The changing tide: the discussion

And the power of the changing tide
blinded by the night
The sweet sound of the changing tide of your nature

Your nature by Hothouse Flowers from their CD An emotional time

6.0 Introduction

Nearly 40 years of study of child language using modern linguistics has brought up one of the richest areas in linguistic research. However, I argued that little attention has been given to processes in language development, i.e. quantifications over an index of time (chapter 2). I introduced non-linear theories that either aim at explaining growth (continuous change) or that offer indications for discontinuities (chapter 3) and a method for the study of language development using dense time series of longitudinal data (chapter 4). The results of the analyses were presented in chapter 5.

The interpretation of the results is directed to the main research question I presented in chapter 1, and which was elaborated in chapter 4. The question whether language development is continuous or discontinuous, is discussed in the light of evidence from this study, i.e. from the analyses and the interpretation of the data. I link this evidence to both linguistic and psychological theories on language development (cf. Ruhland & van Geert, 1998a, Ruhland, Wijnen & van Geert, 1995, Cats & Ruhland, in press, Ruhland, 1998a), and with other empirical findings from the literature.

The method in this study is one of the ways to study quantitative language development, and therefore, some questions cannot be answered. For example, longitudinal spontaneous language does not allow one to test the remaining flags from catastrophe theory, especially those that call for a perturbation. I discuss improvements to a further study of non-linear development, and I plead for a study with an interdisciplinary character.

Finally, I discuss the relationship between DSM and CT, and a third non-linear theory and a collection of models, Connectionism. The goal is to outline a model for language development that is not build on innate structures or rules that prescribe development.
6.1 Flags and fits: discontinuous or continuous development?

At the end of chapter 4, I stated the following research question:

Under the assumption that, according to the literature, function words are introduced very rapidly (at least) and that this reflects the succession of two stages (a telegraphic stage and a differentiation stage), the question is if there is any evidence of a catastrophic change (defined by the flags) in the development of function words in the six children between 1;6 and 3;0 years of age, measured on the basis of frequency analyses in a longitudinal design using two weekly observations.

The discussion in this chapter is preceded by a recapitulation of chapters 2 and 3. The theoretical starting points are discussed in the light of the arguments in favour of either discontinuity or continuity. This will lead to a discussion of the data in relationship with existing linguistic and psychological theories on the empirical and the theoretical level. Explanations of the results come in terms of the shape and of the timing of function words in child language.

Theoretical observations

Theories on development offer a limited prediction on the shape of development. Human behaviour is not exclusively determined by the environment (e.g. the parents), neither by innateness (e.g. genes). With respect to change, I distinguished two sorts of theories. Non-Stage theories predict linear or at best gradual change. Stage theories offer the possibility of sudden change, although sudden changes may be disguised by other factors. Furthermore, I distinguished continuous (linear and non-linear) and discontinuous change. If development is continuous at bottom, change cannot imply stages. However, the definitions of discontinuity and stages are (at least) fuzzy. Glaserfield and Kelly’s (1982) ideas were used to define a stage, and I reformulated their ideas to the definition of ‘a change on another dimension than time or age’. However, this definition is not sufficient. It is unclear what the boundaries of a stage are, and the stage definition lacks a structural account. Transitions from one to the next state are mostly sudden, since a gradual change implies that stages cannot clearly distinguished, unless there are a sufficient static properties in stages. A structural theory has to decide how these static properties differ from real stages.

With respect to language, I discussed theories on language and language development. Linguistic theories offer explanations for the variety within a language, and for the links among languages. Developmental predictions of linguistic theories are
limited, but linguistic theories do have the possibility of explaining structures in language. Underlying structures, traces and movement rules explain the syntax of a language. Features in the syntax of many languages including Dutch are functional categories. They are abstract, syntactic, and important elements in a sentence.

One assumption in continuous linguistic theories is that children have a body of linguistic knowledge called UG. The question is whether UG principles are available to children from the beginning or not, i.e. whether the development of syntax is, in the linguistic sense of these words continuous (all principles of UG are available) or discontinuous (some or all are not available). Generative grammar theories assume that development is guided by principles that explain the order of change. A precise quantitative analysis on the basis of UG is not possible. Change is either a gradual process, e.g. an extremely rapid development (in which the continuity hypothesis is obeyed), or a discontinuous one (UG principles are not present from the beginning). UG makes it plausible that development is constrained by general linguistic rules, that children and adults may learn other languages, and that the learnability problem is solved by postulating innate syntactical knowledge. It is assumed that this knowledge is not specified as to the details of a language, but that it increasingly becomes specific when a child grows up.

A different approach to the study of quantitative paths, continuous or discontinuous (i.e. the psychological meaning), is found in non-linear models. Dynamic systems (continuous) models have been proposed by Thelen and Ulrich (1991) and van Geert (1991) for describing processes in motor and cognitive development. Instead of linear models, their models are based upon non-linear ones. Following van Geert (1991, 1994a), I assume that development is a process of dynamic interactions between growers. The dynamics are also expressed by a sensitivity to small changes in the initial values that can eventually lead to big differences in the outcomes. The language system that develops sets out constraints. These constraints lead to restrictions on possible forms of change of a psychological domain. There are two general applications of dynamic systems models. First, I use the models for fitting growth curves. Second, non-linear equations are used to model language development. In this chapter, I will add a linguistic analysis to my data and van Geert’s analyses and models. Catastrophe theory (i.e. a discontinuous theory) offers criteria that may be employed in order to find discontinuous change. There are eight so called catastrophe flags, associated with specific kinds of empirical data. These flags have to be found in order to demonstrate phase transitions.
Empirical findings

Two opposite approaches to development have been used to answer the following question.

**What are the paths of language development (in quantitative terms)?**

Discontinuous models are applied in two ways: the use of catastrophe flags (the catastrophe detection method) to get indications for discontinuous behaviour, and a direct fit of a cusp model (Cuspfit; Hartelman, 1996), which is based on Cobb (1981), to test three models of development.

Evidence for discontinuous change comes from the catastrophe flags. Out of 8 flags from catastrophe theory, there is evidence for three flags. I found a *sudden jump* in function words. This flag indicates that a variable jumps from one equilibrium to the second. There is also *multimodality*. This flag shows that there is more than one equilibrium (the presence and non-presence of function words). *Anomalous variance* indicates that if there is a transition (or discontinuous change), the variance increases temporarily in an anomalous way, but this flag was found in only two of the six children.

Supplementary evidence for discontinuous change comes from a method of fitting several models to the data by using Cuspfit. Taking (cross-sectional) data as an input, it tests three models (linear, logistic and cusp). The results show that in all cases (articles, modals and pronouns), the cusp model provides the best model. A comparison of three models (linear, logistic, and cusp) shows that the cusp model is the best model to fit the data (according to cuspfit).

Fits based on growth models (van Geert, 1991, 1994a) show that equations with high growth rates (> 1) and a high power (> 1) yield the best fit. These equations are closely connected to catastrophe theory by the power of the equation, and the resulting curves show a rapid and cliff-like increase. That is, if the power of the equation comes close to 2, and the growth rate is high (e.g. close to 2) the resulting growth curve takes the form of a sudden, cliff-like form, accompanied by fluctuations, and a low initial state.

