were voiced).

The remaining cases of consonantal variability was explained by variable gliding of liquids (e.g. *ball* [bɔ:], [bəʊw]) and affricate reduction (e.g. *choo-choo* [tʃɪtʃəu], [du:du::]). This type of variability implies that the processes in question were not entirely systematic, i.e. did not apply every time a given word was uttered. It suggests that they constituted varying attempts to produce the words accurately. Table 6 presents all variable words from session 1.

Table 6	
ball	bəʊ
	bəʊwʰ
	bɔː
boat	bɔːʔ
	bəʊpʰ
	bɔːhp̚
boy	bɔɦː
	bɛɔʰ
choo choo	duːduːː
	ʤuːʤuː
	dəʔʤəʊ̥
	dʲəːʔduh
	tʃɪʰtʃəu̥
	tuduː
doggy	dʊtɛɒː
	tudəː
moo	m̩ːuː
	m̩ːːnuː
more	mːɛ
	mn̩ɛː
	baːəə
more please	mɛʰ mɔː
	ʔmuːubʷæʰ
	nmɛʰəməː
mummy	mæmə
	mæmwə
pop	ʔβʌʔ
	pɛp̚
	bəʔ
	bɛp̚
yes please	mɛʰʔmə

Table 6: Alison's child forms with variable consonants in session 1.

Several other words exhibited variability with regard to syllable structure, mostly due to vowel insertion in the beginning of the word (*mummy* [mæmə], [əməmɛʰ]) or at the end of the word (*stop* [ʔbɑʔ], [bɔːʊ]). There was one instance of final fricative insertion (*mummy* [waːʔmaɪç]). Table 7 presents all tokens with varying syllable structure.

Table 7	
ball	b:ə:wʊ
	bəʊ
boot	buʔ
	ʙuʔhʌ
mummy	əməmɛʰ
	mæmə
	wa:ʔmaɪç
quack quack	dæʔdɛk̚
	gæʔgaʊ̥
stop	bɔ:ʊ
	ʔæɸ
	ʔbɑʔ
more	əmeʊ
	m:ɛ
night	nijɪʔ
	ʔnɪʔ
	n̩:jəʔɛ

Table 7: Alison's child forms with variable syllable structure in session 1.

3.1.4 Section summary

As we have seen, Alison was selecting words according to her skills in producing consonants, but only initial consonants were selected in this way. Only 18% of word initial consonants were affricates, fricatives, liquids or clusters, and the majority of the target words began with a labial consonant. In comparison, 74% of medial consonants belonged to the challenging categories, which were outside the child's repertoire.

However, the modifications that these challenging consonants underwent were rarely segment substitutions, and most often involved the whole word process of consonant harmony. All but one disyllabic words produced were of the C1VC1V type.

Words with codas made up 26% of all targets. Alison did not produce codas consistently, but she found ways of dealing with codas in monosyllabic words by means of glottal stopping (which usually appeared to conform to the target rule, mostly affecting voiceless alveolar stops), or else mainly selecting words with labial harmony between onset and coda. It is likely that the tendency to replace final stops with glottals came from parental input, since glottal stopping of alveolar codas is common in English.

In summary, in session 1, Alison appeared to be a child who could not yet produce all of the target consonants, and whose production was further constrained by the very systematic whole-word process of consonant harmony, as well as by difficulties with codas. Her volubility, coupled with imprecise articulation of consonants, resulted in high variability (70%). The child's word forms were affected by systematic whole word processes, making most of her words similar to one another, which lead to a fairly high T score of 2.06. At that stage, however, selection was still preferred to adaptation, and the overall boldness in attempting challenging targets was not exceptionally high (46%). Table 8 presents a summary of all measured variables for session 1.

Table 8	
T score	2.06
accuracy	57.0%
variability	70%
boldness	56%
consonant inventory	33%

Table 8: Values of measured variables for Alison's session 1.

3.2 CVCV

3.2.1 Overview

At the beginning of the study, consonant harmony appeared very frequently in Alison's disyllables. In session 1, 40% of all words were of the C1VC1V type, and almost half of these words were adapted from targets with two different consonants. Throughout the study, Alison's use of consonant harmony gradually decreased, and an increasing number of C1VC2V words appeared. However, the advance was very slow, and in the last session words with consonant harmony were still almost three times as frequent in Alison's production as in targets (16%, target: 6%). C1VC2V words did not exceed 5% in the first three sessions, but they reached target frequency in session 6 (13%, target: 14%). Figure 1 illustrates changes in frequency in the two categories across sessions.

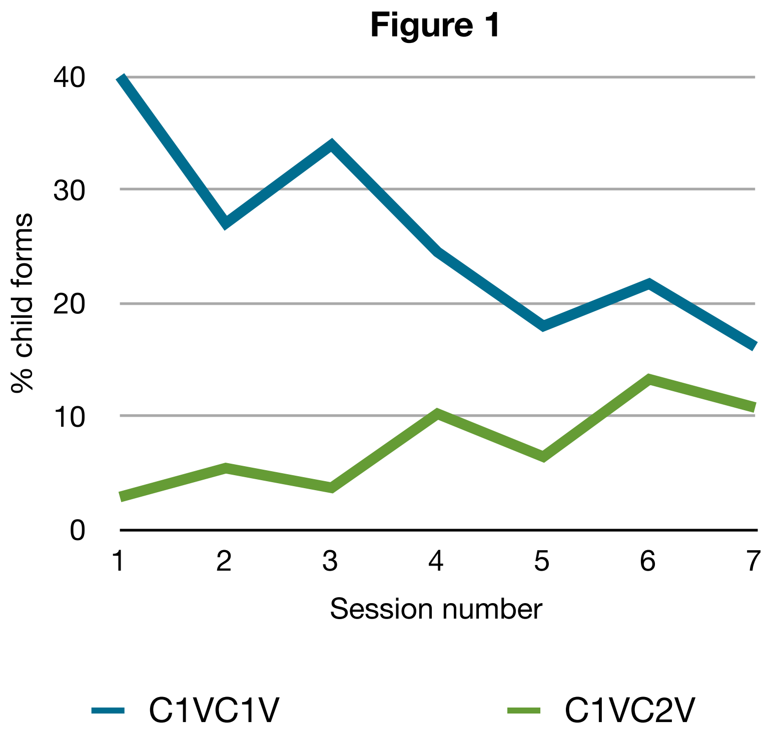

Figure 1: Percentage of C1VC1V and C1VC2V child forms across sessions (Alison).

The extensive use of consonant harmony, along with other simplification processes that will be discussed, made it possible for Alison to attempt many targets containing consonants that were outside her repertoire. In session 3, the child produced 110 different words, i.e. more than any of the three children in any other session. She also attempted more trisyllabic words than the other two subjects. Frequent use of systematic patterns thus corresponded to high boldness in attempting challenging targets. This was particularly apparent in word medial position, where almost 80% of target consonants were fricatives, affricates and liquids. The boldness decreased along with the decreasing use of the pattern from session 3 onwards, to increase again in the last session, when accuracy improved. Figure 2 presents the percentage of attempted difficult consonants in word onset and word medial position across sessions.

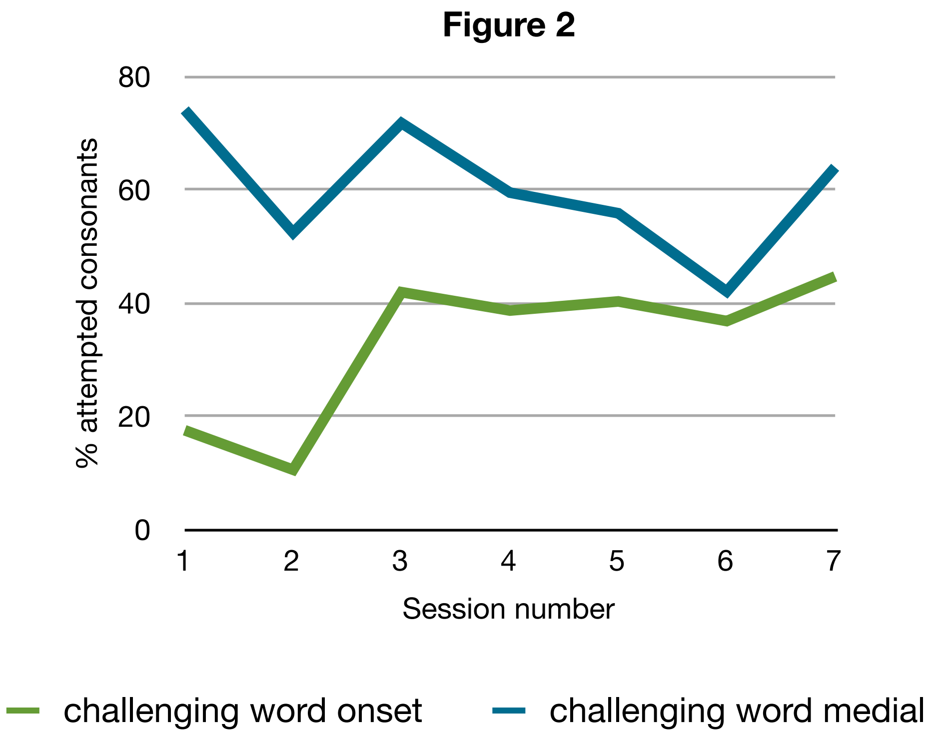

Figure 2: Percentage of challenging word initial and word medial consonants among all attempted consonants across sessions (Alison).

Thus, throughout the study, there was progress in Alison's production of variegated consonants in di- and multisyllables, but that process was slowed down by the fact that many consonants were still outside the child's repertoire, and, perhaps more importantly, by Alison's eagerness to attempt many challenging words. These factors were particularly apparent in session 3, when a large number of words were attempted, and when word templates were the most widespread. That session was the point of lowest accuracy in both word onset and word medial position, and also of the lowest variability, resulting from the fact that the pattern was strong and child forms became very predictable. After session 3, however, accuracy improved, which was accompanied by increased variability. Figure 3 presents variability and accuracy in word onset and word medial position.

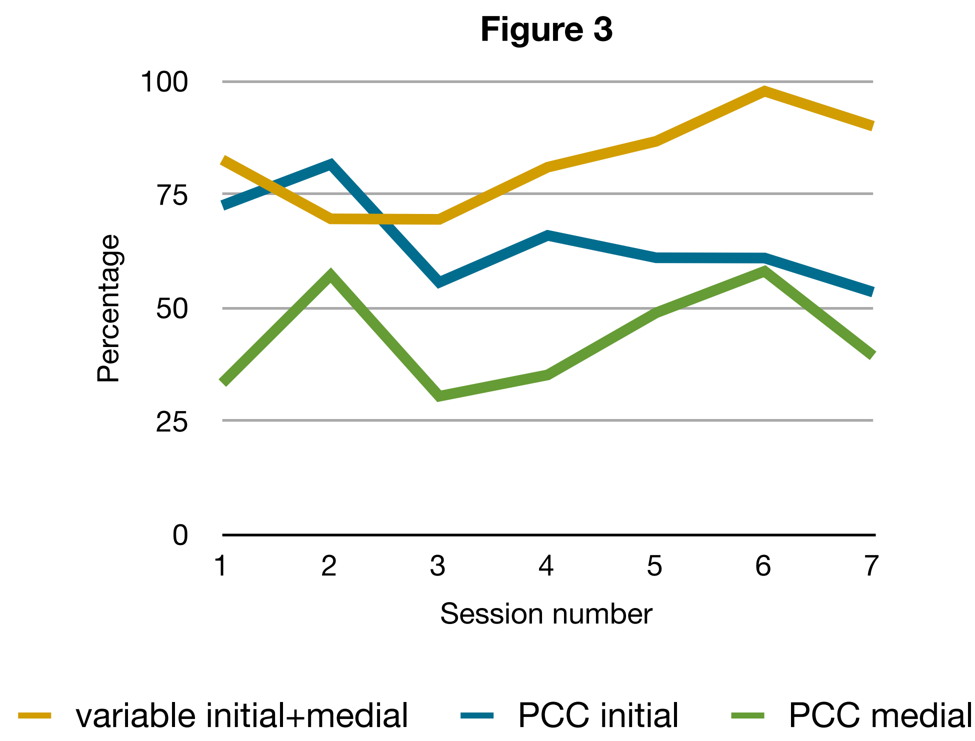

Figure 3: Accuracy and variability of word initial and word medial consonants across sessions (Alison).

3.2.2 Simple onset

Selection and accuracy

The number of C1VC2V words with singleton stop, nasal and glide onsets rose very slowly in the first three sessions. Only four accurate words of this type were recorded in total. It appeared that the only sequence of supraglottal consonants that Alison could produce in CVCV words was a labial and an alveolar stop (*better* [bɛdɛ], *tummy* [dʊbɔ:]). This combination became the basis of the child's own proto-word [bada] (sometimes varying with [wada] and [βɛdə]), which appeared for the first time in session 2. The word, which was most likely related to *over there*, was used very often from that session onwards to describe direction (replacing *here* and *there*) or object (replacing *this* and *that*).

In addition, there was one word with a glottal fricative in word onset (*hippo* [həp^{h}əʊ]). Table 9 presents all selected C1VC2V words with simple onsets.

Table 9					
session 2		**session 3**		**session 4**	
bada	wʌːɖɛʰ	*bada*	βɛdə	*bada*	wɑdə
		better	bɛdɛ		
session 5		**session 6**		**session 7**	
bada	bɛdɛ	*bada*	bədə	*bada*	bɛːdə
tummy	dəbɒʰ	*hippo*	hə̻pːʰə̻ʊ̻		
		tummy	dʊbɔː		

Table 9: Alison's 'selected' C1VC2V words with simple onset in sessions 2-7.

A more frequent CVCV word type involved consonant harmony. However, in the first three sessions most of C1VC1V words were adapted. Selected words of this type were a stable set of high -frequency words (e.g. *mummy*, *daddy*), which were produced repeatedly in many sessions. All these words had nasals and voiced stops with labial or alveolar place of articulation (e.g. *baby* [baːbaː], *nana* [nːɛnɑː]). Nevertheless, given the low frequency of C1VC1V words among targets, it cannot be conclusively established whether there was a genuine preference for labials and alveolars, or whether that preference came from targets. Table 10 presents selected C1VC1V words with simple onsets.

Table 10					
session 2		**session 3**		**session 4**	
baby	baːbaː	*baby*	mbɛbeə	*daddy*	deɪdaːh
Daddy	dɛːdaʰ	*Mummy*	mːəmːɛ	*Mummy*	mːamɪːʰ
Mummy	mːəməː	*nana (banana)*	nːɛnɑːː	*Noonoo*	nʊnɪː
neenaw	ɲːeɪnɒ				
session 5		**session 6**		**session 7**	
baby	beɪbiː	*baa-baa*	baːba	*baby*	beɪbɪ
bo-bo	mbəʊbaʊh	*baby*	beɪbɪʰ	*bo-bo*	boʊbə̃
daddy	dæːdiː	*bo-bo*	bəʊbːoʊʰ	*mummy*	mɒmiː
Mummy	mːɒːmɪʰ	*daddy*	dadɪʰ		
		mummy	mɒmɪː		
		nana (banana)	naːnəʰ		
		Peppa	bɛbɛʰ		
		pepper	bɛpːɛ̰		

Table 10: Alison's 'selected' C1VC1V words with simple onsets in sessions 2-7.

Adaptation and variability

The most common adaptation processed were consonant harmony and coda deletion. We have discussed the CVCV words adapted from CVCVC targets in the previous section, and in this section only syllable onsets will be considered.

Alison showed no apparent preference for the direction of harmony, but there was a strong tendency for labial harmony. There were instances of progressive and regressive labial harmony with alveolars (*bottom* [b:əhpə], *tea pot* [bəhpa:]) and of labials with velars (*buggy* [bəbʊ], *cup box* [bʊʔpɸbʷa:]). The only exception was the word *tummy*, which in session 3 was produced as [nʊnʊ].

Where there was no labial segment, Alison showed no preference between velar and alveolar consonants. For example, in session 2 two words with identical sequence of consonants in syllable onsets were treated differently: *dagger* was produced as [ga:gə], and *doggy* as [dɛdə].

It is also worth noting that although the labial-alveolar sequence was the only one that Alison could produce correctly (cf. Table 9), there were many targets of that type in which the consonants were nonetheless harmonised (e.g. *water* [wɒh:wɒ], *party* [bɑhbɑ]). Thus, all sequences of consonants could be affected by consonant harmony, and apart from the preference for labials, the direction of the process was not systematic. Table 11 presents all adapted simple onset words with harmony.

Table 11					
session 2		**session 3**		**session 4**	
buggy	bəbʊːʰ	*bottom*	b̥ːəhpə	*bunny*	bʙɵbʊː
dagger	gaːgə	*cup box*	bʊʔpɸbʷaː	*water*	wɒhːwɒ
doggy	dɛdə	*digger*	ʔəgiːgɜ		
		doughnut	nːʊːnʊ		
		kettle	gegːə		
		naughty	nːɜʔneə		
		party	bɑhbɑː		
		tea pot	bəhpɑː		
		tummy	nʊnʊ		
session 5		**session 6**		**session 7**	
curtain	tʰəhʊtʰɛ̥ː	*buggy*	bʊbʊːx	*dinner*	nːɪnə
dinner	nːʊnɪː	*dinner*	ndɪːnɛʰ	*pardon*	mbəʊbʊʔ
				water	hɒhɔːh

Table 11: Alison's 'adapted' C1VC1V words with simple onsets in sessions 2-7.

The processes that were most often the cause of variability in CVCV words were processes that could easily be explained by imprecise articulation.The most common of these were the following:

(1) prevoicing and other types of lack of coordination between articulatory features (e.g. *baby* [ba:ba:], [mbabeə], [bβəbeə]; *dinner* [dʊdje:^{h}], [ndi:nɛ^{h}], [n:i:nɛ:])

(2) inconsistent use of adult-like processes, e.g. h-stopping in word initial position (e.g. *hiding* [hada^{h}], [ʔa::də^{h}])

(3) alternating between single vowels and diphthongs (e.g. *buggy* [bəbʊ], [mbɜʊbəʊ])

These minor articulatory processes were present in almost all words that appeared more than once in any given session. However, there were no cases of variable consonant harmony, whereby a word would appear with regressive and progressive harmony in different tokens. It appeared that while the words (even the adapted ones) were generally stable, the child's articulatory skills were not yet developed enough to enable the child to pronounce consonants in the exact same way several times. Table 12 presents all variable CVCV words with simple onset.

Table 12					
session 2		**session 3**		**session 4**	
baby	baːbaː			*bunny*	bʙɵbʊː
	mbabeə				bʊbʙʊː
	bβəbeəʰ			*Noonoo*	həɲʊnaː
buggy	bəbʊːʰ				nʊnɪː
	mbɜʊbəʊ				
	mbʊpːʊː				
	bʊː				
Daddy	ndædaːʰ				
	dɛːdaʰ				
dagger	ŋgaʔuː				
	gaːgə				
session 5		**session 6**		**session 7**	
bada	bɛdɛ	*bada*	bədə	*bada*	bɛɫda̰
	wɜːdɛː		mbəda		bɜːzɛ
bow tie	bəʊhɛː	*daddy*	dadɪʰ		mbɛdə
	pəʊ̥hɛ		dadeɪ		wadə
	peʊ tə̥	*dinner*	dʊdjɛːʰ		baːtɛ̥ʰ
daddy	dædiː		ndɪːnɛʰ		bɛːdə
	dɛːʤiː		ːnːɪːnɛː	*bo-bo*	boʊbə̃
	dɛhəʤiː	*hippo*	ʔɒχpəʊ		bːəʊboʊχ
	ndadi		ʔʊʰboʊ		m̰boʊ̰bʊʔ
hiding	hadaʰ		həp̰ːʰə̰ʊ̥	*Daddy*	dʌːdixḁ
	haɪdæʰ		χəʊbːeʊ		daːdiːç
	ʔaːːdəʰ	*mummy*	mɒmɪː		da̰ːdihə
	hɛdðə		mɒwiː		ndɒːdiχḁ
tummy	bʌdɑ		mbʊmʊɪ̥	*Mummy*	mːʊmːiːx
	dəːbʙʊː		mʊːmʊɪ		mɒːmiç
	dəbɒʰ		mɒmeɪçː		mɒmiː
	n̩ʔn̩ʤəːbʊʰ		mɒβi		mɒmih
					mɒmʊɪʰ
					w̃ə̃w̃ẽɪ̃
					ʔɒmiː
					mːəːmɪχ
				water	ʔɔhʊː
					hɒhɔːh

Table 12: Alison's variable CVCV words with simple onsets in sessions 2-7.

It was thus apparent that producing variegated consonants in disyllables was difficult for Alison, even when the consonants were singleton nasals, stops and glides, which were in the child's repertoire.

3.2.3 Challenging consonants and clusters

Challenging word onset

Alison attempted 6 words with challenging word onset, i.e. onset including a consonant cluster or a singleton fricative/affricate/liquid. There were three words starting with a cluster: *broken*, in which the cluster was reduced to the stop ([beːɸɜː]), *flower*, in which it was replaced with a glottal stop ([ʔæːwa]), and *sweetie*, which was the only word in which the cluster was reproduced, although inaccurately ([hwidi]). However, even this one cluster was variable, and the word also appeared as [ʔiːdiː] and [hiti]. As regards fricatives, they were replaced with a glottal stop (*shower* [ʔəʊwæː], *sugar* [ʔaʔɔː]).

Therefore, fricatives, when they were attempted in session 3 - whether singleton or part of a cluster - most often underwent glottal stopping in word onset. In addition, in *broken* [beːɸɜː] and *sugar* [ʔaʔɔː], the word medial consonant, even though it was a singleton stop in target, was harmonised with the onset. Table 13 presents all targets with challenging onset.

Table 13					
session 3		**session 4**		**session 7**	
broken	beːɸɜː	*ready*	wɛdɛɪ	*sweetie*	hwɪdi
flower	ʔæːwa				
shower	ʔəʊwæː				
sugar	ʔa ʔɔ̰ː				

Table 13: Alison’s targets with challenging onsets in sessions 2-7.

Apart from session 3, difficult onsets were thus uncommon, and the ones that were attempted underwent a considerable amount of simplification. There was also no variability in these words, apart from *sweetie* (as discussed above).

Challenging word medial

Several targets with a difficult medial consonant were attempted, although most of them appeared in session 3. In all but one case the medial consonant or cluster was harmonised with the word onset consonant (the exception being *hungry* [hʊnːɔːʰ] in session 7). No variability was recorded for these words. Table 14 presents all targets with challenging medial position.

Table 14					
session 2		**session 3**		**session 4**	
		boiling	boβo	*Declan*	dæʔdɛʔ
		carrot	gɑʊkaʔ	*monkey*	mːɒʔ̥mːe.ʊ
		coffee	ɟəʰ gɒː	*paddle*	bɒpa
		dolly	dɑːʊdɑː		
		mixer	mɪʔmɪ		
		more please	mːːəʔmɑː		
		puddle	mbʊbʊːː		
session 5		**session 6**		**session 7**	
toilet	dɔːdɔʰ	*toilet*	dɔːdʊʰ	*dolly*	dɒːdɒ
				grandma	mːəməː
				grandpa	bwapɑːʰ
				hungry	hʊnːɔːʰ

Table 14: Alison's targets with challenging word medial consonant(s) in sessions 2-7.

Challenging onset and medial

There was a relatively high number of targets with difficult consonants or clusters in both onset and medial position that were nevertheless attempted by Alison, especially in session 3. In most cases, they underwent consonant harmony in a way similar to simple consonants:

(1) where a labial was available, both onset and medial position were rendered as a singleton labial (e.g. *blanket* [bɑʔbɑː], *Christmas* [məhmːɜː]),

(2) where a labial was not available, the onset was reduced to or replaced with a stop, and the medial consonant harmonised with it (e.g. *thank you* [tede], *Slugsy* [dɔːdʒɪjɔː])

An exception to the above rules in session 3 was the word *driver* [gwaːʊga], in which the initial cluster was retained, although the target alveolar stop was replaced with a velar.

In session 3, there were also three instances of words in which the onset consonant was replaced with a glottal stop, and the medial consonant/cluster with either a glottal or a glide (*help please* [ʔəhwiː], *sausage* [ʔɒʔəː], *sorry* [ʔɑɪjɑːʰ]), which resulted in forms similar to the ones mentioned in section 2.3.2 (e.g. *flower* [ʔæːwa]), which, however, had the glide in target.

From session 5 onwards other, less predictable forms, which were closer to targets also began appearing. First words with affricates were recorded (*changing* [dʒɪjaːdʒeʊ], *jumper* [dʒɔːbʊ]), and in the last session one out of the four attempted challenging targets did not undergo harmony (*bless you* [mbɛʰdɪːjʊ]), and in one onset cluster was retained despite harmony (*grandpa* [bwapɑːʰ]). Table 15 presents all targets with challenging onset and medial position.

Table 15					
session 2		**session 3**		**session 4**	
Lola	ʔɑːjʊ	*blanket*	bɑʔbɑː	*Christmas*	məhmːɜː
thank you	tede	*driver*	gwaːʊgəː		
		help please	ʔəhwɪː		
		sausage	ʔɒ ʔəː		
		sorry	ʔaɪjɑːʰ		
		stir it	dɜːdɜ		
		thank you	dɪːdɨːː		
session 5		**session 6**		**session 7**	
changing	ʤɪjaːʤeʊ̥	*Slugsy*	dɔːʤɪjɔː	*bless you*	mbɛʰ dɪːjʊ
glasses	dəhdæː	*socks*	gɒʔgɒʰ	*grandma*	mːəməː
jumper	ʤɔːbʊ			*grandpa*	bwapɑːʰ
thank you	dɪdəʊ			*thank you*	dɪːdɪʊ

Table 15: Alison’s targets with challenging onset and medial consonants in sessions 2-7.

Although improvement over the sessions could be observed, the more accurate forms were not usually accurate in all tokens. For example, *grandpa* [bwapɑː] in session 7, also had a more predictable form as [bɒbɒ], and *jumper* [dʒɔːbʊ] also appeared without the affricate as [ndɔːbəʰ]. Table 16 presents all variable words with challenging onset and medial position.

Table 16					
session 2		**session 3**		**session 4**	
thank you	ðəːdɪʰ	*thank you*	dɪːdɨːː		
	tede		dəʊdɪɪ̥		
			tɜːdɪː		
		yes please	mɪʔmĩːːç		
			ʔɪ pʷiːʝ		
			ʔʊʰmiː		
session 5		**session 6**		**session 7**	
glasses	dæʔdːə	*yes please*	dəhʊ̥wɪ	*grandpa*	bɒbɒ
	nːdahtæː		jahbiː		bwapɑːʰ
	dəhdæː		jəhəwɪːh		
jumper	ndɔːbəʰ		jɛhpiː		
	ʤʊbʊh		ʔəjɛhwɪː		
	ɟʊːbə		ʔɪjəʔʍɪç		
	ʤɒbʷʊʰ				
	ʤɔːbʊ				
sorry	ʔʊʒɒ̰h				
	hɒːjɒːʰ				
thank you	dɪdəʊ				
	dɪʤu				
yes please	jəhmɪç				
	jʊhmm̥ɪ				
	ndɛ mɪç				
	ˌʔəjɛh bɪ				
	ʔɪjəhmɪʰ				

Table 16: Alison’s variable child forms for targets with challenging onset and medial consonants in sessions 2-7.

3.2.4 Multisyllabic words

Unlike the other two subjects, Alison attempted a large number of multisyllabic words and expressions, particularly in session 3. Most of these contained consonants and clusters that the child could not produce, which posed additional articulatory difficulties. Therefore, the child forms were usually considerably simplified.

Most words retained the target number of syllables, at the cost of consonantal accuracy. All consonants in these words were harmonised (e.g. *octopus* [ʔɒpʰʊpʰʊ]; *Action Man* [ʔaːməmaː]). Furthermore, vowel accuracy was very low due to the words undergoing partial reduplication, so that in trisyllabic words two syllables had to be identical. This process sometimes appeared in the first two syllables (e.g. *computer* [bʊbubɜ], *paddling* *pool* [pʊpʊpɔ:]), and sometimes in the latter (e.g. *choo-choo train* [dʊdɜdʒɜ:], *Pop-up pirate* [pabəbə]).

There were also a few cases of full reduplication. In some of the fully reduplicated words, the number of syllables was also altered. This involved shortening (e.g. *dinosaur* [gɑ:gaʔ], *teddy bear* [bəbɛ:]), and in two cases also lengthening of words, which had an almost identical child form (*strawberry* [ndʒɪɒːwbədʒəʊbə], *trampoline* [dʒaːbɜdʒaba], but note similar target structure).

Finally, three instances of ʔVglV forms were recorded for multisyllabic targets: *butterfly* [ʔɛhɛwʊ:], *orange juice* [ʔɒjɒ.ah] and *flamingo* [ʔəʊwɜwʊ:] (for other examples, cf. section 3.3.5).

There were only two words which retained the target number of syllables as well as different consonants in the child form: *ABC* [ʔeɪbʊɣ:ɪʰ] (session 3) and *holiday* [hɔdɑɪjɛ:] (session 7). In three other words the different consonants were attempted, but the number of syllables was altered: *another* [wabə], *nobody* [neʊbeʊʔ] and *helicopter* [ʔɛviboʊ]. Table 17 presents all multisyllabic targets.

Table 17					
session 2		**session 3**		**session 4**	
pirate Pete	pɛʔpæʔ	*ABC*	ʔeɪbʊɣ̞ːɪʰ	*another*	wabə
		building blocks	bəʊbəbɑː	*flamingo*	ʔəʊwɜwʊːː
		butterfly	ʔɛ hɛwʊː	*octopus*	ʔɒ pʰʊ̥ pʰʊː
		choo choo train	dʊdɜʤɜː	*swimming pool*	həːbːəbʊː
		computer	bʊbubɜ		
		cup of tea	gʊgːɔːgɔː		
		dinosaur	gɑːgaʔ		
		gentleman	dʲɜdɜːdɜː		
		museum	mːumɪː		
		orange juice	ʔɒjɒ.ah		
		paddling pool	pʊpʊpɔː		
		teddy bear	bəbɛː		
session 5		**session 6**		**session 7**	
Action Man	ʔa̰ːməmaː	*elephant*	ʔɛjɛjɛ	*dinosaur*	dɜːdədəː
poopy-out	bɛbəbu	*holiday*	hɔdɑɪjɜː	*helicopter*	ʔɛviboʊ
Pop-up Pirat	pabəbəː	*nobody*	neʊbeʊʔ	*Louisa*	ʔʊn ʔiːjə
		pony tail	boʊbəβɛʔu̥	*trampoline*	ʤaːbɜdʒaba
		strawberry	nʤɪɒːwbəʤəʊbə	*Weetabix*	ʔiːbɪbɪʔɪ̥

Table 17: Alison's multisyllabic targets in sessions 2-7.

Although the above processes often made the words barely recogniseable, they allowed Alison to attempt targets that she would have otherwise been incapable of producing.

As far as variability of multisyllabic words is concerned, it was mostly limited to the articulatory variability that we observed for disyllables. However, in some cases there was also variability in the number of syllables (e.g. *computer* [bɨbɪ], [bʊbubɜ]), which suggests that the pattern was not entirely stable in multisyllabic words. There were also cases of variability in the application of consonant harmony (e.g. *holiday* [hɔdɑɪjɜː], [ʔɑːdədɔʰ]), showing that the target consonants were attempted, at least in some tokens, rather than being permanently specified in their templatic form. Table 18 presents variable multisyllabic words.

Table 18					
session 2		**session 3**		**session 4**	
pirate Pete	pɛʔːbeʰ	*computer*	bɨbɪ	*elephant*	ʔajeɪjə
	pɛʔpæʔ		bʊbubɜ		ʔajɛjɪːʰ
			bʊibɜː	*swimming pool*	həːbːəbʊː
		cup of tea	gʊgːɔːgɔː		ʔəmʔbəbʊː
			dɪbːʊʑɪː		ʔəːbəbʊː
		gentleman	dəjəjɪə		
			dʲɜdɜːdɜː		
		paddling pool	bɛbewʊːː		
			bɪbːɜbuː		
			bʊbʁəbʊː		
			pʊpʊpɔː		
session 5		**session 6**		**session 7**	
Action Man	ʔa̰ːməmaː	*holiday*	hɔdɑɪjɜː	*dinosaur*	dadɒ
	χaːma̰mʊ̰		ʔɑːdədɔʰ		dadʑadʊː
poopy-out	bʁebːəbɜʰ	*nobody*	neʊbeʊʔ		dɜːdədəː
	bəbəʊ̥		nɪʊbeɪʔw̥	*trampoline*	ʤaːbɜdʒaba
	bɛbəbu	*pony tail*	bəʊβabəʊ		ʤawɪʤaʊbə
	ʁ̥bɛbəbʊ		boʊbəβɛʔu̥		
	mbəbəwɒːbwʊː				
Pop-up Pirate	babəbə				
	mbɒːbʁabəə̥				
	pabəbəː				
	b̃aːʥɪbːʌːbɒːbəʰ				

Table 18: Alison’s variable child forms for multisyllabic targets.

3.2.5 ʔVglV template

Across sections, we have seen words that were adapted by Alison to fit the ʔVglV template. This pattern was only commonly applied in session 3. In that session, many words that had an onset fricative or a liquid in target were produced with a glottal stop in the child form. The medial consonants in these words were also replaced with a glide or with the glottal fricative, and in most extreme cases, with another glottal stop (e.g. *sausage* [ʔɒʔəː] or *sugar* [ʔaʔɔː]). Table 19 presents all ʔVglV words (that were also discussed separately in previous sections).

Table 19					
session 2		**session 3**		**session 4**	
Lola	ʔɑːjʊ	*butterfly*	ʔɛ hɛwʊː	*elephant*	ʔajeɪjə
		flower	ʔæːwa	*Elliot*	ʔajeɪje
		help please	ʔəhwɪː	*flamingo*	ʔəʊwɜwʊːː
		office	ʔəhʔɑ̰ː	*uh-oh*	ʔʌːʔːːʊːː
		orange juice	ʔɒjɒ.ah		
		sausage	ʔɒ ʔəː		
		shower	ʔəʊwæː		
		sorry	ʔɑɪjɑːʰ		
		sugar	ʔa ʔɔ̰ː		
session 5		**session 6**		**session 7**	
sorry	hɒːjɒːʰ	*ears*	ʔɪjeː	*ear*	hiːjə
uh-oh	hɒʔoʊ	*uh-oh*	ʔɒʔəːʊ	*Elliot*	ʔeɪjɛ
				flower	ʔaːwæ̰
				hello	ʔḛɪjəʊː

Table 19: Alison's ʔVglV child forms with targets in sessions 2-7.

Few words were adapted to this pattern from session 4 onwards. In the ones that were, only the onset was replaced with a glottal stop, and not the medial consonants (as it happened in session 3).

3.2.6 Section summary

We have seen three very systematic processes in Alison's data, which were used to cope with the problem of variegated onset and medial consonants in di- and multisyllables: consonant harmony, partial or full reduplication and the ʔVglV template. These processes were very powerful, in the sense that all words looked roughly similar to one another, and sometimes they became completely unrecognisable (e.g. *office* [ʔəhʔɑː]). However, they were also powerful in the sense that they allowed for producing a large number of words despite limited articulatory capabilities. Indeed, in session 3, Alison produced 110 different words, which was a large number relative to the other children and even Alison's later sessions. Moreover, the templates allow her to attempt very complex targets, e.g. *gentleman* [dʲʒdʒːdʒː], *paddling pool* [pʊpʊpɔː] or *butterfly* [ʔɛ hɛwʊː]. Nonetheless, even in Alison's most systematic session, there was some variability in template application.

In time, the use of these processes began decreasing, and there were visible signs of slowly increasing flexibility from session 4 onwards. The number of C1VC2V increased throughout the last four sessions and in session 6 almost reached input frequency (13% vs. 14% in the input). At the same time, the percentage of C1VC1V words slowly decreased, although it was still higher than input frequency at the end of the study (16% vs. 6%). To sum up, while Alison still had a lot to learn in terms of co-ordinating different syllable onsets in di- and multisyllables, the patterns provided her with a large vocabulary to draw on in her learning.

3.3 Coda

3.3.1 Overview

From session 2 onwards, there was a gradual increase in the number of codas that Alison produced, although it was very slow. At the end of the study, the frequency of CVC child forms reached 24% (target 46%). CVCVC child forms also began to appear in session 3, but did not exceed 3% frequency in the data (target: 17%). Therefore, with codas in monosyllables at half the target frequency, and codas in disyllables only beginning to be acquired, Alison's acquisition of codas is still very much incomplete in the last session. In session 6 there was a temporary drop in frequency of all words with coda, but it was not related to accuracy (which remained stable), and thus can be attributed to a smaller number of coda targets. Figure 4 presents the development of the two word shapes across sessions.

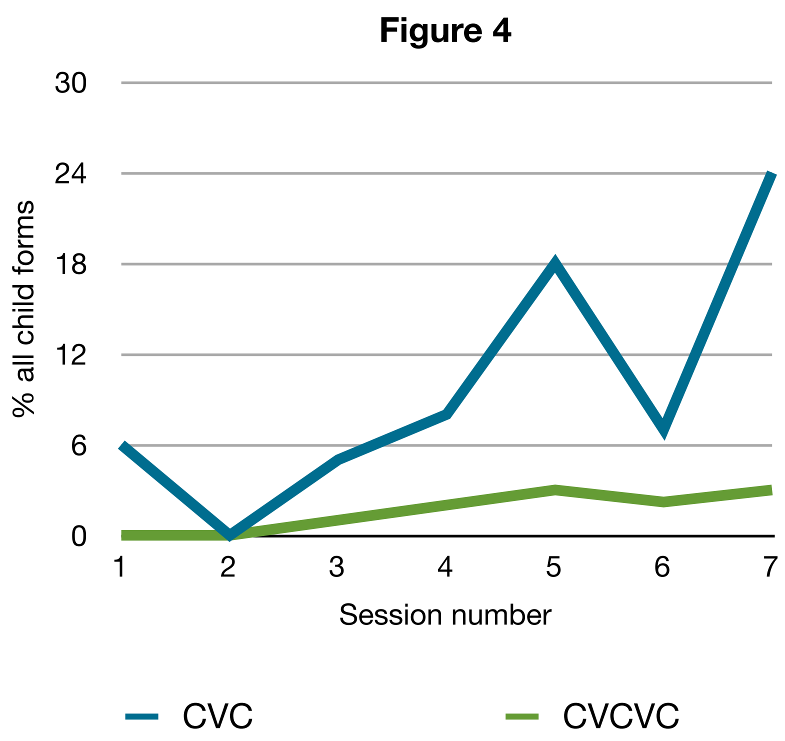

Figure 4: Percentage of CVC and CVCVC child forms in Alison's production across sessions.

Alison's boldness in attempting targets with codas remained constant throughout the study, oscillating around 25-30%. Their accuracy, after a dramatic drop in sessions 2-3, was also developing very slowly, and remained below 50% until the last session. At the same time, variability of codas was increasing along with their accuracy. Figure 8 presents accuracy and variability of codas.

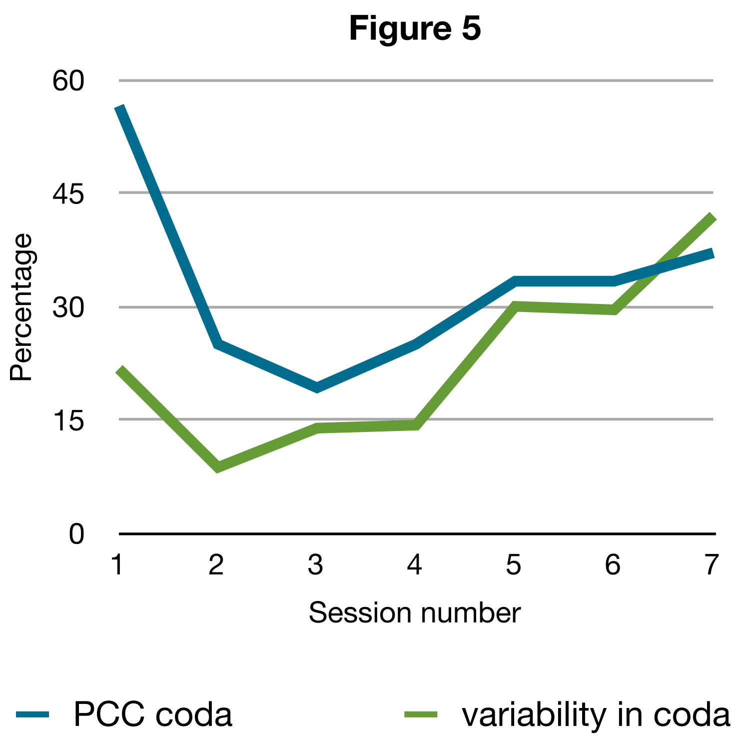

Figure 5: Percent accurate and percent variable codas in Alison's production across sessions.

