Introduction for the special issue/section on developmental transitions

Developmental Transitions: So what's new?

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ABSTRACT

Structural approaches to development, such as Piaget's stage theory, have proved to be problematic in dealing with developmental transitions. More promising in this respect are models of qualitative change that address macroscopical phase shifts in non-linear dynamical systems that arise from quantitative changes at the microscopical level. In this introductory paper, we attempt to clarify the meanings of some of the core terms used in these models so as to set the scene for the subsequent contributions. We stress the relevance of recent advances in catastrophe theory for detecting developmental transitions and suggest that the concept of self-organisation as formulated in irreversible thermodynamics provides a framework for explaining them. As yet, there is a lack of convincing evidence that transitions of interest to developmental psychologists comply with principles of self-organisation that have become well-established for time-evolving systems in other disciplines such as chemistry and biology. Demonstrations of self-organisation in psychologically-relevant simulation models are a first step in attaining such evidence. In this special issue, we concentrate primarily on a common approach to the detection of transitions across a number of domains of development. However, in doing so illustrations are given of the ways in which the hypothesis of self-organisation can be used to account for the mechanisms of developmental transitions.
Introduction

This special issue is concerned with demonstrating how the neglected issue of developmental transitions can be re-vitalised by new methods derived from non-linear dynamical systems theory (Jackson, 1989). Each of the contributions draws on this general theoretical framework in an attempt to integrate it with research traditions in a specific domain of study - a challenge in itself. As a consequence, we expect a three-fold benefit: a better understanding of developmental transitions, new tools for their investigation, and ultimately a general theory of developmental transitions - the latter being the most daunting challenge of all. In this issue, we restrict ourselves primarily to a necessary first step in fulfilling these expectations, namely, the detection of developmental transitions by means of guidelines provided by the principles of non-linear dynamical systems theory.

The terminology used to label this theory is in need of some unpacking if we are to understand its quintessence. Dynamics is the study of the ways in which systems change over time in seeking new optimal states of stability (Morrison, 1991). As such, dynamics does not emphasize mechanical properties like mass, length and stiffness, but rather provides an abstract description of the temporal evolution (or motion) of a system's collective variable which captures its overall behaviour. A system can be either linear or non-linear. Linearity refers to simple proportionality. Thus, for example, if x is proportional to y, then x is a linear function of y. If y is increased by a factor two, then x increases by the same amount, and a plot of x against y takes on a straight line. In such simple linear systems (or equations), there is then a one-to-one mapping between input (y) and output (x). Linear additive equations like these have been of demonstrable value in solving some scientific problems (e.g. in modelling the orbits of planets) and form the basis for most of the statistical tests used by psychologists.

The equations of linear dynamics are sometimes incapable of describing what happens in more complex, natural systems. In these systems, behaviour does not flow smoothly within a certain range of values and make proportional adjustments to external disturbances so as to stay within that range. Instead they reveal non-linearities or abrupt changes to a qualitatively different regime of behaviour when some critical value of the range is exceeded. In order to capture such changes, equations are needed with one or more non-linear terms which may
consist of a variable raised to a power other than zero or one, the product of two or more variables or both. Unlike linear equations, they often require not one solution but a system of equations through which data is fed back into the system as a process of iteration. A well-known example of a non-linear equation based on this process is the logistic difference equation which has recently been applied to modelling both quantitative and qualitative change in cognitive development (van Geert, 1994).

What is interesting about a discontinuous shift in the collective variable of a non-linear system is that it is driven by a linear change in an existing (control) parameter without the addition of a new variable. Subsequent to changing in this way, non-linear systems tend to converge into one of four attractors distinguished by different periodicities in behaviour (see Wimmers, Savelbergh, Beek & Hopkins, this issue). Once attracted, and given time, the system again becomes relatively autonomous from environmental fluctuations that do not exceed a critical threshold. In short, non-linear dynamical systems are ones that display punctuated equilibrium: periods of structural stability interrupted by a sudden change in organization resulting in a qualitatively different mode of stable behaviour. Such change is signalled by the presence of certain phenomena in the system’s collective variable which have been well-documented by non-linear dynamical systems theory. The question then is whether these "fingerprints" of qualitative change can be used to detect transitions of interest to developmental psychologists.