The conclusion must be that, from the discontinuous analyses, it appears that the quantitative development of function words is rapid. There is some evidence for three catastrophe flags, the analyses with Cuspfit suggests additional evidence for a catastrophic change (i.e. the cusp model), and there is more than one mode (or equilibrium) in the data of children according to the analyses with a *kernel density technique* and a *mixtures distributions analysis*. There exists large individual variability in the development of function words in each child. The literature suggests that function
words develop suddenly. Using dense time series I showed that there is indeed a sudden jump in at least some of the children. However, there is insufficient evidence to support the hypothesis of discontinuous change and simultaneously reject the continuous change model.

The next step was to test the continuity hypothesis. Continuous models test development with respect to the general linear or even non-linear (but not “discontinuous”) trend. Continuous models may be linear, polynomial, or logistic with on the x-axis the independent variable (e.g. time or age), and on the y-axis the score of a variable. The important characteristic, however, is continuity in a mathematical (i.e. psychological or quantitative) sense. This does not imply that the psychological model needs to be continuous: a series of discrete learning events could lead to continuity on the mathematical level. For every point in time, there is a score on the y-axis. There are several tests for testing the continuity hypothesis. I tested two models: a linear and a growth one. The conclusion must be that a fit with growth models to dense time series of individual development is much better than a linear fit.

Finally, I presented two sorts of averages to show that age averages hide the dynamics of development. Averages over age show similar patterns as those of Wells (1985), namely s-shaped forms. However, individual paths show that there sudden changes in some of the children. Dense individual time series with two-weekly recordings show that there is at least a sudden change in the use of function words. Averages over the jump, the biggest difference in a set of data, shows, under the assumption of a variable tied process, not an age tied process, that the jump found is still present, which is an extra indication of sudden change.

I offered explanations for the change found, i.e. why the change in function words is sudden. First, the function words might increase due to an increase in other variables, i.e. other independent factors. The best candidate presumably is the amount of words spoken during a session, i.e. language productivity. The words per session increase over time: the production of language increases as the child becomes older. However, it is not possible to determine the direction of the causality. The only to be made is that there is a interrelationship between both language variables. Second, the length of sentences increases in the same age span that function words arise. This fact correlates with the assumption that longer sentences provide slots for function words and functional categories. Third, the parents might increase their use of function words. This would indicate that a child imitates the input directly, or with a time lag. However, analyses do not confirm this hypotheses. The increase in function words is not directly related to the language of the parents, i.e. the input.
6.2 Quantitative and qualitative explanations of rapid change

We have seen that the change found is not caused by the parents or by an increase in the child’s speech productivity. The question that I shall discuss in the present section, is why, if no such external factors suffice, function words show the jumpwise increase as found in the data. I discuss psychological and linguistic theories with respect to behavioural versus underlying variables in the light of the sudden change. The explanations come from two directions. First, I present a quantitative discussion on the shape of change. Second, I discuss the relatively late appearance of function words.

The shape of change: quantitative explanations

A dynamical systems explanation

A dynamical systems approach enables us to clarify why a sudden jump occurs. In a growth model of language variables such as articles, modals and pronouns are various syntactic structures that are considered connected growers. That is, they follow a path of mutually related development. I mentioned earlier that the growth in the use of certain syntactic structures supports the use of pronouns, because these structures provide ‘slots’ into which pronouns fit naturally. On the other hand, growth in the use of pronouns supports the search for syntactic structures in which the placement of pronouns is syntactically governed. Thus, one reason for jumps might be that a variable (e.g. closed class words) gets support from another grower, namely the development of longer sentences with inflected verbs, which results in closed class words growing faster.

In addition to these relationships of mutual support, the disappearance of a competing relationship (e.g. competition with two-word phrases) may lead to a sudden increase in growth rate and a new equilibrium. Thus, a sudden jump may arise because the competition with another grower has disappeared. The grower that jumps to another level of equilibrium no longer suffers from the limitations set by another grower. It may now use all the available resources eventually leading to a jump.

A third explanation is that a precursor relationship, for example, the inflection of verbs, causes a new grower to emerge. In terms of development, this precursor releases certain structural possibilities of the language system. In our model (Cats & Ruhland in press), this relationship is implemented as the coproducer of new syntactic structures. Precursor relationships are ‘pushers’ of new variables. Since the precursor that was chosen on theoretical grounds sets free functional categories, a very rapid development is possible, because these functional categories, unlike the verb inflection rule, do not call
for rule application across lexical items (as in the case of verb inflection) in the case of function words. These categories are filled in by function words in a relatively simple way.

One of the assumptions is that growers in a system or model are forced to grow because there are *attractors*. Attractors are, in terms of thermodynamic theories, points in the developmental landscape that possess less energy. This means that a variable or grower is attracted to the low energy state. This state is not prescribed in a system, i.e. in the language itself. It is a result of the interaction between words, i.e. the process of a grammar. This can be called self-organisation: the organisation of grammatical features is inherent in the way linguistic theory argues that relationships between syntactic elements are organised. This organisation between syntactic features must be acquired in development, and during that process, attractors are states in development. For example, the first attractor in development is vocabulary, i.e. the knowledge of types of words. These words children acquire are lexical items like nouns and non-inflected verbs that refer to entities in the child’s environment. The attractor for function words is at least the length of the utterance. This attractor implies that if an utterance is long enough, i.e. a multiword utterance (e.g. with MLU over 1.75 words per sentence), function words appear. However, I think that this is not viable explanation. There is from a syntactic point of view no strict reason that function words should appear as soon as sentences are long enough. Below, I argue that finite verbs are a more attractive candidate to serve as an precursor for function words than the length of sentences.

The shape of change does not only need to explained from a dynamic systems point of view, it also needs to pay attention to individual differences.

*Pronominal and nominal styles: individual differences*

“Don’t you know that it’s different for girls?” Joe Jackson, *I’m the man.*

In chapter 4, I raised the question whether the distinction between pronominal and nominal (Bloom, Lightbown & Hood, 1975) or referential and expressive styles (Nelson, 1975) enables us to make predictions on the quantitative change we might expect. I argued that there is no compelling reason to believe that a linear, a slow gradual or a very rapid change follows logically from either of the styles that according to Nelson (1975) and Bloom et al. (1975) exist in language development (Ruhland & van Geert, 1998a). Pronominal children may acquire pronouns early, but this development may be either very rapid, slow, or linear. In a similar reasoning, nominal children are late, but when they catch up they may show any quantitative behaviour (from linear to sudden
change). The style of development, so to speak, does not rule out any of the kinds of change proposed. The answer to the question whether the pronominal-nominal distinction matters is that there is only a difference in timing: pronominal children are earlier (in age) in their acquisition of function words, nominal children will catch up later.

Children acquire their basic grammar and language in a few years. But although children normally acquire all aspects of syntax, they are not obliged to use function words like pronouns in the early stages of development. It means that children eventually develop different individual styles (Richards, 1990, Shore 1995, Bates, Bretherton & Snyder 1988). If humans are not obliged to use deictic or referential structures in communication, then every individual development is characterised by a different style of language, although they all end up with the same grammar. Do styles influence quantified development, i.e. the shape of change? There is, like the predictions of the linguistic theories in chapter 4, no reason to believe that styles are directly related to developmental shapes. Presumably there is only an influence on the timing of function words: pronominal children are earlier (in age) in their acquisition of function words, nominal children will catch up later.