3.3.2 Coda omission and glottal stopping

We may recall that in session 1 all CV words produced by Alison were selected CV targets. This changed in session 2, when half of them were adapted from targets with coda. In that session, no codas were recorded, and CV words reached their highest frequency (38%). Throughout sessions 2-7, coda omission most often affected the following consonants:

(1) Fricatives - voiced and voiceless, in all places of articulation (e.g. *off* [ʔɒ:], *drive* [dʒja:], *bath* [bah:], *cheese*[n::i:], *glasses* [dææʰ], *push* [pʊ:]), except for the last session.

(2) Nasals - only cases of alveolar nasal coda omission were recorded (e.g. *Ben* [bæ:], *one* [ʔɑ:]), although CVC words with accurate /m/ in coda were also not produced, which suggests that Alison might have been avoiding targets of that type.

(3) Stops - mostly voiced velars and alveolars (e.g. *bag* [bæh], *head* [ʔæ]), although in sessions 2 and 3 there were three instances of omission of the voiceless /k/ (e.g. *back* [baːʰ], *cake* [tʰæ]) and one instance of omission of the voiced /b/ (*tube* [dʒuːː]).

In addition, in child forms with omitted coda the vowel was often lengthened, and sometimes aspirated. Table 20 presents all CV words adapted from CVC targets.

Table 20					
session 2		**session 3**		**session 4**	
back	baːʰ	*arms*	ʔaɑh	*Ben*	bɛː
Ben	bæː	*bath*	bahː	*George*	dʒɪɔ
bus	bʊʰ	*Ben*	bɛːːʰ	*nose*	nːʊː
cheese	nːːɪː	*cake*	tʰæ	*one*	ʔɑː
fish	ɣi	*cold*	ŋgɒːʰ		
pig	pɸʊ	*down*	daə̥		
post	bʊ	*gone*	ɖɒːɒ̥		
		hand	ʔa̰ːː		
		Joan	dʒʊːː		
		man	mːaː		
		push	pʊː		
		squash	dɒʰ		
		tube	dʒuːː		
		work	ʔɜːʰ		
session 5		**session 6**		**session 7**	
bag	bæhː	*bath*	pah	*Ben*	bɛːː
Ben	bɛː	*bed*	bɛːʰ	*in*	ʔɪːː
cards	gɒʰ	*Ben*	bɛː	*it*	hɪ
drive	dʒɪaːa̰	*big*	pɪː	*please*	mːiːː
eyes	ʔæə	*bump*	bɛ	*put*	bʊ
five	haː	*cold*	tɔː	*side*	ʔaː
green	ti	*drive*	dʒjaː	*spoon*	buː
one	ʔɒː	*glasses*	dæʰ		
please	hʌː	*head*	ʔæ		
stairs	ʔtɛː	*his*	hɔː		
		off	ʔɒː		
		pig	bːːɛʰ		
		twins	dɪːː		

Table 20: Alison’s child forms with omitted target coda in sessions 2-7.

Therefore, apart from fricatives, it was most often voiced consonants that were omitted in the coda position, even though they were preferred in word onset. This also applied to the cases of complex coda omission (e.g. *hand* [ʔaːː], *George* [dʒɪɔ]). Conversely, most voiceless stop codas were replaced by Alison with a glottal stop. As in session 1, many of these were voiceless alveolar stop codas, and the process resulted in adult-like forms. However, in time many more velar (e.g. *book* [bʊːʔ], *neck* [nːɛʔ]), labial (e.g. *stop* [daʔ], *pop* [baʔ]) and complex codas (e.g. *boots* [bʊːʔ]) were also produced in this way. Table 21 presents words of the CVʔ form.

Table 21					
session 2		**session 3**		**session 4**	
boat	bɒʔʰ	*beads*	biːʔ	*back*	ba̰ːʔ
book	mbʊʔ	*book*	bʊːʔ	*bumped*	bʊʔ
boot	bʊːʔ	*boots*	bʊːʔ	*out*	hæːʔ
milk	m̩ʊʔ	*break*	mbɜʔ	*pop*	baʔ
park	mbɒʔ	*hot*	hɑʔ		
		seat	iʔʰ		
		snack	nːːaʔ		
		snap	nːːaʔ		
		stop	daʔ		
		stuck	gʊːʔə̥		
		up	ɒːʔːʰ		
session 5		**session 6**		**session 7**	
back	ba̰ːʔ	*back*	bæʔə̥	*back*	baʔæ̥
big	bɛʔ	*book*	bʊʔʊ̥	*burp*	bœːʔ
hat	hæːʔ	*eat*	iːʔ	*coat*	deʊʔ
neck	n̩ːɛʔ	*knock*	nɒʔ	*out*	ʔaʊʔ̥
out	ʔaʊʔʀ̥	*sit*	ʔɪʔ	*park*	bɒːʔ
pop	bɑːʔ			*shut*	ʔʊʔ
sit	hɪʔ			*sit*	çiʔɪ̥
six	ʔe.ɪʔ			*take*	deɪʔ
what	wɒʔʰ			*walk*	ɛɔ̃ːʔ

Table 21: Alison's child forms with target coda replaced with a glottal stop in sessions 2-7.

It is worth noting that although Alison could not yet produce most codas, she already did have a voicing distinction for stops in that position.

Despite the gradual increase in the number of CVC words from session 3 onwards, and the corresponding gradual decrease in the number of CV words, the CV category remained strong until the end of the study, when their frequency was 20% (target: 8%). It was only in that last session that the percentage of CVC words was finally higher than the percentage of CV words. Still, 7 out of 12 CV words were adapted from targets with codas. The number of CVʔ oscillated between 8%-14% throughout the study. Figure 6 presents the three word shapes.

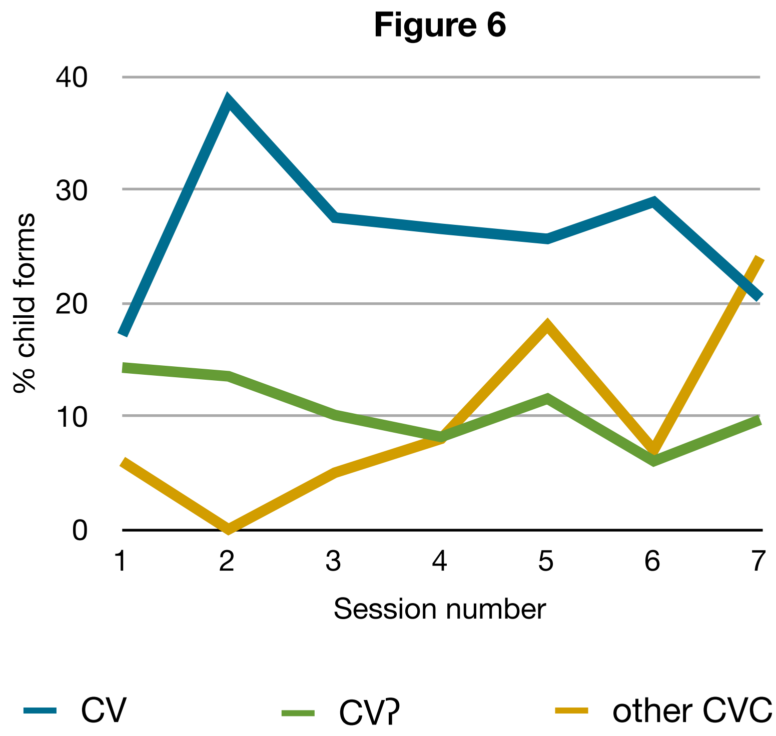

Figure 6: Percent CV, CVʔ and other CVC child forms in Alison's production across sessions.

The first non-glottal codas recorded in session 1 were a labial stop (*pop* [pɛp]) and a fricative (*push* [pəɸ]), both with consonant harmony. In session 2 all codas were omitted. When they re-appeared in session 3, it was again labial stop and fricative codas, and both these types of coda continued to develop from that session onwards. Nasal codas were consistently omitted throughout the study. Perhaps unsurprisingly, given that singleton codas were still highly unstable, very few complex codas were attempted by Alison. Figure 12 presents the overall percentage of CVC words by final consonant.

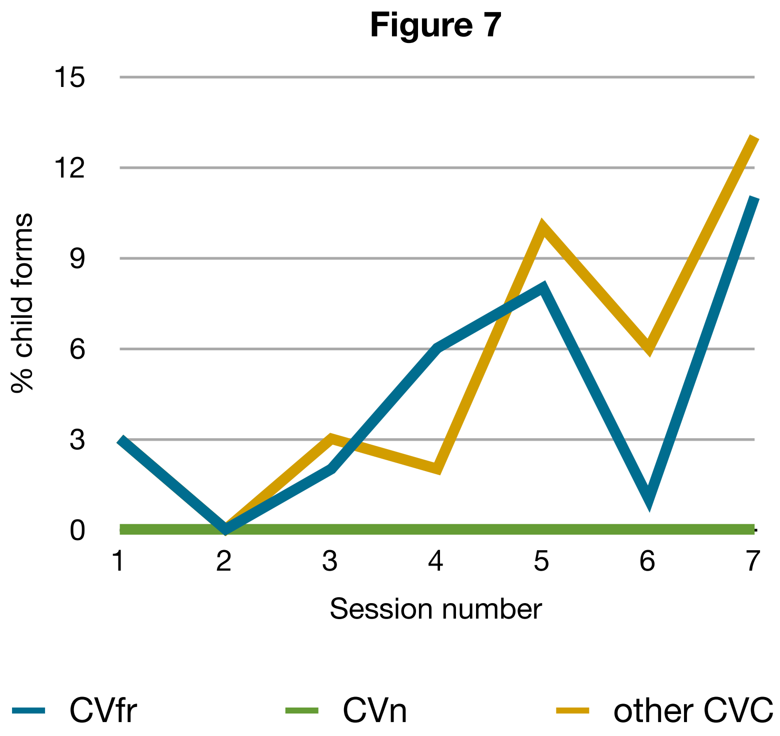

Figure 7: Percent of fricative, nasal and other codas in monosyllables in all Alison's child forms across sessions.

3.3.3 Fricative coda CVC

Although Alison produced the first fricative coda already in the first session, the development of fricative codas was slow. Their frequency increased from 2% to 8% in sessions 3-5, and after a temporary regression to 1% in session 6 (where many fricative targets were omitted, cf. Table 20), it only reached near-target frequency in the last session (11%; target: 14%).

Selection and accuracy

Alison produced almost no target fricatives, which meant that her fricative codas were always inaccurate. After /ɸ/ appeared in session 1, /ɕ/ emerged in session 3, and from session 5 onwards also /f/, /ç/ and /χ/ were used. Table 22 presents all CVfr words with singleton coda in both target and child form (selected), sorted by child coda.

Table 22							
session 3		**session 4**		**session 5**		**session 7**	
juice	dʑʊɕ::	*horse*	ʔɔ:χ	*moustache*	taʊɸ:	*knees*	ni:ç
				mouth	bma:ʊf	*mouth*	maʊχ:
				nose	n̩e:ʊɸ	*yes*	ʔijɪx
				off	ʔɒ:χ		
				shoes	ʔœʊx		
				yes	həjaɕ		

Table 22: Alison's 'selected' CVC words with singleton fricative coda in sessions 2-7.

Apart from the fact that Alison's coda fricatives were not phonetically accurate, there was also no systematicity in how they were used to replace the target ones:

(1) The only fricative in Alison's repertoire which was also present in the ambient language was /f/, but it only appeared in one word and was not accurate (*mouth* [bma:ʊf], session 5). Furthermore, in the same session, it was not used in the only target where it would have been accurate, and was replaced with the uvular /χ/ instead (*off* [ʔɒχ]).

(2) There was variability within sessions. For example, pre-palatal and palatal fricatives /ɕ/ and /ç/ were used in place of coronal targets (*yes* [jaɕ], session 5; *knees* [niç], session 7), but in these same sessions the coronals were also sometimes replaced with /x/, /χ/ and /ɸ/ (e.g. *shoes* [ʔœʊx], *nose* [neʊɸ], session 5; *yes* [ʔijix], session 7).

(3) In two words, there was variability across sessions, when the final fricative was substituted with a different consonant each time. In both cases, the later form was further from the target place of articulation than the earlier one (*mouth* [bma:ʊf], session 5; [maʊχ:], session 7; *yes* [jaɕ], session 5; [ʔijix], session 7).

We can thus see large variability in the correspondence between the target fricatives and the fricatives produced by the child. Coda fricatives were produced in an entirely irregular fashion, and throughout the study almost no target fricatives (except for the one instance of /f/) were accurately produced.

Adaptation and variability

In sessions 3 and 5, final fricatives were also variable within words. In session 3, the variability affected the only word with coda (*juice*), in which the place of articulation of coda varied across tokens: [ɟʊʃ::], [dʑʊɕ], [ndœx]. In session 5, four out of six CVfr words were highly variable. This time, the variability mostly concerned coda omission (e.g. *mouth* [bma:ʊf], [mɛ:]; *off* [ʔɒ:χ], [ʔɒ]). There was also one instance of coda fricative stopping (*nose* [n:ɪʊd]). Table 23 presents words with variable fricative codas.

Table 23			
session 3		**session 5**	
juice	ɟʊʃ::	*mouth*	bma:ʊf
	dʑʊɕ::		m:aʊh
	n̩dœx		mɛ:
			ma:χʊ̥
		nose	neʊh
			ɳ̩:u:
			n̩e:ʊɸ
			ne:ʊ̥
			n:ɪʊd
		off	dɫɒx
			ʔɒ:χ
			ʔɒ
		shoes	ʔɜʊh
			ʔœʊx

Table 23: Alison's CVC child forms with variable fricative coda in sessions 2-7.

Interestingly, there were also many cases of final fricatives being added to targets without coda. As in targets with coda, these most often had other forms in which the fricative was not added. The instances of variable CV words which sometimes appeared with a final fricative were first recorded in session 5 and were still very common in session 7. Most often, the fricative was velar or uvular (e.g. *draw* [dɔ:x]; *star* [dɑ:χ]), but there were also instances of adding a palatal (*knee* [ni:ç]) or a labial (*blue* [bɪʊɸ]). There was also one instance of metathesis (*sea* [ʔi:ç]) Table 24 presents cases of final fricative insertion in CV words (both single and multi variant).

Table 24					
session 5		**session 6**		**session 7**	
draw	dɔːː	*blue*	bɪʊɸ	*blue*	bɪjʊ
	dɔːx		bɪʊ		mbʊx
knee	nːiː			*door*	n̰dɒːʀ̥
	n̰i̝ːç				dəʰ
more	mbɔx				dɔx
	məʊ			*draw*	ʤɔːx
	mːəɔh				ʤɔː
	m̩bʊʰ			*more*	mbʊː
					mːɔʰ
					mːɒːʔɒχ
					mːɔ̃ːːx
					mːʊ̃ːʁ
				sea	ʔiːç
				star	dɑːχ
					n̩dɒːː
					dɒː

Table 24: Alison's CVC child forms with inserted fricative coda in sessions 2-7.

The variable final fricative production in targets with and without coda, their inaccuracy and lack of systematicity, point to two possible interpretations of how Alison's acquisition of coda fricatives was progressing. On the one hand, it is possible that when fricatives began to be more frequently produced in session 5, reversing coda omission resulted in variability and in overproduction of fricatives even in previously accurate CV words. On the other hand, it is possible that all final fricatives were simply results of voicing sometimes ending before the airflow stopped. Under this interpretation, final fricatives in words both with and without fricatives in target resulted from imprecise articulation, and target fricatives were in fact never intended. Three facts appear to support the latter interpretation:

(1) Final fricative omission in session 5 was as frequent and as variable as final fricative insertion (4 vs. 4 words, respectively).

(2) Final fricative insertion was still very frequent in session 7 (6 words), and while no variability was recorded for final fricative omission, all final fricative targets had only one token each in that session, so variability could not be measured.

(3) Final fricatives in both types of targets usually agreed with the preceding vowel, with labials always appearing after /ʊ/ (*blue* [bɪʊɸ], *moustache* [taːʊɸ]), palatals

always after /i/ (*sea* [ʔiːç], *knees* [niːç]), and dorsal fricatives /x/, /χ/ and /h/ most often appeared after /ɔ/ and /a/ (*door* [dɔːx], *horse* [ʔɔːχ]).

However, it is impossible to conclusively distinguish between the above two interpretations in Alison's data. In any case, final fricatives were still far from stable at the end of the study, even if we assume that they were produced intentionally.

In addition to final fricative insertion, there were a very few cases of affrication and fricativisation of final stops, which will be discussed in more detail in the next section. There were no cases of substitution of final fricatives with other segments, the only exception being stopping in the word *nose* [nːɪʊd] (cf. Table 23). Yet, they were highly unsystematic, variable and inaccurate.

3.3.4 Stop and liquid coda CVC

After a few occurrences in sessions 1-4, stop codas began to be frequently produced from session 5 (frequency 10%), and their frequency was at 13% in the last session (target: 23%). Although even in the last session no liquids and not all stops were produced, the ones that appeared were almost always accurate.

Selection and accuracy

Alison's final stops were mostly limited to labials, especially at the beginning of the study. In session 5 two alveolar codas appeared (*feet* [ʔeiʔdʰ], *hide* [had̺]). Nevertheless, alveolar stops were most often glottalised (cf. Table 21), and therefore labials were prevalent in codas until the end of the study. No final singleton velar stops or liquids were recorded throughout the study (although cf. section 3.3.6). Table 25 presents all selected CVC words with singleton stop coda.

Table 25							
session 3		**session 5**		**session 6**		**session 7**	
cup	dʊbːːːp	*drop*	dɹɒːpːʰ	*drop*	ʤʊɒp̚	*beat*	biːd
scoop	kʲʊp	*feet*	ʔeiʔdʰ	*snap*	nːaʔpʰə̥	*big*	bːɪtʰ
		help	heɬ̺pʰ	*yep*	ʔʊjːːepʰ	*drop*	ʤɒʔpʰ̥
		hide	had̺			*eat*	ʔiːtʰ
		nope	nːeʊʔpʰə̥			*tip*	dɪpʰ
		step	dɛʔːpʰ			*up*	ʊ̰ːpʰ
		top	dɒːpʰ			*yep*	jːɛːːʔpʰ
		yep	jɛʔpʰ			*zip*	hɪːʔpʰ

Table 25: Alison's 'selected' CVC words with singleton stop coda.

Both labial and alveolar stops were always accurate, except for an instance of velar fronting in session 7 (*big* [b:ɪt^h]) and variable voicing (e.g. *beat* [bi:d]). Nevertheless, they were often aspirated (e.g. *help* [heɫp^h]), unreleased (e.g. *drop* [dʑʊɒp̚] or accompanied by a glottal stop (e.g. *zip* [hɪ:ʔp^h]), which suggests that Alison still had difficulties with controlling the airflow at the end of a word.

Adaptation and variability

Few cases of alternations of final stops were recorded, and they involved affrication and fricativisation of the coda. In four out of five cases this affected alveolar consonants (the exception being the word *stop*, in which a /χ/ was added to the coda, but the stop was also produced:[dɒ:p^{h}χ]). Table 26 presents all cases of stop coda adaptation.

Table 26							
session 3		**session 4**		**session 6**		**session 7**	
bird	bɜ::ɸ	*hot*	ʔɒʔχ:	*shut*	ʔʊʔʧ	*boot*	bɪʊtɕ
						stop	dɒ:p^{h}χ

Table 26: Alison's CVC child forms with modified target singleton stop coda in sessions 2-7.

In addition, sometimes the affricated coda appeared as a variant of a word that also had an accurate form (e.g. *zip* [ʔɪ:p^h], [hɪ:ʔf]). However, the main source of variability in stop codas were alternations between the accurate rendition, coda omission, and glottal stopping. Table 27 presents all variable words with stop coda in target.

Table 27							
session 3		**session 5**		**session 6**		**session 7**	
book	bʊ	*drop*	dɹɒ:p:ʰ	*back*	bæʔə̥	*big*	m:bɪç
	bʊ:ʔ		ndʒɒʔp		baʔ:pʰ		b:ɪtʰ
snap	daɒp	*feet*	həiʔtʰ	*big*	pɪ:	*boot*	bɪʊtɕ
	n̥ n̥æʔf		ʔəintʰ		mbɪʔh		bɪʊʔ
	n::aʔ		ʔeiʔdʰ	*book*	bʊʔʊ̥	*eat*	ʔi:
		hide	h:a:		bu:wʊ		ʔi:tʰ
			had̥		bʊχ		h:iʔ
				eat	ʔeʔ	*out*	ʔa̰ʊ̰ʰ
					çi::tʰ		ʔaʊʔ̥
					hi:		ʔa:ʊʔχə̥
						sit	hɪʔ
							ʔɪ:tʰə̥
						tip	dɪʔ
							dɪpʰ
							ʔə̰ɪ̰pʰ
						zip	ʔɪʔ
							ʔɪ:pʰ
							hɪ:ʔf

Table 27: Alison’s CVC child forms with variable singleton stop coda in sessions 2-7.

3.3.5 Nasal coda CVC

Not a single instance of a nasal coda was recorded. Most nasal coda targets underwent omission (e.g. *Ben* [bæ:], *spoon* [bu:]). In the only two targets of that type that were produced with a coda the nasal was replaced with a fricative (*green* [di:ç]) or stopped (*tum* [dʊb]). The latter example was also the only target with a labial nasal in coda. There was only one word with nasal coda that showed variation (*down* [da:h], [daʊ], [daʊχ]). Table 28 presents all nasal coda targets.

Table 28					
session 2		**session 3**		**session 4**	
Ben	bæː	*Ben*	bɛːːʰ	*Ben*	bɛː
		down	daə̥	*one*	ʔɑː
		gone	ɖɒːɒ̥		
		Joan	ʤʊːː		
		man	mːaː		
session 5		**session 6**		**session 7**	
Ben	bɛː	*Ben*	bɛː	*Ben*	bɛːː
green	ti			*in*	ʔɪːː
one	ʔɒː			*green*	diːç
				spoon	buː
				tum	dʊb̚

Table 28: Alison's targets with singleton nasal coda in sessions 2-7.

3.3.6 Complex coda

Stop + fricative

Only one attempt at complex stop+fricative codas were recorded throughout the study. The coda was reduced to the stop (*shapes* [ʔeɪʔpʔ]).

Nasal + stop

There were only three words with a nasal-stop or liquid-stop sequence in coda: *jump* [dʑʊp], *help* [heʊpʰ] and *drink* [dːʒɪŋkʰ]. Only in *drink* was the final sequence not reduced to a single consonant. This is interesting, if we recall that both nasals and velar stops were entirely absent from Alison's codas. Thus, Alison only began to attempt these consonants in session 7.

However, there was high variability in how the final sequences were produced, and in many cases different tokens of words exhibited variable coda omission (e.g. *help* [hʊ]) or glottal stopping (e.g. *help* [heʊʔ]). Table 29 presents all nasal/liquid+stop codas.

Table 29					
session 2		**session 3**		**session 4**	
		jump	ʤɨb̚	*jump*	dʑʊp:::ʰ
			ʤʊʔp		tɕɨb̚
					ʤɪʊʔb::βʊ
					tɕʊb:pʰ
session 5		**session 6**		**session 7**	
help	heʊpʰ	*help*	hɪʊp	*drink*	ʤɪŋʔ
	hu		h:eʊʔ		d:ʒɪŋkʰ
	hheʔpʰ	*jump*	ʤʊb		d:ʒeɪnʔn̥
			dʑʊp̚		d:ʒɪnʔ
			ʤʊbɸ	*help*	heʊpʰ
					heʊʔ

Table 29: Alison's targets with complex nasal/liquid+stop coda in sessions 2-7.

3.3.7 Coda in disyllables

As Alison's acquisition of codas in monosyllables was still in progress, she did not attempt many disyllabic words with coda during the time of the study. The few words of that type that did appear had fricative coda almost exclusively (except one child form ending in a stop: *Weetabix* [ʔi:pʷɪp̪ʰ]) and , much like fricative codas in monosyllables, they were always inaccurate. In total, CVCVC words did not exceed 3% frequency throughout the study. Figure 8 presents the overall percentage of CVCVC words by type.

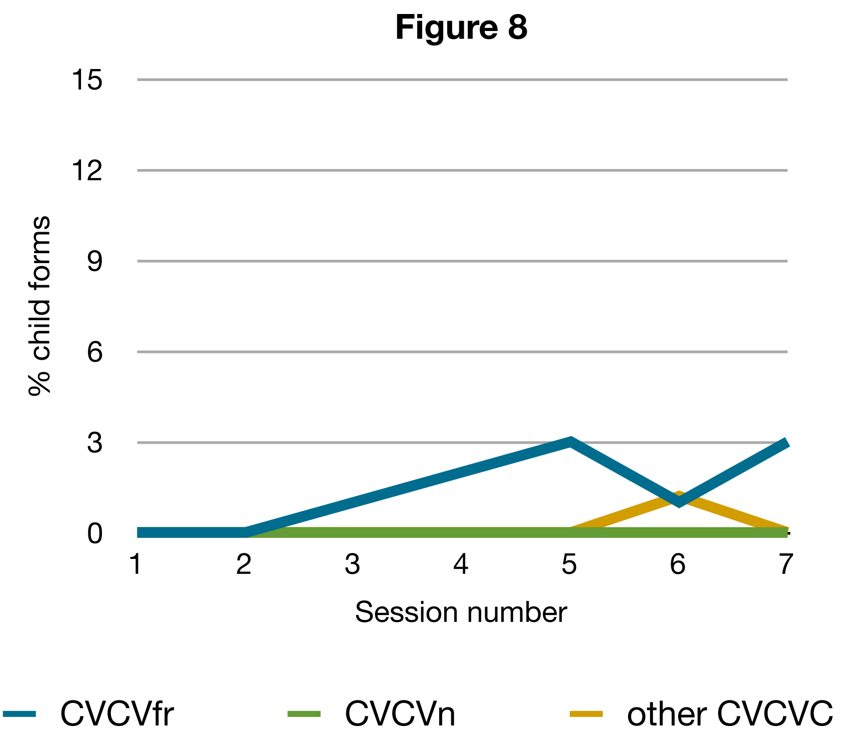

Figure 8: Percent of fricative, nasal and other codas in Alison's disyllabic child forms across sessions.

The first CVCVC word that Alison produced was *yes please* in session 3 (as noted earlier, *please* was not used on its own, suggesting that the expression was learned as a holistic item), which reappeared in sessions 4 and 5, and where the final fricative was rendered as /ç/ or /j/. In the last two sessions, there were several cases of fricativisation of final nasal (e.g. *pudding* [bɜdɒχ]) and stop (e.g. *quack-quack* [gaʔgaʔx]), as well as an instance of a very simplified form for *Weetabix* ([ʔi:pʷɪpʰ], which was the only CVCVC word with stop coda (albeit inaccurate). Table 30 presents all CVCVC words.

Table 30					
session 3		**session 4**		**session 5**	
yes please	mɪʔmɪ̃ː:ç	*bubbles*	pʊbɔːχ	*yes please*	jəhmɪç
		yes please	ʔɪʔpʰɨːʝ		
session 6		**session 7**			
Emily's	ʔɛməjiç	*all gone*	ʔʊnːɒːχ		
toilet	dɔːdɔχ	*pudding*	bɜdɒχ		
Weetabix	ʔiːpʷɪp̠ʰ	*quack quack*	gaʔgaʔx		

Table 30: Alison's di- and multisyllabic targets in sessions 2-7.

While codas in disyllabic words were always inaccurate, there were even more instances of inaccurate final fricative insertion in CVCV targets. As in the case of monosyllables, these were extremely variable, and often agreed with the preceding vowel (e.g. *baby* [beɪbiç], *bo-bo*[boʊbeʊɸ]). Table 31 presents all CVCV words that sometimes appeared with an added fricative in coda.

Table 31							
session 4		**session 5**		**session 6**		**session 7**	
mummy	m̩ː:əmeɪθ	*baby*	beɪbiç	*baby*	beɪbiːç	*bo-bo*	boʊbə̃
	mːamɪːʰ		bɛbʙɛː		beɪbiːx		bːəʊboʊχ
	mːəmːɪx	*Emily*	ʔæːmɪç		beɪbɪʰ		m̰bo̰ʊ̰bʊʔ
			ʔæmɪ	*bo-bo*	bəʊbːoʊʰ	*Daddy*	ndɒːdiχa̻
			ʔɛmə.ɪh		boʊbəʊx		daːdiːç
			ʔæ̰ːmix		boʊbeʊɸ	*Emily*	hɑmʊʤiː
			ʔæmʊnɪʒ	*Emily*	ʔæməji		ʔamiç
		mummy	mːʊːmiːç		ʔæmɜdix	*mummy*	mɒːmiç
			bamɪh		ʔæmʊdːiːç		ʔɒmiː
			mːɒmɪɣ	*mummy*	mʊːmʊɪ		mɒmih
			mameɪɕ		mɒmeɪçː		mːʊmːiːx
		sleepy	ʔɪibɪːç				mːəːmɪχ
			heɪbɪː				

Table 31: Alison's disyllabic child forms with inserted fricative coda in sessions 2-7.

Again, as in the case of monosyllables, it thus appears likely that the few fricative codas that Alison produced in CVCVC targets (cf. Table 30) could have been unintentional, and resulted from the lack of articulatory co-ordination between airflow and voicing.

3.3.8 Section summary

The only type of coda that was consistently produced was labial stops. However, they, too, showed a considerable amount of variability. Most frequently, variability in labial codas involved variation between the stop, a glottal stop and a fricative (e.g. *snap* [daɒp], [næʔf], [n::aʔ]; *stop* [bɔːʊ], [ʔæɸ], [ʔbɑʔ]). Sometimes, both a glottal stop and the target stop were used, showing lack of coordination necessary to control the airflow at the end of a word (e.g. *zip* [ʔɪpʰ], [hɪʔpʰ], [ʔɪʔ]).

Velar stops, nasals and liquids were absent from codas and almost always omitted (mostly voiced stops, nasals and liquids) or replaced with a glottal stop (mostly voiceless stops). This suggests that even though Alison was not yet able to produce these sounds, she did pick up on the voicing distinction.

As regards fricatives, it is arguable that they were not acquired at all. Firstly, all final fricatives were inaccurate, and there was only one instance of a fricative present in the target language (although also inaccurate, *mouth* [bmaːʊf]). At the same time, there was no systematicity in how they were substituted for the target sounds. Secondly, the fricatives were randomly added to open syllables in both mono- and disyllabic words, and the process was equally common as production of fricatives for fricative targets (and in the case of disyllables - more common). Thirdly, the final fricatives most often agreed in place of articulation with the preceding vowel. It is thus likely that fricative codas were in fact omitted throughout the study, but lack of airflow-voicing co-ordination led to the perceptual illusion that they were produced intentionally. This, however, cannot be fully determined without acoustic analysis.

To sum up, there were two common processes in Alison's production of codas. The first was coda omission and glottalisation. Although this happened frequently and was systematic for target consonants that Alison could not yet produce (e.g. nasals), it also occurred for consonants that were in her repertoire. In particular, alveolar and labial stops, which were the only final consonants available to Alison, exhibited a large amount of variability, as they were sometimes produced and sometimes omitted or glottalised. It was thus not the case that once a given consonant was acquired, it was no longer omitted.

Rather, after consistent omission at the beginning of the study, the consonants began appearing more frequently, but not in all targets and tokens. As for the second process, i.e. final fricative insertion, this appeared to also be due to inconsistent articulation. In other words, the general constraint on codas had many different articulatory outcomes, which varied across tokens, types, sessions and targets, suggesting that the constraint was articulatorily motivated.

3.4 Discussion

3.4.1 Segment-based processes

Alison began word production with a narrowly limited repertoire of consonants (33%). In fact, voiced labials /b/ and /m/ appeared to be her only really stable consonants in the first session, and other stops, nasals and glides were used sporadically. Accurate fricatives were almost completely absent from the child's production across sessions. The only consonants that Alison acquired during the time of the study were affricates, and in the last session she only produced 40% of supraglottal consonants of English, showing little improvement from session 1.

Nevertheless, despite the fact that she had few consonants at her disposal, no systematic segmental substitutions were observed in Alison's production. The processes that did occur appeared to be the result of on-line difficulties, in the sense that (a) they were articulatorily motivated, and (b) they were highly variable.

Perhaps the best illustration of the nature of segmental alternations in Alison's data is provided by her production of final fricatives. We have seen a few words with a final fricative in target which also had a final fricative in the child form, although they never appeared with the right place of articulation. However, the data also suggest that these inaccurate fricatives were likely a result of articulatory processes. Firstly, almost all final fricatives that Alison produced did not come from the target language. Secondly, they often agreed in place of articulation with the preceding vowel, and this correspondence appeared to be more important than the place of articulation of the target fricative. For example, *knees* [ni:ç] and *nose* [neʊɸ] had the same fricative in target, but were produced by the child with two different fricative codas, agreeing with the vowel. Thirdly, there was large variability across tokens, such that many words produced with a final fricative had the fricative omitted in other tokens (e.g. *off* [ʔɒχ], [ʔɒ]). Finally, the cases of fricative insertion in open-syllable words were as common as the cases of fricative omission. Taking the above facts into consideration, we concluded that the inaccurate final fricatives in child forms were either the results of on-line articulatory difficulties that had a different outcome on different occasions or a case of entirely unintentional production.

A similar case could be made for other modifications of consonants. As we have observed, when not due to whole-word processes such as consonant harmony, alternating consonants usually involved changes in voicing, prevoicing, fricativisation of stops and other types of lack of coordination between articulatory features. Furthermore, these processes occurred in a highly variable way, and affected even the most stable, labial consonants (e.g. *snap* [daɒp], [næʔf], [n::aʔ]). However, variability in these otherwise stable consonants almost never resulted in a change of place of articulation, suggesting that the targets were attempted, albeit in an imprecise way.

Therefore, modifications to consonants that were recorded in Alison's data were apparently due to inconsistent and imprecise articulation, as exhibited by their scope and variability. More inaccurate alternations, involving change of place of articulation, affected consonants that were outside the child's repertoire (such as fricatives), but their variability did not allow postulating any phonologically-motivated reason for their outcomes.

3.4.2 Whole word processes

In the course of Alison's phonological development, qualitative changes occurred in her phonological system, related to the emergence and then slow disappearance of word templates. In the beginning, Alison produced several codas, and appeared to be using glottal stopping in the adult way, i.e. only in targets with voiceless alveolar stops. She selected many disyllabic targets with labial harmony, as well as adapted a few targets to fit that constraint. However, by session 3, she developed two word templates that were much stronger, namely partial reduplication and the ʔVglV template. These patterns were used mostly for targets that were particularly challenging, with reduplication mainly affecting long, multisyllabic words, and ʔVglV mainly affecting words that had fricatives and liquids in target. Both of these patterns can be traced back to the processes observed in the first session.

As we have seen, when glottal stopping first appeared in session 1, it seemed to follow the adult rule. It only affected final alveolars, to the extent that words which had an alveolar stop in onset, but a labial or velar consonant in coda appeared with the consonants metathesised, so that the final glottal stop corresponded to the alveolar consonant (*stop* [ʔbɑʔ], *truck* [gʌʔ]). In the following session, it spread also to velar codas (e.g. *park* [mbɒʔ]), and for the first time, a ʔVglV word appeared (*Lola* [ʔɑ:jʊ]). Finally, in session 3, glottal stopping was widely affecting alveolar, velar and labial codas, final clusters (e.g. *beads* [biːʔ]), and many syllable onsets that were outside Alison's repertoire (e.g. *flower* [ʔæwa], *office* [ʔəhʔɑː). Therefore, it appears that the pattern of glottal stopping might have emerged from practice in using the adult pattern, and then gradually widened its scope due to the fact that it provided a way of coping with difficult consonants (velar codas at first, and onset fricatives and liquids later). Table 32 presents CVʔ and ʔVglV words in sessions 1-3.

Table 32					
CVʔ					
session 1		**session 2**		**session 3**	
boat	bɔːʔ	*book*	mbʊʔ	*beads*	biːʔ
boot	buʔ	*boat*	bɒʔʰ	*book*	bʊːʔ
night	ʔnɪʔ	*boot*	bʊːʔ	*boots*	bʊːʔ
stop	ʔbɑʔ	*milk*	mʊ̩ʔ	*break*	mbɜʔ
truck	gʌʔ	*park*	mbɒʔ	*hot*	hɑʔ
				seat	iʔʰ
				snack	nːːaʔ
				snap	nːːaʔ
				stop	daʔ
				stuck	gʊːʔə̥
				up	ɒːʔːʰ
ʔVglV					
session 1		**session 2**		**session 3**	
		Lola	ʔɑːjʊ	*butterfly*	ʔɛ hɛwʊː
				flower	ʔæːwa
				help please	ʔəhwɪː
				office	ʔəhʔɑ̰ː
				orange juice	ʔɒjɒ.ah
				sausage	ʔɒ ʔəː
				shower	ʔəʊwæː
				sorry	ʔɑɪjɑːʰ
				sugar	ʔa ʔɔ̰ː

Table 32: The development of Alison's CVʔ and ʔVglV child forms in sessions 1-3.

Similarly, there were instances of reduplication in session 1, which Alison applied when she was requested to add *please* to her utterance (e.g. *more please* [nmɛʰəməː]). Later on, in session 3, reduplication began affecting all multisyllabic targets (*gentleman* [dʲɜdɜːdɜː], *paddling pool* [pʊpʊpɔː]). Table 33 presents partially reduplicated words in sessions 1-3.

Table 33					
session 1		**session 2**		**session 3**	
milk please	mɛʰ mu:			*building blocks*	bəʊbəbɑ:
more please	nmɛʰəmə:			*choo choo train*	dʊdɜʤɜ:
yes please	mɛʰʔmə			*computer*	bʊbubɜ
				cup of tea	gʊg:ɔ:gɔ:
				dinosaur	gɑ:gaʔ
				gentleman	dʲɜdɜ:dɜ:
				museum	m:umɪ:
				paddling pool	pʊpʊpɔ:
				teddy bear	bəbɛ:

Table 33: The development of Alison's partial reduplication pattern in sessions 1-3.

The above patterns allowed Alison to attempt many words that would have otherwise been out of her reach, and resulted in her vocabulary being larger than the other two subjects', despite her having the most limited consonant inventory. Both of the patterns seem to have emerged from the less systematic processes Alison began with. These processes, at first restricted to specific targets (alveolar stops in the case of glottal stopping and utterances with *please* in the case of reduplication) gave rise to the emergence of phonological systematicity, which transformed whole words in a consistent and predictable manner. In this way, during the first three sessions, Alison's words were becoming more and more similar to one another.

3.4.3 Variability and systematicity

While there was large variability in segment-based processes, whole word processes appeared much more systematic. For example, there were very few cases of the same word appearing with progressive and regressive consonant harmony in different tokens, or of words which had a variable number of syllables across tokens. Rather, when the adapted words varied, it was mainly in the phonetic identity of particular consonants (e.g. *Pop-up pirate* [babəbə], [mbɒ:bʁabə:], [pabəbə]), just as what was observed for segment-based processes in more accurate word shapes. Alison's word templates thus appeared relatively stable, and it was the lack of articulatory precision that made them occasionally variable.

Nonetheless, at the peak of systematicity in session 3, apart from the fact that words were less variable due to the stability of the templates, there was a drop in variability also in the rendition of individual consonants. Conversely, the overall variability began increasing from session 4 onwards, along with the decrease in the use of templates. Figure 9 presents variability and T score across sessions.