Detection of developmental transitions

In general terms, a developmental transition can be defined as a change from one stable mode to another in a well-defined developing system during a restricted period of development. What is important in this definition is that the time taken to change, or the transitional period (Connell & Furman, 1984), should be shorter than the time spent in the modes prior or subsequent to the transition. As we shall see, this definition can be more sharply operationalized with the aid of criteria that originated in non-linear dynamics.

It is perhaps the difficulty of defining a transition in empirically useful ways that accounts for its wavering popularity in developmental psychology. In research associated with
the Piagetian theory of stages, its importance as a concept has been in decline since the end of the seventies, and in particular with the advent of Brainerd's (1978) trenchant criticism of stage theory. Brainerd's main point was that if we cannot distinguish between continuous and discontinuous models of development (e.g. by means of empirical criteria subjected to statistical tests), then the simpler (i.e. linear) continuous interpretations should be preferred. This conclusion is at odds with Piagetian theory which, strictly speaking, requires evidence for discontinuity and the domain generality of stages. Brainerd showed that Piaget's criteria in support of this evidence were insufficient.

Recently, that is in the nineties, the concept of transition has undergone a revival due in large part to refinements of models in non-linear dynamical systems theory. In addition to providing a better mathematical underpinning of transition processes, they have highlighted the ubiquity of phase shifts in chemical and biological processes such as those pertaining to embryology. A phase shift, which can be seen as a transition in real-time, involves a compression of a system's degrees-of-freedom around critical points where change takes place spontaneously. Consequently, as Kelso (1990) has pointed out, observations at such 'windows of opportunity' enable one to identify order parameters for different patterns of behaviour and to turn description into prediction. The conceptual baggage associated with phase shifts has been applied with noticeable success to transitions in motor development (e.g. Thelen & Ulrich, 1991). Success in detecting such transitions during a period in which motor abilities show a rapid development requires the employment of a longitudinal design with very frequent measurements as has also been demonstrated for physical growth (Lampl, Veldhuis & Johnson, 1992). We should, therefore, confidently expect the presence of such saltatory change in cognitive development given appropriate intervals between measurements.

It is important to recognize that transitions can be local or domain-specific, and that they do not necessarily imply domain-general stages. While research on domain-specific transitions never completely disappeared, and there are now criteria for identifying them, finding empirical markers for domain-general stages remains problematic. Although Brainerd's (1978) telling criticism cannot be completely rejected, we can reject it in part. It is now possible, though still difficult, to distinguish between discontinuous and continuous models on the basis of empirical data in specific domains.
How then does the detection of this distinction take place? In our view, the detection of transitions can be based on new mathematical insights gained into discontinuous processes from different branches of non-linear dynamical systems theory such as catastrophe theory (Thom, 1975), bifurcation theory, irreversible thermodynamics (Nicolis & Prigogine, 1977) and synergetics (Haken, 1977). While some of these theories are purely mathematical (bifurcation theory) and others originated to answer questions in chemistry (irreversible thermodynamics), physics (synergetics) and biology (catastrophe theory), they all share some common properties such as symmetry-breaking in far-from-equilibrium conditions. Of special interest here are irreversible thermodynamics, synergetics and catastrophe theory. The first two are relevant for the explanation of transitions and catastrophe theory for the detection problem.

In the subsequent contribution (Hartelman, van der Maas & Molenaar), catastrophe theory is presented in some detail. Its application in the social sciences has been geared to the problems of detection and modelling. Detection is based on the use of so-called catastrophe flags or "fingerprints" which concern distinct behavioural phenomena that become manifest prior to and during a transition in a non-linear system. A simple necessary, but not sufficient, flag is bimodality. Behavioural indications of a system in transition show bimodal (or multimodal) distributions. If this flag is apparent, together with some of the others, then a catastrophe or transition has been detected. The next step in using catastrophe theory involves modelling in that it specifies a set of elementary catastrophes, each being a kind of standard model for a discontinuous process which can be fitted to the data. The central element of catastrophe theory is the classification theorem which states that all discontinuous changes can be modelled by seven topological forms. The cusp model is the simplest one that contains a bifurcation mechanism and it will be the focus attention in the next contribution.