Therefore, the data do not allow for an interpretation of the growth curves in terms of styles. The “choice” of either a nominal or a pronominal style by each individual does not automatically lead to the conclusion that a catastrophic change is impossible. Children may follow two possible paths. A child like Abel may differ from other children, but the linear pattern of his development may be explained by the fact that the function words in Abel’s language have not reached the second equilibrium at the end of the recordings, and that there is no “function-words-free” start, i.e. a considerable number of function words can already be found during the first observation.

Another important matter are the subjects in the study. Due to a curious coincidence, all children in the study are boys. A dynamic systems model of development leaves open the possibility of individual paths. There are some claims that the timing of girls is different from boys. Qualitative differences between boys and girls have been described by Huttenlocher, Haight, Bryk, Seltzer and Lyons (1991) who found that the vocabulary spurt is earlier in girls. Most studies reveal that there are various qualitative differences between girls and boys (Maccoby, 1988). She describes research, in which differences between ‘boys in all-boy groups’, compared with ‘girls in all-girl groups’, have been found. For example, boys more often interrupt one another and more often use commands, whereas girls often express agreement with what another speaker has just said and pause to give another girl a chance to speak. Apparently, speech serves more egotistic functions among boys and more socially binding functions among girls. There are communicative differences, i.e. in speech acts (Serbin, Sprafkin, Elman and Doyle
According to Fenson, Dale, Reznick and Bates (1994), differences between girls and boys are small, i.e. girls are ahead of boys. In sum, there are no qualitative differences between girls and boys expected with respect to the development of syntax, and quantitative differences exist only in the timing of the start of the growth of language. With respect to gender differences, age ranges between girls and boys may differ, but that this difference in timing is small. With respect to the shape of development, there is no research that suggests that there are gender differences in quantitative development, i.e. in the growth curves.

A threesome of data, non-linear theories and linguistic theories

Any data set, regardless the complexity of the set, the number and magnitude of fluctuations, etc. can be fitted with a simple or with a highly complex equation. The problem, however, is that fitting alone is an empty exercise. What is needed is a justification for both the quantitative and qualitative patterns of language development. The problem, in short, is: what is the relationship between the data, non-linear theories and linguistic theories?

In Ruhland, Wijnen and van Geert (1995), we discern, at a general level, three types of relationships between a structural theory of development and a growth model. The first possibility is one of independence. Apart from the assumption that growth “must follow a structural possibility of the cognitive system” (i.e. a grower must be present; van Geert, 1991: 4), the structural model and the growth model may be completely autonomous. The growth model is capable of describing the observed changes in performance without recourse to hypotheses on the quality of the developmental process that may follow from a structural model. In fact, this seems to imply that the growers do not entertain any relation to the notions of the structural model. Thus, the growth model neither supports, nor refutes the assumptions of the structural model.

Second, growth models and a linguistic theory are compatible. This comes in two varieties. First, it may be the case that the parameters of a growth model that was constructed inductively (i.e. with the single objective of obtaining a perfect fit with the data) can be meaningfully interpreted in terms of a structural model, and that this leads to (quantitative) predictions that concur with the predictions derived from the structural model. Alternatively, a growth model that was constructed deductively, i.e. by choosing its parameters on the basis of notions and considerations supplied by a structural model, is supported by the empirical data.

Third, growth and linguistic models may contradict each other. Again, we envision two versions of this situation. In the top-down scenario, a growth model that was
informed by a structural model does not fit the data, whereas, possibly, a bottom-up (i.e. based on the data) model does. Alternatively, an inductively constructed model comprises parameters that can be interpreted as refutations of (some of) the core assumptions of the structural model. In either case, the bottom-up model (that was validated by its fit on the data only) may be thought of as the instantiation of a hitherto unidentified structural model.

Thus, there must be a relationship between (elements in) the equations and linguistic theory, because the construction of a dynamic model without any theoretical justification does not make any sense: it is nothing more than a mathematical restatement of several growth curves without any coherence. Structural change can be related to the equations in three ways. First, the carrying capacity, $K$, increases or decreases. This means that a system can grow to a different level. Maturation could be a cause of an increase of $K$. Second, supportive or competitive factors can push a system to a new level. In that case, the carrying capacity itself does not change, but other factors raise or lower the value of $K$. Third, competitive factors may avoid a grower to reach a new level, and consequently the system does not structurally change. In a structural model like a linguistic one, there is, with a competitive factor, basically no change on the underlying level. The syntactic (or more generally, linguistic) knowledge of some variable does not change due to competitive factors. The relationship between $K$ and theories on linguistic development are probably that the theory sets out the constraints, and $K$ follows these constraints set out by the theory. In other words, this is a ‘one way street’ from linguistic theory to $K$.

Suppose that a child learns the rule to use the passive. Consider the following example.

6.1 The standing stones of Callanish on the Isle of Lewis were erected five thousand years ago.

It is not necessary to learn the passive, since all sentences maybe put in the active form. With competition between two language structures, the stronger structure wins. If this is the structure that was already there, the underlying linguistic structure does not change. Thus, if the active form is the stronger structure, passives do not appear in a language, and only examples like in 6.2 appear.

6.2 Druids did not build Stonehenge.

One may question the existence of such competition in language (development). A discussion on this subject, however, would lead too far from the current subject of the section (see MacWhinney, 1997 for a discussion on the solution of the logical problem).
An important question is: how can we relate the structural developmental theories to quantitative notions? In Ruhland et al. (1995) we looked at a few of these linguistic developmental theories and possible predictions they cast on the sort of change. These theories are Maturation, Parameter Setting and Lexical Learning. One of our conclusions was that these structural theories and hypotheses fail to make exact predictions about the forms of change. However, they do provide hints about the particular directions in which change might take place. If, for example, parameter setting is the correct theory of development, we may expect sudden changes. I deliberately say ‘may’, because other factors like memory may hamper a sudden change. Lexical learning, on the other hand, predicts slow and gradual (or even linear) change. All these predictions can be related to a dynamical systems approach. For example, the carrying capacity (K), that is, the equilibrium level of a variable (where K might be the linguistic knowledge of a child), may change either gradually or suddenly. This K-change may occur due to an increase in, for example, memory or an increase of syntactic slots. The question is whether there is any justification in the data for any of these possibilities. Since I found a jump, lexical learning, with its hypothesized linear or gradual increase, appears to be a false linguistic hypothesis. All theories (parameter setting (Hyams, 1986), lexical learning (Clahsen, Eisenbeiss & Penke, 1994) and a range of maturational views (cf. Felix, 1992)) can be tested against the findings of a dynamical systems model. It is not clear yet whether these approaches (dynamical systems modelling and structural, linguistic theories) contradict each other, or whether they are in some way complementary. However, it is plausible that functional categories (e.g. function words) follow a path of mutually-related development, which is supported from a linguistic point of view by assuming that if functional categories are not available in development from the beginning (the reduced competence), these categories develop simultaneously on the basis of the Case module (see chapter 4).

