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*edenda curat*
C. H. van Schooneveld
*Indiana University*

# Temporal Variables in Speech

## Studies in Honour of Frieda Goldman-Eisler

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WOLFGANG WILDGEN

# Models of verbal planning in the theory of catastrophes[1]

If one considers formal models in linguistics, one realizes that in spite of many controversies they are all founded on the formalism of elementary algebra and predicate calculus. The reason is that these models are fundamentally classificatory and static. Their view of language is one of levels, hierarchies, structures, sets of rules, mappings from one set of structures into another set of structures etc. Using the new formal language of catastrophe theory, there is the possibility of emerging from this restrictive paradigm – to see language in the light of its dynamics and creativity and in connection with other sorts of dynamics such as the dynamics of the external world with which we are confronted and the dynamics of our cognitive organization of experience and knowledge. The whole field of language research can thus be reorganized under dynamic aspects; it follows that psycholinguistic theory and especially theories of language production and language understanding are privileged domains for the application of dynamic models.

## *1. Some remarks on the language of catastrophe theory*

I should first like to make some introductory remarks giving a rough idea of the theoretical language of Thom's theories, which underlie the application of his mathematical concepts to the human sciences. Catastrophe theory is a section of differential topology, i.e. it relies heavily on differential equations and their properties on one hand and on topological equivalences on the other hand. Key terms are: structural stability, dynamic fields, flows in dynamic fields, stable attractors and sudden jumps of dynamics from the field of one attractor to a dominant neighbouring field (= catastrophe). The central idea is that a set of fundamental equations of the internal variables x, y, ... such as $V = x^2$, $V = x^3$, $V = x^4$, ..., $V = x^2y$, etc. allows a limited set of *unfoldings* i.e. of deformations by external variables (u, v, w, t, ...). Starting from the notion of topological equivalence of such unfoldings, Thom was able to formulate the classification theorem of elementary catastrophes, which was proved by Mather in 1969. Table 1 summarizes the technical result (Zeeman, 1977: 66).

Table 1

| k: number of external variables | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| c: number of elementary catastrophes found (types) | 1 | 2 | 5 | 7 | 11 | (∞) |

Intuitively this theorem states that one can only obtain a finite number of stable unfoldings if the space of external variables (= control variables) has less than six relevant dimensions. The elementary catastrophes can be interpreted as basic types of dynamic processes achieving stability.

## *2. A short outline of a dynamic model of semantics*

### 2.1. A set of basic postulates

*Postulate* 1: The relation between linguistic sign and extralinguistic referent is not arbitrary, i.e. it is not simply a consequence of social conventions (cf. Lewis, 1969). A mapping from the natural morphology of objects and events into the morphology of language forms can be established. The invariants of this mapping from experience to language can be described within the framework of catastrophe theory.

In this outline we shall consider only the mapping between kernel sentences (clauses with one finite verb and without modifiers) and the states, events and actions they describe.

*Postulate* 2: Language is considered as an intermediate level of organization between the highly complex world we perceive and the multidimensional activities of the brain, which process perceptual information and store them in memory. The language level accomplishes a drastic reduction of the complexity in these two domains and a filtering of a small set of dominant traits. A model can be set up for this filtering of dominant traits using the concept of catastrophe which was introduced by René Thom.

A *catastrophe* in Thom's usage of the term is a very fast and sudden change in a continuous field of attracting (repelling) forces. While the underlying change effected by the external (control) parameters is smooth, the observable changes of the system are discontinuous. These discontinuous features are selected as the defining characteristics of the process.

*Postulate* 3: Basic semantic "gestalts" (kernel structures which are not decomposable in a simple way because of the complex dependencies between parts) can be derived from dynamic patterns with a maximum of four control parameters. They are called *semantic archetypes.*

The restriction to dynamic patterns which have a maximum of four control parameters is plausible but not absolutely decisive. Two considerations are important:

a) In the theory of elementary catastrophes, whose domain is determined by Thom's classification theorem (cf. Table 1), the number of control parameters c is not greater than five (if one postulates that the set of semantic archetypes is finite). The unfolding with five control parameters, called "wigwam", does not contain additional structural information.

b) The development of the brain can be understood as an internal reconstruction of the environmental field which the organism tries to control. It is plausible that the cerebral analogue of the four-dimensional environment is also four-dimensional (in an abstract sense, however).