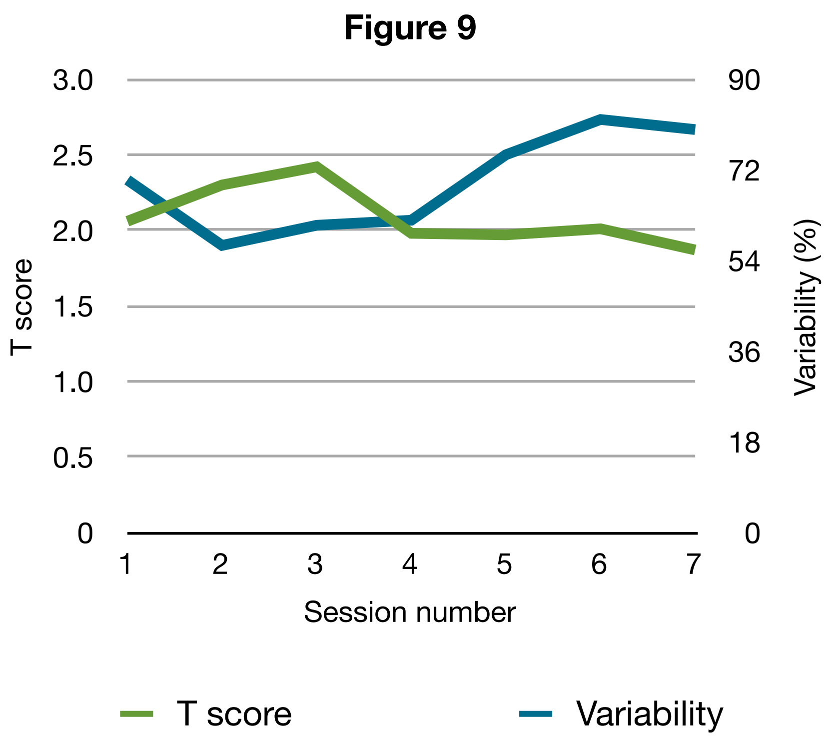

Figure 9: Alison's T score (Y1) and variability (Y2) across sessions.

Variability was high in session 1, when the templates were only beginning to emerge, and then decreased along with the peak of systematicity, although it is worth noting that even in the most systematic session 3, there was some degree of variability observed. As consonants were produced with increased accuracy, it was not the case that once a given consonant appeared, it was no longer omitted or substituted with another one. Rather, after relatively consistent omission in session 3, consonants began appearing more frequently, but not in all targets and tokens. Therefore, the changes in the stability of templates were reflected in the level of variability of the whole phonological-articulatory system.

In this way, variability accompanied the emergence and the gradual fading of templates, suggesting that templates acted as attractors in the child's system, leading to stabilisation of inaccurate forms. The path to overcoming templates thus involved a return of instability. At this stage of development, variability was therefore a sign of improvement of Alison's phonological competence, as it signified the gradual disappearance of inaccurate, child-specific patterns. As expected from the fact that the templates were based in Alison's articulatory routines, the variability affected the whole of her production, and not only the words affected by templates.

3.4.4 Boldness

We have seen that one of the most distinctive characteristics of Alison's speech was her boldness in attempting challenging consonants and word shapes, especially in session 3. She produced far more multisyllabic targets than the other two children, and attempted many consonants that are considered difficult for children at the early stages of word production. Indeed, boldness was the only variable that correlated significantly with accuracy throughout the study (-0.93). Figure 10 presents the two measures.

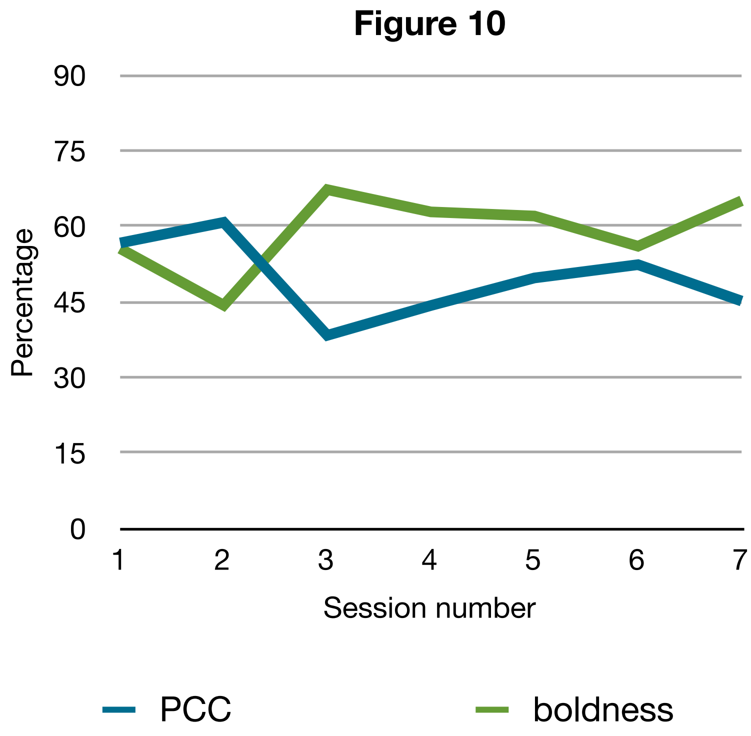

Figure 10: Alison's PCC and boldness across sessions.

In the beginning, Alison usually selected word onsets according to her articulatory capabilities, and she also produced many adult-like coda glottal stops, as well as a few supraglottal coda consonants. She only usually targeted more challenging consonants in the word medial position. These tendencies were reflected in the accuracy of particular word positions in her production, which was relatively high for onset (73%) and coda (57%), while the accuracy of medial consonants was very low (33%). Therefore, the overall accuracy matched the overall boldness, with the two measures at 57% and 56% respectively. Since Alison was a very voluble child, with over four times as many tokens as types, she produced many tokens of fairly accurate words, the choice of which, however, was severely limited by her small consonant inventory (33%).

In the next session, Alison's boldness decreased (44%). Attempting even fewer challenging consonants made her accuracy improve, although there was a slight increase in systematicity, suggesting that templates were beginning to emerge. In the two sessions leading to the peak of systematicity, Alison was therefore producing a large number of tokens of few word types (the number of word types did not change in the first two sessions), which were constrained by her limited articulatory skills. Therefore, Alison's words were already similar to one another (due to word shape and consonant inventory constraints), even before the templates became strong.

As a result, the major change in Alison's phonological system in session 3 was that the word shapes that were accessible to her, which she had practiced in words that were selected to fit them, began being applied to targets that were entirely different. Thus, a sudden increase in boldness corresponded to an increase in systematicity, as templates made it possible to attempt previously unavailable targets, and conversely, the tendency to attempt very challenging targets increased the need to adapt them to fit the child's constraints.

Predictably, these tendencies led to a dramatic drop of accuracy, which plummeted from 61% in session 2 to 38% in session 3. At the same time, the number of word types increased from 39 in session 2 to 110 in session 3. Alison appeared to be more interested in attempting many new words than in repeating the ones she already knew. The detailed analysis of the development of Alison's codas and CVCV words demonstrated, that indeed, it was the multisyllabic, fricative, liquid and coda targets that were mostly affected by the templates (cf. sections 3.3.2 and 3.3.3).

For the accuracy to begin improving again, Alison's boldness had to decrease, which reduced the need for resorting to templates, and thus corresponded to a simultaneous decrease of systematicity. In sessions 4-6, the child's boldness dropped to 63%, and then 56%, while T score remained at around 2.0 (after reaching 2.42 in session 3). Figure 11 presents boldness, accuracy and variability across sessions.

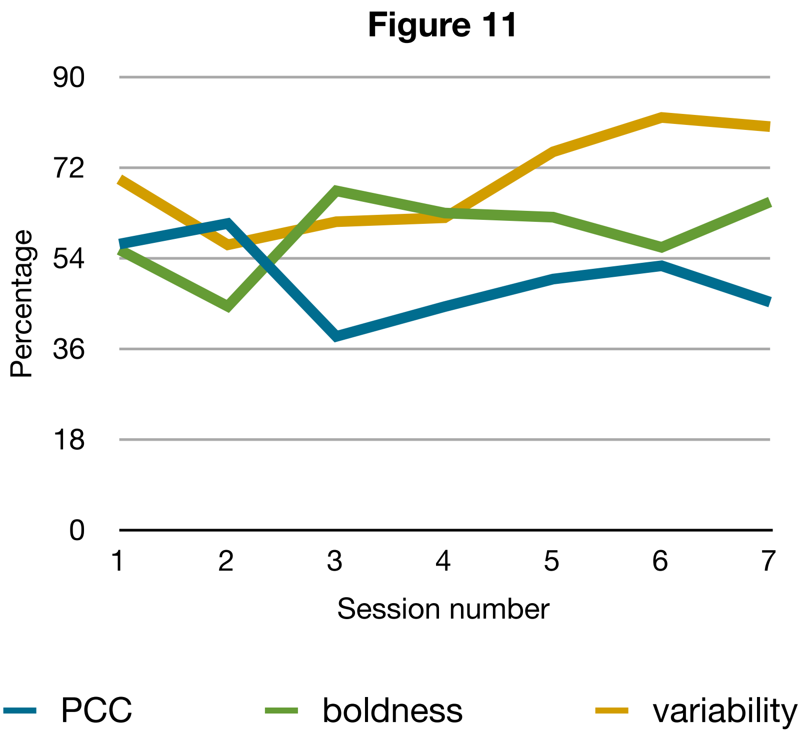

Figure 11: Alison's PCC, boldness and variability across sessions.

3.4.5 Chapter summary

In summary, the picture that emerges from Alison's data is that of development being driven by the interaction of several factors. On the one hand, limited consonant and word shape inventories made the child's production fairly systematic, in the sense that they only allowed for attempting particular types of words. This, coupled with high volubility, which meant that they were practiced in a lot of tokens, could have paved the way for the emergence of templates and the consequent regression of accuracy. On the other hand, it was the increase of boldness in attempting challenging targets that created the need for the well-practiced patterns to be applied in inaccurate ways, leading to high adaptation. In other words, articulatory limitations and the systematicity in the system which resulted from these limitations, transformed into regular alternation patterns due to the child's communicative needs (i.e. being able to use more words). This individual tendency of the child could thus be conceived of as a control parameter, pushing the phonological system into a new state of systematicity, which, however, is based on the previously existing skills and habits, i.e. the initial state. As a result, the development of Alison's accuracy is non-linear, showing two points of re-organisation: first into the templatic organisation, and then out of it, both accompanied by a rise of variability.

4. JUDE

4.1 25-word point

4.1.1 Consonant inventory

Jude reached the 25 word point at the age of 1;3.11, and in that session he produced 41 targets. It is perhaps worth mentioning that in the session before that he only produced 6 words, which means that during the month between the two sessions there was a rapid growth in his vocabulary. However, it is the 25 word point session that is the first one analysed here. The consonants that Jude produced correctly in session 1 only appeared in syllable onsets, and included 7 consonants out of the 15 English consonants analysed (47%). Table 34 presents Jude's consonant inventory.

Table 34

	Bilabial		Labio-dental		Dental		Alveolar		Post-alveolar		Palatal		Velar	
Plosive	p	b					t	d					k	g
Nasal	m						n						ŋ	
Trill														
Tap/Flap														
Fricative			f	v	θ	ð	s	z	ʃ	ʒ				
Affricate									tʃ	dʒ				
Glide	w										j			
Liquid							ɹ	l						

Table 34: The consonant inventory of English with Jude's consonants in session 1 highlighted in grey.

Supraglottal fricatives and affricates were generally absent from Jude's repertoire. There were, however, two instances of almost accurate /ʃ/ and /tʃ/, which were produced by the child as /ɕ/ and /tɕ/ (*fish* [ɪɕ], *chocolate* [tɕata]). While the distinction between postalveolar and palatal fricatives and affricates is not contrastive in English, the fact that they both only appeared in one word each, and that there were other instances where the targets were produced incorrectly (e.g. *cheese* [xiː]) suggest that they could not be considered fully acquired at the time. There was also one instance of the liquid /l/ (*flower*[la]).

Among the more stable consonants, the most frequently used were /t/ (9 words), /b/ (8 words), and /n/ (5 words). Only three words in the data involved the velar /k/ (*cake* [kxi:], *car* [kʰa], *sky* [ca]), and there were no targets with the voiced /g/. This suggests that the child had a preference for labials and alveolars, which showed in his selecting targets that included these consonants.

4.1.2 Word shape inventory

Jude's repertoire of word shapes exhibited tendencies often observed for children at early stages of word production, i.e. right after the transition from babble to words. He had a very strong preference for open syllables and for consonant harmony in disyllabic words. Furthermore, these preferences were clearly apparent not only in selection of targets which met the criteria, but also in a great amount of adaptation: 46% of all words that Jude produced were modified to match his whole-word preferences.

CVCV

Due to his frequent omission of codas, Jude's words were almost exclusively CV and CVCV, with each of these two categories encompassing 16 words (39%). In addition, there were no disyllabic words with variegated consonants. All disyllabic targets with two different consonants in syllable onset underwent consonant harmony. Table 35 presents Jude's CVCV words in session 1 (Table includes words adapted through coda omission, also presented in Table 36)

Table 35					
C1VC1V selected		**C1VC1V adapted**		**C1VC2V**	
baba	baba	*chocolate*	tɕata		
barnaby	bɑbʷi	*circle*	tʰʊtʰʊ		
choo choo	tʰɪ tʰɪ	*dinner*	nɪne		
dada	dadʑa	*football*	babo		
daddy	tatʰɪ	*in there*	ɲɪnɪn:ɛ		
mummy	mʌmi	*noddy*	m:tnɒne		
		trousers	tətɕɪ		

Table 35: Jude's CVCV child forms in session 1.

Coda

The large amount of adaptation among Jude's words was due to coda omission. There was only one word with coda in both target and child form: *fish* [iɕ]. In that word, the onset was omitted, which could be related to the fact that producing the coda required much effort. There was thus a trade-off between word positions. In all other targets with codas, the coda was omitted. Table 36 presents mono- and disyllabic targets with coda.

Table 36					
coda		**coda deletion CVC**		**coda deletion CVCVC**	
fish	ɪç	*cake*	kxi:	*bubbles*	babo
		cheese	xi:	*chocolate*	tɕata
		flower	la	*night night*	nənə
		mouth	ma	*tic toc*	tʊtʰa:
		stuck	tɕʌ	*trousers*	tətɕɪ
		teeth	tʰi:		

Table 36: Jude's targets with coda in session 1.

4.1.3 Consonantal variability and accuracy

There were five processes affecting consonants that appeared in more than 10% of words in session 1. Three of these appeared to be interrelated: palatalisation, affricativisation and affricate reduction. We have already seen two cases of fricative and affricate palatalisation (cf. section 3.1). Palatalisation also sometimes occurred for alveolar stops, usually together with affricativisation (e.g. *dada* [dadʑa], *stuck* [tɕʌ]). While stops were often affricated, affricates were often reduced to stops (e.g. *choo-choo* [tʰu tʰu]). This high amount of randomness in production of affricates provides further evidence that they were not yet acquired, but rather, their production was due to imprecise articulation. Thus, although target affricates were absent, inaccurate palatalisation and affricativisation were common in the data, present in 17 and 13 out of the 100 different word forms respectively.

The other two common processes were reduction of s+stop clusters (all 5 such targets were reduced to the stop) and liquid gliding and vocalisation. Table 37 presents these four most common processes affecting segments.

Table 37			
process	**No. tokens**	**Example**	
liquid gliding and vocalisation	16	*orange*	ɑwɪ
affricativisation	13	*dada*	dadʑa
palatalisation	12	*choo choo*	tɕ tɕ
affricate reduction	10	*cheese*	kʰɪ
cluster reduction ([s]+C2)	5	*star*	da

Table 37: Jude's four most common substitution processes in session 1.

Both the segment-based processes mentioned above and Jude's constraints regarding word shapes resulted in very low consonantal accuracy (51%). Accuracy was thus highest in word onset position (61%), but much lower in the word medial position (48%), as many word medial consonants underwent consonant harmony. The accuracy of codas was very low (33.3%), since these were usually omitted.

In session 1 many words appeared in more than one token and the total number of tokens produced by Jude in session 1 was over four times higher than the number of targets. Sixty-three percent of words that appeared in more than one token varied across tokens with regard to consonants or syllable shape, making Jude start out as the least variable of the three subjects. A large amount of variability was due to variably applying segment-based processes, such as palatalisation and affricativisation of stops, and affricate reduction. For example, *chocolate* appeared as [tɕata] and [ɕɔtə], and *circle* as [tçtɕ], [tɬutɬu] and [txtx] (among other variants). Some amount of consonantal variability was also due to variable devoicing and prevoicing (e.g. *ball* [bɔ] or [pɔ]; *mouth* [ma], [mba]), and liquid vocalisation (e.g. *apple* [aba], [aboʊ]). Variable application of these processes pointed to them being motivated by articulatory difficulties, which made the production of consonants unstable. Table 38 presents all tokens with variable consonants from session 1.

Table 38			
apple	aba	*choo choo*	c c
	aboʊ		t tɕ
baba	bawa		tɕ cç
	baba		tɕ tɕ
	pʌbo		tʰ tʰ
	bava		tʰɪ tʰɪ
ball	abo		tɬ: tɬ:
	boʊ		tʃ tʃ
	bɔ		tx tx
	əbɔʊ	*circle*	tçtɕ
	əmbaʊ		tɬ:
	mbɔ		tɬ:th
	pɔ		tɬʊtɬʊ
cake	kxi:		txtx
	kχɪ		totχo
	cɪcçɪ		tʌtɬʌ
	kɪkʰɪ		tχtχ
car	ga	*hiya*	jaija
	da		aija
	tʰa		haɪə
cheese	xi:	*mouth*	ma
	kʰɪ		mba
chocolate	ɕɔtə	*star*	da
	tɕata		ta
		in there	ɟɛ
			nlɛ
			βæ

Table 38: Jude's child forms with variable consonants in session 1.

In contrast, there was little variability in processes affecting syllable structure. The few recorded cases involved alternations between vowels and syllabic fricatives (e.g. *fish* [ɪɕ], [ç:]), variable onset omission (e.g. *football* [babo], [əbɒ]), syllable addition (e.g. *cake* [kxi:], [kɪkʰɪ]) and one instance of final fricative insertion (*baba* [baba], [baβaχ]). Table 39 presents all tokens with varying syllable structure.

Table 39	
baba	baβaχ
	baba
cake	cɪcçɪ
	kxi:
caterpillar	pItIppkapmpmp mpmpmpmpk
	pia
circle	cɪcç
	tʰkʰɪ
	tʰʊtʰʊ
fish	ç:
	ɪɕ
football	babo
	əbɒ
in there	n:ɛ
	ɪjɛ
	nəna:
	ɲɪnɪn:ɛ
tic toc	ɪɬa
	tʊtʰa:

Table 39: Jude's child forms with variable syllable structure in session 1.

4.1.4 Section Summary

Jude was a talkative child, and he was also bold in attempting challenging word shapes and consonants, as 58% of all consonants he attempted were clusters, fricatives, affricates and liquids in syllable onset (48% of all attempted word onset, 40% of word medial consonants) or coda consonants (22%). All of these were outside his repertoire at that stage.

Therefore, Jude begins as a child who has a relatively small inventory (47%) of relatively variable consonants (variability 63%), and is very systematic with regard to word shapes, producing almost exclusively open syllables and always repeating the same consonant in disyllabic words. This is reflected in a high T score of 2.29. Systematic processes of coda omission and consonant harmony allow him to attempt many targets that he would not otherwise be able to produce, although that requires a large amount of adaptation (46%). This, coupled with imprecise and variable articulation, negatively affects consonantal accuracy, which is relatively low (51%). Table 40 presents all measured variables for session 1.

Table 40	
T score	2.29
accuracy	51.1%
variability	63%
boldness	58%
consonant inventory	47%

Table 40: Values of measured variables in Jude's session 1.

4.2 CVCV

4.2.1 Overview

We have seen that in session 1, disyllabic words with harmony constituted almost 40% of all words produced by Jude. Over 60% of these were adapted from targets with two different consonants. From session 2 onwards, the percentage of CVCV words with harmony rapidly decreased, until the category reached the target frequency in session 5 (7%, target: 6%). In the last three sessions the only C1VC1V words were those which had harmony in target (e.g. *nanny* [nani], *mummy* [mʌmi]).

The decreasing use of consonant harmony corresponded to continuously increasing frequency of CVCV words with variegated consonants. These, too exceeded the target frequency in session 5 (22%, target: 14%). Both C1VC1V and C1VC2V categories remained stable from that session until the end of the study. Figure 12 illustrates changes in frequency in the two categories across sessions.

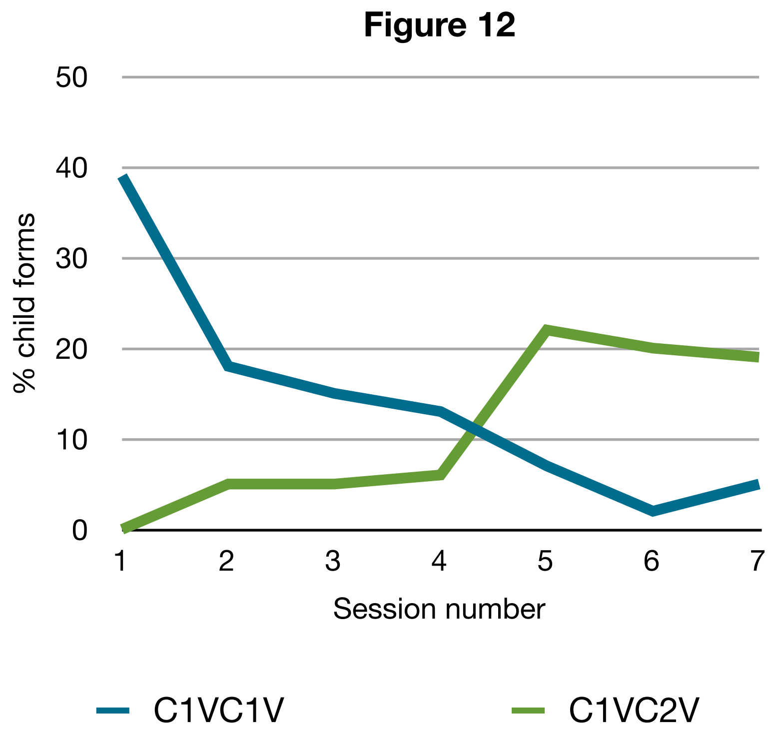

Figure 12: Percent C1VC1V and C1VC2V child forms in Jude's production across sessions.

At the same time, there were changes in how many challenging consonants (affricates, fricatives and liquids) and clusters Jude attempted in word-initial and word-medial position. The percentage of these dropped in session 2, when consonant harmony began to be less commonly used. In other words, when the pattern was strong in session 1, more difficult target words were attempted, because the pattern simplified their form. Reversing the pattern meant that the difficult consonants could not be easily replaced, and therefore they were not attempted that often. Conversely, not attempting many inaccessible consonants decreased the need for using the pattern. However, from session 2 onwards, the percentage of challenging targets increased again. Figure 13 presents the percentage of attempted difficult consonants in word onset and word medial position across sessions.

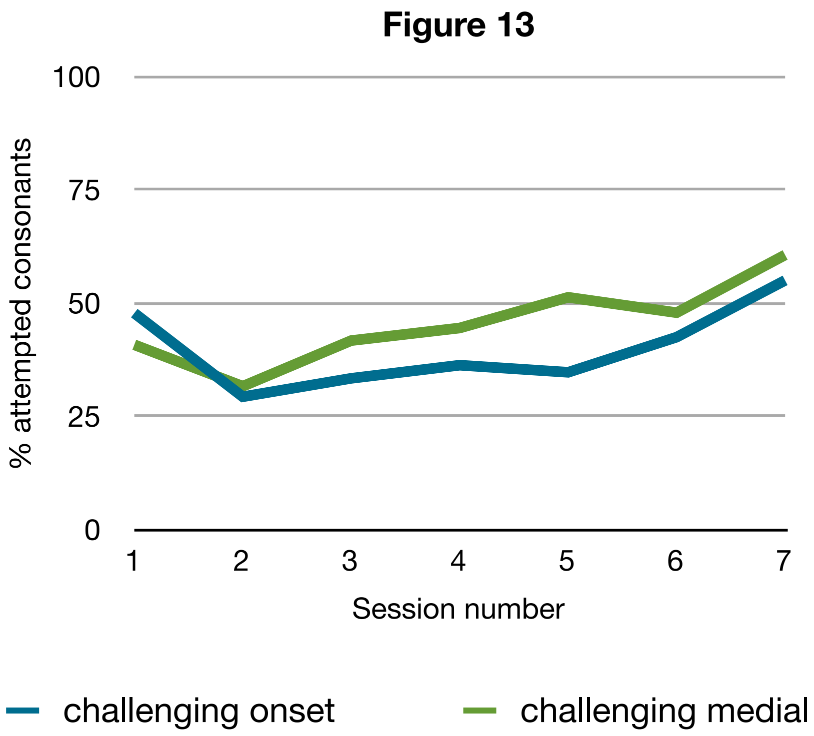

Figure 13: Percent challenging word initial and word medial consonants in all consonants attempted by Jude across sessions.

The increasing boldness in attempting challenging consonants corresponded to increase of accuracy. The accuracy of word onset increased in session 2, although it slightly decreased again in the next session, which was accompanied by a sharp rise in the accuracy of word medial position. Until the last session, the accuracy of both positions remained around 70-80%. Variability of consonants in these positions was relatively high until session 4, but after that began decreasing, even though boldness continued increasing, showing that Jude's skill in producing previously inaccessible consonants was continuously developing. Figure 14 presents variability and accuracy in word onset and word medial position.

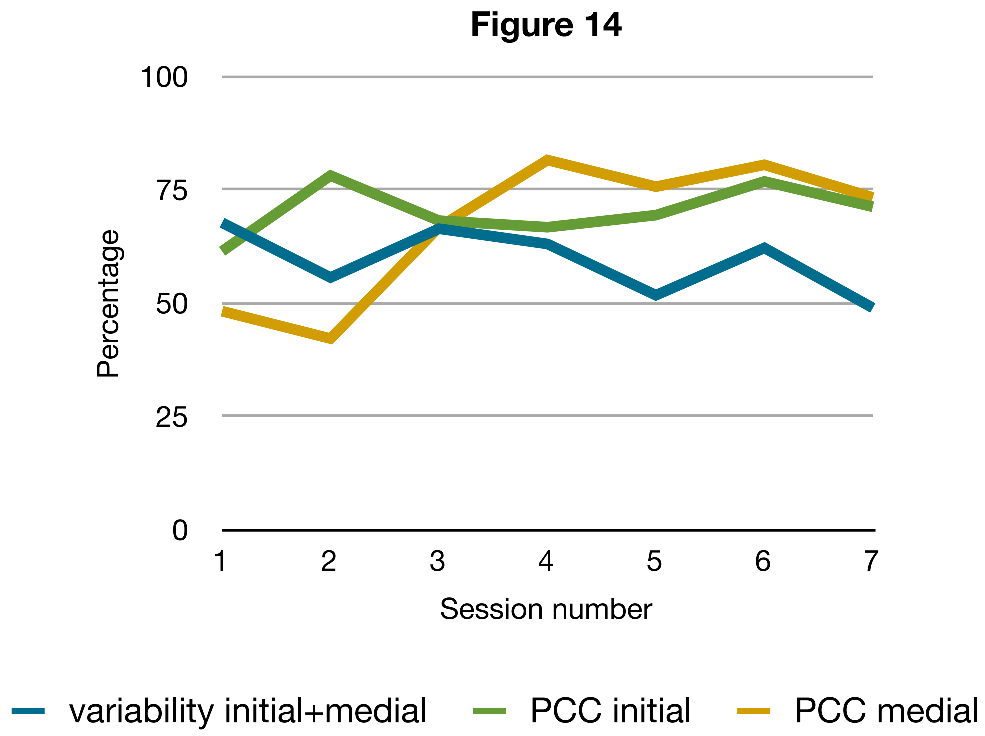

Figure 14: Percent variable and accurate word initial and word medial consonants across sessions (Jude).

4.2.2 Simple onset

Selection and accuracy

Disyllabic words with variegated consonants were not very common until session 5, and that was the case even for words with simple onsets in both syllables, i.e. with singleton stops, nasals and glides. Only two words of this type were recorded in sessions 2-4, *Mickey* [məɪki] and *naughty* [nɔti] (in the latter, the consonants had the same place of articulation, which might have made them easier to coordinate).

However, from session 5 onwards, C1VC2V began to be produced frequently, and there was no visible preference for any particular place or manner of articulation. Labial and alveolar stops and nasals, as well as velar stops, were produced accurately, the only exception being the word *dummy* [hʌmi] in session 5, in which the onset was replaced with a glottal fricative. The word was produced accurately in the next session. Table 41 presents all selected C1VC2V words with simple onsets.

Table 41					
session 2		**session 3**		**session 4**	
		Mickey	məɪki˙		
		naughty	n˙ɔti˙		
session 5		**session 6**		**session 7**	
birdie	bodiː	*birdie*	bɜːdiː	*better*	bɛtə
buggy	bʌgiː	*doggy*	dɔːkiː	*digger*	dɪgə
dummy	hʌmi	*dummy*	dʌmiː	*money*	məniː
Mickey	mɪkʰiː˙	*maybe*	meɪbiː	*naughty*	nɔːtʰi
money	məːniːː	*naughty*	nɒtʰiː		
naughty	nɔːtiː				

Table 41: Jude's 'selected' C1VC2V words in sessions 2-7.

Jude also produced many disyllabic words with consonant harmony which were selected from targets of that type. The number of these words remained stable throughout sessions. Labial and alveolar stops and nasals were prevalent in these words, and they were almost always accurate. The two alternations to the target sounds that were recorded were affrication (*daddy* [dadʒi]) and fricativisation (*poppy* [poɸʊiː]), both in session 6. These, however, did not occur systematically, and therefore appeared to be random.

No velar stops were recorded in this category. Table 42 presents all selected C1VC1V words with simple onsets.

Table 42					
session 2		**session 3**		**session 4**	
baba	baba	*daddy*	dadi˙	*baby*	bəbi˙
bye bye	babai	*mummy*	mʌmi˙	*daddy*	neɪtʰʌdʲi
mummy	mʌmi			*mummy*	mʌmi˙
				nee noh	nen˙ə
				paper	peɪpə˙
				poo poo	bɯ˙bo
session 5		**session 6**		**session 7**	
daddy	dʌdi	*bye bye*	bəʔbaɪ	*daddy*	dadɪ
mama	ma̜ːməː	*daddy*	dadʒi	*mummy*	mʌmɪ
nana	nana	*nanny*	nani˙	*Nee-noh*	niːnɔ
		poppy	poΦʊiː		

Table 42: Jude's 'selected' C1VC1V words with simple onsets.

Adaptation and variability

Disyllables with variegated simple onsets emerged in session 5, and from that session onwards no cases of adaptation were recorded. In sessions 2-3, however, consonant harmony was applied to two words of that type. One of them was *doggie*, which appeared with progressive harmony in session 2 ([dɒdi:]) and regressive harmony in session 3 ([k^həg^hi]). It was later accurately produced in session 6. The other word was *Noddy* ([nɑɲɪ], [nʌni:]), in which nasalisation spread from word onset to word medial position in sessions 2 and 3, even though another word with a similar sequence of consonants was produced without harmony in session 3 (*naughty* [nɔti:]). No other instances of consonant harmony applied to words with simple onsets was recorded, showing that these words only became frequently attempted once Jude's control of variegated consonants was already high.

There was also very little variability in disyllables with simple onsets. The only variable words in this category were: *Noddy*, which in session 2 was produced as [ʝanɪ] and [nɑɲɪ], showing that the two different consonants were attempted, even though consonant harmony was the more common result; *dummy*, which had the onset replaced with a glottal fricative or deleted altogether in session 5 ([æmʋi], [hʌmi]), and the target stop undergoing palatalisation in some tokens in session 6 ([dʌmi:], [ʝʌmi:]); and finally, *naughty*, in which the medial stop varied in voicing. Variability was thus rare and seemingly random. The rest of the time, disyllables with simple onsets did not show variability even in voicing. Table 43 presents all variable CVCV words with simple onset.

Table 43							
session 2		**session 5**		**session 6**		**session 7**	
Noddy	ʝanɪ	*dummy*	æɱʋi	*dummy*	dʌmiː	*naughty*	nɔ:t^hi
	nɑɲɪxa:χ		hʌmi		ʝ͡ʌmiː		nodʊ
			ʔhamʔhi				nɔtɬɪ

Table 43: Judes variable child forms for CVCV targets with simple onsets in sessions 2-7.

4.2.3 Challenging consonants and clusters

Challenging word onset

Consonant clusters, fricatives, affricates and liquids in word onset remained challenging for Jude throughout the study. There were two onset clusters attempted, *playdough*, which appeared in session 6 and was produced correctly, and *spider*, which had the fricative deleted in sessions 3 and 4 ([paɪdə], [pɪdʌ]), and in session 6 reappeared with the onset of child form being a merger of the two target sounds ([βaɪdə]). However, singleton fricatives did appear from session 5 onwards (e.g. *farmer* [fɑ:mɑ]), although their place of articulation varied (e.g. *figgy* [ɸɪgi:], session 6). Similarly, affricates were also not consistently produced, the best example being the word *chockie*, in which the affricate was produced in session 5 ([tʃɔgɪ]), but reduced to the stop in session 7 ([tɔki:]). The only word initial liquid target was recorded in session 7, and it was glided (*runner* [wanə]). Table 44 presents all targets with challenging onset.

Table 44					
session 2		**session 3**		**session 4**	
		spider	paɪdə	*spider*	pɪdʌ̥
session 5		**session 6**		**session 7**	
chockie	tʃɔgɪ	*farmer*	fɑˑmə	*chockie*	tɔki:
farmer	fɑ:mɑ	*figgy*	Φɪgiː	*runner*	wanə
		Jamie	dʒamiː		
		playdough	pʰlɛɪdɔʊ		
		spider	βaɪdə		

Table 44: Jude's CVCV targets with challenging onset in sessions 2-7.

Fricatives and affricates also varied across tokens. In particular, /f/ was realised as /f/, /ɸ/ or /h/ in the word *farmer*, and the affricates in *chockie* and *Jamie* were variably reduced to /c/ and /d/ respectively. Table 45 presents variable challenging word onset.

Table 45			
session 5		**session 6**	
chockie	cɔgiː	*farmer*	fɑˑmə
	cɔʔkiː		ɸɑmə
	tʃɔgɪ	*Jamie*	damiː
farmer	həm:ə		djəmɛɪ
	həmə̤h̤		dʒamiː
	difɑːmɑ		
	ɸɑmə		

Table 45: Jude's variable child forms for CVCV targets with challenging onset in sessions 2-7.

Challenging word medial

As we have seen, there was only one instance of an accurate word onset cluster (*playdough*in session 6), and medial clusters, too, constituted a challenge for Jude. In sessions 2-5 all medial clusters were reduced, even the ones that consisted of a homorganic nasal and stop (e.g. *monkey* [mʊkʰiː], *window* [wɪdoʊ]). This changed in session 6, when two medial clusters were produced (*windmill* [wʊnmɛʊ], *window* [windəʊ]), showing that Jude's skill in producing complex sequences was improving.

As regards fricatives and liquids (there were no targets with medial affricates), only /l/ was produced consistently from session 6 in *yellow*. The fricative /s/ appeared in session 5 in *horsie* [hɔsɪ], but was stopped in session 7 in *Percy* [patʰɪ]. The liquid /r/ was replaced with a labial fricative (*Carrie* [kaβi]). Thus in the word medial position, as in word onset, the consonants that were challenging for Jude at the beginning of the study remained difficult until the last session, although there was improvement, which was apparent in consonant clusters. Table 46 presents all targets with challenging medial position.

Table 46					
session 2		**session 3**		**session 4**	
tick tock	tukʰɒ	*good boy*	bəba̪ˑɪ	*horsie*	hɔziˑ
		in there	nɪnˑnɪnɛ		
		monkey	mʊkʰiː		
session 5		**session 6**		**session 7**	
good boy	gʊbbɔɪ	*windmill*	wʊnmɛˑʊ	*camera*	kʰæmpbʷə
horsie	hɔsɪ	*window*	windəʊ	*Carrie*	kaβi
window	wɪdoʊ	*yellow*	ijɛlɔʊ	*Percy*	patʰɪ
				yellow	jɛlɔʊ

Table 46: Jude's targets with challenging medial consonant(s) in sessions 2-7.

Further evidence for the instability of fricatives was provided by the high variability observed for the only word which had an accurate alveolar fricative in some tokens, i.e. *horsie*. In sessions 4 and 5 it appeared with the medial fricative varying between /s/, /z/, /ɕ/, /ʑ/, /ʃ/ and /θ/, i.e. all coronal places of articulation. Table 47 presents all recorded forms of that word.

Table 47			
session 4		**session 5**	
horsie	hɔːʃʒiː	*horsie*	hɔtɬɔːɕi
	hɔziˑ		hɔʔθiː
	ɔɕiː		χːʃɪˑ
	ɔ̰ʑ̥i̤ː		dɔːsi
	tsɔ̰sɪ̥ː		hɔʃi
	ʔɒθɪˑ		hɔsɪ
	hɔθi		

Table 47: Jude's child forms for the word *horsie*.

There were no other cases of variability in CVCV words with a challenging medial consonant.

Challenging onset and medial

While cases of consonant harmony were rare in words with at least one simple syllable onset, words which had a difficult consonant or cluster in both onset and medial position were often harmonised, especially in sessions 2-4 (e.g. *circle* [tʰʊtʰʊ], *tractor* [gʌkʰə]). In sessions 5-7 these words became more accurately produced, although the consonants often underwent substitution (e.g. *circle* [θːːaŋʔkʊ], *tractor* [twaʔkʰə]). Especially in the last session, the only systematic process observed was /r/-gliding (e.g. *driver* [dwaɪvə]). Table 48 presents all targets with challenging onset and medial position.

Table 48					
session 2		**session 3**		**session 4**	
choo choo	tətʊ	*choo-choo*	tʃtʃʉː	*circle*	gəʔkʉːɣ
circle	tʰʊtʰʊ	*circle*	nːdɛzʲɪkoʊ	*tractor*	kaʔkʊa
		la la	laːləˑ		
		tractor	gʌkʰə		
session 5		**session 6**		**session 7**	
driver	æ̰ːˑɪbʌɪtɬ͡ʎɪbɜː	*circle*	θːːaŋʔkʊˑ	*driver*	dwaɪvə
lolly	lɔli	*thank you*	θʌŋk'(.)uː	*reindeer*	wɛɪndɪə
thank you	hʊːkɪʊ	*tractor*	twaʔkʰəˑ	*Santa*	santə
tractor	tʃɪaʔkə			*thank you*	θɛɲkjʊ
				very	ʋɛʋɪ

Table 48: Jude's CVCV targets with challenging onset and medial consonants in sessions 2-7.

These challenging targets also exhibited relatively more variability, including variable segments (e.g. *circle* [kʰəxuː], [tʰəxʊ]; *choo-choo* [tʊtʉː], [tʃtʃʉː]) as well as syllable shape (e.g. *tractor* [gəkʰ], [gʌkʰə]; *Santa* [tæntə], [θ:əmp], [θan]). Table 49 presents all variable words with challenging onset and medial position.

Table 49							
session 2		**session 3**		**session 4**		**session 7**	
choo choo	dʊtɕr	*choo-choo*	dɜːtʉː	*circle*	gəʔkʉːɣ	*driver*	dəʊaivə
	tɕtʊ		tʊtʉː		kʰəxuː		dwaɪvə
	tətʊ		tʃtʃʉː		tʰəxʊ		tβai·və
circle	kxkɬ	*tractor*	gə·kʰ				twaɪvə
	t:kx:		gʌkʰə			*Santa*	tæntə·
							santə
							θanta
							θ:əmp
							θan
							θanda

Table 49: Jude's variable child forms for CVCV targets with challenging onset and medial consonants in sessions 2-7.

Multisyllabic words

Jude did not attempt many multisyllabic words. The ones that he did attempt underwent syllable deletion (*Barnaby* [bɑbɪ]) and/or consonant harmony (*Nicola* [lɛla]), or were more subtly modified due to Jude's difficulty with affricates (e.g. *majesty* [madɛtɛi]), fricatives and clusters (e.g. *screwdriver* [tu:daɪbə]). These words were rare and, in addition, not variable. Table 50 presents all multisyllabic targets.

Table 50					
session 2		**session 3**		**session 4**	
barnaby	bɑbɪ			*Nicola*	lɛ·la
caterpillar	kap:ɪdə				
session 5		**session 6**		**session 7**	
Barnaby	bʌbi:	*umbrella*	bæl·æ	*majesty*	madɛtei
screwdriver	tuːdaɪbə			*oopsie daisy*	opʔdeiʑɪ
				screwdriver	twɪpdaɪvə

Table 50: Jude's multisyllabic targets without coda in sessions 2-7.

4.2.4 Section summary

We have seen a gradual disappearance of the C1VC1V preference from session 1. Data from subsequent sessions show a steady improvement in dealing with variegated consonants, and a steady decrease in the use of consonant harmony. As the number of cases of consonant harmony decreased, more difficult consonants were attempted, and these often underwent modifications (e.g. affricate reduction, fricative stopping, liquid gliding). However, substitutions were variable across tokens (e.g. affricates being reduced or not, fricatives being stopped or varying greatly in place of articulation, the liquid /r/ being replaced with /w/, /ʋ/ and /β/).