With respect to the discontinuity and continuity debate in linguistics, the data are not suited for deciding for or against either one, since this debate calls for a different approach in which a qualitative reasoning is requested. The continuity-discontinuity debate is a theoretical battle that cannot be won with quantified data. In this study, it is assumed that the rules of UG are not violated, and that therefore linguistic continuity is preserved. What seems plausible is that the absence of function words at least suggests that functional categories are not visible in the language of children, and therefore, not present on an empirical level.
The timing of change: qualitative explanations

Explanations of a linguistic kind

To continue the linguistic reasoning of the previous paragraph, and bearing in mind that the rapid development of function words is not caused by independent variables like vocabulary, or the input (i.e. the parents), I will argue that a syntactic organisation could be responsible for the development found. This has to do with the order of change, but also with the shape of change, since the way new syntactic properties are introduced is decisive for the possible change and relationship between function words.

One of the assumptions is that early child language can be rewritten in the form of a linguistic tree, which is build of lexical categories (NP, VP, PrepP and AP). There are three approaches to early child language, that I introduced in chapter 4: functional projections are either completely absent (lexical-thematic hypothesis), partly present (reduced competence), or all available. For example, Clahsen et al. (1994) assume that there is one functional projection, namely F. The question is what this F could be. Let me start with an assumption, and then find evidence for it. The assumption is that Inflection, i.e. finiteness of verbs, is the first functional category. Finite verbs serve as a glue between other building blocks (mainly lexical items like nouns). Empirical clues have been provided by Vainikka (1993), Wijnen (1996), and Powers (1997). They provide some evidence that Vfin is the first F acquired. If the assumption proposed here, i.e. the first F is I(nflection), is correct, the functional phrase contains the inflected verb, and the basic tree looks like figure 6.1, where F is any functional category (IP), and the other abbreviations are lexical categories (see chapter 2). One or more of the categories in brackets, NP, PrepP and AP, may appear in early language, i.e. when only one functional category exists.

With the introduction of functional categories (by means of, for example, function words), the tree ‘grows’. The growth of the tree means that branches are added. These branches represent new functional categories. Growth in terms of branch addition does not violate the linguistic continuity assumption. The introduction of function words and
functional categories leads to a tree similar to that of Figure 6.2. The point here is the increased complexity of the child’s syntax.

Ferdinand (1996) shows that early child language does not lack all functional categories, but neither are they all present. Suppose that not all functional categories are available (see figure 6.1). New functional branches may be added all at once (e.g. as predicted by Parameter Setting) or one by one. Every new branch is instantaneously added to the tree. That is, there is a sudden jump in the equilibrium. Nevertheless, the effect in the behaviour may be gradual, because non-linguistic causes could be responsible: a slow increase of memory may hamper the instantaneous introduction of new linguistic elements.

The variables in this study belong to functional categories. Determinative pronouns and articles belong to the Determiner Phrase, personal pronouns take the position of the Specifier of the Complementizer Phrase, whereas modal verbs belong to the class of Auxiliaries Phrases. It is assumed that according to linguistic theory Case depends on inflected verbs. The introduction of finite verbs (Wijnen, 1996), i.e. IP, might release the class of other functional categories (see also Vainikka, 1993). This might also be true for language development, since in the case of Peter and Josse personal pronouns, for instance, does not start to grow until the verb inflection process is completed or close to completion. Other functional classes might be induced by similar syntactic processes. The conclusion is that finite verbs develop first, and this leads to the development of other functional categories, for example on the basis of Case distribution. This presumably is one of the mechanisms of change, inducing function words to grow.
On the basis of two empirical findings it is assumed that reduced competence is presumably the right hypothesis for early language development. First, finiteness (Wijnen, 1996) precedes the development of function words (Ruhland et al., 1995). In other words, these analyses confirm the reduced competence since finite verbs (a functional category) precede function words, i.e. there is no ‘all functional categories come in one go’. Empirically, there is support for the precursor relationship of verbs to other functional categories. Second, case distribution sets free a range of slots for functional categories. Theoretically, this means that the order of empirics is supported by a linguistic analysis.

In sum, the linguistic analysis serves as a formal model of qualitative change and as the account for the origin of linguistic knowledge. With respect to the quantitative findings of this study, however, neither linguistic hypotheses nor the ordering of the stages predicts or explains the shape of quantitative change.

A second issue concerns the question of the production as a function of comprehension. Criticism may hold that a child’s production of function words is the direct result of an increase in the comprehension of function words. Production may either follow comprehension, precede comprehension, or they may develop simultaneously. According to Petretic and Tweney (1977), comprehension precedes production. This implies that children do not have a problem of understanding function words. Other studies seem to confirm this finding. With regard to comprehension and production of word order in early child language, Roberts (1983) found that in Brown’s stage I (MLU 1.00 - 2.00) comprehension is verb specific, and comprehension precedes production. Studies on the comprehension of complex (in terms of syntax) sentences support the findings of comprehension preceding production, for example under the influence of phonological and rhythmic constraints (cf. Gerken & McIntosh, 1993), and although there are only few studies on the comprehension of function words by children, the conclusion may be reached that the rapid development of function words is not likely to be caused directly, for example, by a sudden change in comprehension, since comprehension is already completed by the time a child produces function words.

Transition mechanisms have had different interpretations and explanations. In Piagetian theory, for example, they were interpreted as change within the equilibrium model. In the case of conservation, for instance, a child can be forced into new conservation strategies because old habits do not function anymore. In the development of function words, there are no conflicts since function words do not fight for space (e.g. syntactic space or psychologically defined space like memory) with another variables. Nouns and pronouns (a nominal and a pronominal style) cohabit peacefully in a language. However, the lack of function words has been explained by the fact that function words
have weak stress and that the omission of function words in telegraphic speech stage is caused by stress. Explanations of the early absence of functional categories and words often refer to some form of performance limitations. For instance, since function words receive only little stress, they are not easily perceived by the child and are therefore difficult to learn. Valian (1991), for example, claims that the omission of sentential subjects is best accounted for by performance factors. Gerken, Landau and Remez (1990) found something similar: the omission of function words is not caused by an encoding limit (i.e. problems with the input), but it is caused by phonological constraints. This evidence has been found in Dutch too (Wijnen, Krikhaar & den Os, 1994).

The phonological constraints might be the reason why children do not notice function words in the input of the parents. However, there is a problem with this assumption: why do children observe function words in a later stage (that is, in the differentiated stage)? The hypothesis is that an increase of memory leads to a bigger memory and attention span, which in turn leads to the introduction of function words. Empirical studies (e.g. Elman, 1993) are needed to turn the hypothesis into an answer, i.e. to relate the introduction of linguistic variables to non-linguistic issues (e.g. an increase of the memory span) when a linguistic analysis cannot explain that introduction.

*Instability of the developing language system*

There is still more evidence that the introduction of function words is not a gentle, gradual or linear process, but one that reactivates or even reorganises the system. The reorganisation is expressed in the difficulties of planning complex sentences. From the literature we know that the end of telegraphic speech is accompanied by non-fluencies. These act as indicators of instabilities of the changing system. The change of the system is expressed in an increase of productivity which is accompanied by disfluencies in the language of a child (Wijnen 1990). A child has problems in planning her utterances because there are new syntactical elements that make the utterances longer, but also more complex. The introduction of function words leads to planning problems which are not syntactic. This indicates that several ‘modules’ (from phonological to semantic, and also non-linguistic modules) are affected by the change in the system, which becomes less stable, or even unstable. Elbers and Wijnen (1992) found a relationship between the development of function words and non-fluency. Apparently, perturbances on one level (in terms of development of function words) leads to instabilities on the other (in terms of fluency). In other words, an increase of knowledge (i.e. the knowledge of how and when to use function words) is strongly related with the development of fluency. The
Discussion

disfluencies in the language of third year of life have been referred to as developmental stuttering: a temporary deterioration in the language of children.