These postulates give only a rough summary of a semantic theory based on recent developments in the mathematics of dynamic systems. For an introduction to this field and a fuller treatment of the theoretical claims and practical accomplishments of a dynamic theory of language the reader should consult Wildgen (forthcoming 1979), or the preliminary reports: Wildgen (1978 ab).



### 2.2. Two examples of semantic "gestalts" derived from elementary catastrophes

a) The "cusp"

The "cusp" has one internal variable; the starting potential is $V = x^4$. This function is unfolded by two external (control) parameters u and v: the unfolding function is: $V = x^4 + ux^2 + vx$. These functions stand for a huge class of functions which by smooth transformation of the system of coordinates can be reduced to this form. As we want to find the catastrophic lines of this unfolding, we first seek the attracting minima and repelling maxima of the field. This can be done by computing the first partial derivation to x: $\frac{\delta V}{\delta x} = 4x^3 + 2ux + v$. The critical points of V fulfill the equation (1):

$$(1) \quad 4x^3 + 2ux + v = 0$$

For the definition of the catastrophe we need the saddle points where new minima appear (or old minima disappear). We therefore compute the second partial derivation; for the saddle points the first and the second derivation is zero:

$$(2) \quad 12x^2 + 2u = 0 \qquad (\delta^2 V/\delta x^2)$$

The resolution of the system of equations (1) and (2) isolates the effect of the control parameters u and v, which govern the behaviour of the system. Equation (3) is the function called "cusp"; its graph is shown in figure 1 as a projection from the curved plane of critical points (equation 1) into the "bifurcation" plane of the control parameters (equation 3).

(3) $27\,v^2 + 4\,u^3 = 0$

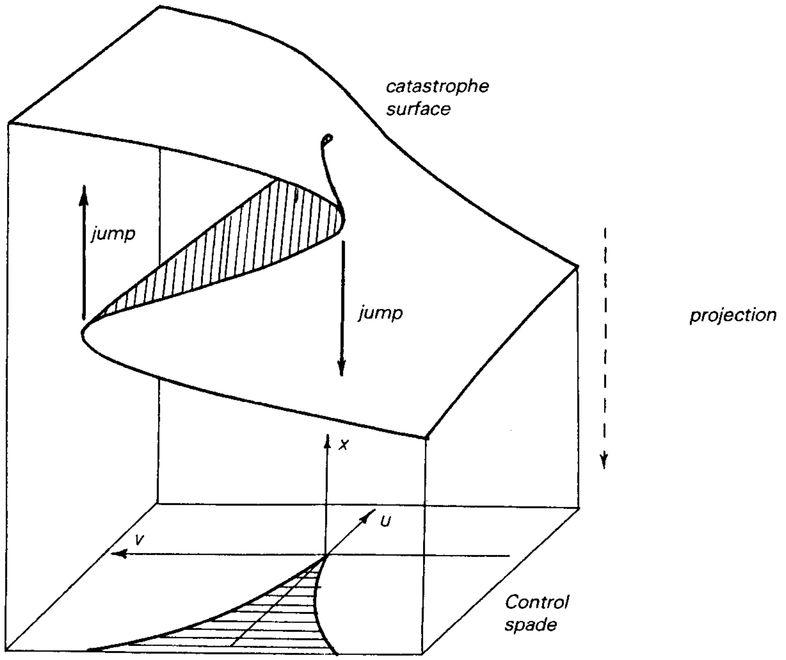
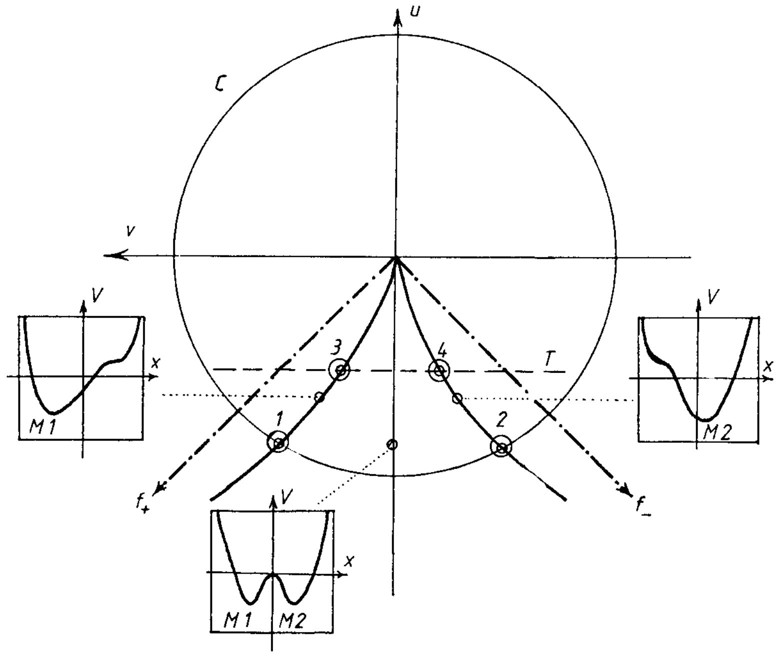