To sum up, in the later sessions it was apparent that the difficulties that Jude had were not related to the fact of having to produce two different consonants, but rather to the specific phonetic identity of the particular consonants. The variability that was observed suggests that it was the lack of skill in their production that resulted in different outcomes on different occasions. While even the difficult sequences were accurate in some tokens, it is the stability that comes with practice that will need to appear in Jude's articulation in order for them to be fully acquired.

4.3 Coda

4.3.1 Overview

Jude's production of codas rapidly increased throughout the study. By session 4, CVC words had almost reached the target frequency, and in session 5 also CVCVC words began to be produced consistently. By the end of the study the frequency of both CVC and CVCVC words was close to their input frequency with 32% (target: 46%) and 23% (target: 17%) respectively. Figure 15 presents the development of the two word shapes across sessions.

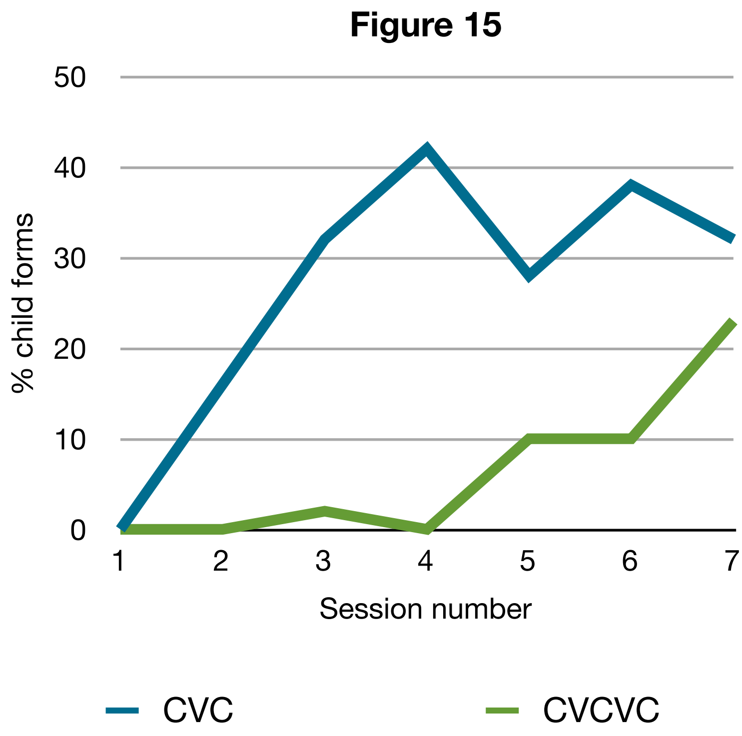

Figure 15: Percent mono- and disyllabic words with coda in Jude's child forms across sessions.

In general, throughout the study Jude made steady and linear progress in his production of codas, even though there were no significant changes in the percentage of codas attempted (between 20% and 30% of all attempted consonants throughout the study). There was a period of variability of coda consonants, while the accuracy was systematically improving. In the last three sessions, when accuracy reached almost 90%, variability finally decreased. Figure 16 presents accuracy and variability of codas.

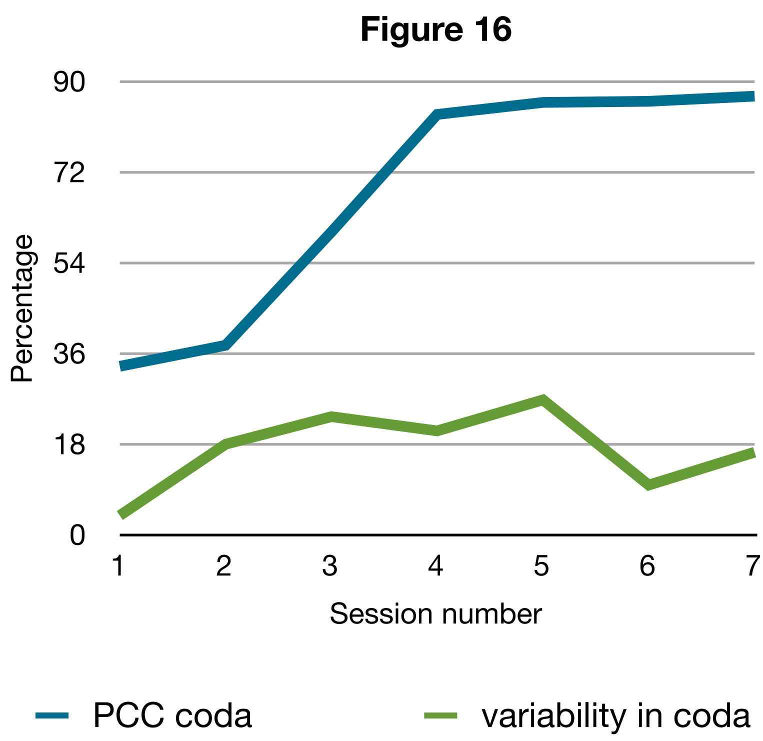

Figure 16: Percent accurate and variable codas in Jude's coda production across sessions.

4.3.2 Coda omission and glottal stopping

As we have seen, in session 1 over a quarter of Jude's CV words (5 out of 16) were adapted from targets with codas. In session 2 there were two more words with omitted coda: *back* [ba], and *bang* [ba]. In addition, one word was reduced to coda only (*shoes* [ɕ:]). A similar case was recorded in session 3 (*horse* [ɕ::]). These two forms were treated as CV for the purpose of analysis, since they required minimal effort in production. After session 2, coda omission was very rare in the data. Table 51 presents all CV words adapted from CVC targets.

Table 51

session 1		**session 2**		**session 3**		**session 4**		**session 5**		**session 7**	
cake	kxi:	*back*	ba	*horse*	ɕ::	*what*	wɔ̢	*Luke*	lʲʊ	*don't*	do
cheese	xi:	*bang*	ba							*five*	faɪ
mouth	ma	*shoes*	ɕ:								
stuck	tɕʌ										
teeth	tʰi:										

Table 51. Jude's child forms with omitted target coda in sessions 2-7.

While coda omission did appear relatively frequently at the beginning of the study, replacing codas with glottal stops was not common in Jude's data. There were two cases of glottal stopping in CVC words in session 2 (*spot* [pɒʔ], *stuck* [daʔ]), but after that the only recorded word of this type was *that* [daʔh], [daʔ]. Thus, glottal stopping in coda was very rare and usually adult-like (complying with the Welsh English input).

As the number of cases of coda omission decreased, there was a rapid increase in the number of codas. This also corresponded to a decrease in the number of CV child forms in general. While in session 1 they made up 39% of all of Jude's words, by session 7 the percentage dropped to 9%, almost reaching the input frequency (8%). Figure 17 presents a comparison of the changes in percentage of CV and CVC words in Jude's speech.

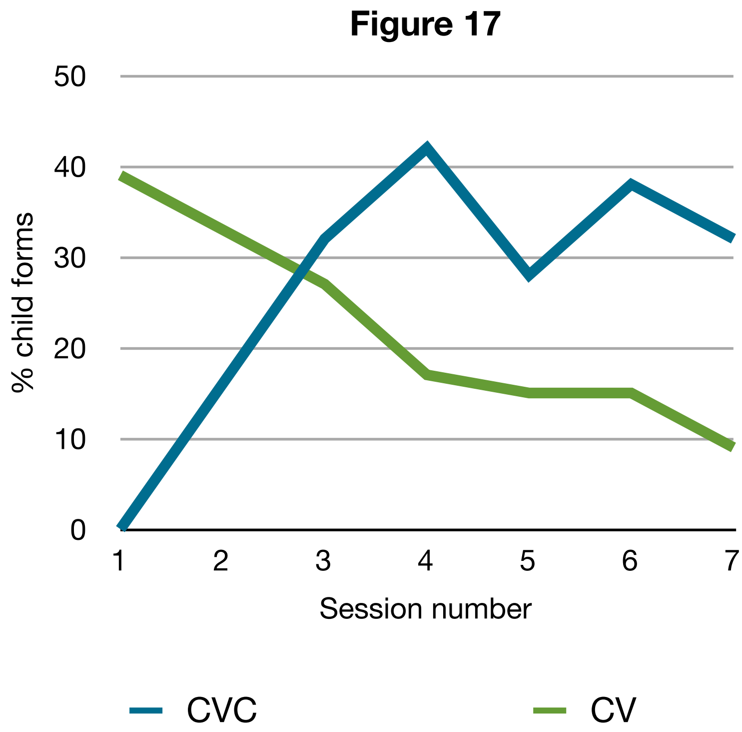

Figure 17: Percent CVC and CV child forms in Jude's production across sessions.

The first instance of a word with coda in session 1 was a fricative (*fish* [iɕ]), and fricative codas were the first to emerge (sessions 1-2), followed by nasal and stop codas (session 3). Complex codas (mostly stop+fricative and homorganic nasal+stop) were also attempted from session 3 onwards, but they were still fairly infrequent by the end of the study. Figure 18 presents the overall percentage of CVC words by final consonant.

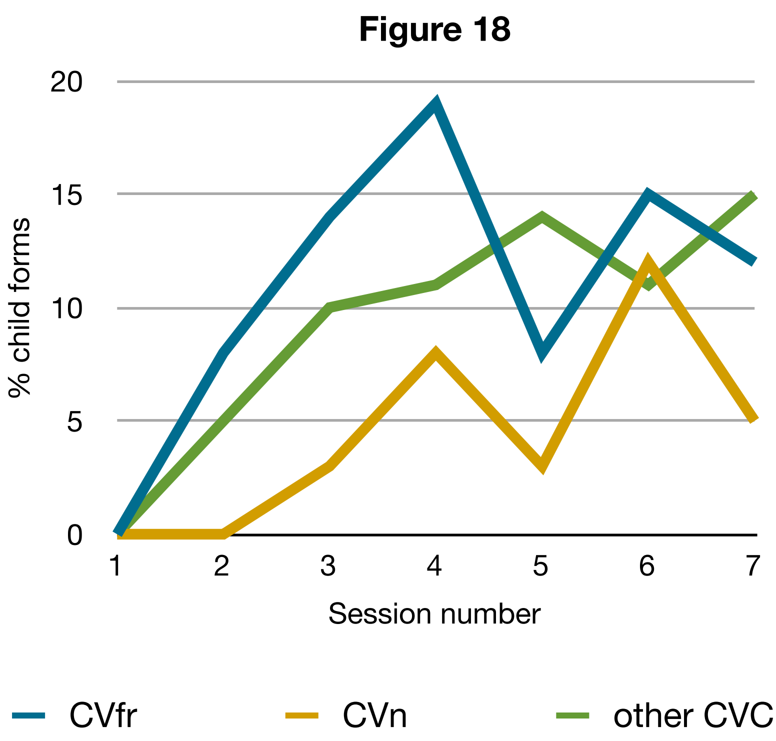

Figure 18: Percent monosyllabic words with fricative, nasal and other coda in all Jude's child forms across sessions.

4.3.3 Fricative coda CVC

The first type of codas that Jude acquired were fricative codas. The first recorded coda in session 1 was a fricative (*fish* [iɕ]). We have also seen two cases of simplification where only the fricative coda was produced (*shoes* and *horse*, both reduced to [ɕ:]). From session 2 onwards the frequency of monosyllables with final fricatives in the data increased, and by the end of the study, CVfr words made up 12% of Jude's words, almost reaching the target frequency (14%).

Selection and accuracy

As regards the accuracy of the fricatives, it steadily improved. At first, Jude only produced non-target [ɕ] and [χ] (*toes* [tʊχ], *please* [piɕ]). In session 3, two more voiceless coda sibilants appeared (e.g. *push* [pʊʃ:], *fish* [ʍɪs]). In session 4, the interdental /θ/ was added to the repertoire of coda fricatives, as a substitution for /s/ (*juice* [dʊθ]). Finally, /z/ (session 5) and /f/ (session 7) began to also be produced (e.g. *please* [tʰiz], *roof* [wɪʊf]). Table 52 presents all CVfr words with singleton coda in both target and child form (selected), sorted by child coda.

Table 52					
session 2		**session 3**		**session 4**	
please	piɕ	*bus*	baʊs	*boys*	bəɪs
toes	tʊχ	*fish*	ʍɪs̪ˑ	*ears*	ijɛːs
		house	aʊs̪	*eyes*	aɪs̝
		kiss	kəs	*fish*	βɪːʃ
		please	tʰɪɕˑ	*juice*	dʊθ
		push	pʊʃː	*mouth*	maʊʃː
		toes	to̝ˑɕ	*nose*	nəʊɕ
				this	dis
				toes	tʲɔʊs
session 5		**session 6**		**session 7**	
cars	kɑːs̪ˑ	*house*	haʊθ	*fluff*	Φlɑf
cows	kaʊz	*mice*	maɪs	*grass*	gʷaˑsʲ
crash	tʰʌˑɕ	*piece*	pʰiːs	*off*	of:
kiss	kəs	*please*	pliːs	*oops*	opθ
please	tʰiz	*stars*	tʰɑːz̥	*please*	pliːz
teeth	θiːθ	*this*	ðɪs̪	*roof*	wɪʊf
		toys	tɔɪs	*this*	dɪθ
		yes	ɟɹɛːs		

Table 52: Jude's 'selected' CVC words with singleton fricative coda in sessions 2-7.

It is worth noting that in the early stages of acquisition, final fricatives were often produced unsystematically. Namely:

(1) The same target consonant was replaced with two different non-target consonants (e.g. session 2: *toes* [tʊχ], *please* [piɕ]).

(2) The same target consonant was sometimes produced correctly, and sometimes replaced with another consonant (e.g. session 3: *push* [pʊʃː], *fish* [ʍɪs]).

(3) The target consonant was replaced with another consonant in one word, but used as a substitution for a different consonant in another word (session 4: *mouth* [maʊʃː], *juice* [dʊθ]).

In other words, at the time when the fricatives were not yet stable, their production varied across words. While examples in (1) could be explained by the same articulatory factors as in the case of Alison (i.e. the final fricative matches the vowel), the same cannot be said about examples in (2) and (3), where the fricatives were much less systematic even in articulatory terms. This variability could not be attributed to either word position (they were all singleton codas) or influence from other consonants in the word (i.e. consonant harmony). The correspondence between target consonants and the ones produced by the child was not therefore not systematic in a phonological sense, but rather it was motivated by articulatory difficulties.

Adaptation and variability

Apart from variability across types, there was variability across tokens, which suggests that the errors were also not related to word templates. The primary source of variability in fricative codas was imprecise place of articulation, which led to variation between /s/, /sʲ/, /ʃ/ and /ɕ/ (e.g. *kiss* [kɛʃ], [kəs]; *push* [pʊɕ], [pʊʃː]). Furthermore, in a couple of words not only the final fricative was variable, but also the syllable shape of the word. For example, in session 2 *please* was sometimes produced as [piɕ], but sometimes the final fricative was omitted ([kxiː]), and sometimes the word underwent even more extensive reduction to [kç]. Similarly, while cases of lisping were observed, they also were not stable and varied across tokens of some words (e.g. *please* [pʰəlːiːθ], [pliːz]). Table 53 presents words with variable fricative codas.

Table 53									
session 2		**session 3**		**session 4**		**session 5**		**session 7**	
please	kç	*push*	ʀ̥ʊɕːː	*crash*	tʌːsʲ	*fish*	ʀ̥ɪʂ̻	*please*	pʰəliːθ
	kxiː		pʊɕ		tʰʌˑɕ		ʂ̻ː		pliːz
	piɕ		pʊʃː	*kiss*	kɛ̥ːʃ		ʃː		
					kəs		ʊ̆ʂ̻		
				please	cəːs		βɪːʃ		
					tʰiz		βɪːʂ̻		
				push	pʰʊːtʃ	*juice*	dʊθ		
					pʰʊθ		dʊΦː		
						toes	tʰʊɕ		
							tɔˑsʲ		
							Φiˑtʲɔʊs		

Table 53: Jude's variable child forms for CVC targets with fricative coda in sessions 2-7.

To sum up, variability across word types and across tokens in final fricatives points to the errors being due to on-line (articulation and/or processing related) difficulties the child was facing, rather than to phonological motivation.

There were several cases of adaptation in this type of codas, which involved final fricatives being added to targets ending in vowels. For example, *four* was produced as [hɔɸʃ], [hɔɸi] and [ɸɔɸ]. These cases were fairly infrequent, and often variable across tokens. Table 54 presents cases of final fricative insertion in CV words (both single and multi variant).

Table 54									
session 2		**session 3**		**session 4**		**session 5**		**session 6**	
cow	kaʊ	*square*	nʊala	*cow*	ka·ʊ	*four*	ΦɔΦ	*key*	kʰiç
	kaʊɸ		wæː		kʰa·Φ				
			wəː:j	*four*	hɔ̜Φi̥				
			wɛːhː		hɔΦʃ				
					ΦɔΦ				
				go	go·Φ				

Table 54: Jude's CVC child forms with inserted fricative coda in sessions 2-7.

Another type of adaptation resulting in final fricatives involved affrication and fricativisation of final stops, and will be discussed in more detail in the next section. However, there were no cases of substitution of final fricatives with other segments, with the single exception of affrication in the word *push* [pʊtʃ] (cf. Table 53).

4.3.4 Stop and liquid coda CVC

Stop and liquid codas in monosyllabic words appeared in session 2, and by the end of the study their overall frequency was 15%. Although this was still considerably below target frequency (23%), they were always accurate in terms of place of articulation, although voiceless stops were used almost exclusively (e.g. *cloud* [klaʊt]).

Selection and accuracy

In session 2, one liquid coda (*ball* [bol]) and one accurate stop coda was recorded (*bike* [baic]). Velar codas were the first and the most common in this category, and they were also usually accurate, only sometimes varying with the palatal /c/ in the word *bike* [baɪc] (although cf. section 4.2 on these consonants in syllable onset). The first instance of an alveolar stop was recorded in session 3 (*spot* [ɲɛbʌtʰ]), although in that session all other stop codas involved a velar consonant (e.g. *stuck* [tʌk], *back* [bakʰ]). However, by the next session, velar and alveolar stops were equally common (e.g. *leg* [lækʰ], *lid* [lɪt]).

Labial stop codas were the last ones to be acquired. They only appeared in session 6 and only 2 words in total were recorded: *sheep* [ʃip] and *scoop* [gu:p] (although cf. section 4.2.6 on their appearance in complex coda). The liquid /l/ also did not appear regularly. Although present in session 2 (*ball* [bol]), it only reappeared in two other words in session 7 (*girl* [gʌl], *hill* [hɪl]). Table 55 presents all selected CVC words with singleton stop and liquid coda.

Table 55					
session 2		**session 3**		**session 4**	
ball	bol	*back*	bakʰ	*bike*	əbaɪc
bike	baic	*bike*	bəɪkʰ	*boat*	boʊtʰ
		Luke	lʊʔkʰ	*leg*	læˑkʰ
		spot	ɲɛːbʌtʰ	*lid*	lɪt
		stuck	tʌk	*like*	laɪkʰ
				red	ʊwatʰ
				shout	çaʊtʲ
session 5		**session 6**		**session 7**	
bed	bad	*allowed*	laʊːʔt	*back*	ba:k
bike	baɪk	*bike*	baɪʔkʰ	*cloud*	klaʊt
head	hæ̞d	*dark*	əʔda̤hk	*girl*	gʌl
lid	lɪd	*lid*	lid	*hill*	hɪl
milk	mʊk	*red*	wɛd	*Luke*	noʊkʰ
not	nʌʔtʰ	*sheep*	hɪʃip	*loud*	laut
pig	pʰɪ:k			*not*	nːɔt
stuck	dʌʔk			*Scoop*	gu:p
				that	da̤ʰt
				what	wʌt

Table 55: Jude’s ‘selected’ CVC words with singleton stop or liquid coda.

Once they began to be produced, almost all stop codas were faithful to targets with regard to place and manner of articulation. The only exceptions here were the two cases of palatalisation in *bike* ([baɪc], [baɪk]) and a few cases of adaptation, which we will discuss in the next section. However, all velar and labial, as well as most alveolar stops were voiceless (e.g. *leg* [lækʰ], *loud* [laʊt]) and often aspirated. No systematic segmental substitutions were observed in this category of codas, and all variability concerned inconsistent affrication and fricativisation of the final stop (see next section).

Adaptation and variability

There were occasional cases of adaptation in CVC words with stop coda that involved consonant harmony. Consonant harmony in these words was always triggered by velar consonants, regardless of whether they were in coda or onset (e.g. *goat* [gok^h], *duck* [gak^h]) . The harmony first appeared in session 2, and then continued to appear sporadically until session 4. However, most velar stops in codas did not trigger harmony (cf. Table 55). In addition, there was one instance of stop coda being a result of fricative stopping (*five* [ɸa:ɪb]). Table 56 presents all cases of stop coda adaptation.

Table 56							
session 2		**session 3**		**session 4**		**session 6**	
duck	gak^h	*goat*	gok^h	*catch*	k^{h}ʊaʔk^h	*five*	Φaː˙ɪb
				duck	k^{h}ak^h		

Table 56: Jude’s child forms with target stop coda modified in sessions 2-7.

Another source of inaccuracy was the fact that a small percentage of words ending in stops were adapted to fit in the CVfr category. There were three words in which a fricative was used to replace the target stop: *book* [p^{h}ʊx], *apart* [p^{h}aʃ], *big* [bɪx]. Furthermore, some words exhibited variability in stop coda. That meant that even though an accurate form was recorded, in other tokens the stop was not produced correctly. In those cases, variability also always involved affrication or substitution with a fricative (e.g. *bed* [bad], [mbɛdʒ]; *lid* [lid], [lið]). Table 57 presents all variable words with stop coda in target.

Table 57									
session 2		**session 3**		**session 4**		**session 5**		**session 6**	
bike	baic	*bike*	bəɪkʰ	*boat*	boʊtɕ	*bed*	bad	*lid*	æliːθ
	baikx		bəɪx		boʊtʰ		mbɛdʒ		aʊːlɛʔlɪ ˑt
	bai		bəɪʔk	*out*	æʊtʰ	*eight*	eɪʔtʰ		liːð
			bɛkʲʰ		æʊtʃ		eɪʔtʃ		lid
			biʔbiˑb əɪ		aʊ				
					aʊsˑ(..) tʃʊ̥				
					aʊtɕ				
				red	bwæˑs				
					ʊwatʰ				
				shout	çaʊtʲ				
					hɪjəʊtʃ				

Table 57: Jude's CVC child forms with variable stop coda in sessions 2-7.

As in the case of fricative codas, fricativisation of stop codas was entirely irregular. It thus appears that when it occurred, it was related to imprecise articulation.

The fact that final fricatives were never stopped, but final stop were sometimes affricated or substituted with a fricative points to fricatives being easier to produce for the child in this word position. Further evidence is provided by words which did not have coda in target, but had an added fricative in the child form (cf. Table 54).

4.2.5 Nasal coda CVC

Selection and accuracy

CVC words with nasal codas appeared for the first time in session 3, and exceeded the target frequency of 6% already by session 4. They were also almost always accurate. There was a single case of consonant harmony in session 3 (*man* [mʌm]) and a single case of replacing /n/ with /m/ in session 4 (*green* [dɪm]). Apart from these two words, all singleton nasal codas were accurate. Table 58 presents CVC words with nasals in codas.

Table 58					
session 2		**session 3**		**session 4**	
		man	mʌm	*again*	gɛn
		mine	maɪn	*gone*	gon
		moon	mʊn	*green*	dɪm
		mum	mːʌːmˑ	*hand*	hæn̥
				mum	məm̥ˑ
				name	nɛɪm
				one	wən
session 5		**session 6**		**session 7**	
mine	maɪnˑ	*gone*	gəʊn	*down*	daʊn
one	wɔ̝ːn	*ham*	hæˑm	*one*	wən
		home	hɔʊm	*stone*	təun
		horn	hɔːn	*train*	twɛɪn
		man	maˑn	*van*	havan
		moon	muːn		
		nine	mʌin		
		one	wɒːˑn		
		Sam	ɕam		
		ten	daˑn		
		train	tweɪn		

Table 58: Jude's words with singleton nasal coda in both target and child form in sessions 2-7.

Adaptation and variability

There were no consistent substitutions of nasal codas, and they also exhibited very little variability. In session 2 there was only one nasal target, *mine*. In that word, the final nasal was not produced, but sometimes omitted ([ma:], [maɪ]), and once replaced with a fricative ([maɪç]). However, given that there were no final nasals produced in that session and that fricatives were sometimes added to words ending in vowels (cf. Table 54), it is likely that the fricative was not a substitution for the nasal, but rather belonged to the category of open syllable targets which had a fricative added in the child form. Substituting nasal coda with a fricative did not occur again, and the rest of the variability observed involved confusion between nasals (e.g. *one* [wɒn], [woʊm]). Table 59 presents all variable CVn words.

Table 59							
session 2		**session 3**		**session 5**		**session 6**	
mine	ma:	*mine*	ɪmaɪn	*name*	məɛˑn	*one*	wɒːˑn
	maɪ		man		nɛɪm		woʊm
	maiç		mɐm				
			mɛˑɪ				

Table 59: Jude’s variable CVC child forms with target nasal coda in sessions 2-7.

It is worth noting that whenever there was variability between final /m/ and /n/, it was justified by other segments in the word. For example, in *mine* [man], [mɐm] and *one* [wɒ:n], [woʊm], the final consonant could have been affected by the initial labial, while in *name* [məɛn], [nɛɪm], it was the result of metathesis. The errors thus appear to be due to problems in co-ordination between different consonants in the word, and the fact that the words also appear in an accurate form suggests that metathesis and consonant harmony were rather tendencies in co-ordination than systematic processes. The only word that could not be explained by co-ordination problems is *green* [dɪm], which, as the single instance, appears to be random.

4.3.6 Complex coda CVC

Stop+fricative codas

The first instance of a complex coda was recorded in session 2 in the word *book* [bʊkχ]. It was inaccurate, i.e. the target had a singleton stop coda, which was followed by the uvular fricative in the child form. As regards attempts at stop+fricative and affricate targets, the codas were reduced to the fricative in session 3 (*box* [bbɔɕ], *lights* [laɪç:]), but produced correctly from session 4 onwards (e.g. *cats* [ɟats], *fridge* [ɸɪːdʒ]). A reverse (fricative+stop) sequence was first attempted in this position in session 4 (where the fricative was replaced with a glottal stop, *passed* [pa:ʔt], and one more attempt was recorded in session 6 (produced accurately, *loft* [lɔft]). Table 60 presents accurate and inaccurate complex codas in CVC words.

Table 60					
session 2		**session 3**		**session 4**	
		box	bbɔɕ̞	*cats*	ɹa̤t̤s͡
		lights	laɪçː	*milk*	məʊkx
				passed	pa̰ːʔt
session 5		**session 6**		**session 7**	
fridge	Φɪːdʒ	*beans*	biːnð	*called*	koˑʊdʒ̥
		bed	bæːdʒ̥	*six*	θːːːɪcs
		lives	lɪˑbθ	*touch*	tɔt̥ʃ
		loft	lɔft		
		six	sʲiːˑksʲ		

Table 60: Jude's targets with complex stop+fricative and affricate coda in sessions 2-7.

We may recall that the inaccurate *book* [bʊkχ] appeared two sessions before complex coda targets were mastered, and other cases of affrication remained after that (e.g. *called* [koʊdʒ], *bed* [bædʒ]). This suggests that the cases of final fricative insertion and coda affrication were unlikely to be related to learning to produce complex sequences. Rather, they were more likely a general tendency in articulating singleton codas.

Nasal/liquid+ stop codas

The first type of complex codas that Jude produced which did not involve fricatives were homorganic nasal+stop sequences. The first attempt at that type of coda in session 2 was inaccurate (*round* [waʊd]. However, given that a singleton /d/ in coda only appeared in session 5 (*lid* [lɪd], cf. stop table), we can conclude that the voicing of the final stop in *round* [waʊd] likely came from an attempt at the nasal consonant. It is possible that the cluster was not reduced, but the co-ordination of velum movement was not precise enough to result in two consecutive sounds.

In session 3 Jude also produced *jump* [dʊmp]. It is worth noting that this was long before singleton labial stops in codas appeared (session 6, cf. Table 56). Several other words with a homorganic nasal+stop were recorded later in the study (e.g. *didn't* [dʲɛnt]), and the cluster was always retained in the child form.

In session 4 liquid+stop codas emerged, and two words of this type were recorded: *milk* [məʊʔkʰ] and *field* [fio:ld]. While the coda was accurate in the latter, in the former the liquid was vocalised. In all other codas of this type recorded later in the study, the liquid was vocalised as well. Table 61 presents all nasal/liquid+stop codas.

Table 61					
session 2		**session 3**		**session 4**	
round	waʊd̥	*jump*	dʊmp	*field*	fio꞉ld
				milk	məʊʔkʰ
session 5		**session 6**		**session 7**	
		bang	baŋk	*called*	ko˙ʊdʒ̥
		didn't	dʲɛnt		
		help	haʊpʰ		
		sink	θɪŋk		

Table 61: Jude’s targets with complex nasal/liquid+stop coda in sessions 2-7.

The fact that both voiced alveolar stop and labial stop first appeared as a result of an attempt at a cluster with a homorganic nasal suggests, that the nasal+stop sequences facilitated production of stops for Jude.

4.3.7 Coda in disyllables

We have seen that in session 1, codas in many (C)VCVC targets were omitted. In session 2, however, there were no (C)VCVC targets or child forms recorded. The first two disyllabic words with codas appeared only in session 3: *Thomas* [æmɛtʃ] and *night-night* [nʌnʌɕt]. It is perhaps worth noting that the onset in *Thomas* was omitted just like the onset of the first monosyllabic word with coda (*fish* [ɪɕ]). This suggests that the parts of the word that are challenging to the child draw his attention, so that onset becomes unstable. Indeed, in the next session, the only two disyllables with coda also did not have onset in target (*airplane* [hɛpeɪjn], *open* [ʌpʰɛn]). However, from session 5 onwards CVCVC words were frequently produced with both coda and onset.

As in the case of monosyllables, fricatives were the first to appear regularly in CVCVC coda, and in session 5 five out of seven CVCVC words had a final fricative. In session 6 nasals were used as frequently as fricatives, but in both sessions 5 and 6 there was only one CVCVC word with stop coda (*beep-beep* [biʔbi:pʰ]). Figure 19 presents the overall percentage of CVCVC words by type.

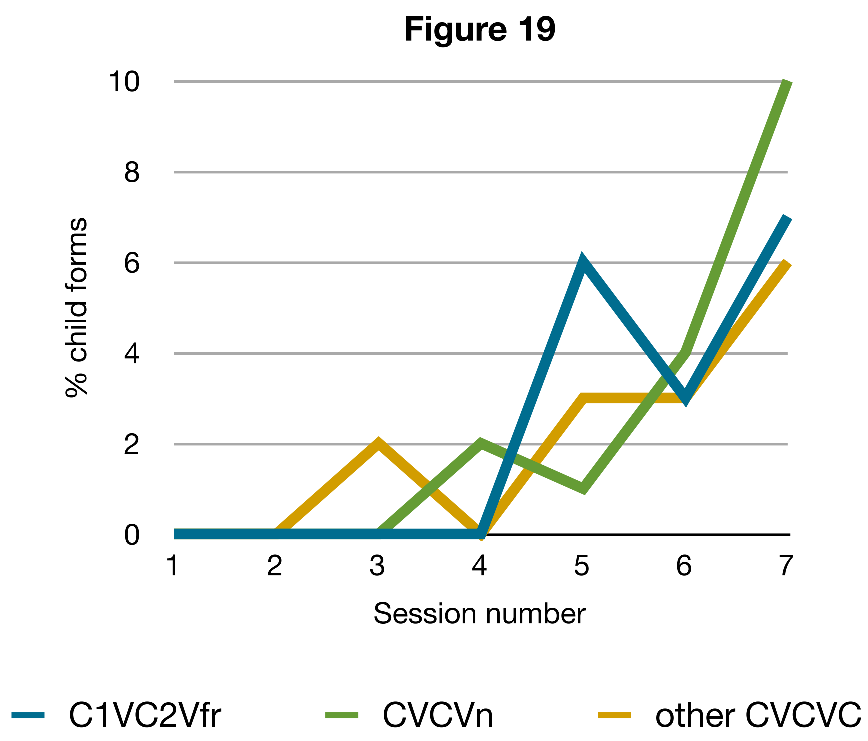

Figure 19: Percent disyllabic words with fricative, nasal and other coda in all Jude's child forms across sessions.

Therefore, although stop codas in monosyllables were produced frequently from session 3 onwards, it was only in the last session that the CVCVC stop codas became as frequent as nasals and fricatives, although stops in other positions had been in Jude's repertoire from session 1. Table 62 presents all CVCVC words.

Table 62					
session 5		**session 6**		**session 7**	
apples	æpɔ̥ːθ	*beep-beep*	biʔbiːpʰ	*allowed*	alaʊd
beep-beep	bɪ̰biːpʰ	*behind*	beəhaɪn	*broken*	bwɔʊkən
bottom	bɒtəm	*chicken*	tɪkɪn	*carrot*	kavət
fingers	hiːʤ̺ˑΦ	*hiding*	haɪdin	*Clarabel*	kʰaləbel
horsies	hɒɕɪz	*letters*	lɛtɪəˑz̥	*crispies*	kwepiːθ
minutes	mənətʰ	*sausages*	sɒtiʔdiˑs	*drivers*	dɹaivəːs
Thomas	tʰɔməs	*seven*	θɛβʊn	*driving*	dwaɪvɪn
		triangle	twaɪŋɔł	*Elen*	ɛlɛn
		wheel	wijəl	*fire engine*	faɪɛndɪn
		witches	witɕið	*garden*	gaːtən
				granddad	gwanːaːʈ
				hiding	haɪdɪn
				Merry Christmas	mɛʋɪʔkwiməθ
				moment	wʊˑmən
				present	bʋɛjɛnt
				pudding	pʊðin
				Rudolph	wʊdɔˑf
				sausage	θɔkɛːt
				sausages	sətʰɪdɪʂ
				seven	sːɛʋən
				snowman	nɔʊman
				Thomas	tɔmə̤θ
				Travis	tw avih

Table 62: Jude's CVCVC child forms in sessions 2-7.

The only type of inaccuracy observed in codas of disyllabic words concerned place of articulation of final fricatives (e.g. *witches* [witɕið], *crispies* [kwepiːθ], *fingers* [hiːdɪɸ]). However, these fricative substitutions were highly inconsistent, and most final fricatives were accurate. There was also very little variability in this category, as only three words had more than one form (all in session 7):

(1) *behind* [beəhaɪn], [bəhaɪm], where the final nasal varied between /m/ and /n/, as in some monosyllables (e.g. *one* [wɒn], [woʊm])

(2) *witches* [witɕið], [witid], where the final fricative underwent lisping in some tokens but was stopped in others (this was also the only instance of final fricative stopping apart from *five* [faɪb]

(3) *moment* [wʊmən], [ʊməʔ], where the final nasal was replaced with a glottal stop.

Apart from the above irregularities, all types of consonants were almost entirely stable in CVCVC codas.

4.3.8 Section summary

Fricatives were the most readily accessible sounds in coda position for Jude. Firstly, they were the first type of codas he produced (already in session 1, when no other codas were recorded, there was one word with fricative coda). Even after all types of codas were produced in CVC words, the skills in their production were not immediately transferred to disyllabic words. Therefore, acquisition of CVCVC words began with the ones ending in a fricative.

Secondly, even at the early stages of producing coda fricatives, variability and inaccuracy of those consonants was limited almost entirely to place of articulation, and not manner (throughout the study, only two instances of final fricative stopping were recorded).

Thirdly, while fricatives were not substituted with stops, stops were often substituted with fricatives or affricated. This was so regardless of the fact that stops exhibited more overall accuracy, meaning that they did not often vary with regard to place of articulation. Furthermore, there were several cases of fricatives being added to open syllable targets. Therefore, the preference for fricatives in the coda position could not have been related to them being the child's best mastered sounds (as stops and vowels were, predictably, far more stable). Rather, the possible reason might have been issues with controlling airflow at the end of the word. We will discuss the general trends in the acquisition of final fricatives in more detail in Chapter 6.

In terms of adaptation and substitution, apart from coda omission in session 1, no systematic processes were observed in Jude's production of codas. Neither syllable shape nor phonetic identity of consonants were consistently altered, and there were also no systematic word templates. Whenever errors occurred (as in the case of the above mentioned final fricative insertion, or varying place of articulation of fricatives), they were irregular and impossible to predict on the basis of targets. The highly irregular manner in which they occurred usually pointed to on-line difficulties in production.

4.4 Discussion

4.4.1 Segment-based processes

In session 1, Jude's consonant inventory was at 47%, placing him in between Alison (33%) and Rebecca (53%). He mainly produced stops, nasals and glides, and there were first instances of fricatives and affricates in his words. By the end of the study his inventory improved and included 73% of all target consonants. In the last session, apart from the consonants already present in session 1, Jude produced the liquid /l/, labio-dental fricatives /v/ and /f/, and he was beginning to produce the alveolar fricative /s/, which, however, was still occasionally replaced with the interdental /θ/.

In the course of development, a large amount of segmental alternations in Jude's data was clearly due to imprecise articulation. Minor variation was present throughout the study, and included voicing (e.g. *car* [ka], [ga]), prevoicing (*bike* [pʰəɪkᵏ], [mbɛkʰ]), palatalisation and affricativisation of stops (e.g. *tea* [tʰiː], [ciː], [tʃiː]). Variation of this type pointed to lack of coordination between articulators. Apart from that, there were also many instances of processes usually categorised in the literature as substitutions, in which target consonants were replaced with segments differing from target by more than one feature. These included affricate reduction, cluster reduction, and liquid gliding and vocalisation. Nevertheless, the large amount of variability observed in how these processes were used made it impossible to classify them as phonological. Sometimes the variability meant that the resulting consonants were different in different tokens (e.g. *cheese* [kʰi], [xiː], *horsie* [hɔʃi], [hɔʔθiː]), but very often there were also words in which the problematic segments were produced accurately in some tokens and modified in others in the same session (e.g. *Jamie* [damiː], [djəmɛɪ], [dʒamiː]; *star* [sta], [tah], [tʃah]).

It thus seemed that even the more complex substitution processes were related to articulatory issues, just as were the minor variation such as variable voicing. The main difference between the two types of processes appeared to be in the difficulty of the target consonant. All of the complex substitution processes affected consonants that are particularly challenging to children at the beginning of word production: liquids, affricates, fricatives and consonant clusters. These segments were produced further from targets, and were more variable (in the sense that in some tokens they could be reduced or omitted altogether) than more stable consonants, such as stops (which usually only varied in voicing and nasalisation). Nevertheless, their instability, as well as the fact that they affected almost exclusively the more challenging consonants, made it unlikely that the nature of the two types of alternations was different. In other words, it appeared that affricate reduction, for example, was just as much a result of articulatory difficulties that affricates posed for the child, who had not yet acquired them, as prevoicing, which signified lack of finer precision in coordinating articulatory features in stops.

4.4.2 Whole word processes

Starting from highly systematic production in session 1, Jude's word shapes gradually become more flexible throughout the time of the study. He began with strong constraints related to babble: open syllables and repeated consonants. In session 1 these constraints led to a high degree of adaptation through consonant harmony and final consonant omission, which affected almost half of the words that the child produced. However, both codas and C1VC2V shapes emerged soon after that and continued developing in the following sessions. Jude steadily progressed towards fully accurate production, so that in the last sessions he was able to use all types of word shapes, both mono- and disyllabic, and showed no preferences for particular consonants in particular positions. There were a few instances of final fricative insertion in open-syllable targets, which, however, were very rare and variable, and suggested problems with controlling airflow at the end of words rather than a systematic tendency.

Although the emergence of the strong C1VC1V template could not be followed longitudinally, as the pattern was already at its peak in session 1, we may recall from the introduction that this tendency in children has been often traced back to articulatory routines coming from babble. Thus, the only word shape systematicity observed in Jude's data was one motivated by articulatory routines that were most likely entrenched before his first words.

4.4.3 Variability and systematicity

Jude's T score decreased from a high 2.29 in session 1 to a very low 1.26 in session 7. Similarly, the percentage of adapted words dropped from as much as 46% to as little as 6%. The accuracy of his word shapes was practically at the target level at the end of the study, when he used all target word shapes and almost never resorted to adaptation.