Summary of linguistic explanations

The predictions and explanations of quantitative behaviour that follow from linguistic theories are very poor. Although these theories discuss the what of development pretty accurately, the how is a problem. This also means that a linguistic analysis can never be sufficient for the study of language development, under the required assumption that development is both a qualitative and a quantitative process.

Syntax trees provide a structural account for the production of linguistic structures. Since the system is not yet stable, which is indicated by the planning problems, this instability indicates a system in transition. None of the structural accounts explain the exact form of quantitative development.

Non-linguistic change

Neuronal development as a condition for sudden change

Another explanation of sudden development has been proposed in Wimmers (1996). Since all behaviour is based on neuronal activity, the development of language must relate to brain structures. One option is that the brain does not develop, but that is impossible. It is generally known that at birth cell formation and cell migration is completed, but that long-range connections are still to be established (Bates, Thal & Janowsky, 1992). Second, if brain structures develop linearly or gradually, then there is no one-to-one relationship between the sudden introduction of function words and the gradual brain development. Third, the brain may develop in spurts. In that case, language development might, as a result, also develop spurt wise. Evidence on the relation between neuronal structures, neuronal development and language development is scarce. Thatcher (1991) presents evidence that the brain develops in stages: neurological development is responsible for stages and discontinuous development. Although Thatcher has not related this stagewise brain development to age related language development, the first stage roughly ends with the spurt that was mentioned in Bates et al. (1992), and Thatcher’s study may help us understand the fact that brain development is a possible candidate for the results found (see also Fischer & Rose, 1994 for an extensive discussion on discontinuities in brain growth, and the relationship with behaviour).
As has been pointed out by Bates et al. (1992), a relationship with grammar exists only on the basis of correlates: “the relationship between synaptogenesis (i.e. rapid acceleration in number of synapses within and across regions of cortex) and language learning is less direct, i.e. an enabling relation” (p. 105). A brain growth burst eventually provides more storage capacities, which enhances the speed of the grammatical process. This is supported by three facts. First, the process of word learning is already on its way, and it has consequences for the grammar to be build. That is, if more words are learned, a child may lengthen his sentences to express relationships between words. This is the first step in development which leads to structural patterns (like SVO patterns in English and SOV patterns in Dutch). Second, capacity-related changes in non-linguistic cognition correlate with grammatical changes, which suggest that language and non-linguistic development are timed by a common factor. Thus, it is timed by a common factor, and therefore there may be a relation between both, so that correlations may be high, but it does not explain the grammatical changes. Third, language development is not the consequence of a specific and localized language module that guides the transition from first words to grammar. Evidence for this is that children can recover from left-hemisphere damage after the second year of life. The switch from first words to grammar is not the finish of hemisphere specialisation, but an intermediary stage of changing neurological patterns.

It is likely that change is induced by neurological changes, but it is unlikely that neurological changes are responsible, in a one to one scenario, for the development of specific domains of language. Interestingly, in my overview of the catastrophe model, I argued that this implication does not necessarily follow from the premise that the overt use of already present function words (as instantiations of functional categories) depends on gradually increasing performance resources. In fact, if they are present as an underlying or latent structure, catastrophe theory predicts that their emergence in the form of overt speech occurs more or less explosively. In this sense, catastrophe theory is compatible with the assumption that language production is the expression of underlying syntactic rules that are either present at the beginning or emerge at a later stage but are in any case dependent on performance limitations that must be overcome somewhere along the developmental path. However, if the process underlying the acquisition of function words is one of gradually expanding the domain of application, by means of learning and/or imitation of phrases in which function words occur, we expect to find a gradual increase pattern with fluctuations that amount to mere stochastic variance. Recall that, according to catastrophe theory, a continuous decrease of performance limitations does not lead to the prediction of continuous increase in the frequency of function words, especially not if the use of function words depends on the presence of latent factors such
as underlying syntactic knowledge. This continuous increase of function words is not only depending on performance limitations, but also on the value of the splitting parameter in the Cusp model. If this value is high, the developmental path taken is a discontinuous one.

**Increase of memory**

Although an increase in the brain volume that is responsible for a growth in memory might be a ‘correlate’ (Bates et al. 1992) of language development, it is not plausible that changes in a specific language domain (for example, functional categories) are caused by specific brain areas. However, the increase of synapses is probably responsible for a change in memory capacity. This could lead to an (sudden) increase of function words. So, Bates Thal and Janowsky found, so to speak, “soft evidence” for a relation between function words and an increase of memory. This soft evidence is a correlate between brain spurts, memory and language development.

An increase of memory or attention (due to, for example, neurological changes) could lead to the increase of function words, but immediately the question “But why function words?” pops up. Hard evidence for the relation between function words and memory is given by Elman (1993). He has shown that the limitation of short term memory can act as a source for increasing complexity. This is what he calls ‘starting small’ (in terms of memory capacity), and it might contribute to the fact that attention is given to specific parts of the environmental input that are developmentally most relevant. For example, due to a limited working memory span, attention is restricted to nouns and verbs in the early stages of child language. This in turn might lead to child language in which function words are temporarily missing. Elman’s theory is an example of a positive instead of a restrictive interpretation of the function of performance limitations. In sum, function *words* are presumably left out in early child speech because of certain (non-)linguistic factors like phonological constraints or memory limitations. This does not rule out, however, that the relevant functional *categories* may be present on an underlying level. Elman’s finding does not explain the rapidity of change either.
The shape and timing of function words in child language: a summary

Two issues constitute the core of this section: the timing and shape of development. I related evidence for both aspects into a converging model of language development. Here I shortly present a model that pays attention to the linguistic and psychological reality of development.

Since the forms of change were the main subject of this study, I will discuss them first, with a special emphasis on the relationship between the data in chapter 5 and the theories on (language) development. However, I argue that the timing of function words is not independent of the shape of change.

The quantitative explanations stretch out over the dynamic systems that were used for the fitting of the empirical data. One reason for jumps might be that a variable (e.g. closed class words) gets support from another grower, which results in closed class words growing faster. The disappearance of a competing relationship (e.g. competition with two-word phrases) may also lead to a sudden increase in growth rate and a new equilibrium. Precursor relationships cause a new grower to start growing. Growers in a system or model are forced to grow because there are attractors. Attractors are low energy states, that are not prescribed in a system, i.e. in the language itself, but the result of word combinations, i.e. the process of a developing grammar. The organisation of grammatical features is inherent in the way linguistic theory argues that relationships between syntactic elements are organised. These syntactic features are acquired due to attractors in development.