In mathematical terms, elementary catastrophes are points where the first two derivatives of the potential function governing the underlying dynamic approach zero. At these points of instability, new equilibria are formed and jumps between them can occur. The classification theorem locates such points in one of several elementary catastrophes, each having a distinctive topological form. The appropriate topology depends on the number of independent or control parameters. The cusp model requires one dependent and two independent parame-
It has been used in many applications, but the one that is most illustrative for our needs is the cusp model of conservation acquisition proposed by van der Maas and Molenaar (1992). We briefly describe its main features here.

In the study of conservation acquisition, four groups of subjects can be distinguished across a number of relevant models. The first group fails to understand the task and will show some form of guessing. The second group understands the task but is mislead by some perceptual cue. In the case of conservation of liquids, this cue is the height of the liquid column. The third is the transitional group, and the fourth correctly responds to the conservation task on the basis of compensation, reversibility or both. It is common to most models of conservation acquisition to posit a cognitive conflict in the transition phase. Thus, the transitional subject is depicted as facing two conflicting strategies or argumentations which brings him 'far-from equilibrium', to put it in the language of non-linear dynamics.

It is difficult to give a precise idea of what constitute such conflicting forces. Generally speaking, they can be couched in terms of a perceptual and a cognitive factor. The perceptual factor consists of the misleadingless of the conservation task as well as the subject's sensitivity to perceptual cues (referred to as field dependency). The cognitive factor involves knowledge of conservation rules, short-term memory and the presence of back-up strategies such as counting. We treated these factors as control or independent parameters. The dependent or order parameter is, of course, conservation performance on some task. The cusp model is shown in Figure 1.

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Figure 1 about here
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This three-dimensional model can be compared with a regression model having two independent or predictor variables. The cusp sheet, which is folded in a characteristic manner, represents the expected values of the behavioural variables (in percentages of correct responses) for various values of the independent variables. The values of the independent variables increase from the back to the front of the figure. When both independent variables have high values, then more than one value for the behavioural variable can be realised - an impossibility in standard linear and non-linear regression models. In the case of the cusp,
there are two stable modes of behaviour with an inaccessible mode in between them. In other areas of the control surface (defined by the independent variables) only one mode is possible.

The cusp model provides a simple (and mathematical) means of distinguishing between the four groups of subjects in the acquisition of conservation. The first group, the guessers, have low values for both independent variables. They are both insensitive to the misleading cues and unable to apply the conservation rules since they do not understand the task at all. As the model shows, they are expected to score at chance level. Interestingly, the second group, the non-conservers, score below chance level: they have a high value for the perceptual factor and a low one for the cognitive factor. The conservers, in contrast, have low and high values for the perceptual and cognitive factors respectively. For these three groups, only one mode of behaviour is possible. The fourth group, the transitional subjects, have high values for both control parameters reflecting the effects of two concurring modes of behaviour.

Figure 1 also illustrates a typical time path. While all kinds of paths are possible when the control parameters change, the path of interest is that from non-conserver to conserver (path A). The cusp model predicts a sudden jump from the non-conserver to the conserver mode at the moment that the so-called bifurcation set is passed.