At the same time, in his first, most systematic session, the variability observed in Jude's words was the lowest among the three subjects. The whole word patterns of consonant harmony and coda omission made the child's words stable and not prone to variation. In the next three sessions, as the templates were gradually disappearing, variability increased. At the peak of variability in session 4, 80% of words which appeared in more than one token were variable. After that, variability dropped back to the level from session 1, but this time it corresponded to a much lower T score (1.64), as whole word templates were no longer used. Figure 20 presents variability and T score across sessions.

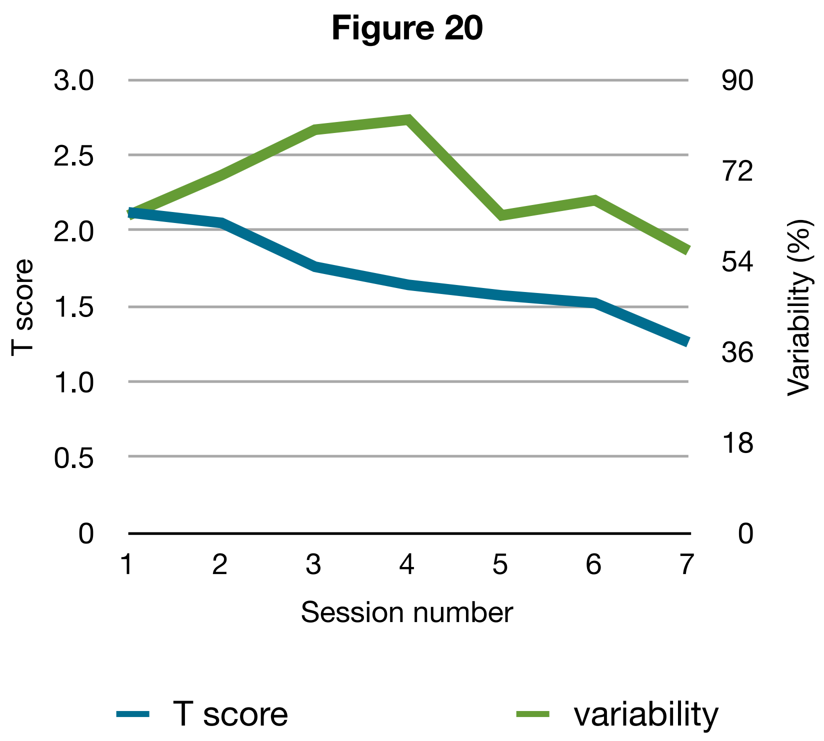

Figure 20: Jude's T score (Y1) and variability (Y2) across sessions.

Therefore, the period of high variability accompanied the transition from strong word shape systematicity to a more flexible repertoire of diverse word shapes. As Jude's phonological system was reorganising, there was a significant increase in instability of all consonants and words that were parts of it. After that, however, when templates entirely disappeared from the child's production, and accuracy of consonants improved, variability considerably decreased, reflecting a stable state of almost target-like phonology.

4.4.4 Boldness

Two features of Jude's speech were the most noticeable in session 1. First of all, he was the the most systematic of the three children, with a very high T score of 2.29, due mostly to almost half the targets he attempted being adapted to fit his word shape constraints. Second of all, he was also the most voluble subject. As in the case of Alison, the high systematicity of Jude's production meant that many words were similar to one another, and by producing many tokens, the systematic patterns could have been further entrenched.

High systematicity made Jude begin with very low PCC in session 1 (51.1%). However, from then on, his consonantal accuracy steadily increased, and in the last two sessions it reached 80%. The development of accuracy significantly correlated with T score, which exhibited a continuous drop (correlation -0.90). It thus appears that as words were adapted less often, consonants were articulated more and more precisely. Increasing articulatory accuracy lessened the need for adapting words, and conversely, the diminishing frequency of imposing preferred word shapes on target words might have enabled particular consonants to receive more attention. It is likely that the relation between accuracy and systematicity was bi-directional, as increasing accuracy in producing consonants could have lessened the need for adapting words, as well as for attempting them repeatedly. Figure 21 presents the two variables across sessions.

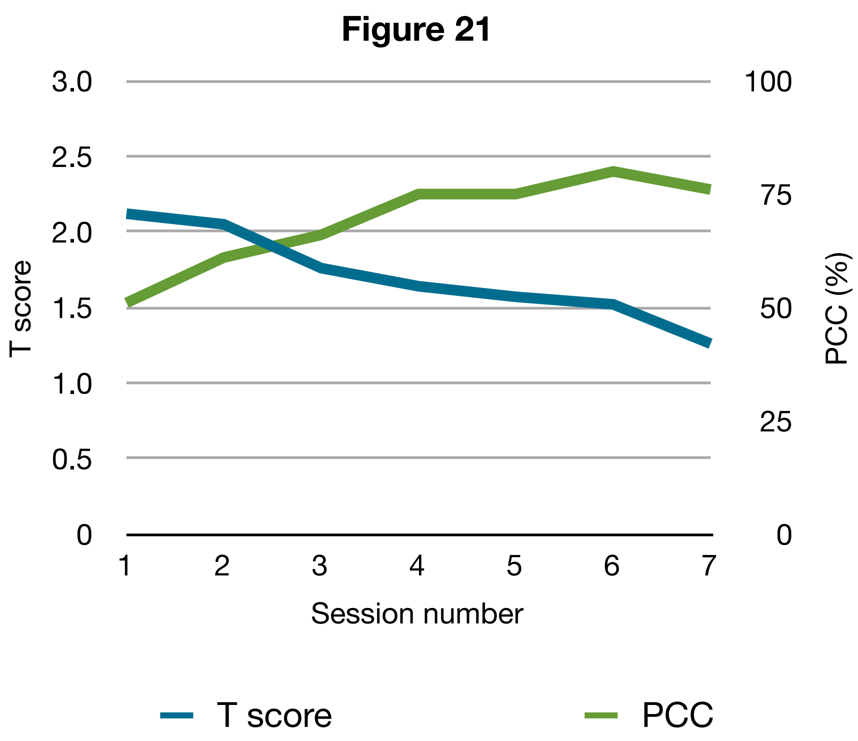

Figure 21: Jude's T score (Y1) and PCC (Y2) across sessions.

As regards boldness in attempting difficult consonants, Jude initially showed a lot of boldness, often choosing targets which were outside his articulatory capabilities. This was particularly apparent in word onset and word medial position. While Alison and Rebecca were both very conservative in selecting accessible word onset consonants in the first session, challenging consonants that Jude attempted in this position constituted 48% of all onsets he produced. This was made possible by his very strong word templates, which meant difficult consonants could have been easily harmonised with easier ones. As we have seen, the boldness decreased in session 2, along with template use. After that, it steadily increased, as the accuracy of individual consonants improved. Therefore, the increasing PCC was not due to avoiding difficult segments, but rather signified genuine improvement in the child's articulatory skills. Figure 22 presents boldness, variability and accuracy across sessions.

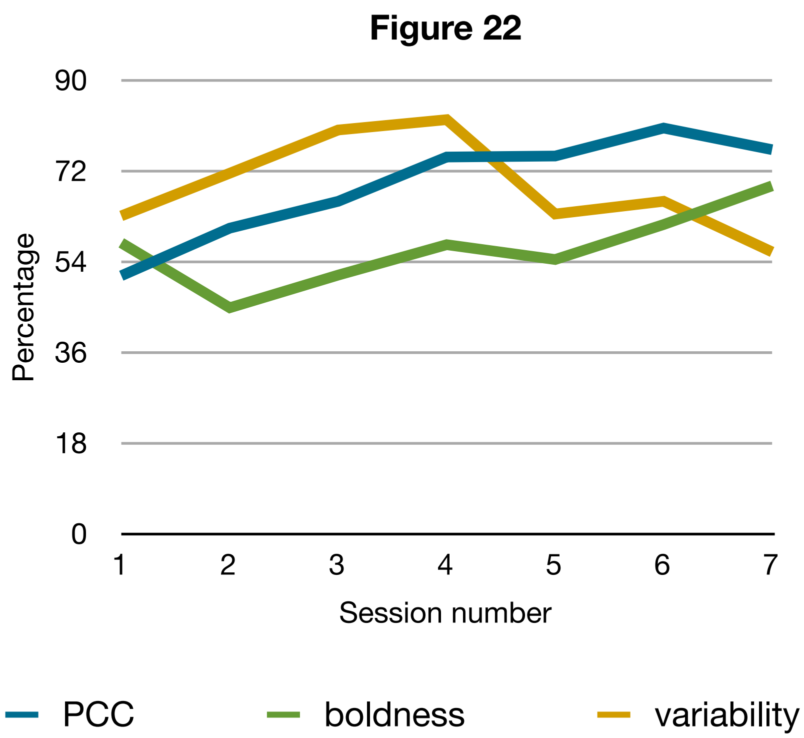

Figure 22: Jude's PCC, boldness and variability across sessions.

4.4.5 Chapter summary

In summary, from initially high systematicity, strong word shape constraints and frequent adaptation, Jude steadily progressed towards high consonantal and word shape accuracy. In order for that to happen, his systematicity had to decrease, and for a short time he was not able to attempt as many challenging consonants as when the use of templates was at its peak, nor could he produce as many words (the number of word types in sessions 1 and 2 was 41 and 39, respectively). Furthermore, the drop of systematicity was accompanied by a large increase of variability. However, after the templates disappeared, from session 3 onwards, Jude's phonological system steadily became more and more target-like. The child's path of development was thus the result of the interaction between the initial, stable and templatic state of his system, and his use of language, as reflected in his boldness.

5. REBECCA

5.1 25-word point

5.1.1 Consonant inventory

Rebecca reached the 25 word point relatively late, at 1.6;27. In this first session included in the analysis, she produced 38 words. Presumably due to her late start in producing words, which meant having had more vocal practice, Rebecca had a large consonant inventory already in session 1. Out of the 15 English consonants included in the analysis, Rebecca accurately produced 8 (53%) in at least two targets. Table 63 presents Rebecca's consonant inventory in session 1.

Table 63

	Bilabial		Labio-dental		Dental		Alveolar		Post-alveolar		Palatal		Velar	
Plosive	p	b					t	d					k	g
Nasal	m						n						ŋ	
Trill														
Tap/Flap														
Fricative			f	v	θ	ð	s	z	ʃ	ʒ				
Affricate									tʃ	dʒ				
Glide	w										j			
Liquid							l	ɹ						

Table 63: The consonant inventory of English, with Rebecca's consonants in session 1 highlighted in grey.

Apart from the above consonants, there was one instance of the liquid /ɹ/ (*rocks* [ɹatʃ], but the liquid was glided in other words) and of the fricative /ʃ/ (*push* [pʊʃ]). Although the fricative only occurred once among the accurate child forms, there were no other targets with these consonants (unlike for the liquid /ɹ/). Moreover, Rebecca produced them very frequently inaccurately, as substitutes for alveolar fricatives (e.g. *bath* [baʃː], *see-saw* [ʃiːʃaː]) and liquids (*Marjorie* [maːdʑəʃɯ]). Although the child did not select many targets that included these sounds, it was apparent that she had an articulatory tendency to produce them.

Apart from the preference for post-alveolar (and sometimes palatal) fricatives, Rebecca appeared to favour labial consonants in word onset, and coronal and dorsal consonants in coda. Words beginning with /b/, /m/ and /p/ constituted the majority of her accurate word forms, with 6, 5 and 4 words in each category. At the same time, there was only one target with a final labial, and in the child form the stop was glottalised (*beep-beep* [baʔbaʔ]).

5.1.2 Word shape inventory

Rebecca was also skilled in producing many different word shapes. There were no cases of consistent word shape adaptation in session 1, and no clear preference for any particular shape.

CVCV

There were three disyllabic words with variegated consonants, and four with the same consonant repeated. None of the C1VC1V words was adapted by the child, but rather, they were all selected from C1VC1V targets. However, even though all CVCV targets were produced fairly accurately, their number was relatively small, which could suggest that Rebecca did not yet feel entirely comfortable with producing them, but instead of adapting more targets to more accessible forms, she did not attempt very many of them. Table 64 presents Rebecca's CVCV words in session 1.

Table 64					
C1VC1V selected		**C1VC1V adapted**		**C1VC2V**	
baby	bʌ^{h}buː			*doggie*	dɑŋgiː
choo choo	t^{h}ət^{h}ɔ			*Marjorie*	maːdʑəʃɯ
pee-poh	bʊploʊː			*master*	amaɕː ɕə
see-saw	ʃiː ʃaː				

Table 64: Rebecca's CVCV child forms in session 1.

Coda

Although Rebecca did not yet produce disyllabic words with codas, she also almost never attempted any such targets, and there was only one instance of coda omission in a disyllabic word (*beep-beep* [baʔbaʔ]). There were also no instances of coda omission in monosyllables, and the child produced a wide range of CVC words, ending with stops, fricatives and affricates. As mentioned earlier, all codas that the child produced were coronal or dorsal, while a great majority of onsets were labial. Nevertheless, all types of codas were selected with regard to manner and approximate place of articulation, meaning that even if C1-labial+C2-coronal/dorsal was Rebecca’s preferred shape, she never modified words to fit that preference. Table 65 presents mono- and disyllabic targets with coda.

Table 65					
coda		**coda deletion CVC**		**coda deletion CVCVC**	
arch	haʔtʃː			*beep beep*	baʔbaʔ
ball	balː				
bath	baʃː				
book	bʊkʰ				
legs	ɬac				
mat	matːʰ				
one	wadn̩				
pat	paʔtʰ				
pig	piːk˺				
push	pʊʃ				
rocks	ɹatʃ				
what's that	çætʰ				
yes	jɛɕ				

Table 65: Rebecca’s mono- and disyllabic targets with coda in session 1.

5.1.3 Consonantal variability and accuracy

There were two segment based processes that occurred in at least 10% of words. The most common one was palatalisation, which mostly affected alveolar fricatives in coda position (e.g. *yes* [jɛɕ]), but also one interdental fricative (*bath* [baʃː]), alveolar stop (*two* [tʲoʊ]) and an onset fricative (*see-saw* [ʃiːʃaː]). Apart from that, there were four cases of velar fronting, one word-initially (*car* [da]) and the other three in coda, which could have been due to assimilation with the following fricative (*rocks* [ɹatʃ]).

Large consonant inventory , coupled with lack of any word shape simplification strategies, as well as relatively rare substitutions were the factors that made Rebecca’s accuracy much higher than the other two children’s, at 67%. The accuracy of word initial position was the highest (77%), mostly based on accurate labial consonants. The accuracy of word medial position followed at 67%. The accuracy of coda was the lowest, due to the child’s tendency to produce inaccurate final fricatives and affricates, but it was still relatively high as compared to the other children (50%).

Rebecca’s words were relatively variable, with 71% of all words which appeared in more than one token differing with regard to consonants or syllable shape across tokens. Most variability concerned particular consonants. Specifically, there was much variation in the degree of palatalisation (e.g. *book* [bʊkʰ], [bʊc]; *two* [tʲoʊ], [to:], [tʃu:]). Other consonants varied in voicing (*bye* [bai:], [pai:]), or precision of articulation (e.g. *one* [əvan:], [əwan:], [wadn]). There was only one case of substitution that could not be accounted for in terms of articulatory difficulties alone, where the bilabial glide was replaced with a post-alveolar fricative (*one* [ʃan:]). This apparently random substitution (the glide was produced in other tokens) could further confirm Rebecca’s tendency towards producing post-alveolar fricatives, although it did not seem to be a regular process. Table 66 presents all tokens with variable consonants from session 1.

Table 66	
baby	bʌʰbauː
	bʌʰbuː
ball	badn̩
	balː
book	bʊc
	bʊkʰ
bye	baiː
	paiː
Marjorie	maːdʑəʃɯ
	macɪci
one	əvanː
	əwanː
	ʃanː
	wadn̩
rocks	ɹatʃ
	hatʰ
see-saw	ɕiː ɕaː
	ʃiː ʃaː
two	tʲoʊ
	toː
	tʃuː

Table 66: Rebecca’s child forms with variable consonants in session 1.

There were only four words which varied in syllable structure across tokens. In two of these, the variability concerned word onset (in both cases a having a glide in target), which was sometimes deleted (*yes* [ɛ:ɕ], [jɛɕ]), or sometimes appeared with an added initial vowel (*one* [əwan:], [wadn]). The other two words varied with regard to the number of syllables, which was sometimes reduced. Table 67 presents all tokens with varying syllable structure.

Table 67	
choo choo	tʰətʰɔ
	tʃəː
Marjorie	macɪci
	maʔci
one	əwanː
	wadn̩
yes	ɛːɕ
	jɛɕ

Table 67: Rebecca's child forms with variable syllable structure in session 1.

5.1.4 Section summary

Despite having relatively well developed production skills, as evident from the large consonant inventory (53%) and lack of strong word shape constraints, Rebecca was neither particularly voluble, nor bold in attempting commonly challenging consonants. Only 50% of her words had an affricate, a fricative or a liquid anywhere in the target, which was less than for the other two children. She was particularly conservative in her selecting of word onset, and only 13% of onset consonants she attempted belonged to one of these difficult categories. The percentage was much higher for medial consonants (56%), which corresponded to lower accuracy of this position. However, she did attempt more codas than Jude and Alison, and words with codas made up for 29% of all her vocabulary.

In summary, Rebecca begins as a highly accurate but also very conservative child. Her selecting less challenging targets, coupled with advanced articulatory skills, results in high consonantal accuracy (65%) and a very low T score of 1.47. It also means that she never has to adapt words to fit any particular word shape (adaptation 0%). The only apparent tendency in her word production is that of producing fricatives and affricates, especially in word coda, although these are almost always inaccurate. At the same time, she is highly variable in her production (71%). Table 68 presents all measured variables for session 1.

Table 68	
T score	1.47
accuracy	65%
variability	71%
boldness	50%
consonant inventory	53%

Table 68: Values of measured variables in Rebecca's session 1.

5.2 CVCV

5.2.1 Overview

Although there was a preference for harmony in disyllables in Rebecca's first session, we may recall that it was only observable in a tendency to select targets of this form. Therefore, while the category made up for almost 20% of all words, there were virtually no instances of adaptation, i.e. applying consonant harmony to targets with variegated consonants. This was also the case for later sessions, so that no adaptation in the C1VC1V category was recorded.

In time, the preference for selecting C1VC1V targets disappeared as well. By session 3 both C1VC1V words and C1VC2V words were close to target frequency, with the former at 1% (target: 6%) and the latter at 15% (target: 14%). Figure 23 illustrates changes in frequency in the two categories across sessions.

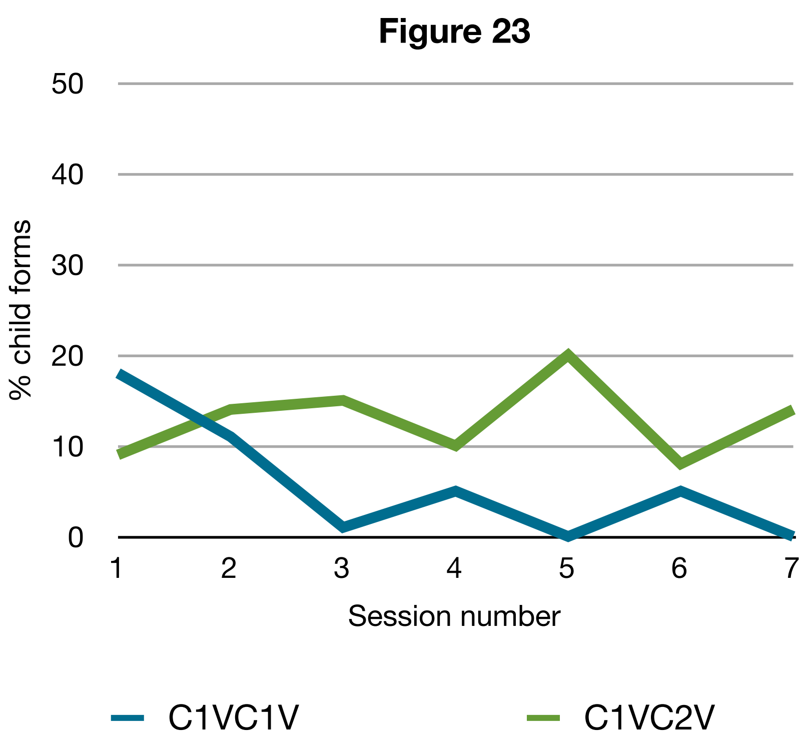

Figure 23: Percent C1VC1V and C1VC2V child forms in Rebecca's production across sessions.

As Rebecca's preference for targets with consonant harmony disappeared, she also began attempting an increasing number of challenging consonants in word onset. Thus, from selecting targets which were easily accessible in terms of word shape and consonantal difficulty, the child progressed to a stage where she was more willing to attempt challenging consonants and structures. Figure 24 presents Rebecca's boldness in attempting challenging onset and medial consonants.

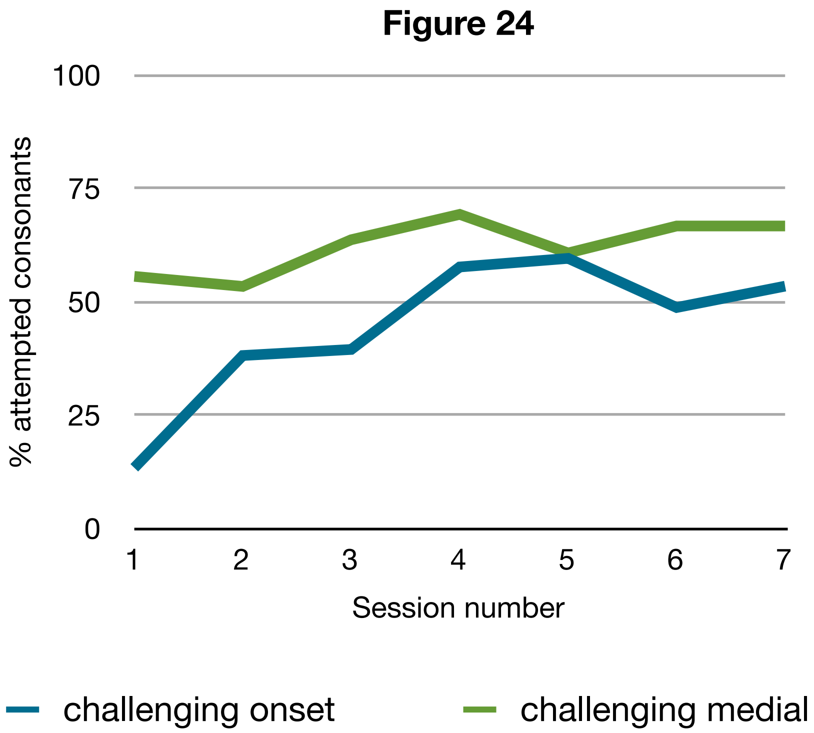

Figure 24: Percent challenging word initial and word medial consonants in all consonants attempted by Rebecca across sessions.

Interestingly, Rebecca's boldness in producing more difficult shapes and sounds did not correspond to changes in accuracy. In other words, while accuracy of word onset and word medial positions remained around the same level until session 6, there was a change in how conservative the child was in selecting targets to produce. It appeared that Rebecca almost always focused on words that had the shape and consonants which she felt most secure producing.

This 'conservative' approach also seemed to have its effect on variability, which remained at the low level observed in session 1 for the following three sessions, and then decreased even further. Figure 25 presents the percentage of attempted difficult consonants in word onset and word medial position across sessions.

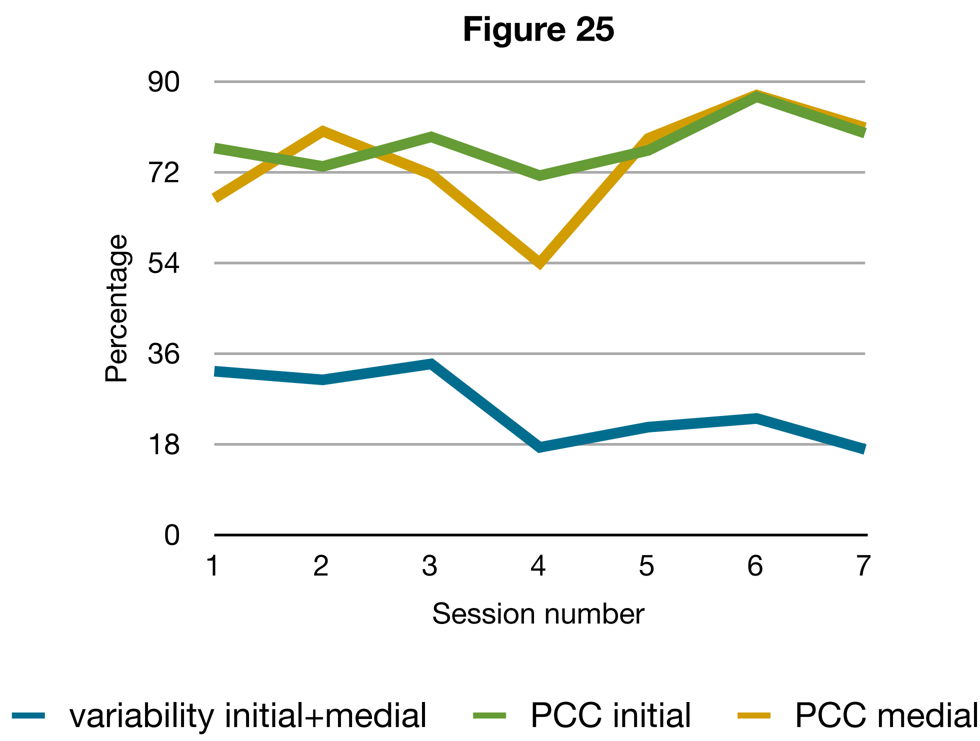

Figure 25: Percent variable and accurate word initial and word medial consonants in Rebecca's production across sessions.

5.2.2 Simple onset

Selection and accuracy

Disyllabic words with singleton stop, nasal and glide onsets in both syllables were a stable and accurate category. Most places of articulation of stops and nasals were faithful to targets and there was no visible preference for any sequences of consonants over others. Apart from occasional variation in voicing (e.g. *water* [wada:]), the only modifications to target were one case of affrication of the onset alveolar stop (*tummy* [tʃami]) and one case of velar fronting (*buggy* [bʌdɪ]). Table 69 presents all selected C1VC2V words with simple onsets .

Table 69					
session 2		**session 3**		**session 4**	
dinner	dənæ	*doggy*	dɔgɪ	*buggy*	bʌdɪ
tummy	tʃami	*money*	manɪ	*teddy*	tɑ:dɪ
		paddy	padɪ		
		teddy	tadɪ		
		water	wada		
session 5		**session 6**		**session 7**	
dada	dælæ	*dinner*	dɪnə	*don't know*	dənəʊ
water	wadaː	*happy*	hapɪ	*teddy*	tʰadɪ

Table 69: Rebecca's 'selected' C1VC2V words with simple onsets in sessions 2-7.

After the first session, disyllables with the same, simple consonant repeated in both syllable onsets were only common in session 2. As in session 1, these were all selected from targets of the same form, and included common high-frequency words such as *mamma*, *nana* and *bye-bye*. After that, the category practically disappeared, and only two C1VC1V words were produced by the end of the study (*bye-bye* [pəpɑɪ] in session 4 and *mamma* [mɑmə] in session 6). Table 70 presents all selected C1VC1V words with simple onsets.

Table 70					
session 2		**session 4**		**session 6**	
baa baa	babæ	*bye bye*	pəpɑɪ	*mama*	mɑmə
bye bye	baːbaɪ baːbaɪ				
dada	dada				
daddy	dadi				
mamma	mama				
nana	nana				
papa	papa				

Table 70: Rebecca's 'selected' CVCV words with consonant harmony in sessions 2-7.

Adaptation and variability

As mentioned earlier, there were no instances of C1VC2V words being consistently adapted to the C1VC1V category, although one word, *doggy*, in session 3 appeared with harmony or near-harmony in two tokens ([goɟɪ], [dɔdɪ]) in addition to being produced correctly in other tokens ([dɔgɪ], [dɔɟɪ]). Apart from that, the only variation observed across tokens concerned voicing (e.g. *dinner* [tɪnɑ:], [dɪnə]) and in one case, palatalisation (*teddy* [taɟɪ]). Table 71 presents all variable CVCV words with simple onset.

Table 71					
session 3		**session 5**		**session 6**	
doggy	dɔgɪ	*tower*	dawːɪ^h	*dinner*	tɪnɑ:
	dɔdɪ		t^{h}awɪ^h		dɪnə
	dɔɟɪ			*teddy*	t^{h}adɪ
	go goɟɪ				t^{h}atɪ
teddy	tadɪ				
	^{h}ɕtadɪ				
	taɟɪ				

Table 71: Rebecca's variable CVCV child forms with simple onset in sessions 2-7.

5.2.3 Challenging consonants and clusters

Challenging onset

Difficult consonants (fricatives, affricates and liquids) and clusters in onset position were attempted very rarely until the last session. However, the ones that were attempted were always accurate or close to accurate (e.g. *pretty* [pjɪtʲɪ]). The only exception was *flower*, which appeared in a simplified form [ʃɛloʊ], that presumable originated from the Rebecca's earlier fixed form [ʃalʊʃ] (cf. section 5.3). In the last session, challenging onsets were frequent and accurate. Table 72 presents all targets with challenging onset.

Table 72					
session 2		**session 3**		**session 4**	
		cd	sidi	*flower/s*	ʃɛloʊ
		pretty	pjɪtʲi:		
session 5		**session 6**		**session 7**	
		Zida	sɑɪdɑ	*ladder*	ladə
				lady	lɛɪdɪ
				play-dough	tlɛdʊə
				shadow	ʃat:ʊ
				sticky	stɪcɪ

Table 72: Rebecca's CVCV targets with challenging onset in sessions 2-7.

Words of this type were also not very variable. The only variability recorded in challenging onset consonants concerned the articulation of word-initial fricatives. In two words, these varied between different coronal places of articulation: *CD* [ɕidi], [sidi] in session 3 and *Zida* [ʃada], [sɑdə], [tsɑɪdə] in session 6.

Challenging medial

Rebecca attempted challenging consonants and clusters in intervocalic position slightly more often than in word onset. This mostly concerned the liquid /l/, which was absent word-initially up until session 7, but appeared frequently in word medial position already in session 2 (e.g. *hello* [hɛləʊ]). The liquid was thus stable, and in one word it also affected onset, when *yellow* was rendered as [lələ] in session 4. In session 5, also the liquid /ɹ/ was produced correctly (*hooray* [hʊ:ɹe:ɪ]).

As regards word medial clusters, these were recorded in three words. In *camera*, which appeared in sessions 2 and 3, the cluster was metathesised ([kłama]), but in the other two words it only underwent slight modifications (*pencil* [pəʔtsɑ:], *cowboy* [kχałbo:ɪ]).

Medial fricatives were not attempted. Table 73 presents all targets with challenging medial position.

Table 73					
session 2		**session 3**		**session 4**	
camera	kɬama	*camera*	cłɪma	*pencil*	pəʔtsɑː
hello	hɛləu	*dolly*	doli	*yellow*	lələ
yellow	cɬalei	*welly*	wʌlə		
session 5		**session 6**		**session 7**	
cowboy	kχaɬboːɪ				
dolly	tɔli				
hooray	hʊːɹeːːɪ				

Table 73: Rebecca's CVCV targets with challenging medial consonant(s) in sessions 2-7.

This category of words also did not exhibit much variability. The small amount of variability recorded concerned variable substitutions (*hello* [hɛləu], [heɪjəʊ]; *yellow* [lalou], [jæjoʊ]), voicing (*dolly* [dɒli], [tɔli]) and palatalisation of fricative (*pencil* [pəʔtsɑː], [pʰɑʔtʃəː]). No other words were variable.

Challenging onset and medial

Words that posed a challenge in both onset and medial positions were the only ones that underwent a considerable number of modifications, although these usually did not affect the syllable shape of the word. In this category, there were instances of liquid gliding (*rella* [jɛja], even though medial /l/ was stable in other words, cf. Table 73), assimilation of place of articulation (esp. velar to alveolar, e.g. *finger* [findɐː]), and cluster reduction (e.g. *reindeer* [wɪnɪɒ]). Table 74 presents all targets with challenging onset and medial position.

Table 74					
session 2		**session 3**		**session 4**	
shoulder	ʃuːalɛ	*cellar*	ɕɛlə	*finger*	findɐː
		rella	jɛja		
session 5		**session 6**		**session 7**	
cowboy	kʰaboːːɪː	*fluffy*	flafɪə	*scary*	ʃtawɪ
finger	fɪnda	*reindeer*	wɪnɪɒ	*story*	stɒɹi
strawberry	stɹabɹi			*tractor*	twatə

Table 74: Rebecca's CVCV targets with challenging onset and medial consonants in sessions 2-7.

There was also more variability recorded in these words, most of which concerned variable reduction of clusters (e.g. *strawberry* [stɹabɹi], [tɹabu]). Table 75 presents all variable words with challenging onset and medial position.

Table 75					
session 2		**session 5**		**session 6**	
shoulder	ʃuːalɛ	*cowboy*	kχałboːɪ	*fluffy*	łafiə
	ʃəʊɛ		kʰaboːːɪː		flafɪə
	ʃuːwə	*strawberry*	stɹabɹi		fɹafiə
			tɹabu		lafɪ

Table 75: Rebecca's variable CVCV child forms of targets with challenging onset and medial consonants in sessions 2-7.

Multisyllabic words

Multisyllabic words, although not attempted frequently apart from session 5, were the ones that most often appeared in much simplified child forms, undergoing modifications that often resembled whole-word templates (albeit they were not used for less challenging targets). These involved:

(1) reduplication (*pilipala*, Welsh for *butterfly,* [pɪlaʔpɪlaʔ])

(2) syllable reduction (*caterpillar* [katʰɛpʰła], *Balamory* [balmʊi])

(3) other whole-word simplification (*triangle* [tʰadija:], *christmas tree* [twɪzɪtʰwiə], *oopsie daisy* [paplɪdisɪə])

The only multisyllabic word that was produced fairly accurately was *another* [ɛnəvə] in session 7, although earlier it had appeared with the first syllable deleted in session 5 ([ladə]). Table 76 presents all multisyllabic targets.

Table 76					
session 2		**session 3**		**session 4**	
pilipala	pʰiɬa pʰiɬa			*pilipala*	pɪlaʔpɪlaʔ
session 5		**session 6**		**session 7**	
another	ladə	*christmas tree*	twɪzɪtʰwiə	*another*	ɛnəvə
Balamory (TV show)	balmʊi			*oopsie daisy*	paplɪdɪsɪə
caterpillar	katʰɛpʰɬa				
oopsie daisy	hauʔodeːsiː				
pilipala	pʰɪlɪpʰala				
triangle	tʰadijaː				

Table 76: Rebecca’s multisyllabic targets in sessions 2-7.

Nevertheless, the only variability recorded in this category of words concerned the reduplicated word ‘pilipala’ (*butterfly* in Welsh), which appeared in many different, albeit similar forms, presented below in Table 77.

Table 77			
session 2		**session 5**	
pilipala	pʰiɬa pʰiɬa	*pilipala*	pʰɪla
	pila		pʰɪlpʰɪl
			pɪbila
			pʰɪlɪpʰala

Table 77: Rebecca’s different tokens of the word ‘pilipala’ (*butterfly*) in sessions 2-7.

5.2.4 Section summary

The decrease of Rebecca’s preference for C1VC1V disyllabic words appeared smooth throughout the study, with almost no adaptation and systematic patterns or substitutions. Yet, it was apparent that this was the result of the fact that the child preferred to only attempt word shapes and consonants that were easily accessible to her. This also resulted in high accuracy across sessions.

Nevertheless, when Rebecca did attempt more challenging targets, she used simplification strategies and substitutions, which affected her accuracy, and which she did not need for simpler words. In particular, the liquid /l/ was stable in intervocalic position early on, but underwent gliding and fricativisation in multisyllabic words. Similarly, velar fronting was more likely to occur in challenging targets. Finally, multisyllabic targets were the only type of words that underwent whole-word simplification processes, such as reduplication.

To sum up, high accuracy and low variability in Rebecca's production of disyllables was not always due to precise articulation, large consonant inventory and skills in producing variegated consonants. Rather, it was in a large part due to the fact that the child preferred to attempt targets that did not require advanced articulatory skill.

5.3 Coda

5.3.1 Overview

Already in the first session, Rebecca produced codas in monosyllables with almost target frequency (39%, target: 43%). In session 2, disyllabic words with codas appeared for the first time, and soon they too reached target frequency, in session 3 (20%, target: 17%). Therefore, even though the accuracy of the final consonants still required improvement, producing closed syllables was not a challenge to Rebecca at this stage of development. Figure 26 presents the development of the two word shapes across sessions.

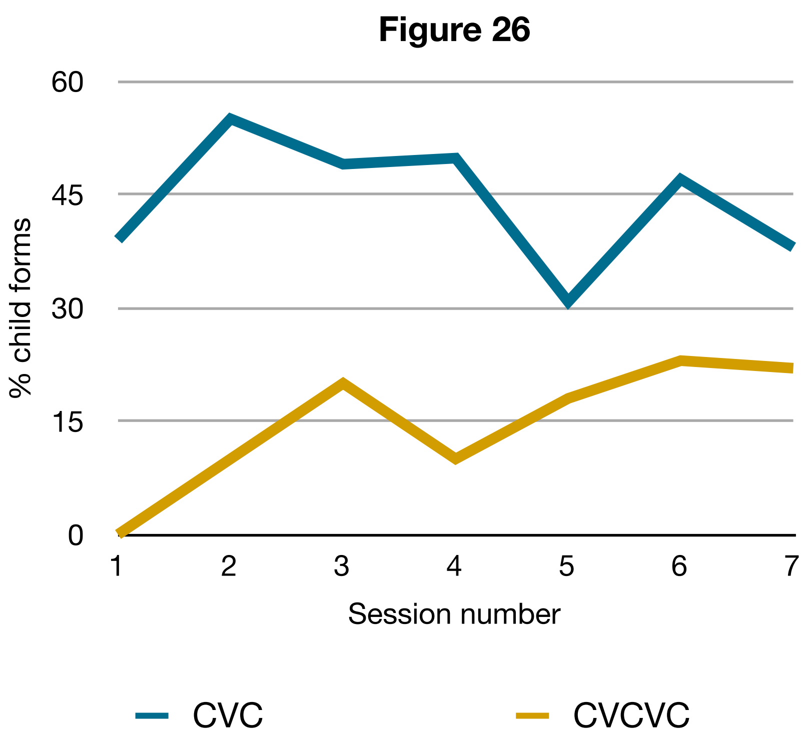

Figure 26: Percent mono- and disyllabic child forms with coda in Rebecca's production across sessions.

Already at the beginning of the study, Rebecca was producing codas with little variability and around 50% accuracy. There were also no significant changes in how many codas she attempted, and across sessions these made up between 30% and 40% of all consonants she attempted. Throughout the sessions, the variability was low, and accuracy gradually improved. Figure 27 presents accuracy and variability of codas.

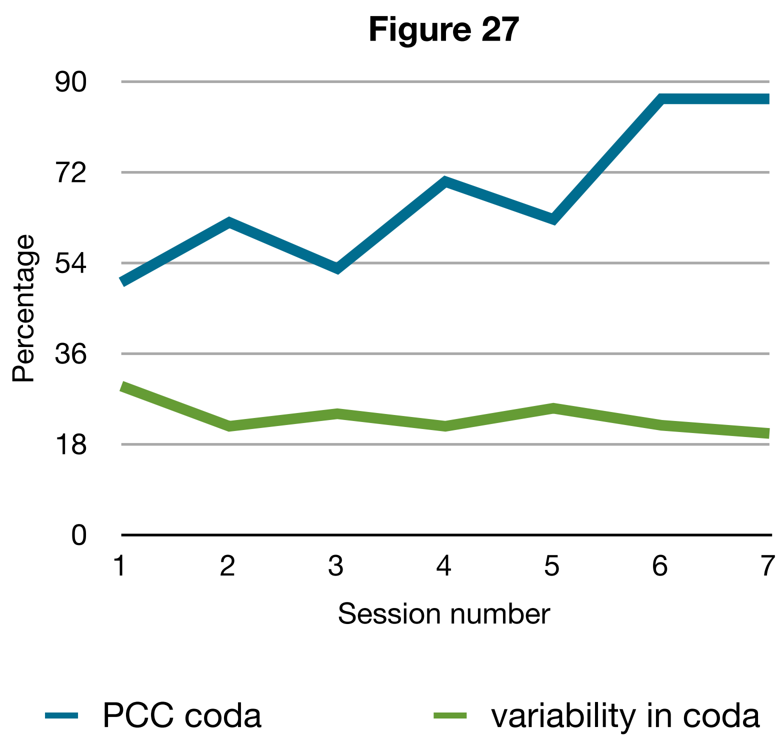

Figure 27: Accuracy and variability of Rebecca's codas across sessions.