As it turned out, the different styles, i.e. pronominal and nominal ones, account for individual differences. These differences are found in the rapidity (in terms of age) of the use of, for example, pronouns. Nominal children in the early stages use mainly nouns to refer to other people and things. The differences in style do not account for the difference in speed of development. There is only a difference in timing: pronominal children are earlier (in age) in their acquisition of function words, nominal children will catch up later. Apart from styles, there could be differences between boys and girls. Due to a curious coincidence, all children in the study are boys. There are no qualitative differences between girls and boys expected with respect to the development of syntax, and quantitative differences exist only in the timing of the start of the growth of language. With respect to the shape, there is no research that suggests that there are gender differences in the form of quantitative development. In short, all children acquire an adult level of linguistic competence. Since there are no qualitative differences between boys and girls, the predictions of the developmental order of a syntactic variable have to be the same for girls and boys.
I discussed the relationship between the data, non-linear theories and linguistic theories. Elsewhere we discerned, at a general level, three types of relationships between a structural theory of development and a growth model (Ruhland et al. 1995): independence (the structural model and the growth model may be completely autonomous, the growth model neither supports, nor refutes the assumptions of the structural model), compatibility (inductive construction that leads to quantitative predictions, and deductive construction, i.e. by choosing its parameters on the basis of notions and considerations supplied by a structural model) and contradiction. A dynamic model needs a structural theory. With this theory structural change is related to quantitative change. For example, if there is an increase in the carrying capacity $K$, if there are supportive or competitive factors that push a system to a new level (where $K$ itself does not change, but other factors raise or lower the value of $K$), or competitive factors that avoid a grower to reach a new level with as a result that the system does not structurally change, a linguistic theory explains the relationships between variables and the quantitative change of these variables.

Structural theories and hypotheses fail to make exact predictions about the forms of change. However, they do provide hints about the particular directions in which change might take place. All predictions can be related to a dynamical systems approach. It is plausible that function words follow a path of mutually-related development, which is supported from a linguistic point of view by assuming that if functional categories are not available from the beginning (the reduced competence), these categories develop simultaneously.

This timing of change is explained by a language internal change. I argued that children do not have problems with the comprehension of function words. Furthermore the developing language system is unstable in the third year of life, i.e. in the period when children acquire function words. Developmental stuttering is a well known phenomenon: children have problems in planning their sentences. Given these facts, and the findings of this study, I propose the following model. Children have lengthened their sentences by the time they acquire inflected verbs. These inflected verbs, in a manner of speaking the glue between the acquired lexical categories, release functional categories. If we add to the inflection of verbs that in the same age span phonological constraints gradually disappear and that, probably due to changes in the brain (i.e. synaptogenesis), memory increases so that function words may appear, the converging evidence helps to understand the timing and shape of function words in development.

In sum, linguistic theories provide qualitative explanations for the development of function words. However, these explanations only concern the relative moment or order of development, not the speed or shape of development. That is, the development of
function words is explained in terms of order, not in terms of suddenness. A dynamic systems explanation is a resources dependent explanation. The two sorts of explanation combined are complementary or even overlapping, help to explain the speed of change.

6.3 Non-linear models of development

In this section, I discuss the relationship between several non-linear models. These models help us to untangle two problems. First, there is an account for the shape of change, both continuous and discontinuous. Second, there is a solution for the innateness problem. The first issue on shape is discussed in Changes in language development, the second issue is discussed in the section on Connectionism. The goal is to show that the application of non-linear models reaches further than a discussion on the shape of change, and that we ultimately come to a model of language development that is not build on rules but on relative simple inductive reasoning.

Changes in language development: two brotherly theories

Dynamic systems theory

It is assumed that developmental processes guide the acquisition of language structures. Whether they remain the same over time (age) in the period they are acquired is questionable, since language development is not local, it does not take place within the same age and module (in terms of sorts of linguistic structures that are acquired) domain. Rather, development is a mixture of processes that stretch out over the local mode. Suppose discontinuous changes occur in language development. These changes may, in the course of development, be taken over by a continuous (e.g. learning) model. In that case all energy, attention, motivation, etc. can be spend on other variables and processes.

In the following example, this idea is worked out for child language. Suppose a child is learning to inflect verbs. First, he needs to know what verbs are. A simple rule may help the child to select the right words that are verbs. Since this is not a study on the basic problems of mechanisms, it is taken for granted that a child somehow knows what verbs are. Once he has mastered the inflection rule, he is able to switch his attention to other language variables. Verbs undergo a process of automatism. From that moment on the child may spend time and energy on acquiring other language variables. It is assumed that vocabulary, sentence lengthening, and the inflection rules for verbs (amongst other variables, and other modules like semantics or pragmatics) are precursors of functional categories (Ruhland et al. 1995, Cats & Ruhland, in press). Once verbs (the last
‘acquisitional item’ before function words emerge) set free other functional categories, verb inflection no longer consumes energy, in terms of, for example, attention, effort, memory load, to process the knowledge of inflection. All time and energy may be spend on the development of function words. This development of function words is, so to say, the result of selforganising structures. The interpretation of the language the child hears is switched from inflection rules to rules that address other syntactic slots. The local model of language development is directed to another variable, that is supported by control variables. The developmental model is assimilated into a dynamic systems model.

Observational data are in general very well suited for applying dynamic growth theory, which describes the transient processes of change towards an eventual equilibrium level. Observational studies of the kind reported in Ruhland and van Geert (1998a) will in general not suffice to really prove the existence of a discontinuity in the underlying equilibrium level. Some of the flags are indicative of the occurrence of a cusp catastrophe, but require the experimental manipulation of relevant control variables. In a dynamic growth model the variables are also control variables of each other. The problem with language, however, is that the control variables are not yet known, or are too general (like the length of the utterance), or are local and temporal (like related linguistic rules or properties whose emergence supports that of new principles or rules). The notion of discontinuities in equilibrium level, however, is naturally related to structural theories that view language development as the emergence of rule-governed structures, of parameter setting etc.

One of the advantages of our model is that it is possible to make predictions on the process that is covered by the model. If we change values, for example, the growth parameter of one grower, the result is most likely that not only that specific grower is changing (e.g. the speed of change), but since it is assumed that growers are coupled (i.e. the growers use the same resources), the change of one parameter causes the whole system to change. Of course, growers use only some of the sources at any moment in development. For example, when a child has mastered the phonology of his language, which, for instance, influences the development of a vocabulary, the phonology is internalised, which means that phonology no longer relies on memory. This change of individual growers may also depend on a change of the parameters in the equations. Basically, the value or strength of the parameters in a model may either stay the same over age, change at every step in time, or change due to temporary changes in other variables or resources. Which one is most likely in development? If parameters remain constant over age, this means that resources remain constant over time. This is not likely: memory, for instance, increases gradually over age (Case 1985). If parameters that influence equilibria change constantly over age, we would not find equilibria. Most likely,
therefore, is the assumption that parameters change locally and temporarily. Age and resource specific models, i.e. models with parameters that change due to a change in one or more resources, have yet to be developed.

A quantification of language development uncovers the process of acquisition. Fitting the data with non-linear equations is one step of applying dynamic systems theory to development, but there is another use of the equations. This involves the building of a model. This model (Cats & Ruhland, in press) is a dynamic systems model build of non-linear equations. A non-linear model makes it possible to predict dependent variables in relationship with each other. There is a mutual relationship between growers, since they rely on the same psychological resources like memory, attention, etc. The model describes individual trajectories, which means that situational, temporal and individual variation is part of the model. Furthermore, these models describe a process, not a product, which is a fundamental insight in change as it occurs in development. Basic characteristics are that in these models variables are mutual and non-linearly related. In a mathematical sense, the equations are iterative, that is, the present state of a system is depending on the previous state, and the output of the previous state is the input of the present state. Intriguingly, jumps, fluctuations and regressions are intrinsic to the system. That is, they are not part of the equations that monitor the process in the model.