Given that Hartelman et al. discuss this model in more detail, we use it here to explain what is meant by the detection and modelling of catastrophes. The modelling aspect stems from the tradition of Zeeman (1976) who developed many different catastrophe models. It is his type of application that has been the butt of some criticism (Zahler & Sussman, 1977). The problem is that, as with multivariate regression models, we need a fit to data to test the model. At the time Zeeman proposed his models it was not possible to statistically fit such models to data. Since then, Cobb & Zacks, 1985 has devised a statistical catastrophe theory based on a general set of stochastic differential equations. In doing so, he tempered Thom's (1975) fully deterministic theory with the addition of an important element of stochasticity. Technically, this involves transforming a cusp catastrophe function into a probability density function. This is an important addition in that it is becoming increasingly recognized that complex non-linear systems display random behaviour without any external influences, particularly in the neighbourhood of transitions (see Beek, Hopkins & Molenaar, 1993). Moreover, stochasticity (chance) and determinism (necessity) are now both acknowledged as
being inadmissible ingredients of any theory of developmental change (Stent, 1981). Cobb's contribution to catastrophe theory can be improved still further as will be shown by Hartelman et al.

Catastrophe detection (based on the work of Gilmore, 1981) focuses on specific behavioural phenomena that occur in the cusp. Three of these phenomena or flags have been mentioned already: the sudden jump, multi- or bimodality, and inaccessibility. The fourth flag is divergence which becomes evident if we follow the path (B) from back of Figure 1 to the front. Along this path, behaviour can transverse either the upper or lower sheet. Thus, for example, when a guesser is trained on both the perceptual and cognitive factors, there will be an increase or decrease in his score, but it will not remain at chance level. Hysteresis is the fifth flag, which should accompany regressions in development. Put simply, it means that a much larger change in the control parameter is required to re-establish the old state. An example is that ice changes into water at 0°C, but that water freezes at -4°C if there are no disturbances. It is still an open question as to whether hysteresis can be detected in conservation acquisition. In using counter suggestion, Piaget was in sense testing for hysteresis in that with this method he probed the stability of the present state and for the presence of a new or old one.

There are three other flags, which according to Gilmore (1981), can also occur before a transition. Anomalous variance, or critical fluctuations in Haken's (1977) synergetics, refers to a marked increase in behavioural variability or more technically to fluctuations around the mean state of the collective variable. In classical physics, such fluctuations were only accorded a minor role in the process of change or simply treated as unwanted noise. However, under the aegis of non-linear dynamics, they are now regarded as stochastic forces which are crucial in driving the system away from its current macroscopic state. Divergence of linear response and critical slowing down become apparent when perturbations are added to the process of transition. Simply stated, the former refers to large fluctuations near the transition and the latter to the increased time the process needs to re-equilibrate. Both critical fluctuations and critical slowing down are cardinal properties of self-organizing systems - a topic we return to in the next section. The flags, and their operationalizations in developmental psychology including whether they occur before or during a transition, are discussed in greater detail by
Catastrophe detection involves a tripartite sequential process: the translation of the flags to appropriate experimental designs, experimentation itself, and data analysis derived from valid statistical models of these flags. In the case of the phase transition between liquid and ice, this is a relatively simple process. However, it becomes inordinately more difficult to flag developmental transitions in living systems. Furthermore, Gilmore (1981) warned that the detection of just one flag is not enough - they should occur in concert. There are also important differences in the ease with which each of the flags can be applied. Thus, for example, bimodality requires only large cross-sectional samples of test scores, whereas hysteresis has already proved to be troublesome in applying it to perceptual multistability tasks in adults such as the Necker cube illusion (Ta'eed, Ta'eed, & Wright, 1988).

The importance of each of the flags depends largely on the alternative models for the transitional process in question. If the alternative model is a simple linear model, bimodality and the sudden jump are already sufficient to distinguish between this alternative model and the transition model based on catastrophe theory. More difficult are alternative models that include continuous accelerations, like in some non-linear regression models. Such models in some cases also predict bimodality. Moreover, in practice it is not possible to distinguish between sudden jumps and continuous accelerations in longitudinal psychological experiments in which we measure each month or week. We might try to measure at a higher frequency but whether a jump is really instantaneous is difficult to decide. It is better to take a look at the other flags. Continuous acceleration models do not mostly predict anomalous variance, critical slowing down and divergence of linear response. These flags are then sufficient criteria for the detection of the transition. The most convincing flags, however, are divergence and hysteresis which are not predicted in any alternative developmental models.