5.3.2 Coda omission and glottal stopping

After session 1, there was not a single instance of coda omission in CVC words. Similarly, there was only one instance of coda omission in a CVCVC word, in session 7 (*wake up* [wɛɪtʊ]). Rebecca also did not use glottal stopping in coda position in either accurate or inaccurate manner. There were only two instances of replacing coda with a glottal stop: *stuck* [cəʔ] in session 4, and *look* [lɒʔ] in session 7.

There was no connection between the development of closed syllables and the frequency of open syllables. At first, the proportions between different types of codas in monosyllabic words were the same as in targets, with stops and liquids occurring most frequently (21%), followed by fricatives (15%) and nasals, which only appeared sporadically (3%). Between sessions 3 and 6 the percentage of stop and liquid codas considerably decreased (reaching 9%). During this time, the most frequently produced codas were fricatives (peaks: 20% and 18% in sessions 3 and 6 respectively) and nasals (peak: 17% in session 4). It appeared that in each session Rebecca was focusing on only a single type of coda (which then exceeded target frequency), while other types were largely ignored. At the end of the study, the proportions returned to the target frequency. Figure 28 presents the overall percentage of CVC words by final consonant.

Figure 28

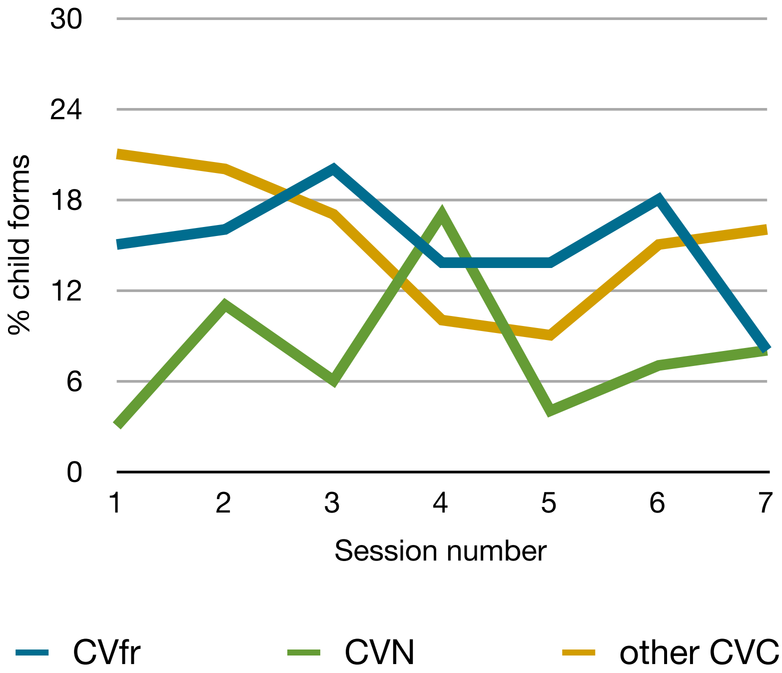

Figure 28: Percent monosyllabic child forms with fricative, nasal and other coda in Rebecca's production across sessions.

Disyllables with coda began to be frequently produced in session 2 and their frequency increased throughout the study. However, the proportions of particular coda types were not the same as in monosyllables. Stops and liquids showed the slowest development, only getting close to target frequency in the last session (6%, target: 7%). Nasals were more common, and by session 5 they were produced almost as frequently as they appeared in targets (5%, target: 6%). Fricatives were the dominant type, and they reached target frequency already in session 3 (6%, target: 5%). Fricative codas in disyllables also showed a developmental curve similar to fricatives in monosyllables, with two peaks in sessions 4 and 5. The development of nasals, stops and liquids was more linear. Figure 29 presents the overall percentage of CVCVC words by final consonant.

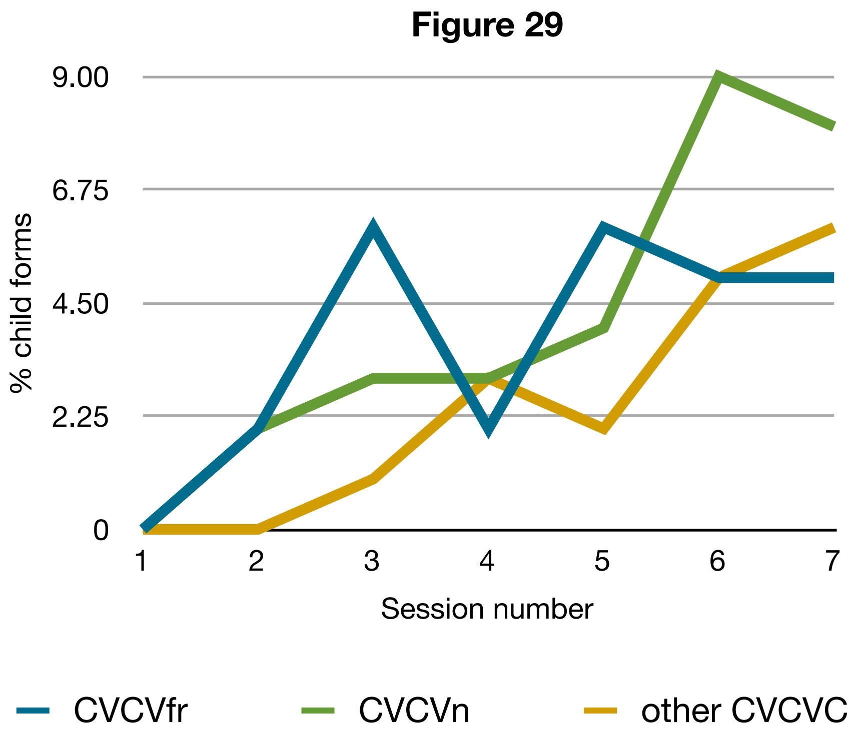

Figure 29: Percent disyllabic child forms with fricative, nasal and other coda in Rebecca's production across sessions.

Given that Rebecca acquired CVCVC words early in the study (unlike the other two children), we shall discuss both monosyllables and disyllables together.

5.3.3 Fricative coda

Selection and accuracy

Up until session 5, Rebecca attempted almost exclusively coronal fricatives /s/, /z/ and /ʃ/ in coda position. At first, these were almost always rendered as /ʃ/ or /ɕ/ (e.g. *nose* [nʊʃ]; *mouse* [læɕ]). In session 3 first instances of only slightly palatalised /s/ appeared (e.g. *juice* [dʒɪsʲː]; *peas* [pɪsʲ]), and from session 5 onwards the alveolar /s/ was produced correctly (the only exception being *mice* [əmɑiɕ] in session 6). In session 7 the first occurrence of /z/ was recorded.

As regards labio-dental and dental fricatives, the former appeared sporadically from session 3 onwards, while the latter only began to be attempted in session 6, and were replaced with /f/ (e.g. *bath* [baf]). Table 78 presents all CVfr words with singleton coda in both target and child form (selected).

Table 78					
session 2		**session 3**		**session 4**	
brush	baʃ	*brush*	bjæɕ	*grass*	tjaʃ
horse	ʊʃ	*close*	klʊɕ	*stars*	djas
mice	məʃ	*eyes*	æɕ	*this*	ʔɨʃ
nose	nʊʃ	*fish*	ɸɯʃ	*toes*	tʰɒʃ
peas	piʃ	*house*	aɕ	*yes*	jɛʃ
push	pəʃ	*juice*	dʒɪsʲ:		
shoes	ʃʊʃ	*mice*	maʔɕ		
toes	tʊɕ	*mouse*	læɕ		
yes	jɛʃ	*pies*	paisʲ:		
		peas	pɪsʲ		
		off	af:		
		shoes	tɔʔ ʃʊʃ		
		stairs	stɪɕ		
		toys	tʊɕ		
session 5		**session 6**		**session 7**	
goes	doʊs	*bath*	baf	*eyes*	ai:z
hiss	hesː	*brush*	bwʊʃ	*give*	dɪf
leaf	lif	*have*	haf	*his*	hɪs
this	n̩dɪs	*juice*	ɹus	*miss*	mɪs
those	dios	*mice*	əmɑiɕ	*woof*	wəf:
		off	ɒf	*yes*	jɛs
		teeth	tʰɛɪf		
		with	wɪf		
		yes	jɛs		

Table 78: Rebecca's 'selected' CVC targets with singleton fricative coda in sessions 2-7.

Coronal fricative codas were the most common in monosyllables, and they were also the only ones produced in disyllables. Varying between /ʃ/ and /ç/ at first, they were produced accurately from session 6 onwards. Table 79 presents all CVCVfr words with singleton coda in both target and child form (selected).

Table 79					
session 2		**session 3**		**session 4**	
nose	nʊʃ	*close*	klʊç	*stars*	djas
	nəu		klʊɕ		tɑ
yes	jɛɕ	*flowers*	ʃalʊç		
	jɛʃ		ɕalɯɕ		
		juice	dʒɪsʲ:		
			ɟɪsʲ:		
			ɟʊɕ:		
			dʑʏɕ:		
		peas	pɪsʲ		
			pi:ɕ		
session 5		**session 6**		**session 7**	
hiss	hesː	*have*	haʊ	*eyes*	ɑid
	heɪʃ:		ʔɑv		ai:z
starfish	wasːdavɪtʃ		haf		aɪs
	sṭaɹɪs		ʔɑβ		
		mice	əmɑiɕ		
			ʔɒʊtwɑɪs		

Table 79: Rebecca's 'selected' CVCVC words with singleton fricative coda in sessions 2-7.

Adaptation and variability

The only processes observed in codas were the gradually decreasing degrees of palatalisation of coronal consonants and the replacing of the dental /θ/ with the labio-dental /f/. Neither of the two appeared categorical and fully regular. As regards palatalisation, at first the fricatives varied between /ʃ/, /ɕ/ and /ç/. This across-token variability only occurred in alveolar targets (e.g. *close* [klʊç], [klʊɕ]; *yes* [jɛɕ], [jɛʃ]). Later on, when palatalisation began disappearing, only alveolar targets were produced with alveolar consonants, but also in a variable manner (e.g. *hiss* [hes:], [heɪʃ:]). Since palatal targets almost never showed variability (the only exception being *starfish* [sdavɪtʃ], [staɹɪs], session 5), it appears that palatals and alveolars were two separate categories for Rebecca. The child did attempt to produce the alveolar targets, and the palatal fricatives she produced instead were caused by imprecise articulation. As articulation improved, variability of those consonants disappeared entirely. Table 80 presents words with variable fricatives in coda.

Table 80					
session 2		**session 3**		**session 4**	
flower	ʃalʊʃ	*dolly's*	doliç		
session 5		**session 6**		**session 7**	
flowers	flawaʃ	*Santa Claus*	sadəcłɒs	*doggies*	dɑdɪs
starfish	sta̩ɹɪs	*teddy's*	tʰɛdɨs	*strawberries*	ʃtɹɒbəɹi:s
				whiskers	wɪstəz

Table 80: Rebecca's disyllabic and longer child forms with variable singleton fricative coda in sessions 2-7. (variable fricative coda in monosyllables not recorded)

As regards interdental-labiodental substitutions, these only appeared twice (cf. Table 78), and therefore it was not possible to draw conclusions about the regularity of that process in coda.

There were two types of adaptation which resulted in fricative coda. One was final stop affrication, which will be discussed in the next section, and the other one was final fricative insertion. The only recorded cases of this process come from session 3, and concern disyllabic words. The fricative (/ʃ/, /ɕ/ or /ç/) was added to three words ending in a vowel (examples (1)-(3) below) and one ending in a nasal (4):

(1) apple [abʊʃ]

(2) flower [ʃalʊç]

(3) window [ɪnoʊɕ]

(4) shopping [ɕambɪn:ɕ]

We may recall that before session 5 there were only two accurate CVCVfr words recorded (cf. Table 80). Therefore, the peak in frequency observed for this category in session 3 was mostly due to the above cases of adaptation. We shall return to this question later on (see section 1.6). For now, it is important to note that Rebecca produced inaccurate final fricatives in disyllables before she began producing them correctly.

5.3.4 Stop and liquid coda

Selection and accuracy

In session 2, Words in this category most often had a coronal or dorsal stop in coda. Labial stops were much less common, and in none of the sessions more than two words of that type were recorded. Similarly, final liquids were produced very infrequently. Before session 7 only two liquid codas were recorded. In one of them the liquid was a substitute for the target /r/ (*door* [goɫ]), and in the other one the coda was accurate but the onset was omitted (*bull* [ʊɫ]). Therefore, it was apparent that these consonants were still challenging for the child. In session 7, their frequency increased and they were all accurate.

Common ways in which the child forms departed from adult targets were voicing (most final stops were voiceless) and aspiration (most final stops were aspirated), as well as fronting of velars. Velar stops were sometimes fronted to palatals (e.g. *like* [lɛc], *back* [bac]), and sometimes to alveolars (e.g. *big* [bɪt]). Table 81 presents selected CVC words with singleton stop and liquid coda with a stop or liquid in child form.

Table 81					
session 2		**session 3**		**session 4**	
bag	bac	*back*	baʔkʰ	*big*	bɪt
cup	tæpʰ	*door*	goɫ	*dot*	tɒtʰ
eight	ɪ̇tʰ	*eat*	ʔɪt	*eight*	ʔɛtʰ
head	hatʰ	*up*	ʌpʰ	*that*	ɹat
like	lɛc			*up*	ʔʌpʰ
look	lu:k			*what's that*	ʃatʰ
make	mɪk				
neck	nːac				
spade	bieɪtʰ				
up	ʌp				
what	wət				
session 5		**session 6**		**session 7**	
book	ʔʌbːːʊcʰ	*big*	bɪt	*all*	ɒɫ
bull	ʊɫ	*book*	bʊc	*back*	bac
crab	tɹab	*hot*	xɒtʰ	*big*	bət
flag	ʷlacʰ	*look*	lɒcʰʔ	*bowl*	pɒ:l
like	lat	*need*	nɪt	*cup*	tʌp
look	lʊ:kʰ	*seat*	əsi:tʰ	*eat*	ɪd
not	nɒtʰ	*sit*	setʰ	*food*	fɒtʰ
shape	ʃeɪp	*sleep*	sli:pʰ	*got*	dət
		what	wɒʔt	*head*	hɛt
				it	ɪt
				plate	plɛɪt
				sit	sɛt
				small	smɒl
				tail	tɪel
				with	ɹid:

Table 81: Rebecca's 'selected' CVC words with singleton stop or liquid coda in sessions 2-7.

As regards codas in disyllables, alveolar stops were even more prevalent among these than in monosyllables. There were no CVCVC words ending with a labial stop, only one ending in a velar (*nick nack* [nɪkɪjak]) and only two ending in a liquid (*good girl* [dʌtəl], *spoonful* [spʊnfʊl]), both of which appeared in the last session. Table 82 presents all selected CVCVC words with singleton stop and liquid coda.

Table 82					
session 2		**session 3**		**session 4**	
		nick nack	nɪ kɪ jak	*blanket*	blɑdɪtʰ
				circle	ʃɒtɑʔ
session 5		**session 6**		**session 7**	
astronaut	asn̩ɒːtʰ	*blanket*	blankʰetʰ	*blanket*	plankɛtʰ
rip it	ɹɪbɪtʰ	*finished*	fɨnɪʃtʰ	*good girl*	dʌtəl
what's that	wɔsætʰ	*little bit*	lɨtəbɪtʰ	*passion fruit*	pʰaʃənfɹutʰ
		upset	ʌpsatʰ	*spoonful*	spʊnfʊl
		what's that?	wɒsʲda:tʰ	*what's that*	wɒsatʰ

Table 82: Rebecca's 'selected' CVCVC words with stop or liquid coda in sessions 2-7.

Although alveolar and velar stops were the ones used most frequently in both mono- and disyllables, in session 3 they underwent a period of extensive affrication. Seven out of 11 CVC words, and 2 out of 3 CVCVC words with singleton coda had the final stop affricated. This affected both alveolar (e.g. *pat* [paʔtɕ]) and velar stops (e.g. *bag* [bacç]). Table 83 presents all words with singleton target stop coda affricated.

Table 83							
session 2		**session 3**		**session4**		**session 5**	
bead	ɪtɕ	*bag*	bacç	*hurt*	ʔɒtʃ	*carrot*	tawatʃ
heart	atʃʰ	*bed*	ba:tɕ	*out*	ʔatɕ	*notepad*	opʰætʃ
		bird	butɕ				
		book	bʊcç				
		coat	tɕʊtsʲ				
		night night	ʔaʔatɕ				
		pat	paʔtɕ				
		pirate	pajitɕ				
		sit	çitsʲ				

Table 83: Rebecca's mono- and disyllabic words with affricated target stop coda in sessions 2-7.

Adaptation and variability

As we have seen, there was variability in velar fronting of coda across words, since in some words the velars were fronted to palatals, in some to alveolars, and in some cases they were produced accurately. Moreover, there was also variability across tokens, whereby the same word could have different forms in the same session, with the final velar realised differently in each of them (e.g. *look* [lʌc], [lu:k]; *bag* [bat^{h}], [bac]).

Other variability included final stop affrication (e.g. *bead* [bic], [bicç], [ɪtɕ]; *hot* [xɒt^{h}], [hɒts]), glottalisation (e.g. *dot* [tɒt^{h}], [tɒʔ]) and omission (e.g. *got* [dət], [də]). However, no type of variation apart from stop coda affrication appeared frequently. Table 84 presents all variable words with stop and liquid coda in target.

Table 84					
session 2		**session 3**		**session 4**	
bag	bat^{h}	back	bac	*big*	pɪtç
	bac		baʔk^{h}		bɪt
	bə				pɪʔ
bead	ɪtɕ				bɪkə
	bicç				pɪtə
	biç			*dot*	tɒʔ
	bic				tɒt^{h}
eight	ɪ̇t^{h}				
	ɪtɕ				
look	lʌc				
	lu:k				
session 5		**session 6**		**session 7**	
crab	twap̚	*big*	bed	*big*	bɪb
	tɹab		bɪt		bət
			pɪɟ	*cup*	tʌp
		hot	hɒts		tʌb
			xɒt^{h}	*good girl*	tədɒlə
		look	lʊtɕ		dʌtəl
			lɒc^{h}ʔ	*got*	dət
			lɒt		də
				small	mɑɹ
					smɒl

Table 84: Rebecca's variable child forms for mono- and disyllabic targets with stop or liquid coda in sessions 2-7.

There was no adaptation in terms of replacing fricatives or nasals with stops.

5.3.5 Nasal coda

Selection and accuracy

Both alveolar and labial nasals were frequent in the data and no alternations were observed in sessions 2-5. In session 6, the first case of vowel epenthesis was recorded (*down* [tɑʊnə]), and in session 7 that process affected 5 out of 7 CVn words. However, it was not justified by any difficulties that nasal codas could pose for Rebecca, as they had been long present in her repertoire. It was a sudden change in articulation of the final nasals that remains unexplained. Table 85 presents 'selected' CVC words with a singleton nasal in coda.

Table 85					
session 2		**session 3**		**session 4**	
bam	bəm	*one*	wan	*balloon*	blʊn
one	wan	*bum*	bam:	*bam*	pɒm
phone	ʃum	*plum*	a plam	*one*	wʌn
plane	plɪn	*phone*	χɪm	*pram*	plɑm
tum tum	tʌm tʌm			*seven*	ʃɛbn
yum	nam			*some*	ʃʌm
				sun	ʃʌn
				ten	tʰ:ʌn
				turn	tɑn
session 5		**session 6**		**session 7**	
balloon	blu:n	*can*	tʌn	*doing*	dʊɪnə
one	wʌn	*down*	taʊnə	*done*	dənə
skin	ʃkɪn	*one*	wɑn	*down*	taʊn
		pram	pʰʍʌm	*gone*	dɒnə
		some	sʌm	*line*	laɪnə
				plum	plʌm
				spoon	spʌnə

Table 85: Rebecca's 'selected' CVC words with singleton nasal coda in sessions 2-7.

Final nasals in disyllabic words exhibited the same stability as final nasals in monosyllables, and they also often appeared with an added schwa in sessions 6-7. Table 86 presents all 'selected' CVCVC words with a singleton nasal in coda.

Table 86					
session 2		**session 3**		**session 4**	
all done	haːdandn̩	*alldone*	aðan	*sleeping*	slɛpɪn
button	badən	*allgone*	ɔlgən		
		button	ba^{h} batɪn		
		iron	ajlɪn		
		open	oʊpən		
		tum-tum	tam tam		
session 5		**session 6**		**session 7**	
airplane (it's airplane)	t^{h}ɒlplɛn	*all done*	ʔɒtɑnːə	*alldone*	ɪdæn
all done	ʔadan̩ː	*bathroom*	əbaθɹɒmə	*climbing*	klɑmɪn
earring	æːɹɪn	*come on*	t^{h}əmɒn	*closing*	kləʊsɪn
Haloween	halahɪn	*having*	havɪn	*eating*	itɪn
lemon	lamən	*pom pom*	p^{h}ɒmp^{h}ɒmə	*everyone*	ʔɑʊən
this one	jaʔɟwan	*sit down*	sɨdɐʊnə	*having*	havən
		sitting	sːɪtɪn	*lion*	lɑɪən
		this one	ʔɪswʌn	*muffin*	mʌfɪnə
		woken	wɒʊkən	*rolling*	wolɪnə
				sitting	sɪtɪn
				washing	wɑʃɪn

Table 86: Rebecca's 'selected' CVCVC words with singleton nasal in coda in sessions 2-7.

Adaptation and variability

There were no cases of adaptation observed in this category of words. The small amount of variability that was present differed across sessions. In session 2, the final consonant in one token of *plane* was harmonised with onset ([plim]). In session 3, there were two cases of variable palatalisation of the final /n/, as well as one word that had a variant with an added final fricative (*open* [oʊpən], [oʊpəns]). We may recall that in the same session, there were several words which only appeared in such form (cf. section 5.3.2). Finally, in session 7, all variability concerned the addition of the final schwa, which appeared in some tokens, but did not appear in others. Table 87 presents all variable words with nasal coda.

Table 87							
session 2		**session 3**		**session 4**		**session 7**	
plane	plɪn	*button*	baʰ batɪn	*sun*	ʃʌn	*down*	taʊn
	plim		baðɪnʲ		ʃ:		daʊnə
		one	wadn			*lion*	lɑɪən
			waɲ				lɑiənə
			wan			*muffin*	mʌfɪnə
		open	oʊpəns				nəfʌn
			ʊp			*one*	wən
			oʊpən				ʊənə

Table 87: Rebecca's variable mono- and disyllabic words with singleton nasal coda in sessions 2-7.

5.3.6 Complex coda

Complex stop+fricative coda

The first two instances of a complex stop +fricative coda were recorded in session 3 (*beads* [bɪtsʲ], *eats* [itɕ]). In that session, there was also one target with a liquid+fricative sequence in coda, in which the liquid was vocalised (*balls* [baʊsʲ]).

Interestingly, while final singleton stops were often affricated in the child form, accurate affricates were almost absent. The first final affricate target was recorded in session 4, and it was reduced to the fricative (*orange* [ʔɒwɪnʃ]). The same process applied to *arch* in session 5 ([aʃ]) and *touch* in session 6 ([tɐ:s]). The first affricate that was preserved in the child form appeared in session 6 (*sausage* [sʲɒsʲɪtsʲ]), and then in session 7 (*porridge* [pʰɒɹɪts]). Therefore, even though inaccurate affricates were used extensively already in session 3, accurate affricates only appeared in session 6, and even then they were fronted to /ts/. It is thus highly unlikely that final stop affrication was a substitution process that replaced stops with affricates, as affricates were not produced correctly long after the process was gone.

Unlike affricates, final stop+fricative clusters were produced correctly from session 3 onwards (e.g. *beads* [bɪtsʲ]), although they most often underwent palatalisation (e.g. *eats* [itɕ], *arms* [ʔʌmʃ]), and velar stops were usually fronted up until session 6 (e.g. *six* [ʃɛtʃ], *blocks* [blatʃ:]). The reverse, fricative+stop sequences posed more difficulty and were always reduced to the fricative (e.g. *lost* [ləʃ]), until the last session. Table 88 presents all 'selected' complex codas.

Table 88					
session 2		**session 3**		**session 4**	
lost	ləʃ	*balls*	baʊsʲ	*arms*	ʔʌmʃ
		beads	bɪtsʲ	*balloons*	cɛl:ɑʔpəlʊns
		eats	itɕ	*dots*	tɒʔtɒʔtʃ:
				legs	lɛtʃ
				orange	ʔɒwɪnʃ
				six	ʃɛtʃ
session 5		**session 6**		**session 7**	
blocks	wɔtʃəblatʃː	*boots*	butsʲ	*breakfast*	bɹɛfəst
cloud/s	kl̩aɕ	*bubbles*	bʌbəls	*closed*	kjʊtsv
last	læʃ	*oops*	ʔɒpʰ	*happens*	hapɛns
gloves	glavsː	*sausage*	sʲɒsʲɪtsʲ	*likes*	lɑɪs
arch	aʃ	*touch*	tɐ:s	*needs*	ʔʊts
oops	ʔʌpɕ			*next*	nɑʃtʰ
shapes	ʃɛpʃ			*porridge*	pʰɒɹɪts
lollipops	lɒlapapʃ				

Table 88: Rebecca's 'selected' mono- and disyllabic words with complex stop+fricative and affricate coda in sessions 2-7.

There was little variability in this category of words, and it mostly concerned the place of articulation of the final fricative, which varied between /ʃ/, /ɕ/ and /ç/, as in singleton codas. There were also two cases where in the final velar+fricative cluster the velar was variably omitted (*legs*[lɛtʃ], [ləʃ], session 4; *likes* [lɑɪs], [jats], session 7).

Complex nasal/liquid+stop coda

At first, nasal+stop and liquid+stop sequences were reduced to the stop (e.g. *milk* [mɪkʰ], *different* [dɪfɪn]). In session 3, the preserved stop was also affricated in two out of three words (*drink* [dicç], *milk* [mɪcç]). Given that the same process affected singleton stops, it is unlikely that the final fricative was an attempt at the other consonant in the target cluster. The same two words later reappeared in session 6 with accurate coda (*drink* [dwenc], *milk* [m:ɪlkʰ]). Table 89 presents all final nasal/liquid+stop sequences.

Table 89					
session 2		**session 3**		**session 4**	
milk	mɪkʰ	*drink*	dicç	*different*	ʔədɪfɪn
		milk	mɪcç	*find*	fɑnd
		pink	piʔc		
session 5		**session 6**		**session 7**	
		drink	dwenc	*bump*	bʌmpʰ
		milk	m:ɪlkʰ	*want*	wɒnt

Table 89: Rebecca's mono- and disyllabic child forms for targets with complex nasal/liquid+stop coda in sessions 2-7.

The little variability recorded involved variable reduction of the final cluster in *find* [fɑnd], [hʊn:]; (session 4) and *want* [wɒnt], [vən] (session 7). In addition, already in session 2 there appeared one variant of *milk*, with an added fricative at the end ([mɪkʰ], [mɪc], [mɪcç]).

5.3.7 Section summary

As regards particular types of codas, all consonants apart from dental and labio-dental fricatives were accessible to Rebecca in coda position from session 2 onwards. In addition, Rebecca was the only one out of the three subjects who began producing disyllabic words with codas early in the study, and she also successfully attempted words with complex coda. Coda omission was almost entirely absent, and the only alternations that appeared somewhat regularly were velar fronting, final fricative insertion and final schwa insertion (the latter only affecting final nasals and only in the last two sessions).

Velar fronting was fairly frequent, but far from entirely systematic, as in many words the final velar was retained. It was somewhat more likely in complex stop+fricative codas, which could be attributed to assimilation, as most final fricatives had palatal place of articulation.

The pattern that was the most apparent in the data was the one concerning final fricatives., which appeared in session 3. In that session, 84% of stop coda targets were affricated. There were also accurate stop+fricative coda sequences produced, as well as affrication of stops in reduced final nasal/liquid+stop clusters. In addition, fricatives were added to four disyllabic targets ending in liquids, vowels and nasals. The pattern was thus very widespread in the data.

However, target affricates were reduced long after session 3 (up until session 6), which means that it is implausible to postulate a rule in the child's system which would substitute stops (which had been in Rebecca's repertoire) for affricates (which had been absent in accurate form from Rebecca's repertoire). Similarly, it is unlikely that the final fricatives came from overgeneralisation of the possessive or plural morphological ending, since in session 3 there were already first examples of productive use of the possessive (*dolly* [dɔli] vs. *dolly's* [dɔlɪç]) and the plural -s (*pie* [paɪ] vs. *pies* [paisʲ:]). Moreover, the -s was not added to monosyllabic targets without stops in coda, which suggests that the process was related to articulation of stops.

The only cases of final fricative insertion in words without target stop coda involved disyllables. At that time, disyllables with fricative coda were not yet very common. The peak in their frequency observed in session 3 was directly related to the four words which had an added fricative in coda. It was only the second peak in session 5 which corresponded to an increase in the number of accurate CVCVfr words. Similarly, the peak in frequency of monosyllables with fricative coda observed in session 3 was related to the pattern. In session 4 both mono- and disyllabic words with fricative coda returned to their previous frequency. Figure 30 presents frequency of CVfr and CVCVfr words accross sessions.

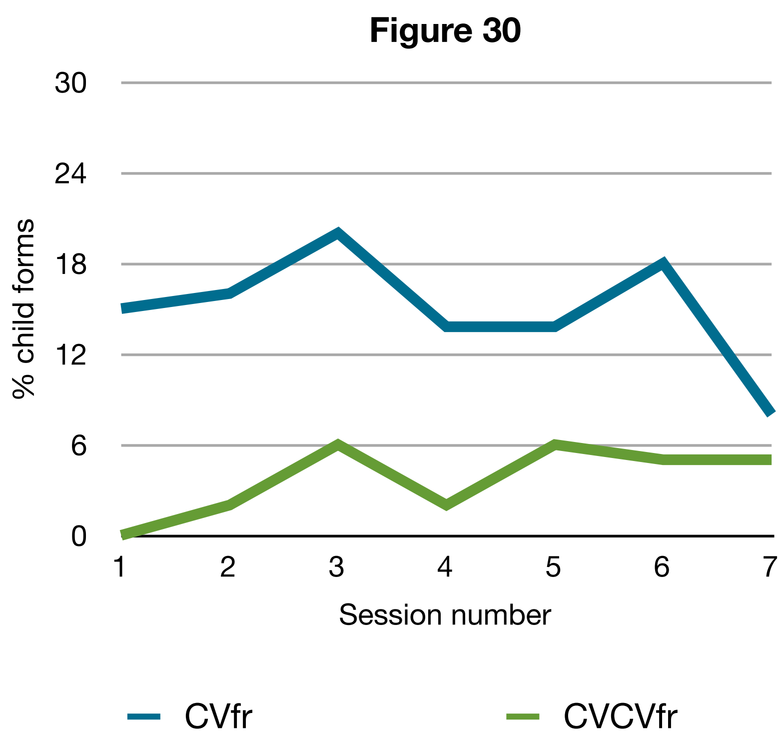

Figure 30: Percent mono- and disyllabic child forms with fricative coda in Rebecca's production across sessions.

It thus appears that a pattern of final stop affrication, that was most likely articulatorily motivated in monosyllables, was generalised to more difficult disyllabic words, regardless of whether they matched the criteria necessary for its occurrence in CVC words (i.e. stop in coda). This might have facilitated production of codas in disyllables, which were still challenging to the child. Over one third of (C)VCVC words in session 3 (5 out of 13) were adapted to fit the pattern .

In summary, in the process of learning to produce codas, Rebecca did not often resort to substituting target consonants. Rather, it appeared that she focused on particular type of coda in each session. The only fairly regular process was observed in session 3, when most of the child's codas were fricatives, and majority of them did not come from targets. Nevertheless, the process appeared to be a tendency related to articulation of target stops, and where it was not, it was related to the more challenging, disyllabic words. As in the case of Jude and Alison, final fricatives thus appeared to have a special status among codas, such that they were acquired first, and they were also the ones most likely to be added inaccurately.

5.4 Discussion

5.4.1 Segment-based processes

Rebecca began with a large consonant inventory as compared to the other two children (53%), and by the end of the study, she had acquired 80% of all target consonants. The only consonants she still did not produce in the last session were affricates (which were usually fronted to alveolar place of articulation) and interdental fricatives /θ/ and /ð/.

However, in the process of learning to consistently produce fricatives and velar and alveolar stops, several alternations could be observed frequently in her data. Among processes that occurred regularly for particular target segments, fronting of velar stops (to palatal and to alveolar place of articulation) and palatalisation of fricatives and affricates were the most common processes. Even though the processes in question were relatively regular, the fact that they all resulted in palatal consonants in child forms suggests a general preference for the palatal place of articulation. Furthermore, there was large variability in how the processes were applied.

In particular, although velar fronting was common, in many words the final velar was retained. The proportion of fronted velar targets varied between 50% to 80% across sessions. Even at the end of the recordings, when the child's pronunciation was fairly accurate, half of velar targets were still being fronted. Nonetheless, that also meant that from the earliest session, Rebecca was producing velar targets correctly 30% to 50% of the time. Furthermore, there was large variability in the results of the process, whereby some velar consonants were fronted to palatal /c/, while others to alveolar /t/. Similarly, palatalisation of fricatives and affricates, when it was most common, affected only 40% of all suitable targets. Where it appeared, it often affected the consonants to a varying degree in different tokens (e.g. *shoes* [ʃʊʃ], [çʊç]).

Therefore, even the most regular segment-based processes appeared to have a strong articulatory basis, i.e. a general preference for the palatal place of articulation, and they varied to a degree which suggested that they were not pre-planned strategies. Rather, velar stops, and alveolar and post-alveolar fricatives and affricates tended to be mispronounced by Rebecca, who was still in the process of acquiring them. However, the fact that they were often also produced correctly in other tokens or word types, means that any modifications most likely resulted from imprecise articulatory skills and on-line production difficulties.

5.4.2 Whole word processes

There were very few clear instances of word shape adaptation in Rebecca's data, all in session 3, and these involved adding a final fricative to CVCV targets. The process affected four words, and it was the only pattern that involved inserting a non-target segment. However, in that session, there were also frequent cases of final stop affricativisation. This process mostly affected alveolar and palatal stops, even though it did not affect these consonants in other positions in the word.

Before session 3, Rebecca produced many fricative codas. Due to the widespread palatalisation, these usually had post-alveolar or palatal place of articulation. The general tendency of palatalisation, as well as practice in producing palatal fricatives word-finally, were apparent in the data, and could have contributed to the emergence of the final stop affrication process. As a result, palatal fricative codas were the most common in the data. Table 90 presents all words with fricative in coda in sessions 1-3.

Table 90					
Fricative coda					
session 1		**session 2**		**session 3**	
arch	haʔtʃ:	*brush*	baʃ	*brush*	bjæɕ
bath	baʃ:	*horse*	ʊʃ	*close*	klʊɕ
push	pʊʃ	*mice*	məʃ	*eyes*	æɕ
rocks	ɹatʃ	*nose*	nʊʃ	*fish*	ɸɯʃ
yes	jɛɕ	*peas*	piʃ	*house*	aɕ
		push	pəʃ	*juice*	dʒɪsʲ:
		shoes	ʃʊʃ	*mice*	maʔɕ
		toes	tʊɕ	*mouse*	læɕ
		yes	jɛʃ	*off*	af:
				peas	pɪsʲ
				pies	paisʲ:
				shoes	tɔʔ ʃʊʃ
				stairs	stɪɕ
				toys	tʊɕ
Coda affricativisation					
session 1		**session 2**		**session 3**	
		bead	ɪtɕ	bag	bacç
		heart	atʃʰ	bed	ba:tɕ
				bird	butɕ
				book	bʊcç
				coat	tɕʊtsʲ
				night night	ʔaʔatɕ
				pat	paʔtɕ
				pirate	pajitɕ
				sit	çitsʲ
Final fricative insertion					
session 1		**session 2**		**session 3**	
				apple	abʊʃ
				flower	ʃalʊç
				shopping	ɕambɪn:ɕ
				window	ɪnoʊɕ

Table 90: Rebecca's child forms with accurate fricative coda, with affricated target stop coda and with inserted fricative in sessions 1-3.

Given Rebecca's palatal preference and skill in producing final fricatives, it appears plausible that the instances of final fricative insertion in CVCV targets could be an extension of those general articulatory tendencies. It is likely that this was the result of the fact that the child was at that time beginning to produce codas in disyllabic words. Therefore, even this short and limited display of systematicity in the speech of the otherwise very accurate child can be traced back to her articulatory tendencies, as well as to the demands posed by the task of learning to produce disyllabic words with coda.

5.4.3 Variability and systematicity

As we have seen, there were no strong whole word patterns in Rebecca's data. Therefore, the majority of variability concerned the articulation of individual segments, particularly coronals and velars. Similarly, changes in T score were mostly due to apparent preferences in selecting particular word shapes, as adaptation was virtually absent.

In the first session, there were still traces of preference for consonant harmony in disyllabic words, the T score was 1.47 and variability was at 70%. Both variability and T score decreased in the next session (with values of 62% and 1.14 respectively), when that tendency was overcome. For the next three sessions (sessions 3-5), the T score was at 1.39, reflecting Rebecca's strong tendency to focus on a particular word shape in each session. In session 3, words with fricatives in coda (mono- and di-syllabic) were prevalent, in session 4 words with nasal coda were selected, and in session 5 there was a rise in multisyllabic words. Rebecca's systematicity thus consisted of very specific preferences in her choice of targets, rather than of adapting words to fit her favourite shapes. It was only in session 6 that all word shapes were evenly distributed in the child's speech.

At the same time, there were changes in variability, which increased at the onset of the particularly selective period in Rebecca's production, then dropped, and finally increased again when the systematicity was about to decrease again. Figure 31 presents variability and T score across sessions.

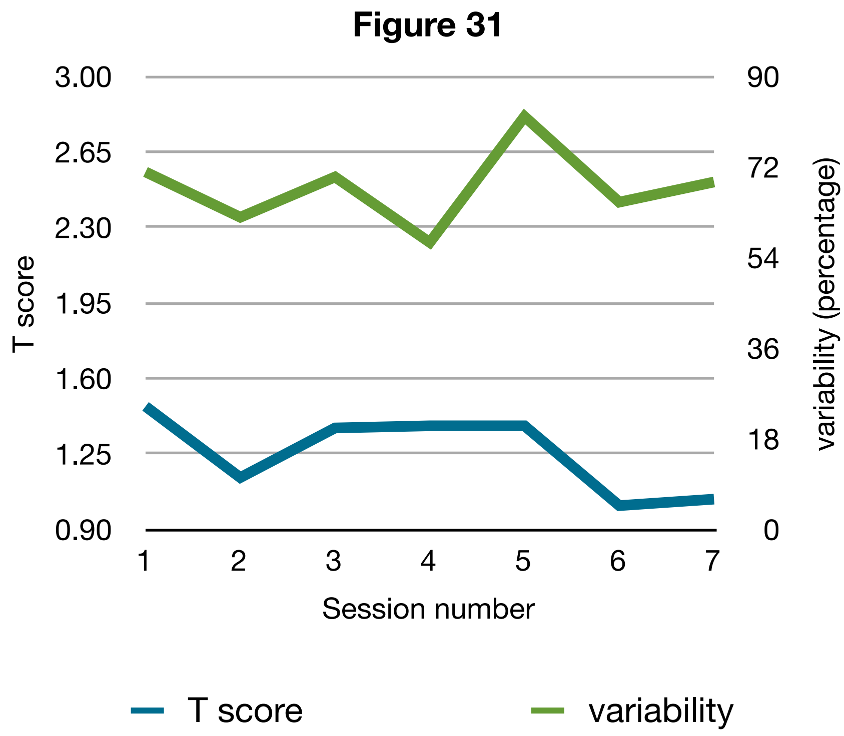

Figure 31: Rebecca's T score (Y1) and variability (Y2) across sessions.

Therefore, Rebecca's development went through a phase during which the child was very selective in her choice of targets, attempting words of particular shapes. Nonetheless, the accuracy of individual consonants varied in the period of transition to and from the phase of selectivity.