A theory is needed to link the equations to a process. Any random series of numbers may be fitted with an (non-)linear equation. However, a model with only equations is just a fitting procedure. The prediction are empty. A structural or functional model prescribes, first, the variables in a model, and, second, the relationships between the variables. Furthermore, since there are several variables and parameters in the non-linear equations, a model of connected growers would lead to an enormous amount of the parameters. A reduction of this amount of parameters is needed because an overload of parameters will eventually fit any series of numbers. In other words, every data point (empirically or randomly chosen) is fitted by an individual parameter. This is in fact not a model (i.e. a reduction of reality), but reformulation of reality in terms of parameters.

The construction of a model needs to consider language impairments, e.g. deafness. If these impairments yield different timing or shape patterns of development, and if the dynamic systems model is correct, these patterns must be part of the model, under the assumption that the basic structural patterns do not differ from normal children. However, longitudinal studies with dense time series of language impaired children are scarce, so conclusions are hard to reach, but the main thinking is research on language impaired children could provide extra evidence that a dynamic systems model is correct, i.e. that development depends on other growers. New research might reveal some interesting views on the development of, for example, language delayed or impaired
children. The evidence of normal and impaired children may converge to a model of change, which correctly reflects language development.

Lastly, the model may be so strong that any data set may be explained with the model. A random model with any choice of the variables and their parameters is so strong that there is an overkill of parameters. To avoid this problem, one must also try to model random series. If the model is still capable of producing good fits, the model is simply too strong to be applied to development. In future research (Ruhland, 1998b) building models and testing these models against random time series will elicit the power of these models.

_Catastrophe theory_

The choice for catastrophe theory and its flags as the theory and model for development has its limitations. Although development is best fitted by the cusp, one might object that a Catastrophe model is not a real model for development since it is a local model. A local model explains changes on a very small ‘window’ of time, e.g. age. Being a local model, only temporary changes are explained. Since development takes place over time, a model of language development has to extend beyond the local ‘mode’. Catastrophe theory models phase transitions. The strong point of this theory are the criteria, i.e. the flags, that must show up together. The density of the data need a minimum since three points studies reveal a linear increase (Ruhland, 1998b), but since a rapid increase and multimodality is found using two weekly recordings, catastrophe theory and its flags is applicable to the data in this study.

Elsewhere I argued that both observational studies and experiments (i.e. a structured form of observation) are required to reach the heart of language development (Ruhland, 1991). Catastrophe theory quite clearly shows that this is a correct observation. The stability of a system can only be tested by using experiments. However, the first step in the application of non-linear models was to use longitudinal observational data. Now we have a better view on processes in language development we can start to use the technical form of observation.

The exponent or power of the non-linear equations of a dynamic systems model acts upon the shape of the equation. If the power of an equation is close to 2, the equation shows a form of change that resembles the sudden jump in Catastrophe Theory. This theory is useful for the detection of phase transitions. However, not all (also non-language) growers take the shape of a rapid increase or even discontinuous change. To meet other developmental paths that have to be fitted by a restricted class of equations, dynamic systems theory is complementary to Catastrophe Theory.
The non-linear models that have been discussed so far cannot explain the emergence of language structures, because these models describe change in development. Connectionism shows us how account for the innateness problem.

**Connectionism**

Connectionist models have been applied to language development by Elman et al. (1996). Their book, *Rethinking innateness*, elaborates the question to what extent innateness is needed to explain the acquisition of language (from phonology to syntax). Dynamic systems models are useful to fit developmental paths, as this study shows. However, dynamic models can not be used to study the genesis of behaviour. Recently, the discussion on innateness and new behaviour has been taken up by Elman and others (Elman, 1993, Elman et al., 1996). But what is connectionism? Connectionism is a family of computational principles. Simple Hebbian rules (i.e. learning rule that specify how much the weight of the connection between two units, for example, nodes in a neural network, should be increased or decreased in proportion to the product of their activation; this activation is also closely connected to the input that, for instance, a neural network receives) lead to learning that is not the linear result of those rules. Connectionist models tend to make use of constraint satisfaction, distributed representations, learning on the basis of local information only, etc., but there are plenty of connectionist models that fail to follow one or another of the characteristic principles.

Connectionism can be used to implement any theory. In the discussion of these models, for example, a model of the past tense, it is not the question whether some connectionist model can handle the past tense, but rather, what would a connectionist model that did handle the past tense have to look like. For example, in English people appear to freely generalize the -ed morpheme to words with unfamiliar sounds.

6.3. Rick webbed today.

Likewise the Dutch use the -te/-de morpheme to establish the past tense of a new verb. Standard models tend to have trouble accounting for this phenomenon without the assumption of innateness.

The difference between connectionism and dynamic systems models is that the first aims at explaining the (epi)genesis of behaviour, while the latter are needed to fit growth curves to find out about the shape of change. A second difference is that connectionist models are learning models. This means that such a model receives any input, and on the basis of the input, the model renders some output, whereas dynamic systems models try
to explain the form of change and interactions between variables. Both models may be at their best if we combine them. First, we have an explanation and a description of the process. Discontinuity is demonstrated by Catastrophe theory. It is not a vague theory that pours old concepts from, for example, a Piagetian framework into a formal theory, and it is applied to development using indicators for discontinuous change. Dynamic systems theories describes continuous, but non-linear change. This non-linear change covers the dependence on resources, the growers that are connected, and modelling of humps and bumps as basic elements of development. However, these two models do not explain the origin of development. Second, we have a group of models that can explain the origin of development without the assumption of innate structures. Connectionist models get us out of the discussion on whether or not innateness is needed. The charm of both sorts of models, i.e. process and origin models, is that we do not need a deus ex machina or a homonculus to explain where our knowledge comes from, neither do we need to assume linear change as the basic form of development. What we do need in both cases are the right models that can explain the structural component.

The assumption of linear change and innateness is too simple to capture the richness of a language, and of a process. Selforganising patterns, as a result of the language itself, emerge from processes on a ontogenetic scale. Due to, for example, memory, phonological and rhythmic patterns, and syntactic ordering, the child starts to play with language, and at the same time, he discovers patterns of his language. Non-linear models explain development without the use of prescribed states or structures. This, however, does not mean that we do not need the linguistic theories that I discussed in chapter 2. These theories, which ever one is chosen, give a thorough underpinning of the variables that should be studied in language development, and these theories can explain order and structure in development. Crucial in a design of non-linear modelling is that linguistic entities and psychological processes meet.

6.4 ‘Houston, Tranquillity base here: the Eagle has landed’: final remarks

The non-linear fitting of data and the building of models are necessary to uncover growth and development. Structural models provide the qualitative underpinning of the research domain to which non-linear models were applied to. Of course, non-linear and structural models stress different issues. Furthermore, the flags from catastrophe theory have no definite, conclusive value. They are indicators of discontinuities, i.e they make it plausible that development is discontinuous. The changes found and presented constitute a small part of the human time scale, namely the change from the prefunctional category stage to the functional category stage. It is not possible, and also not desirable, to generalize over
other age periods. In addition, there may be a simple reason why no catastrophic change was found: children have the option of employing different styles to their personal development. This, however, does not follow directly from studies on the acquisition of function words, since there is no compelling reason to believe that two styles of language make a catastrophic change impossible. In fact, any change is possible, since there is no obligation of changing discontinuously, or even non-linearly. The data in this study show the empirical foundation of this individual variability.