Finally, the flags are also useful to operationalize more sharply the conceptual definition of the transition. It is a change in behavior that must be sudden, from one mode to another, jumping across impossible modes, at a level depending on the direction of change, critically dependent on initial conditions, inducing increased behavioral variance near the jump as well as large oscillations and a delayed recovery of equilibrium behaviour after perturbation.

Before introducing the other three contributions to this special issue in terms of their...
domains of application, we will try to place their endeavours in a broader context. Non-linear dynamics, of which catastrophe theory is one part, has more to offer than just the detection and modelling of elementary catastrophes and related entities. It also suggests an explanation or general mechanism for developmental transitions based on the notion of self-organization in complex, non-linear dynamical systems.

**Explanation of developmental transitions**

Transitions and their emergent properties belong to the most puzzling phenomena in developmental psychology. They continue to exert a challenging fascination on developmental psychologists and other students of human behaviour, some of whom have used enigmatic labels to convey the difficult of arriving at a proper solution. Thus, Boden (1990) speaks of 'impossibilist' creativity, Fodor (1980) of the learning paradox, Penrose (1989) of non-computational insights, and Popper (1959) of non-logical new ideas. In Fodor's terms, how can a system of some complexity (capable of propositional logic) turn itself into a more powerful system (capable of predicate logic)? A variety of solutions have been offered in different fields. As an illustration of the diversity, consider the following proposals: equilibriation (Piaget, 1978), self-modification (Klahr, 1989), reflective abstraction (Campbell & Bickhard, 1986), representational redescription (Karmiloff-Smith, 1992), reorganization (Powers, 1973), backpropogation (McClelland & Jenkins, 1991), natural selection (Edelman, 1987) and genetic structures (Fodor, 1980). Clearly, little consensus has been reached on the mechanisms of developmental transitions.

Non-linear dynamical systems theory holds an important theoretical promise, one that can provide a new solution for the occurrence of developmental transitions. This solution or hypothesis maintains that self-organization is an important mechanism of developmental transitions. Self-organization is a process whereby an open system acquires a new state without specific interference from the outside. Its signal feature is that with a continuous change in one (or more) control parameters new states may emerge spontaneously purely as a function of the dynamics of (non-linear) interactions between the system's components. There is no ordering imposed from the external environment and no homunculus issuing commands
from within. The control parameter does not specifically prescribe a new state, but rather creates the necessary conditions for acquiring it such as multistable states and critical fluctuations. The notion of self-organization is not new to psychology having been, for example, a central tenet in Köhler's (1940) theory of perception in which perception was depicted as an autonomous process of order creation and stimuli as boundary conditions modifying the activity of the brain. The difference between Köhler and now is that we have the tools for flagging the presence of self-organization and a more principled explanation for how it operates.

One of the origins for an explanatory framework germane to self-organization can be found in the work of Prigogine (Nicolis & Prigogine, 1977) which is concerned with irreversible changes in both pre-biotic and living systems. These changes, or non-equilibrium phase transitions, begin with a stable system which then becomes an unstable system (i.e. dissipative structure) far-from-equilibrium, and finally is stabilized in a more complex equilibrium. Once re-stabilized, the system cannot return to its initial state - hence the term irreversible. Such transitions have been demonstrated in a variety of physical, chemical and biological processes, the prototypical example being the Beluzhov-Zabotinsky (BZ) reaction which displays temporal or spatial self-organization depending on whether or not the reactors are stirred (Winifree, 1980). An important characteristic of such self-organizing systems is, that when new ordered regimes arise beyond a non-equilibrium transition, the complexity or level of organization of the system has increased.