5.4.4 Boldness

Throughout the study, perhaps the most striking characteristics of Rebecca's speech was how conservative the child was in selecting targets that were easily accessible. The tendency to focus on targets which did not pose too many challenges to the child, resulted in high accuracy thrughout the study. Even though Rebecca began with much more advanced articulatory skills than the other two children, as apparent from her large consonant inventory and virtually target-like production of codas in monosyllables, in session 1 she was also the least bold of the three subjects. In that session, only 50% of all consonants she attempted belonged to one of the difficult categories, i.e. fricatives, affricates, liquids and clusters, and for word onset this proportion was as low as 13%.

In sessions 2 and 3, boldness went up. This meant that Rebecca was attempting more consonants more often. However, at the same time (in session 3), she became very selective with regard to word shapes she attempted. As we may recall from the detailed analysis of Rebecca's production of codas and CVCV words, many difficult consonants she could produce were only accurate in certain word position (e.g. /l/ only in word onset). Therefore, although Rebecca was attempting these consonants, she also selected targets which had them in particular word position. For example, she focused on fricative codas in session 3, but only three targets had a fricative in onset in that session.

Predictably, when Rebecca did attempt more challenging word shapes, such as multisyllables or words with fricatives and liquids in more than one word position, these were inaccurate and sometimes even underwent simplification processes that were surprising in the speech of a child with such high accuracy (e.g. reduplication). Therefore, in sessions 3-5, there was a stagnation in accuracy. T score was the only variable which significantly correlated with accuracy (r=-0.89, N=7, p<0.01). Figure 32 presents the two variables across sessions.

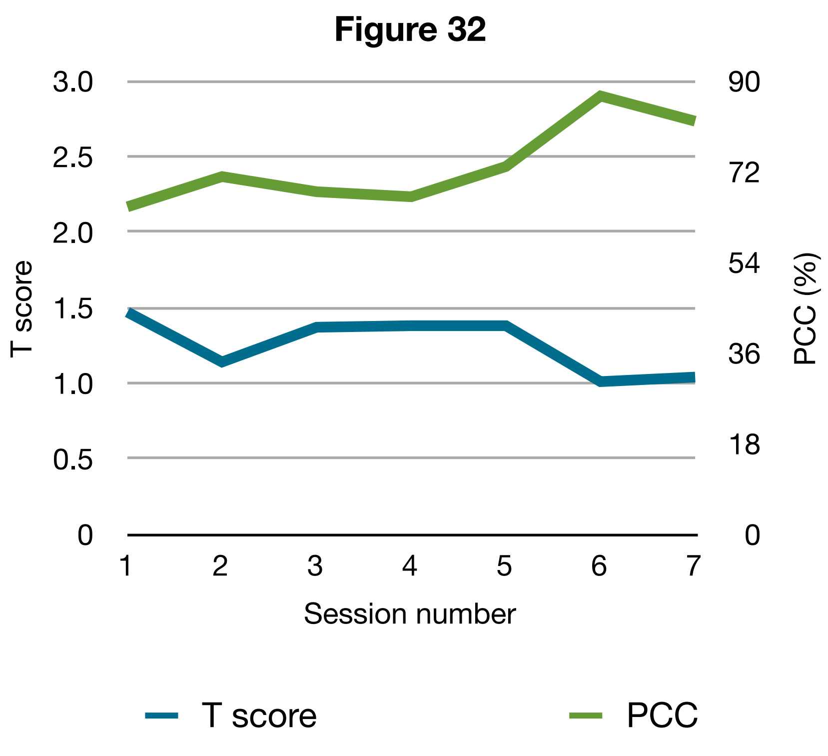

Figure 32: Rebecca's T score (Y1) and PCC (Y2) across sessions.

Nevertheless, the strong tendency to select particular word shapes never resulted in a wide-scope adaptation pattern of the type that we observed for Alison. While there were a few adapted words in session 3, these were too rare to be classified as the defining characteristics of Rebecca's phonological organisation at that time. It appeared that frequent production of final fricatives was an articulatory tendency that had the potential of being generalised to more targets, but it was not powerful enough to push the system out of its stable state. Two factors might have contributed to that. Firstly, Rebecca did not exhibit the same willingness to attempt very many new words as Alison, and the number of words she produced rose much more slowly (from 34 to 71 in sessions 1-3). Secondly, Rebecca's advanced articulatory skills meant that selecting only accessible targets still allowed for a diverse vocabulary, while in Alison's case, the number of words she could produce accurately was severely limited by her poor articulation. These properties of Rebecca's phonological system made it too stable for any wide-scope reorganisation to be triggered by the final fricative routine.

In sessions 6-7, when the child's attempted word shapes became more diversified, accuracy picked up again. It appeared that the developing articulatory skills motivated Rebecca to attempt more word shapes, while at the same time her attempts at different word shapes stimulated further development of articulatory skills. At that time, also the child's boldness in attempting challenging consonants increased. Figure 33 presents variability, boldness, accuracy and T score across sessions.

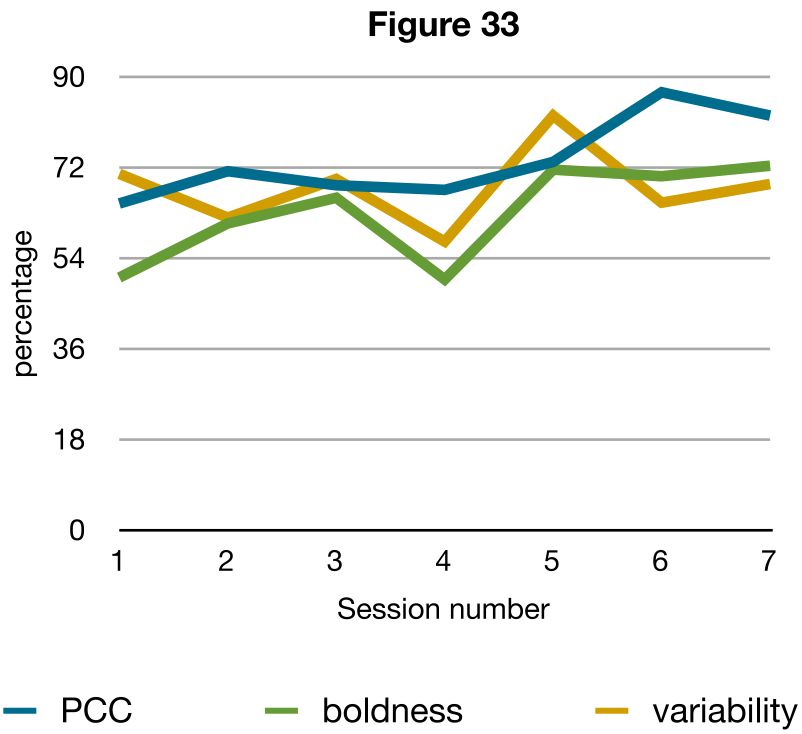

Figure 33: Rebecca's PCC, boldness and variability across sessions.

5.4.5 Chapter summary

In summary, throughout the study, Rebecca progressed from 70% to almost 90% accuracy. Although variability in realisation of particular consonants meant there was still room for improvement, in the last session her words were very close to targets. However, the observed improvement in accuracy did not progress linearly throughout sessions. Rather, there was a period between sessions 3 and 5 when the child's phonological system converged at a stable state, which, although fairly accurate, was not showing improvement. This was due to the child's selecting particular, accessible word shapes and not practicing other, more challenging ones. At the same time, although it considerably slowed down the development of accuracy, it was already diverse enough not to allow for systematicity to spread across all word production. Therefore, although some articulatory routines were observed, they did not result in strong templates that would lead to adaptation. It seemed plausible to say that Rebecca's individual tendency to not attempt very many words and not repeat them too frequently also facilitated the long but relatively smooth path to higher accuracy.

6. KEY FACTORS IN PHONOLOGICAL ACQUISITION

6.1 Accuracy

6.1.1 Accuracy of individual consonants

The general order of acquisition of consonants, as well as the most common segment-based processes observed in the three children were similar to those reported in previous studies. All three subjects produced labial consonants /b/, /w/ and /m/, as well as the alveolar nasal /n/ consistently in syllable onset from the beginning of the study. Labial consonants have often been reported to be favoured by children acquiring English (Stoel-Gammon, 2011), and labials and nasals reappear in normative studies as the first ones to be acquired by English children (Templin, 1957; Prather et al. 1975; Smit et al., 1990; Dodd et al., 2003). While only one of the studies looked at 2 year olds (Prather et al. 1975), and the other typically focused on older children, the usual lower age limit being 3;0, the data of Alison, Jude and Rebecca confirm that labial consonants are accessible to children from the very earliest stages. The small number of words produced by children this young and the limited range of targets they attempt does not allow for reliable estimates of percentage of accurate use. However, the fact that virtually all words with labials in target had at least one token accurate with respect to the labial consonant, as well as the fact that targets with labial onsets appeared to be actively selected by Alison and Rebecca, suggested a strong labial preference. As regards word final position, the inventories of the subjects were compatible with the findings of Stoel-Gammon (1985), who observed that voiceless stops (in particular alveolars) are the first to be acquired in this position. Although Alison began her production of codas with labial stops, both Rebecca and Jude preferred alveolar stops and post-alveolar fricatives. In addition, all three children produced mainly voiceless consonants in coda, and voiced (i.e. voiceless unaspirated) consonants in onset of words until the end of the study.

Similarly, the substitution processes used by the children were also compatible with previous findings. The most common process found in all three subjects were liquid substitutions, which included gliding, vocalisation and fricativisation, as well as cluster reduction patterns. This confirms the findings of Preisser, Hodson and Paden (1998), who in their analysis of data from children aged 1;6-2;6 years, found liquid deviation and cluster reduction to be the most common processes. In their study, the mean percentages of occurrence were 93% for cluster reduction and 91% for liquid deviation in the 1;6-1;9 age group. Affricates, which are not expected to be fully acquired by all children at this age (Olmsted, 1971; Prather et al. 1975), also posed difficulties to the subjects, and de-affrication was present in the data of all three children throughout the study. Nevertheless, all three subjects also displayed a tendency to affricate final stops. Finally, frequent velar fronting was observed in Rebecca (mean percentage of occurrence 45% in Preisser, Hodson & Paden) but not in the other two children. The processes of gliding, cluster reduction, de-affrication and velar fronting are reported by Dodd and colleagues (2003) to still be present in over 10% of normally developing children at the age of 3;11, and are thus to be expected from children under the age of 2;0, such as Alison, Jude and Rebecca.

Findings regarding fricatives were particularly interesting. These are typically acquired later in development (Prather et al. 1975; Dodd et al. 2003) and were not mastered by any of the three subjects by the end of the study. However, this is not to say that they were entirely absent, as each of the three children had their own fricative-based patterns. Alison produced final fricatives very frequently, although they were not accurate and were often added to open-syllable targets. Rebecca had several instances of final fricative insertion, but in her case the fricatives were all palatals, while in Alison's data they usually depended on the preceding vowel. Moreover, Rebecca's fricative insertion appeared to be due to her general preference for final fricatives, which constituted the majority of the words she attempted, especially in session 3. Finally, Jude, too, had a preference for coda fricatives from the beginning of the study. They were the first codas he produced, often replacing the target stops, and in some cases, especially in the first sessions, words were reduced to just the fricative. All three children began producing final fricatives before onset fricatives.

That fricatives are likely to be acquired first in the word-final postvocalic position has often been reported (Ferguson, 1975; Farwell, 1976; Stoel-Gammon, 1985; Dinnsen, 1996; McAllister Byun, 2011). Farwell (1976) examined in detail the process of acquisition of fricatives by seven children, and found that different children exhibited different approaches or strategies in learning to produce these challenging consonants. In particular, three of Farwell's subjects produced vowelless words with fricatives in the same way that was observed in Jude's data. Furthermore, one other subject in Farwell's study exhibited a preference for fricatives, such that she attempted very many targets containing them from the very early stage. Rebecca's selecting of a large number of fricative words in session 3 seems to resemble that strategy. Detailed analysis of Alison's data revealed that her final fricatives were very often just a continuation of the vowel, most likely due to imprecise articulation. However, the fact that the child did produce them, and that they sometimes appeared in child forms of targets which had a fricative in coda, means that eventually the resulting experience in producing final fricatives may contribute to the acquisition of those consonants. Therefore, it could be termed an 'accidental' path of acquisition.

The segmental preferences and errors observed in Alison, Jude and Rebecca were thus similar to those exhibited by other children acquiring English. Nevertheless, underneath general similarities there were considerable individual differences between the children in both the repertoires of consonants they could produce and in the patterns of errors observed in their data. For example, while all three children struggled with producing fricatives, they differed in which fricatives they did produce (Alison mainly used velars, glottals and labials, Jude preferred interdentals and alveolars, while Rebecca favoured post-alveolars and palatals), what targets they attempted and how they coped with the troublesome consonants. Furthermore, even the most common segment-based processes, such as liquid substitutions, resulted in different outcomes on different occasions. There was thus considerable intra-child variability that did not allow for specifying phonological context which would predict the child form on the basis of the target. The processes were not systematic. Finally, the processes could rarely be explained as substituting an easier segment for a more difficult one. For example, onset affricates were often reduced to stops by all three subjects. However, the process of final stop affrication was equally common. Therefore, the processes, although observed commonly in children acquiring English as reported in the literature, largely depended on factors concerning the individual child, the individual word, the individual word position, as well as the individual instance of the sound. Therefore, the overall similarity did not go beyond what could be explained by general articulatory constraints in young children and the target language being acquired, but the resulting difficulties were dealt with somewhat differently by each of the three children.

6.1.2 Accuracy by word position

The development of accuracy took a different shape in each of the three children, with Alison's accuracy exhibiting a clear U-shaped curve, Jude's accuracy showing more or less steady linear improvement across sessions, and Rebecca's accuracy going through a period of stagnation before improvement. Figure 34 presents PCC for the children across sessions.

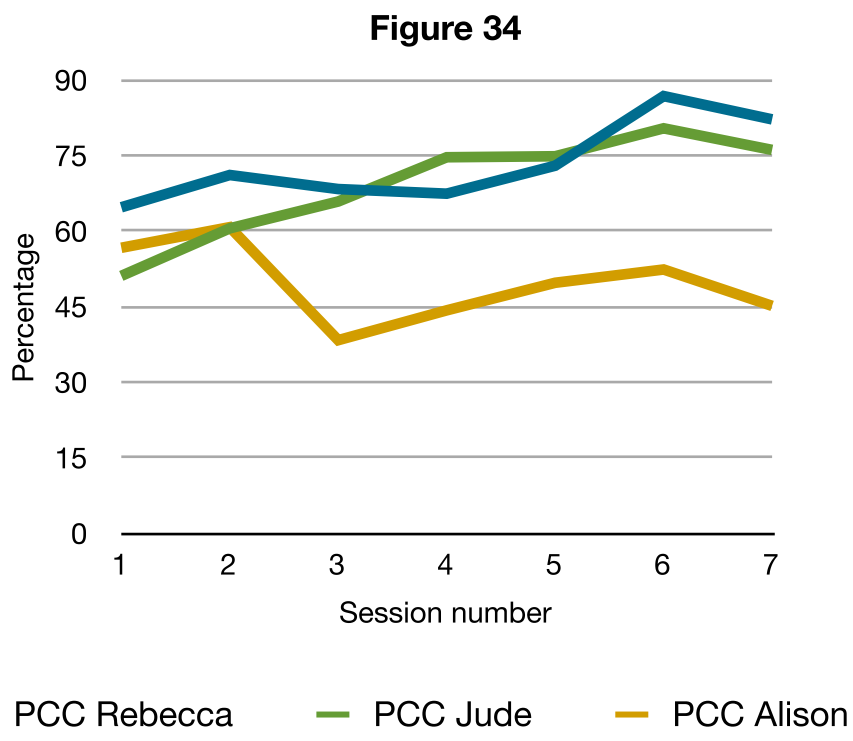

Figure 34: Rebecca's, Jude's and Alison's PCC across sessions.

In the beginning, Rebecca was the most accurate, and Jude the least accurate among the three children. However, while Jude's accuracy then began steadily increasing, Rebecca's accuracy did not significantly improve until session 5, while Alison's accuracy dropped dramatically in session 3. Thus, in the three months from the beginning of the recordings, the ranking of the children according to their consonantal accuracy changed entirely, with Jude being the most accurate, and Alison the least accurate of the three. The development of accuracy proceeded in a non-linear way and initial accuracy did not predict further progress.

An even more complex picture emerges from comparison of detailed PCC for different word positions across the children. Figure 35 presents PCC for initial, medial and final position across sessions for the three subjects.

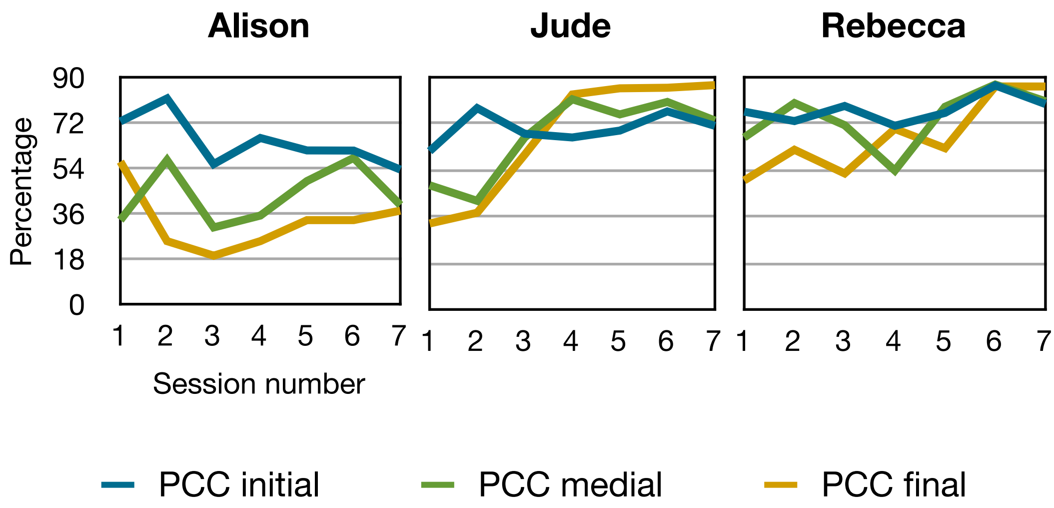

Figure 35: PCC for word-initial, word-medial and word-final position across sessions by child.

Alison begins with high onset accuracy, mostly owing to her selecting onset targets that she is able to produce (i.e. labials). She also has the highest coda accuracy among the three children in the first session. Her medial consonants are often affected by consonant harmony, which makes them the least accurate. However, in the next session her coda accuracy drops dramatically (due to final consonant omission), and in session 3 onset and medial position accuracy follow the same pattern (due to reduplication and glottal stopping patterns). Although Alison's accuracy slightly improves after the drop, at the end of the study it is still lower than in session 1 for onset and coda position, and the same for medial position.

Jude was the only one among the three children who did not select words according to their onset in the first session. While Alison and Rebecca mostly attempted targets beginning with labials, which resulted in high accuracy of this position for both of them, Jude made more errors in word onset. The accuracy of his codas was very low, as they were almost always omitted, and the accuracy of medial position was affected by consonant harmony. In the next session the accuracy of his word onset improves, but then drops slightly and remains at roughly the same level for three sessions after that. During this time, the medial and coda positions steadily become more accurate, and by session 5 all three positions are equally accurate. It thus appears that the accuracy of onset temporarily comes to a halt when the other two word positions begin to improve.

For Rebecca, the greatest challenge are coda consonants, and the accuracy of coda position undergoes linear improvement throughout the study, as she selects an increasing number of words with different codas to produce. At the same time, the accuracy of onset and medial positions shows regression, despite these positions having very high accuracy in the beginning. It is only when the accuracy of codas reaches a level comparable to the accuracy of the other two positions that all three positions continue improving.

The patterns of accuracy development in the three children clearly illustrate how different positions in the word pose different challenges to children. Moreover, they suggest a strong interaction between the accuracy of different positions in the word, such that when producing consonants in a particular position requires improvement, the development of other positions is affected. In the case of Rebecca and Jude, improving accurate onset consonants is temporarily abandoned when codas begin to develop, while in the case of Alison, a regression in accuracy of codas leads to a drop in accuracy of other positions as well.

6.1.3 Accuracy and systematicity

Interaction between different word positions which may affect consonantal accuracy has been reported in several studies which looked at children's production of geminates (Finnish: Savinainen-Makkonen, 2007), long consonants (Welsh: Vihman, Nakai & DePaolis, 2006; Arabic: Khattab & Al-Tamimi, in press) and clusters (Polish: Szreder, in press). These studies have found that the presence of the consonants and clusters in question tend to negatively affect the accuracy of onset position in children's production. The effect has been attributed to salience and attention factors, whereby the length of these segments as well as, in the case of clusters, the articulatory challenge they pose draw the child's attention away from the onset position. In the case of the three children learning to produce codas, it appears that the improvement in their production was related to less 'focus' on the accuracy of other word positions. The development of accuracy therefore seems to depend on at least two other factors beside learning to produce individual consonants. Namely, the consonants then have to be learned in different word positions and they have to begin to be co-ordinated with other positions.

This interdependence implies that improvement of phonetic accuracy is positively related to the development of co-ordination of gestures within syllables and words. It is thus expected that word shape systematicity, which reflects non-adult-like tendencies in co-ordination, will be negatively related to accuracy. Figure 36 presents PCC and T score for Alison, Jude and Rebecca.

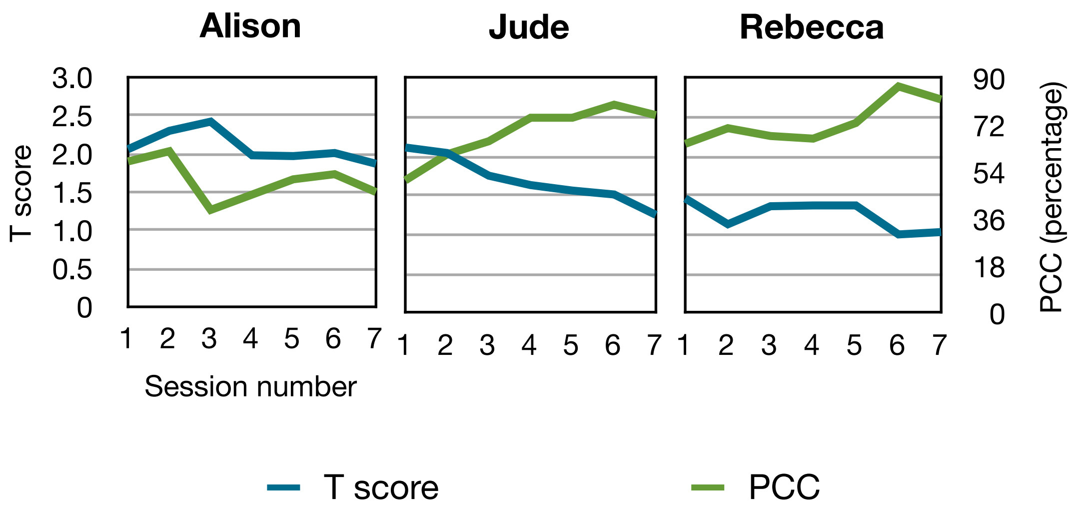

Figure 36: T score (Y1) and PCC (Y2) across sessions by child.

A negative correlation between accuracy and T score was observed for two of the subjects: Jude (r=-0.90, N=7, p<0.01) and Rebecca (r=-0.89, N=7, p<0.01). Furthermore, the influence of systematicity of word shapes on accuracy of particular consonants is even more apparent if we consider the correlation between systematicity and accuracy of particular word positions. For both Rebecca and Jude there was no correlation between T score and word onset accuracy (r=-0.55, N=7, p>0.1 and r=-0.23, N=7, p>0.1respectively). However, the relationship was slightly stronger for word medial position (r=-0.74, N=7, p<0.1 and -0.84, N=7, p<0.1) and even more so for accuracy of coda (r=-0.84, N=7, p<0.05 and -0.93, N=7, p<0.01). Therefore, in the two children, their syllable shape constraints had a big impact on their overall accuracy and were one of the main factors contributing to child errors.

Nevertheless, the qualitative analysis of Jude's and Rebecca's data reveals that their systematicity patterns were in fact considerably different. Jude had strong consonant harmony and coda omission patterns, which affected accuracy through target consonants being assimilated with other consonants in the word or omitted. It was the reversal of these strategies that enabled improvement of accuracy. However, Rebecca's systematicity reflected mostly selection strategies, which consisted of attempting types of words (and codas in particular), that the child was in the process of learning. Therefore, Rebecca's preferred word shapes were ones which she already could produce but not entirely accurately. Yet, she did not attempt targets that were entirely out of her repertoire. Therefore, in her case, the word shapes were usually accurate, although the rendition of particular consonants was still imprecise. Improvement of accuracy for Rebecca thus proceeds through practice of consonants, rather than reversing any alternation patterns. We shall return to these individual differences in systematicity in section 6.3.

6.1.4 Accuracy and boldness

The only child for whom no correlation between accuracy and T score was observed (either overall or in particular word positions) was Alison. While accuracy did show a sharp decrease corresponding to the increase of systematicity, and then improved afterwards, the PCC continued increasing until session 6, while T score remained at a roughly stable level. Thus, although templates had an obvious impact on the accuracy of consonants, there must have been other factors that contributed to the development of accuracy. Two factors in particular appeared significant. Firstly, Alison began with the smallest consonant inventory among the three children. Therefore, in her case the issues regarding articulation of particular consonants were of much more importance than to Jude, for whom co-ordination of consonant within words was the main obstacle in achieving adult-like performance. As a result, decrease in use of templates did not lead to instant rise in accuracy as in the case of the boy. Rather, Alison then had to develop more articulatory control, as Rebecca, although starting from a much less advanced point. (For more on this topic, see section 6.2). Secondly, for Alison, the main obstacle in achieving high accuracy (and the only factor that was highly correlated with PCC, although r=-0.93, N=7, p<0.01) was her boldness in attempting challenging targets. Figure 37 presents boldness and PCC for all subjects.

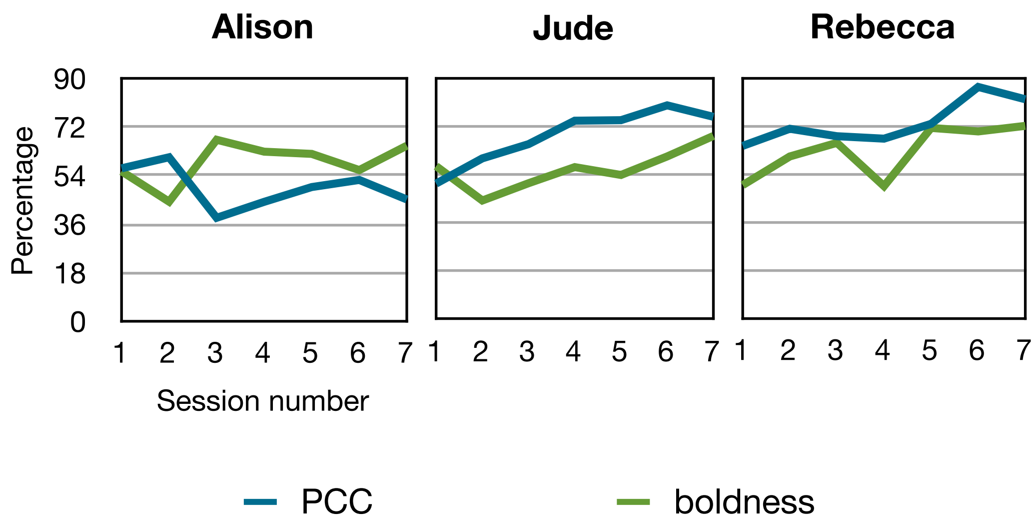

Figure 37: PCC and boldness across sessions by child.

Therefore, for Alison's accuracy to progress, the child had to stop frequently attempting targets that were out of her repertoire. This further confirms that poor articulatory skills were in large part responsible for Alison's low accuracy. When she attempted more challenging targets, these came out inaccurately. At the same time, the child's use of templates facilitated attempting otherwise difficult targets. On the other hand, the correlation between boldness and accuracy was positive for Rebecca (r=0.75, N=7, p<0.05). As we have seen, this was because Rebecca almost never attempted overly challenging targets. Therefore, for less articulatorily advanced Alison, boldness appeared to be the reason for low accuracy, as it resulted in attempting targets that the child could not produce faithfully. At the same time, for more advanced Rebecca, boldness in attempting consonants that children at this age find difficult only appeared when the child had already acquired a considerable skill in producing them, through selecting a large number of words of a particular shape to 'practice'. In this way, there was a complex interaction between accuracy, and articulation, systematicity and boldness that depended on the individual tendencies of each child.

6.2 Variability

In Chapters 3-5 we have seen that the three children's word forms exhibited a large amount of variability. There were many cases of intra-word variability, whereby the same word appeared with different consonants or with different syllable structure within one session. There were also equally many cases of inter-word variability, whereby the same target consonant in the same or similar context was substituted with different consonants in different targets, and conversely, two different target consonants were often produced the same by the child. We have argued that the fact that child substitutions were inconsistent to such extent virtually excluded the possibility that the processes were motivated phonologically. It is worth noting that the nature of variability observed strongly mirrored the findings of Ferguson and Farwell (1975), which led them to the conclusion that early phonologies operate on words rather than particular segments.

6.2.1 Variability and articulation

Two further observations were made regarding specific types of variability. Firstly, prosodic variability, which involved variation in syllable structure, was much less pronounced than variability of particular consonants. That is to say, variable words were more likely to differ with regard to phonetic detail of consonants than with regard to number of syllables or presence/absence of codas and onsets. Secondly, phonetic variability, while widespread and frequent, was also limited. This meant that consonants most often varied in terms of voicing and manner of articulation, but were surprisingly stable with regard to place of articulation. Instances of alternations in place of articulation were most often attributable to whole word effects, i.e. consonant harmony or assimilation with a neighbouring consonant or vowel, so that they suggested on-line difficulties in articulation and planning.

The paradox of large amount of variability that is nonetheless surprisingly restricted has previously been pointed out (Studdert-Kennedy, 1986) and it can be construed as an argument for a motoric basis of variability. An account that would see variability as a function of strictly motoric issues would make two important predictions: (1) that variability should linearly decline along with steadily improving motor control (Smith & Goffman, 1998; Goffman & Smith, 1999); (2) that later chronological age should correlate with lower variability regardless of the stage of linguistic development (Sosa & Stoel-Gammon, 2006). However, a comparison of variability patterns in Rebecca, Jude and Alison does not confirm these predictions. Figure 38 presents variability in the three children.

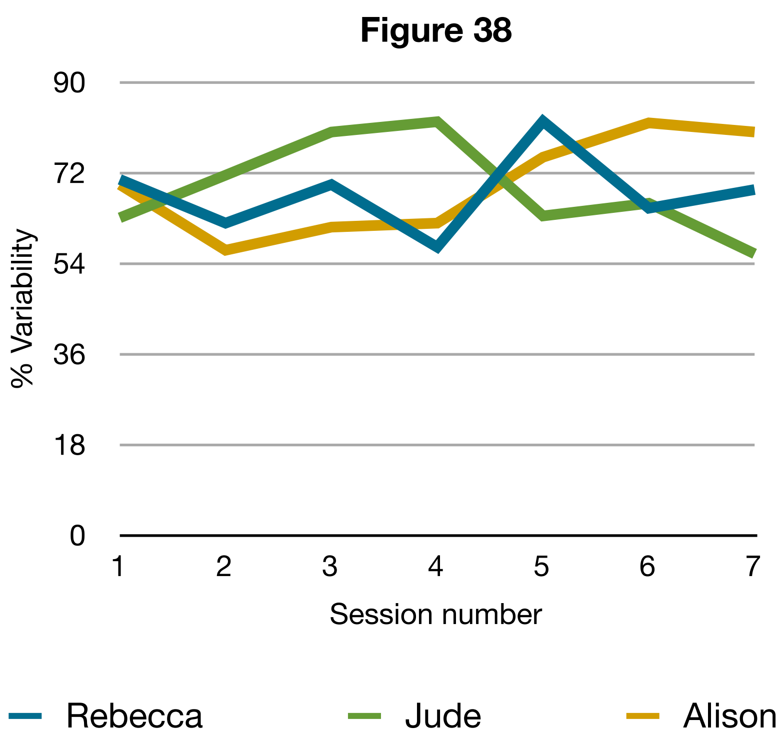

Figure 38: Rebecca's, Jude's and Alison's variability across sessions.

As is apparent from the graph, none of the children exhibited a linear pattern of change in variability. For Alison, variability was high at the beginning, then went through regression, and after that became even higher than in session 1. For Jude, who started as the least variable child, the trajectory of variability was the exact opposite to Alison's, with a high initial rise and then drop. In the case of Rebecca, variability showed two peaks in sessions 3 and 5, with a dip between them, but was almost the same in sessions 1 and 7. Therefore, within the six months of the study there were no signs of variability either linearly increasing or decreasing.

Similarly, the prediction that chronological age would determine the degree of a child's variability was also not borne out by the data. Rebecca was the oldest of the subjects and had the largest consonant inventory, which suggests that her motor development was more advanced than the other two children's. Nevertheless, she began with a level of variability that was the same (and even minimally higher) than Alison's and Jude's. Moreover, the peak in her variability was also as high as the other subjects', even though it occurred in session 5, when her command in producing different consonants and syllable shapes was even more well-developed. In comparison, Alison had the smallest consonant inventory and was one of the two younger children in the study. It would be expected that poor motor control, coupled with rapidly expanding vocabulary should lead to high variability. However, session 3, in which she produces the largest number of words, is also her second least variable session. This stability cannot be attributed to low token/type ratio (which meant that words were not often repeated), since variability was calculated only on the basis of multitoken words. Therefore, it appears that the patterns of variability exhibited by the three children cannot be attributed solely to motoric factors.

6.2.2 Variability and vocabulary size

Another possibility, which was also considered by Sosa and Stoel-Gammon (2006), is that variability will depend on the size of vocabulary. Such a finding would be compatible with the approach that postulates that segmental organisation arises as a result of expanding vocabulary (Lindblom, Studdert-Kennedy & MacNeilage, 1983; Walley & Metsala, 1990; Lindblom, 1992; Walley, 1993). Under this account, phonemic contrast emerges as a result of the fact that a large vocabulary requires more refined contrasts to maintain differentiation. However, Sosa and Stoel-Gammon (2006) did not find a correlation between vocabulary size and variability, and such correlation was also not present in the current study for Rebecca (r=0.24, N=7, p>0.1), Jude (r=-0.32, N=7, p>0.1) or Alison (r=0.41, N=7, p>0.1) . Figure 39 presents variability as a function of vocabulary size for all three subjects in all sessions.

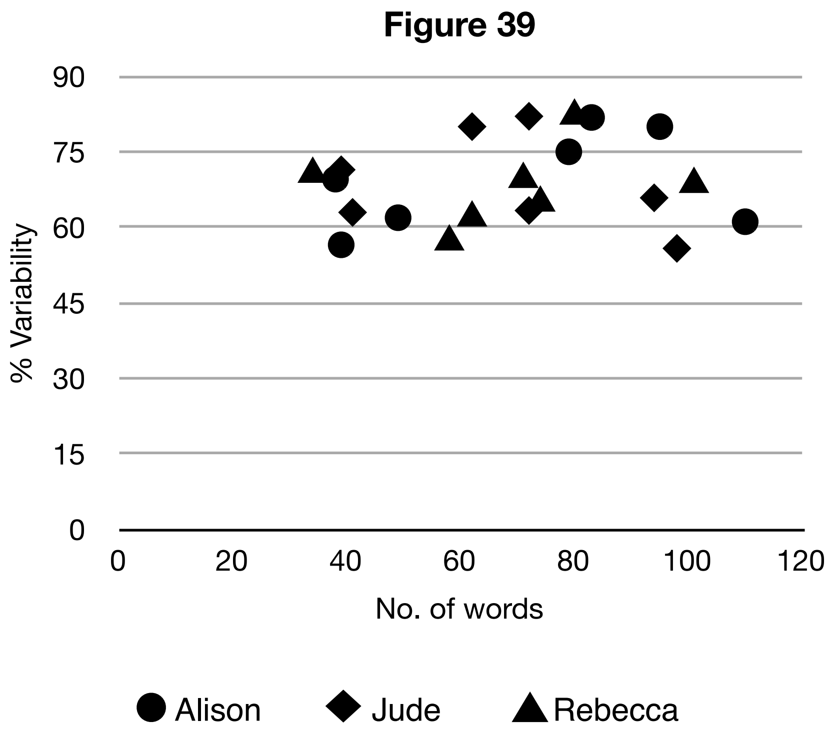

Figure 39: Variability as a function of vocabulary size for all subjects and sessions.

The lack of interdependence between vocabulary size and variability confirms Sosa and Stoeal-Gammon's finding that the postulated stability due to emerging segment-based organisation, if it occurs, does not occur in the early stages of development (i.e. first 100 words). Therefore, variability at that time cannot be fully explained by lack of phonemic representations.

6.2.3 Variability and boldness

Another option would be to attribute variability to the increase in challenging words and consonants the child attempts. Leonard and his colleagues (1980) found that unstable consonants were more likely to be variable in words in which more than one aspect was unstable. In this view, variability in development would be expected to increase as the child attempts more and more challenging targets (Vihman, 1993). We have seen in the previous chapters that indeed, such a relationship could often be observed. Specifically, more challenging consonants exhibited larger variability and were more likely to be assimilated with other consonants in the word. The more stable consonants, such as labial stops, tended to vary only with regard to voicing, while the more challenging ones, such as fricatives and affricates, often exhibited variability in manner, and sometimes place of articulation. Furthermore, we have seen that the number of attempted difficult targets did increase with time, as all three children exhibited a strong tendency to select more accessible consonants and words. However, overall there was no correlation between boldness (i.e. the percentage of attempted challenging sounds) and variability for Rebecca (r=0.5, N=7, p>0.1), Jude (r=-0.57, N=7, p>0.1), or Alison (r=0.29, N=7, p>0.1). Figure 40 presents variability as a function of boldness in all children in all sessions.

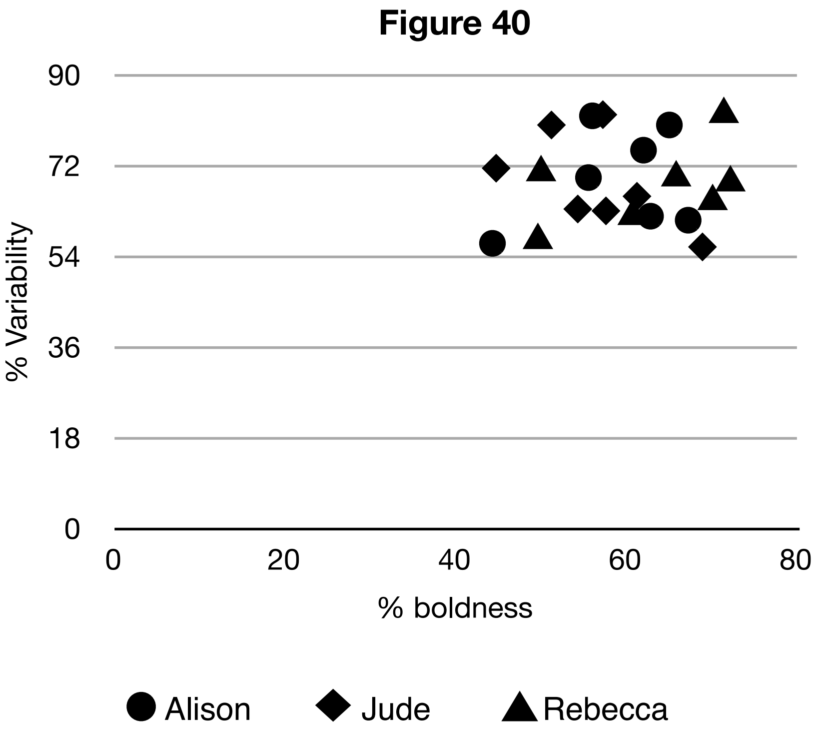

Figure 40: Variability as a function of boldness for all subjects and all sessions.

Thus, variability in the data could not be fully explained by any of the three potential factors mentioned in the literature. There was no link between variability and chronological age, which suggests variability was not due solely to motor control issues. There was no link between variability and vocabulary size, which means that variability could not be attributed exclusively to lack of phonemic awareness. Finally, there was no link between variability and boldness in attempting challenging consonants, which shows that variability is not simply a function of increased difficulty of targets. This is not to say that these factors were irrelevant. However, there must have also been other important factors at play.