The evidence presented in this chapter converges into a framework, where timing and shape of change contribute to the development of syntax. This developmental, mathematical psycholinguistic approach reveals the two important issues in the study of language development: structure and process are like brother and sister. The claim of transitional change (i.e. the flags of catastrophe theory) gets stronger if additional catastrophic flags are found. An experimental setting is needed to find (some of) the other flags, such as critical slowing down. This setting makes it possible to perturb a system. Perturbations test the stability of a system undergoing change. The stability is better if the speed of slowing down after a perturbation is high. Furthermore, hysteresis, which is a strong explanatory flag, requires an experimental setting (see also chapter 3 for an example of hysteresis in an experiment). The discovery of the control parameter(s) makes it possible to manipulate a system. Words per session or the size of working memory might be appropriate candidates. I presented a count of words per session, but the problem is that this variable does not change linearly. A rapid or stepwise increase in the control variable (e.g. in Peter’s case) is problematic: this sudden increase makes it hard to prove that the change in a dependent variable is caused by a small change in the independent (i.e. control) variable. More catastrophe flags are needed, especially those that call for a manipulation of one or more control variables. These control variables have to be manipulated in a linearly way to find, for instance, divergence. Further research, with an experimental setting, is needed to prove the existence of other flags.

Methodologically, this study could be extended to other elementary issues of development. High density recordings (e.g. weekly or even daily ones) might prove that fluctuations and variation are characteristic for daily or weekly rhythms. In a pilot study, we collected daily recordings. The analyses of these recordings revealed that two weekly fluctuations can also be found on a daily scale, but these fluctuations appear to be less extreme (i.e. a smaller amplitude) and with a different frequency. In other words, there seems to be stability on a day by day basis (De Goede & Ruhland, 1998). De Weert and van Geert (1997) demonstrate that this daily and weekly variability also exists in social-emotional development. A data collection needs the correct time index. The lack of recordings in between two weekly recordings may be problematic, since there may be
fluctuations between the sessions. However, daily recordings have two objections. First, there are practical objections. A daily recording schedule is labourious. Second, time series require a certain density to uncover developmental paths. Traditionally, this density has been treated in a rather simple way, namely by using three data points with an interval of several months. Three points, e.g. one occurring two months before the transition, one in the transition period and the third one two months after the transition, make the development of a variable look more or less linear (Ruhland, 1998b). Recording every two weeks seemed to cover the development of syntax most adequately. The present method is meant as a heuristic exploration of the efficacy of the method. Empirical evidence, however, is not yet available. In our model (Cats & Ruhland, in press) an increase of the number of recordings beyond a certain frequency did not lead to a better fit, i.e. there is no improvement with simulations using a one week interval. That is, the simulation showed that with the use of random numbers and weekly intervals there is no significant increase in the explanation of the paths found (Cats & Ruhland, in press).

The length of the recording was one hour (cf. Nelson, 1973). The question is: does the increase of recording time yield other insights? The answer is unclear. One reasoning would be that an increase of recording time probably will only lead to quantitative differences. The absolute numbers of the use of a variable changes during the increased recording time, not the overall qualitative shape of change. Of course, the recording time in the sessions should have a minimum. Since half hour sessions (used as an index of anomalous variance) show considerable differences in at least some of the children, recordings shorter than an hour are dubious. Research using longer recording sessions still awaits the rigours of (statistical) testing. The importance of the length of recording is at its height in a transition period, i.e. when there is no stable equilibrium. We are now performing a day by day study to find out more about the variability on the day level. Daily variability may be sensitive to the moment of the day (e.g. morning vs. afternoon). Smaller scale analyses, on a day and week level, are now interesting, since the general and individual patterns are known.

The choice of function words leads to the question whether function words change qualitatively during development. This is an important question in a study on development and change. There is some evidence that determinative pronouns like this and that change during development: children use these words with pointing in the early stages of development. However, within the age range of the sudden change (in the third year of life), the local system of functional categories and function words is assumed to remain constant. Evidence that they do not change is that function words have a constant place in the utterances of a child. Furthermore, there is a constancy in the input: function
words have a constant place in the parental sentences. The frequency of function words of the parents, and their use of function words is high. In short, there is no reason to assume that these words qualitatively. The study of quantitative language development must, in order to prevent such qualitative change to happen, rely on linguistic studies that reveal through experiments whether qualitative change is taking place.

The end

One of the biggest achievements of mankind in this century was the first man of the moon. It was more than a step forward, even for mankind. The techniques and procedures, the use of computers, and the wish to go to the natural satellite that circles the earth, led to the first footprints on the moon. In a similar fashion, but on a much smaller scale, this study seized the opportunity, within the field of human development, of attacking the problem of how to analyse individual paths of development. I think it is fair to say that this exploration of new worlds in language development research has been successful in terms of the landing of a new method on child language. In comparable terms of the landing on the moon, this study revealed that linear and unimodal analyses of development, or structural linguistic analyses of language development alone, are methods that are too narrow, too restricted to describe and explain all aspects of language development. If we apply these new methods to language development, we will come up with new insights, and with panoramic views, just like the astronauts of Apollo 11 who successfully landed on the moon and went live on television in July 1969. I quote: “We have a beautiful view of the earth here, it is absolutely fantastic.” It is the difference between Apollo 11 and 13 (which was the Apollo mission that got into big problems after one of the oxygen tanks had been blown up), it is the difference between a successful landing and a near-catastrophe. After all, it’s numbers that make the difference.

Voyages to other planets and other lunar systems are still undertaken to seek new life forms and to boldly go where no man has ever gone before. For example, Mars has been visited in summer 1997. In psychology, researchers have boldly gone where no researcher has gone before with introduction of new methods for the study of development of linguistic structures. This view is brought into focus by non-linear models. The reasoning is build on the combination of disciplines, i.e. the use of complementary approaches. The data collection consists of intensive recordings of child language over a long period. Frequency counts were used, and the results support non-linear, continuous development. I found complementary evidence for a reorganisation in language development, but I do not intend to claim that this is the end of non-linear
analyses. This study is the start of more interdisciplinary studies using new techniques like non-linear models and computer assisted analysis. Especially the link between the origin and shape of behaviour, structural models, quantitative analyses, and brain structures (as the origin of behaviour) need more study. Furthermore, the question is whether other language variables than function words undergo the same change. The acquisition of a rule like verb finiteness (Wijnen, 1996), for example, is a gradual process. Future research should elucidate rapid or transitional change in other variables or on other linguistic levels (e.g. on a phonological or semantic level). Such evidence has been stated verbally by Fikkert (1992), who found a more or less sudden change in the mastering of stress patterns. The question is whether this change is also sudden in terms of a growth model or in a catastrophe model. The answer to this question and other questions on changes in language development lies ahead, and it is a fascinating and promising challenge for non-linear models.

This study is one out of a growing body of studies that hopefully mark a changing tide. Not only because it has an interdisciplinary character using linguistics and psychology, but also because it uses new techniques of non-linear modelling, and dense time series to elicit the shape of change.