According to Nicolis and Prigogine (1977; see also Prigogine & Stengers, 1984), self-organizing processes lie at the root of a very fundamental question concerning the possibility of life. Their argumentation on this point is very relevant to discussions on the 'impossibility' of qualitative development. In their historical overview of natural science, Prigogine and Stengers (1984) end with a deliberation on the troublesome Second Law of Thermodynamics - troublesome in that at first sight it, in tandem with the First Law, seems to forbid any process of self-organization. According to this Law, there is a universal trend towards a state of disorder called the thermodynamical equilibrium through irreversible increases in positive entropy (i.e. internally generated disorder). Locally, order can increase through the importation of external energy, but only as a short-lived fluctuation. As a result, systems will
loose stability and ultimately disintegrate, instead of developing to more complex forms of organization. However, in both evolution and development, complexity and order clearly increase - not only to a very high level, but also for a significant amount of time. How can one reconcile these facts with the disordering dictates of the Second Law? Briefly, dissipative or far-from-equilibrium systems preserve a state of minimal entropy production through transferring positive entropy to the immediate surroundings at a faster rate than they actually produce it. In doing so, new equilibrium points or thermodynamic paths can be formed which, if strong enough, can wrest control of the system's dynamics from maximum entropy production. In this way, the system evolves towards states of increasingly greater complexity in local defiance of the Second Law (or perhaps more aptly as a by-product of the law's dissipative processes). The work of Prigogine and many others can be seen as an enterprise concerned with showing that self-organization is consistent with the Second Law, and yet leads to order instead of disorder. Self-organization explained in this way demonstrates why and how complexity can increase, and how development is possible without introducing some mystical entity corresponding to an 'élan vital'(under which we would include such modern notions as schemes, representations and programmes).

If self-organization is a valid explanation for the creation of life as Prigogine holds, then it might also explain qualitative change in cognitive development. If we think of the cognitive system as complex, dynamical and non-linear (at least in terms of its neural mechanisms; see Molenaar, 1986), then spontaneous reorganizations of the conceptual space (Boden's terminology), progressive re-equilibration (Piaget) or derivations of more powerful logics from simpler systems (Fodor) are possible - if by that we mean consistent with the laws of physics. This does not mean that we have a proper understanding about the specific processes of self-organization in the brain that can really explain qualitative change. Until now, the hypothesis of self-organization as a mechanism of developmental transitions is based on metaphorical reasoning - at least in developmental psychology (Robertson, Cohen & Mayer-Kness, 1993; van der Maas, 1995). In developmental biology, which is concerned with less complex systems, it has achieved a quite different status in that it is being subjected to rigorous mathematical modelling (e.g. Kauffman, 1993). For us though, there are two important reasons why we should approach the hypothesis with caution.
Firstly, it corresponds in some aspects with a number of earlier proposals, none of which provided particularly illuminating insights into the mechanisms of self-organization. Nevertheless, we are convinced that self-organization as presented here has new and practical advantages over and above the earlier proposals, but that these remain to be demonstrated. Strictly speaking, the only, but not unimportant, advantage of the new hypothesis is that it focuses our attention on a concrete challenge, namely, how can we apply the new models, techniques and mathematics from the rapidly growing field of non-linear dynamics to our little biotope, developmental psychology?

Secondly, this question turns out to be a difficult one to answer. Within non-linear dynamical systems theory, self-organization is not fully understood, at least not mathematically. It appears to occur in various physical and biological preparations, and can be simulated on the computer by cellular automata. Observing self-organization in these cases is based on a detailed description of the process in question. Given that exemplary chemical processes, such as the BZ reaction, can be almost completely observed and controlled, the claim that they comply with the principles of self-organization is quite convincing. But how can we prove the claim in systems that cannot be controlled and are only observed in a very small subset of their behavioural state spaces? Currently, we do not have a complete answer to this question. However, it is generally accepted that self-organizing processes are characterized by the co-occurrence of other non-linear phenomena such as chaos, criticality, periodic behaviour and phase shifts.

At this point in time, the best way to uncover evidence of self-organization is through the simulation of requisite processes by means of computer models, particularly those dealing with neural networks. The idea is that we first need a demonstration of self-organization in a simulation model that is psychologically relevant to be assured that self-organization may indeed be a mechanism that generates developmental transitions. Such models must not only be psychologically relevant, but also biologically plausible, show phase shifts in behaviour and learn to solve tasks without any apriori instructions. In biology, convincing demonstrations are available (Boerlijst & Hogeweg, 1991), but in developmental psychology we are still awaiting them (Raijmakers & Molenaar, 1993).