6.2.4 Variability and systematicity

The fact that variability does not follow a linear trajectory is compatible with the Dynamic Systems Theory. We may recall that variability under this approach is taken to reflect changes in the organisation of a system. Therefore, rather than linearly decreasing or increasing as a result of improvement, it is expected to increase before and after periods of systematicity, signaling a phase transition in a given system's dynamic. In this sense, variability is more a mode of behaviour of the system that emerges during any significant transition than it is a direct effect of a particular value of a single variable. We have argued that word shape systematicity, often leading to the emergence of templates, is a phase in the development of phonological organisation. Indeed, the points of highest systematicity corresponded to low variability. This is illustrated in Figure 41, which presents variability and T score for all three subjects.

Figure 41: T score (Y1) and variability (Y2) across sessions by child.

Therefore, in Alison's session 3, at the peak of systematicity, variability is low. The same is true for Jude, who begins with high systematicity and low variability. In Rebecca this is not as clear, as she did not develop strong templates at any point, although her dip in variability in session 4 corresponds to an increased T score. However, high variability corresponds to both increasing T score before the peak of systematicity (Alison and Rebecca) and decreasing T score after the peak of systematicity (Jude and Rebecca). Therefore, there was no linear correlation between variability and T score, since variability appeared to increase along with emerging systematicity, then decrease when systematicity reached its peak, and then increase again when systematicity was disappearing. In consequence, the highest variability in the two children who developed templates (i.e. Jude and Alison) was observed for medium T score (either decreasing or increasing).

Detailed qualitative analysis of data from individual children allows us to examine the reasons why chronological age, lexicon size and boldness did not play the expected role. Firstly, variability did not reflect poor motor control and vocabulary size, as exhibited by Alison, who was least variable when she was producing the largest number of words, i.e. in session 3. We have seen that what allowed Alison to expand her vocabulary so extensively in that session were her very strong templates, and that these templates emerged as a way of overcoming articulatory constraints (resulting from poor motor control). Therefore, the reason why neither poor motor control nor large vocabulary size corresponded with large variability was that the two factors were related to the emergence of templates, and templates were not highly variable. In other words, Alison's articulatory constraints coupled with the demands of expanding vocabulary, led to developing a mode of organisation which enabled producing many words with easily accessible articulatory routines. Although the emergence of templates in Jude could not be traced, his templatic organisation at the beginning of the study has the same qualities. Similarly, variability did not correlate with the number of attempted difficult words and consonants, because templates also facilitated attempting challenging targets.

The Dynamic Systems approach defines variability as behaviour of the child's phonology resulting from re-organisation and not as child anomaly that has to be overcome to achieve the stability of adult-like production. It also defines the child's phonology as self-organising, rather than linearly progressing towards the adult model. Under such view, it is easy to see how poor motor control, expanding vocabulary and boldness in attempting challenging targets could be predicted to result in qualitative changes in the organisation of the child's phonological system and therefore to a considerable decrease in variability. This also means that there may be several re-organisation stages before the system reaches full stability that will not be disturbed by mismatch with adult language. Therefore, the final question that we shall consider is how variability is related to accuracy, i.e. how the system develops as more and more compatible with the adult language. Figure 42 presents accuracy and variability in the three subjects.

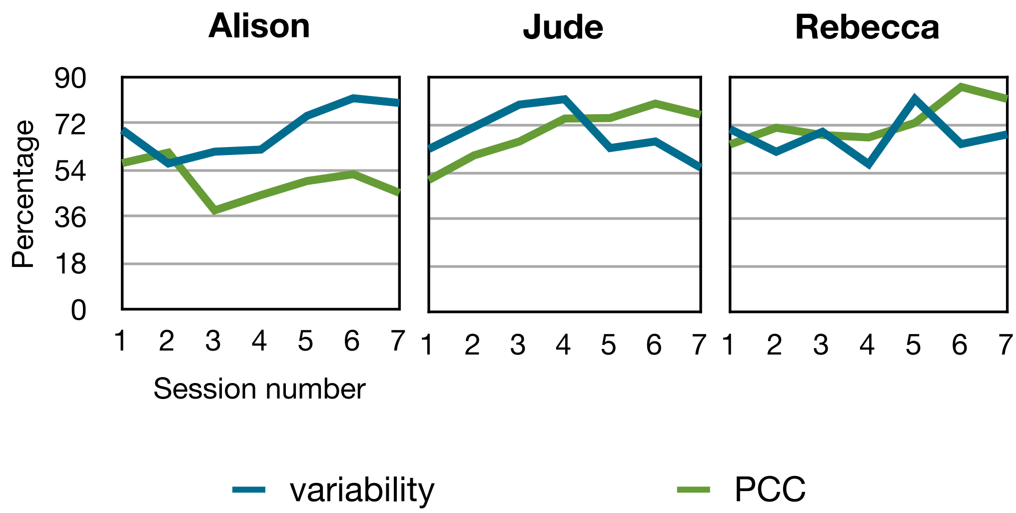

Figure 42: Variability and PCC across sessions by child.

It appears that accuracy and variability increase simultaneously in all three subjects after the period of systematicity passes (and in Rebecca's case they are similar across the study). However, in the two children who reach high accuracy of above 70%, i.e. Jude and Rebecca, variability then begins to decrease. This is particularly apparent in Jude's data, where variability and accuracy both go up from the most systematic session 1 onwards, but in session 4 variability begins to decrease, although accuracy is still improving. However, the above data includes all types of variability and overall accuracy, which means that the relationship between the two is not obvious. The picture is clearer if we consider only the development and variability of a particular word position. Figure 43 presents accuracy and variability of codas, which were the most challenging for all three children. The percentage of variable codas is calculated on the basis of the total number of multitoken words, and not only targets with coda, as many codas were inserted.

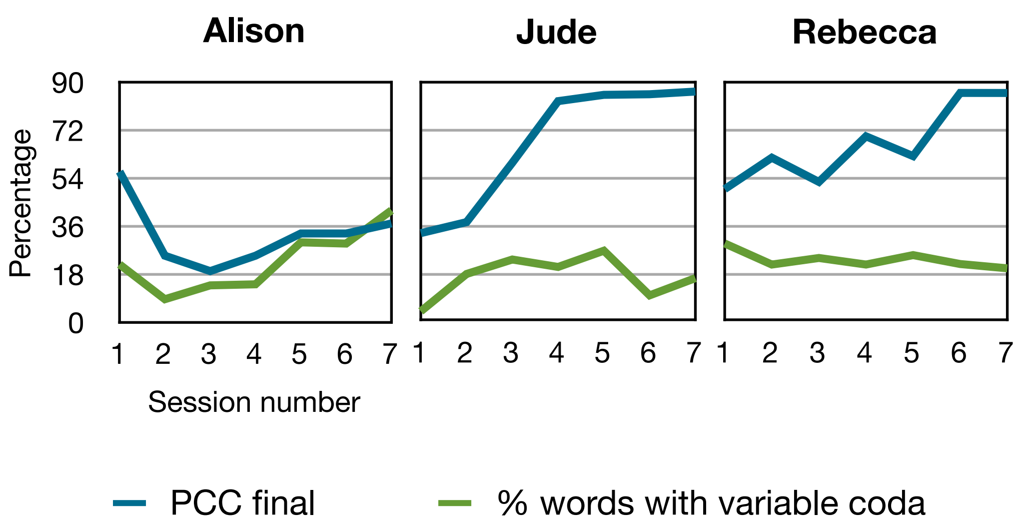

Figure 43: PCC and variability of codas across sessions by child.

The figures show that increased variability only accompanies increase of accuracy in Jude and Alison, i.e. the two templatic children, who used coda omission. Although codas produced by Rebecca were variable in terms of affricativisation and palatalisation, they were consistently present from the beginning of the study. In her case, variability remains practically unchanged across sessions. At the same time, Rebecca's accuracy in producing codas improves, although it is a long and slow process. In comparison, accuracy of Jude's codas shows a rapid increase, going from 37% to 83% within two sessions. This spectacular rise in accuracy is accompanied by a period of increased variability, which then decreases after session 5, while accuracy remains stable. As for Alison, both accuracy and variability continue increasing after the peak of systematic coda omission (session 3), but accuracy is still low in the last session.

These patterns imply that where imperfect accuracy is not a result of systematic whole word processes but rather of imprecise articulation, as in the case of Rebecca, variability remains at a roughly stable level. This relatively low but consistently present level of variability could be thus attributed to motor control. The measure of accuracy, PCC, is calculated on the basis of single token lists, which only include the most adult-like version of each type. Therefore, increasing PCC with persistent variability across tokens suggests that target consonants are produced in an increasing number of words, but the accurate child forms are not yet stable. It is expected that as the child's motor control improves further, variability will slowly decrease.

At the same time, Jude's rapid progress in producing codas is due to reversing the pattern of coda omission, which is a process of transition from stable templates to stable accurate production, and as such entails an increase in variability. Once high accuracy is reached, only the articulatorily motivated variability remains. For Alison, whose accuracy is improving much more slowly, presumably due to poorer articulatory skills, variability does not decrease before the end of the study. That is to say, despite reversal of the pattern, articulatory constraints are still very strong and do not allow for fast improvement of accuracy.

In summary, it was observed that variability did not linearly correlate with any of the three potential factors postulated in the literature, or with any other variable measured in this study. However, there is evidence that motor skills explain some portion of variability observed, as apparent in variability being present even at higher levels of accuracy, and by most of it being limited to articulatorily motivated processes. Furthermore, the degree of variability in the data, as well as the fact that it is related to whole word patterns, are compatible with Ferguson and Farwell's (1975) conclusions about the word being the basic unit of phonological organisation at early stages of development. Finally, the increase in not only prosodic but also segmental variability as a function of phases of systematicity point to the reciprocity between top-down cognitive processes (in this case templates) and articulation. Therefore, it appears that variability interacts in a non-linear way with other developmental factors, both motoric and phonological, and that it is due to re-organisation stages in the system.

6.3 Systematicity

As in many previous studies which looked at children's whole word strategies (Menn, 1971; Waterson, 1971; Ferguson & Farwell, 1975; Priestly, 1977, Macken, 1979; Vihman & Velleman, 1989; Vihman, Velleman & McCune, 1994), both quantitative (T score) and qualitative analyses revealed a considerable degree of whole word systematicity in the data of Alison, Jude and Rebecca. Furthermore, we have seen that systematicity interacted in complex ways with accuracy and variability. In terms of the link between systematicity and accuracy, there was a high negative correlation between T score and PCC for two subjects, Jude and Rebecca, suggesting that whole word strategies were one of the main factors responsible for the mismatch between child forms and adult targets. We have argued that the reason why there was no such correlation in Alison's data was that her poor articulation (as evidenced by almost no improvement in the size of her consonant inventory during the study), as well as strong tendency to attempt challenging targets continued to impede the development of accuracy even after template use began to decline. As regards the connection between systematicity and variability, we have seen that in both children who used strong templates, i.e. Jude and Alison, peak of systematicity corresponded to low phonetic and prosodic varability, and that there was a sharp rise in variability accompanying the decline in template use. Moreover, in Alison, who did not begin with templates, variability was considerably higher before their emergence. It is expected that the same effect could be present in Jude, although it is impossible to test that on the basis of the data. However, there was no clear relationship between systematicity and variability in Rebecca's data. Figure 44 presents T scores for all three subjects across sessions.

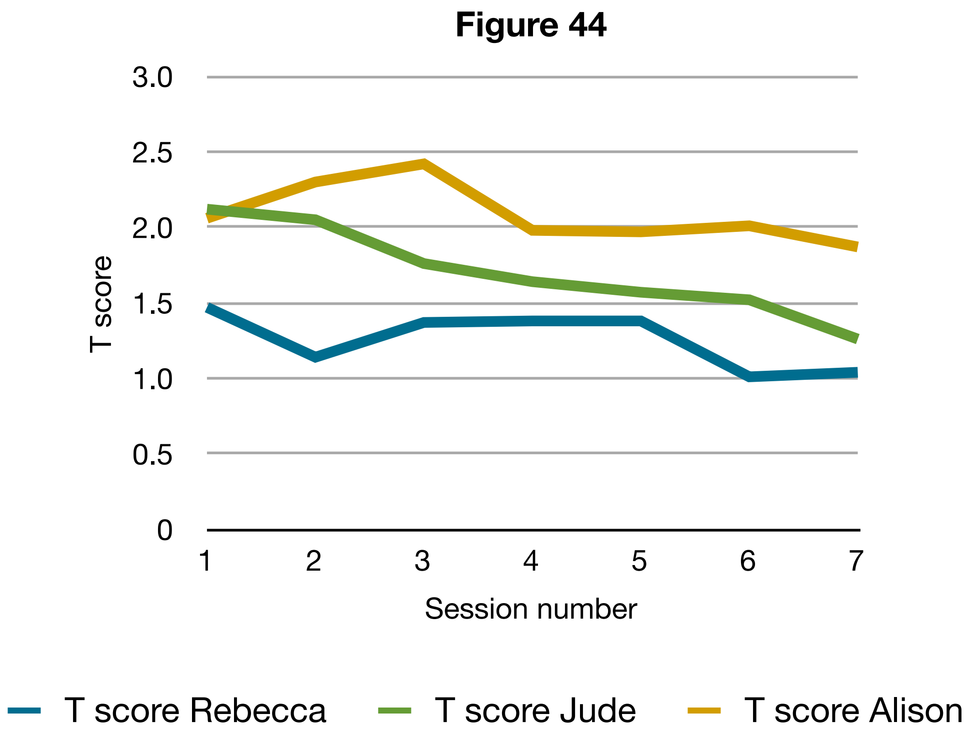

Figure 44: Rebecca's, Jude's and Alison's T score across sessions.

As is apparent, Rebecca's T score was considerably lower than the other two subjects', even at its peak. This was the result of the fact that Rebecca's systematicity appeared to be of a different type. The changes in her T score followed from her tendency to select a particular word shape in each session, so that there was a strong dominance of that shape among the words she produced. These 'favourite' word shapes usually involved words with a particular type of coda, such as fricatives in session 3 or nasals in session 5. In this sense, Rebecca was systematic, in that she exhibited a clear pattern of focusing on producing word shapes that she was in the process of learning, but avoided word shapes that were too challenging (such as multisyllables). This made her pattern of selection different from the patterns found in the data of Jude and Alison, who usually selected their best-practiced word shapes, but also attempted many targets which were entirely outside their repertoire. As a result, Rebecca's word shapes were almost always accurate, while Jude and Alison's often underwent adaptation to a different form. Therefore, while Jude's T score was mostly the function of the percentage of adapted word forms (r=0.94, N=7, p<0.01), and a similar tendency was observed for Alison (r=0.78, N=7, p<0.05), there was no such connection for Rebecca (r=0.06, N=7, p>0.1). Figure 45 presents T score and adaptation in the three subjects.

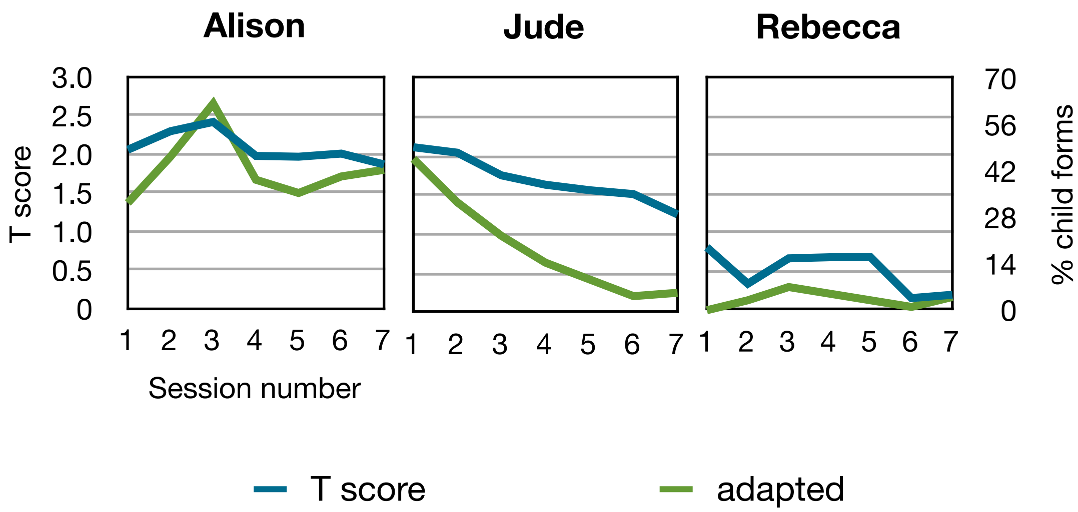

Figure 45: T score (Y1) and percent words adapted to fit a preferred syllable shape (Y2) across sessions by child.

Rebecca's low T score range was thus an effect of practically non-existent adaptation patterns in her data. While the other two children had favourite patterns which served as a basis for adaptation of targets which did not meet the requirements, Rebecca's systematicity showed mainly in selection, and selection that concerned a different shape in each session. The only instances of adaptation in Rebecca's data were observed in session 3, when her particularly pronounced preference for final fricatives resulted in a few CVCV targets appearing with an added fricative at the end. This pattern, however, was not wide-spread and disappeared by the next session. Two possible explanations can be proposed. Firstly, Rebecca's articulatory control was already very well developed at that stage, and the fact that she could attempt many varied targets could have reduced the need for a template that would serve as a strategy of coping with challenging forms. Also, she did not often attempt targets that were entirely outside her repertoire, and she was already beginning to produce accurate final fricatives in disyllabic words. Secondly, it is possible that the pattern became stronger in the month between sessions, which this study did not capture. Such was the case with Jude, who went from 6 diverse forms in his pre-25w.p. session to almost 40 words and strong templates in the next one (session 1). However, even if that explanation is true, that would still mean that Rebecca's pattern was less persistent than the other two children's.

It has been proposed that templates may be a strategy which allows children to expand their lexicons despite limited articulatory resources (Vihman, 1996; Vihman & Velleman, 2000; Keren-Portnoy et al., 2009; Baia 2012). Such a hypothesis is confirmed particularly by Alison's data, in which the peak of systematicity corresponds to a dramatic rise in the number of words. However, T score does not correlate with lexicon size in her case (r=0.07, N=7, p>0.1), as after the drop in the number of words following the decrease in template use, the child's vocabulary then begins expanding again. This latter pattern was also observed for Jude, whose T score decreased throughout the study, which strongly correlates with steadily increasing vocabulary size (r=-0.96, N=7, p<0.001). However, the rise of vocabulary size from 6 to 38 words in the month preceding the beginning of the study, and the fact that his templates developed during that time, suggests that there was also a considerable lexical expansion related to the emergence of systematicity. There was no clear interaction between the two factors for Rebecca (r=-0.63, N=7, p>0.1). Figure 46 presents T score and vocabulary size in the three children.

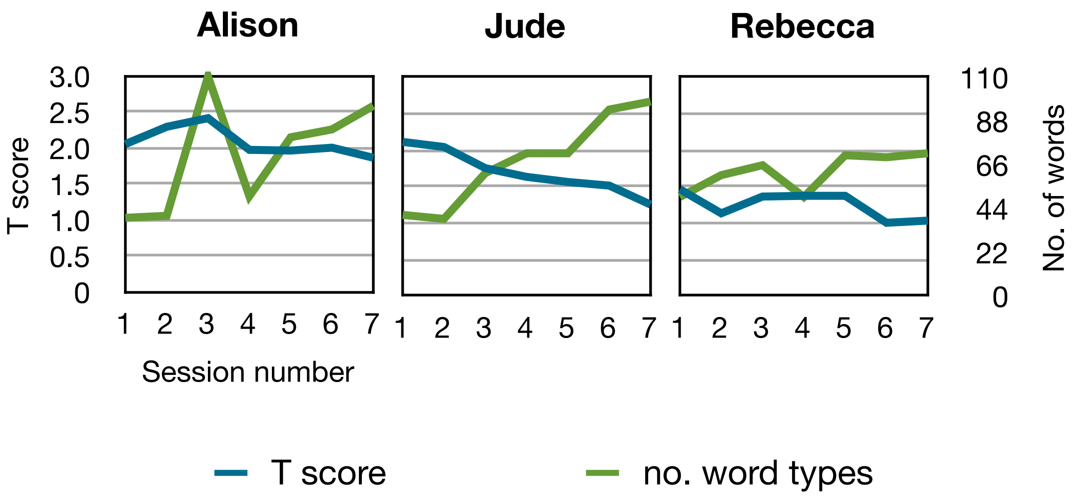

Figure 46: T score (Y1) and number of produced word types (Y2) across sessions by child.

Thus, it appears that vocabulary size shows a similar pattern of interaction with T score as was observed for variability. Namely, lexical expansion corresponds to both increasing T score, as use of templates facilitates attempting more words, and decreasing T score, when the system becomes more flexible, with a temporary drop at the transition from strong templates to more variegated production. Interestingly, the same relationship was observed for boldness. In both Jude and Alison, the decrease in the use of templates corresponded to a drop in boldness. At the same time, in Alison and Rebecca, for whom the increase in systematicity began during the time of the study, that increase also corresponded to increased boldness. However, the two appeared to have different reasons: for Alison, systematicity corresponded to boldness, as the strong templates allowed her to attempt challenging targets, which then underwent adaptation to the preferred form. For Rebecca, systematicity was reflected in boldness, as her selection pattern made her attempt an unusually high number of final fricatives. Nevertheless, these were not adapted but reproduced correctly. Furthermore, Rebecca's boldness dropped during her period of systematicity, which showed that she also selected words which were not particularly difficult. Finally, for all three children, boldness increased by the end of the study, as their accuracy was developing. Figure 47 presents T score and boldness in the three subjects.

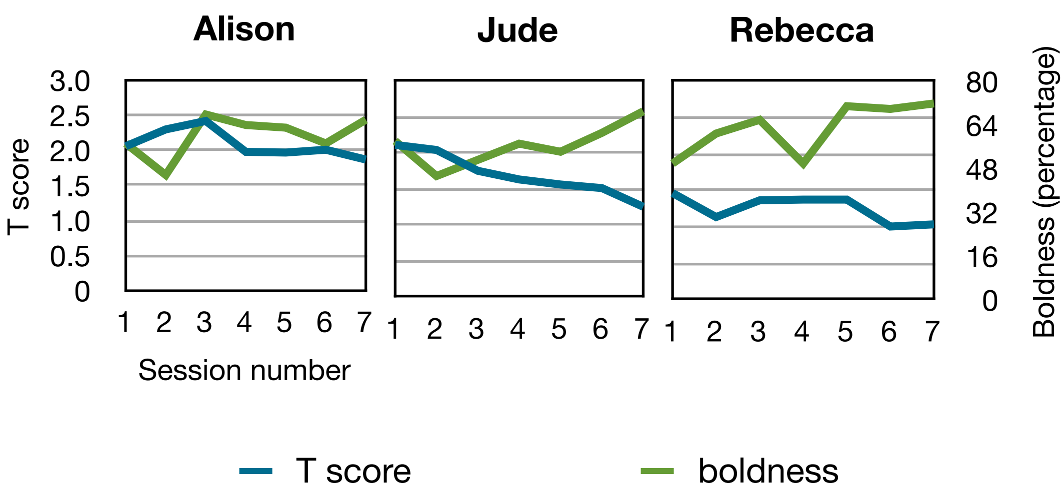

Figure 47: T score (Y1) and boldness (Y2) across sessions by child.

Therefore, there were sharp differences in the type of systematicity observed in Jude and Alison, as compared to that observed in Rebecca. It is possible that selection and adaptation are in fact distinct processes, which have different sources and different outcomes. It is also possible that selection may be a common phenomenon that in some cases leads to adaptation. We may recall from chapter 1 that Vihman (1993, 1996) proposed articulatory filter, which is a process by which babbling children pick up more easily on the sounds they are able to produce. If a similar process occurs in later word learning, as suggested by our data, then that would imply selection being one of basic strategies in phonological acquisition. A hypothesis that linked templates to earlier period of selection was also proposed by Priestly (1977), whose son appeared to select several, initially accurate, words of particular shape before he developed a pattern of adapting other words to that shape. This is also compatible with data from Alison, whose glottal stopping of consonants began as accurate glottal stopping of voiceless alveolar codas, and from Rebecca, who displayed a short tendency to insert fricatives word-finally in disyllables at a point of selecting many fricative codas in monosyllables, although that tendency never developed into a widespread template. Therefore, while attempting and practicing 'favourite' word shapes is likely to be the precursor to templates, it is possible that such selectivity should not be taken to reflect the same type of phonological organisation as patterns of adaptation. This conclusion follows from the fact that in this study longitudinal changes in degrees of selectivity did not correspond to the same effects for the whole of the system as changes in degrees of adaptation. Specifically, they were not preceded and followed by variability, they did not result in an increase in vocabulary size and they did not trigger greater boldness in attempting challenging targets in the same way they did for the other two children. Nevertheless, T score did correlate with accuracy for Rebecca, due to her selection being based on words she did not yet know how to produce well.

It is possible that it is the difference in the specific pattern of selection that leads to the different outcomes for different children. Such a hypothesis would be compatible with the findings of Vihman and Nakai (2003), DePaolis et al. (2011), and Majorano et al. (submitted) who demonstrated that children that were already advanced in producing particular consonants (more than one VMS or over 200 instances of a particular VMS) preferred listening to words containing other consonants. Conversely, in DePaolis' study, children who only had one stable consonant preferred listening to passages containing that consonant. It thus appears that a large consonant inventory might motivate selection of new, difficult sounds to produce (such as final fricatives in Rebecca), whereas a small consonant inventory could lead to selecting familiar forms (such as CVCV words in Alison). In this study, it was the latter pattern of selection (i.e. sticking to easier forms) that led to adaptation. The pattern that favoured less familiar targets, although it did result in a temporary articulatory routine of adding a final fricative to open-syllable targets, did not evolve into a wide-spread top-down alternation pattern. In summary, it appears that for a strictly templatic type of production, selection provides an entry point, but more factors need to be in place. In particular, the factors that appeared to facilitate the emergence of templates, i.e. the main difference between Alison and Rebecca, was the size of consonant inventory (33% vs. 53% in session 1, respectively).

7. CHILD PHONOLOGY AS A DYNAMIC SYSTEM

7.1 Overview

We set out to explore the possibility of conceptualising phonological development as a process of self-organisation of a complex, nonlinear dynamic system. Such an approach would see the emergence of a phonological system as the result of interaction of various sub-systems. In particular, we investigated the interaction between the following factors:

(1) accuracy, understood as motoric development leading to eventual articulatory precision and progress in co-ordination of articulatory gestures;

(2) systematicity, understood as top-down processes of generalisation across different word forms;

(3) variability, understood as lack of systematicity in output constraints or in the realisation of these constraints;

(4) boldness, understood as the child's individual inclination to attempt consonants that are challenging for children at the early stages of development.

The purpose of the study was to establish the patterns of interaction between the above factors and examine the causes and effects of that interaction on the process of phonological development. In this respect, we asked four specific questions that follow from the hypothesis that phonological system develops as a dynamic system which is to a large extent driven by the child's own production (articulation):

(1) Is there evidence that segment-based processes are articulatory in essence and follow from on-line difficulties?

(2) Can the emergence of phonological systematicity (top-down) be traced back to earlier articulatory processes (bottom-up)?

(3) Do the periods of systematicity evolve through phase transitions, surrounded by periods of increased articulatory variability?

(4) Is development non-linear and is it related to individual tendencies in production?

The results support the view that child phonology can be treated as a dynamic system. Firstly, the consonant modification processes observed, in the cases where they are not the result of whole-word processes, appear to be motivated by on-line articulatory difficulties. Secondly, these individual articulatory preferences and routines result in the development of individual whole-word templates. Thirdly, in both children who developed strong templates understood as adaptation strategies, the period of systematicity corresponded to predicted changes in the amount of phonetic and prosodic variability in production. Finally, each of the children followed an individual path, and none of the children showed linear progress in accuracy. We shall now discuss in more detail how these results contribute to our understanding of early phonological organisation as a dynamic system.

7.2 Structure

The parts of the system that respond to phase transitions by increased variability constitute the **collective variable** (or order parameter) of that system. In this study, increased variability related to changes in whole-word systematicity was observed in both prosodic and phonetic features of words, suggesting that both articulatory precision and co-ordination of articulatory gestures within words constitute the building blocks of the phonological system. In particular, variability was not limited to the words directly affected by the templates in question, but rather reflected the overall instability of the system as it underwent reorganisation to and from templates.

The **control parameters**, that is the key factors that trigger instability in the system which leads to a phase transition, were different for different children at different stages. For Alison, increased boldness led to the emergence of adaptation patterns. For Jude, the decline in the use of templates led to rapid improvement of accuracy. For Rebecca, no reorganisation was observed, and variability remained on a stable level throughout the study. In her case, accuracy only depended on what targets the child selected to attempt.

At the same time, the control parameters that were identified only had an effect on the system if particular initial conditions were met. For Alison, boldness led to the emergence of templates because it was coupled with strong articulatory constraints. Even though Rebecca's boldness increased during the time of the study, it did not lead to reorganisation, as the child's articulatory skills were much more advanced. Similarly, the decline in the use of templates by Jude resulted in significant improvement of accuracy, whereas for Alison, who still had poor articulatory skills, accuracy remained fairly low even after the templates were considerably less strong. Therefore, the organisation showed high sensitivity to initial conditions.

7.3 Properties

One of the main characteristics of dynamic systems is their complexity, which is reflected in the complex structure of the system and the complex pattern of interaction between its components. One aspect of the complexity of pattern is that the components are multifunctional, so that they do not have a pre-assigned role but rather perform different functions depending on the situation. Another feature that is related to complexity of pattern is that there is reciprocity, or circular causality between the behaviour of the system's components and the phase relationships between them, so that the two mutually motivate one another. In addition, the components of the system interact in nonlinear way, leading to qualitative changes in the system's organisation. Finally, the development of the system follows a highly individual path.

7.3.1 Multifunctionality

In Chapter 1, we discussed *motor equivalence* as a sign of multifunctionality. In that process, different components compensate for disabled or underdeveloped sub-systems to achieve the goal. Lexical expansion is undoubtedly one of the most important goals in linguistic development, as it is a necessary prerequisite for achieving communicative competence. Children at the early stages of producing words are in a position where they already understand the referential function of language and have the basic ability to co-ordinate sounds into word-like units, but they do not have the necessary skills to produce all the words of a language correctly. Enriching the lexicon in this situation requires a strategy that would maximise the number of words in the productive lexicon with the articulatory resources available. Vihman and Velleman (2000) proposed that templates constitute such a strategy for children. This hypothesis was confirmed by the data in this study, which showed a dramatic increase of vocabulary size in the two children who developed templates (although for Jude, that increase occurred before the beginning of the study). In this way, templates may compensate for low accuracy.

However, as the use of templates decreases and articulation improves, lexicon begins growing again. Similarly, Rebecca, who was the oldest child and had the largest consonant inventory at the beginning of the study, slowly but steadily expanded her vocabulary across sessions. Therefore, lexical expansion can be facilitated by either patterns of adaptation or well developed articulatory skills (and it is likely that there are other possible factors, which were not observed in this study), and in the case of one of these factors being underdeveloped, the other is employed to achieve the communicative goal.

7.3.2 Circular causality

However, it should not be assumed that templatic organisation is a conscious choice on the part of a child, or a strategy that the child consciously adopts. Rather, systematicity emerges from the interaction of low accuracy coupled with a preference for a particular familiar pattern, and with high boldness in attempting new targets. Selecting a simple familiar pattern leads to entrenchement of the articulatory routine, and attempting many difficult targets leads to the pattern being spread to targets which do not have the favoured form. In this way, low accuracy and high boldness result in the emergence of templates, and templates in turn result in low accuracy and high boldness, as they lead to dramatic modifications of targets and enable the child to produce many new words. Therefore, there is *circular causality* between the state of the phonological system (systematic whole-word patterns) and the factors acting upon it (articulation and communicative intention).

Circular causality is also a defining property of dynamic systems, where no direct causal relationship can be postulated between the mode of co-ordination of components and their individual actions. In Chapter 1 we used co-ordination between oscillating fingers as an example of that effect. In that case, the fact that the fingers were moving symmetrically defined the phase relation between them, and the phase relation defined the way in which they were moving. Similarly, low accuracy and high boldness define templatic organisation in the child's phonology, but at the same time templates are the cause of accuracy being low and boldness being high.

7.3.3 Nonlinearity

The relationships between variables observed in this study show that their interaction is nonlinear. There was not a single factor that would significantly linearly correlate with accuracy for all three children. However, there were patterns in how the factors interacted that pointed to nonlinear changes in the children's phonological development. In particular, boldness and vocabulary size were high at the peak of adaptation strategies in Jude and Alison, decreased after that, and increased again when template use disappeared and consonantal accuracy improved (i.e. in Jude and Rebecca). These stages of reorganisation were preceded and followed by increased variability in the whole system, reflecting qualitative shifts in the emerging phonological organisation.

7.3.4 Sensitivity to initial conditions

Perhaps the most striking fact about the data in this study is that development followed a very different path for each of the three children. Alison, who began with a small consonant inventory, initially selected preferred word shapes, which in time led to the emergence of word templates and significant drop of accuracy. When her boldness in attempting particularly challenging words decreased, the use of templates diminished, and accuracy improved. However, the improvement in accuracy was slight, due to Alison's still underdeveloped articulatory skills. Jude, who began with strong templates, but also with a much larger consonant inventory than Alison, became less systematic within two sessions. This led to rapid improvement of accuracy and eventual decrease in variability, after which boldness reappeared along with improved skills in attempting different word forms. Finally, Rebecca began with a large consonant inventory and a preference for selecting only minimally challenging targets. Even though this systematicity resulted in a temporary articulatory routine, it did not lead to the emergence of templates, and Rebecca's accuracy, variability and vocabulary size did not show the same link with systematicity as in the other two children.

Therefore, the three children's phonological development depended in large part on the initial state of their articulatory skills (as reflected in the size of consonant inventory) and their individual tendencies in attempting challenging targets. Moreover, it was also highly individual in the particular patterns they used. However, it did not seem that these differences were due the children being different types of learners, as has previously been suggested (Nelson, 1973; Bates, Bretherton & Snyder, 1988; Bates, Dale & Thal; 1995). Rather, the particular learning 'strategies' adopted appeared to be the result of a combination of articulatory constraints and communicative goals. In this sense, they were compatible with the description proposed by Lindblom, Studdert-Kennedy and MacNeilage (1983), according to which individual developmental paths are shaped by the interaction of partially fixed factors in perception, motor skills and social conditions, which do not have a predetermined order of emergence. Rather, different parts of the phonological system develop in response to partially random factors acting upon it, in an order that is not fully predictable. However, the constraints of child articulatory constraints, human cognition and environment (including the ambient language) are still strong enough to guarantee very similar end results. And that is precisely the nature of dynamic systems: their organisation is flexibly defined by the goal they have to achieve, but the precise path of moving towards the goal is not preprogrammed. In the words of Charles Ferguson (1986, p. 41) 'each child has a unique pattern of development, as determined by the particular input received, individual patterns of playing with the input and the child's own output, the nature of the communicative interaction in which the child participates, and the various acquisition strategies used.' However, on the basis of the analysis of the data in this study, we would like to argue that the acquisition strategies are in fact also emergent from the child's own constraints and experience.

7.4 Limitations and directions for further research

The data support our proposal and point to the child's development proceeding through a series of phase transitions whereby several factors and their interrelations contribute to the emergence of a phonological system. The development is therefore individual, and patterns that appear depend on particular difficulties a given child is facing. However, it is clear that the description presented here is more a theoretical metaphor aimed to show that the hypothesis is conceptually valid than a definitive demonstration that it is correct.

7.4.1 A mathematical model of child phonology

In order to definitively demonstrate that the interdependencies observed here have the exact properties of those described in the study of dynamic systems, precise mathematical dynamic equations have to be established that would fit the patterns described qualitatively here. For that to be possible, a computer model of phonological acquisition in the Dynamic Systems framework must be developed. It is hoped that this study, which identifies possible key factors to be included, as well as outlines the predicted direction of interaction between these factors, is a first step in developing such a model.

Importantly, it would be preferable to use denser data to feed the model. In the current study, the emergence of templates in Jude could not be examined, as the patterns developed within the month between sessions. Weekly, or possibly twice weekly recordings would ensure that children can be accurately compared and that no developmental stage is overlooked, which is particularly important if the data are to be analysed mathematically. Furthermore, it is expected that there are other factors that participate in shaping the individual developmental paths in child phonology. In particular, it is likely that parental input should be included in the further study as parts of the system that may greatly influence its organisation. Finally, the general precaution that has to be made concerns the fact that our data come from only three children. It is possible that examining data from a larger number of children would provide more insights into different modes of coordination between components of the phonological system, and different types of reorganisation it can undergo.

It is proposed that the approach to child phonology presented in this dissertation would lend itself to an application of a Markov model. In a Markov model, the child's own production and the input from adult speech could interact to result in the child's developing expectations regarding the possible assembling of speech units. The expectations would be based in the probability of hearing a given unit (in own or others' production) after having heard a certain string of units, and as such would constitute a way of conceptualising phonological representations. Specifically, this type of representations would be sensitive to what the child attempts (i.e. boldness), how they produce it (articulation), and the input they are exposed to. This interaction may then result in child-specific predictions and generalisations (systematicity), which are expected to emerge through a phase transition, thus leading to variability. This type of modeling could make it possible to arrive at a mathematical description of the emergence of systematicity and the U-shaped curve in development, based on dynamic equations derived from the interdependencies between factors acting upon the developing phonological system which were described in this study. Furthermore, it could provide a way of explaining what triggers the progress towards adult-like production. It is possible that increasing the weights attached to adult input, as opposed to mostly relying on instances of the child's own production can be an important factor in the eventual abandonment of templatic strategies (Dimitar Kazakov, PC, 2012).

7.4.2 Memory

Apart from the variables examined in this study, memory should also be considered as one of the possible factors that contribute to the emergence of adaptation patterns. We have seen that word templates are based in the child's individual articulatory routines, but the rapid vocabulary expansion related to the emergence of templates (as observed in Alison and Jude) suggests that the role of memory in the process requires further investigation. In addition, memory and attention factors should also be examined in relation to substitution processes. While these are usually articulatorily motivated, it is certain that memorising and retrieving words play an important part in the process of production, and are likely to contribute to the high amount of variability present in the data. Unfortunately, it was impossible to study these variables on the basis of the data in this study.

Therefore, in order to arrive at a fully satisfactory description of early phonological development, the interaction between memory and articulatory issues should be studied in depth. One possible way of distinguishing between the two factors would be to examine children's reliance on templates in learning novel words, as opposed to applying templates to familiar words. The prediction here would be that a purely articulatory routine should not be used differently for novel vs. familiar items, and its entrenchment should lead to modifying already practiced words equally often as newly acquired ones. The main predictor of the use of templates should then be articulatory complexity of lexical items, rather than the degree of their familiarity to the child. In contrast,a result showing increased reliance on templates in learning novel words would indicate that the origins of templates are also closely linked to memory. Memory should then be included as a variable, and its interaction with the factors discussed in this study should be examined. For example, it would be interesting to determine whether there are periods of variability in children's performance in terms of retrieving words, and whether these periods of variability correspond to qualitative changes in their phonology.

7.4.3 Phonological processes

It is hoped that the results of this study will contribute to further development of phonological development research methods. Specifically, we postulate that the study of child phonology should not rely solely on selected, most accurate or most frequent child forms, and that variability should not be excluded from analyses. The results of this study indicate that limiting the data in this way may lead to overestimation of systematicity in children's production. It is believed that further investigation of patterns in variability would contribute to much better understanding of the nature of early phonological organisation.

Similarly, including articulation in the scope of phonological research could also be beneficial in trying to determine the structure of the developing phonology. In particular, substitution processes should be examined from the perspective of articulatory issues before they are taken to reflect the organisation of child phonology. Alison's production of final fricatives is perhaps the most striking example of a process which could be interpreted as a phonological rule, but which proved to result from airflow control, as evidenced by the fricatives depending on the preceding vowel. Therefore, it is argued that variability and articulation should not be omitted from child phonology studies.

7.5 Conclusion

The results of this study show that no approach to phonological development that predicts linear improvement of accuracy and linear increase in vocabulary size, accompanied by linear decline of variability and use of child-specific whole word strategies can account for what can actually be observed in child data if they are analysed individually. Furthermore, no approach to phonological development which does not include articulation as an important factor contributing to the emergence of the phonological system is likely to capture the nature of the process. Dynamic Systems Theory is a framework that can explain nonlinearity, variability and periods of systematicity observed as the key properties of developing phonology. It also makes it possible to incorporate articulatory factors as well as individual tendencies in attempting words into the description of phonological acquisition, as valid components of the emerging system. As such, it supports the notion that there is continuity between the development of structure in nature and the development of structure in human cognition.

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