This special issue is not devoted to the provision of such demonstrations and hence, it is
not our intention to provide a conclusive confirmation of self-organization as a mechanism for developmental transitions. Inspired by this hypothesis, however, our less ambitious goal is to find evidence for the transitions as they occur in a number of domains of development.

**Domains of development**

The three remaining contributions attempt to investigate empirically domain-specific developmental transitions using the methods of catastrophe theory and associated theories as well as methods that have evolved in each domain. All these investigations, which started in 1992 or slightly later, have just been completed. Data extraction and analysis are derived from a variety of cross-sectional and intensive longitudinal designs. The available results, and especially the integration of dynamical concepts with traditional methods, are sufficiently innovative to justify reporting.

All three projects concern children in the first two of life. In this period, many functions develop rapidly, which is an advantage, but they are also complex and sometimes difficult to measure exactly. Developmental changes in the age groups under consideration take place in many areas. Here we focus on transitions in the development of language (from one to two word sentences), the development of the motor system (from reaching to reaching and grasping), and on regression phenomena associated with a series of developmental transitions.

In the first of these empirical contributions (Ruhland & van Geert), a well-known transition in language development is re-investigated from a dynamical perspective. Brown (1973), among others, reported a large and rapid increase in the number of closed class or function words used. This increase was built up from more specific acquisitions of word types and ways of combining words in sentences. Data were extracted from data bases such CHILDLES and from Dutch longitudinal studies. By counting the frequencies of word types at intervals of approximately 2 weeks, various behaviours were operationalized and measured. The development of closed words resembles the cubic logistic growth (van Geert, 1994) in conforming to a steep, step-like increase. Finding such a fit complies with a sudden jump. The only other flag to be detected is multimodality. Reasons for the lack of evidence of the other flags in this domain of development are discussed.
The next contribution (Wimmers et al.) concerns transitions in the development of prehension. This project draws its general theoretical inspiration from synergetics and its more domain-specific concepts from an integration of Bernstein's (1967) ideas on movement coordination and Gibson's (1979) ecological approach to perception. Variousy termed the natural-physical approach to perception and action, it has proved to be an important source of ideas and data for transitions in both real time and developmental time which go beyond the immediate boundaries of movement coordination. Infants were studied in a laboratory setting on a weekly basis from 8 to 24 weeks of age. The transition of interest is that of reaching without grasping to reaching terminating with grasping. Preliminary evidence is given for the presence of four flags in this transition: the sudden jump, bimodality, inaccessibility, and critical slowing down. In testing for the presence of a sudden jump, data were fitted to one of van Geert's (1994) models.

The final contribution (de Weerth & van Geert) does not focus on a specific transition, but more on the consequences of transitions in early development for everyday behaviour. The disequilibrium state before a jump to a new stable state is expected to have a negative influence on a range of interrelated behaviours such as crying, smiling, body contact etc. These transition-related expressions of negative behaviours are called regression states. Direct home observations were carried out once a week on four mother-infant pairs from birth up to the age of 15 months. Multiple sources of data were used to examine the nature of the regression states associated with a number of transitions in early development.

In conclusion, we hope that the four contributions to this special issue as well as Fischer's concluding comments, will demonstrate collectively new possibilities for the further promotion of research on developmental transitions. In our opinion, the strict criteria of catastrophe theory and related theories will help us in the detection and, in the end, the explanation of developmental transitions.
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Figure legend

Figure 1: A cusp model of conservation acquisition. The cusp surface represents the conservation test scores for different values of the independent cognitive and perceptual variables. In the area of transition, two stable modes of behaviour are possible (e.g. one with high and the other with low scores).
behavior surface of conservation

residual group

p=0.5

nonconservers

p=0

transitional group

p=1

sudden jump

m

path B

p = conservation test score
m = perceptual factor
n = cognitive factor

p=0

p=0.5

p=1

neutrality, m=0 and n=0

bifurcation set = area of transition

m=0 and n=0

path A

p = conservation test score
m = perceptual factor
n = cognitive factor