Figure 1

In figure 2 only the bifurcation plane and typical generic sections in it are shown. Processes along these section lines define the semantic "gestalts" or archetypes (in the terminology of R. Thom) of our dynamic theory of language.

The two stable minima in fig. 2, M1 and M2, are interpreted as the dynamic positions of noun phrases. Between the two legs of the cusp there is a conflict of minima which is resolved at the points (1, 2, 3, 4) in which the sections cross the cusp line (cf. ◎ in fig. 2). The process jumps into the dominant minimum (cf. fig. 1). The type of process occurring in the neighbourhood of point 1 (cyclic section c in fig. 2) is characterized in scheme 1, whereas scheme 2 depicts the corresponding process in the neighbourhood of point 2.



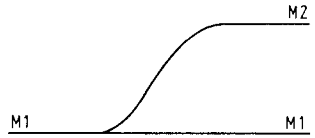



*C, T = sections*
*$f_+$, $f_-$ = rotated axes*
*◎ = bifurcation of the process*
*M1, M2 = minima of the function V*

Figure 2

Scheme 1


Scheme 2




These dynamic structures can be interpreted as the archetypes of transitive sentences, M1 being the subject, M2 the object. In scheme 1 the object is *affected* or influenced by the subject. It may cease to exist, be caught or be taken over by the subject which is not so radically affected by the catastrophe.

Examples: The cat catches the mouse.
Peter gets money.
John puts his hat on.

In scheme 2 the object is *effected* (brought to life/existence, created, moved, thrown, ejected, given away).

Examples: John throws the ball.
Bill pays five dollars.
The firm dropped the employee.

Instead of taking directly the control parameters u and v as semantic dimensions, one can define two conflicting factors $f_+$ and $f_-$ by a 135° rotation of the coordinates (cf. fig. 2). They are interpreted as semantic polarities. A process such as section T in fig. 2 catches the dynamic of a change.

Examples: The student woke up ($f_+$ = awake) versus
The student fell asleep ($f_-$ = asleep)

b) The "butterfly"
Generic sections in the control space of this unfolding lead to the archetypes of sentences with three obligatory noun phrases. The third noun phrase corresponds to a minimum M3 which by a first bifurcation is separated from M1 and by a second bifurcation is integrated into M2.

Example: Eve gives an apple to Adam
M1 M3 M2

In the present context these derivations should only serve as an evidence of the existence of a semantic theory based on elementary catastrophes. In the following chapter aspects of the model of verbal planning which can be conceived on this basis will be presented.

## *3. A dynamic model of verbal planning*

The model reported in the following chapter gives only a rough idea of a dynamic theory of speech production. Although central notions such as topological resonance of dynamic systems (cf. Thom, 1974: 198–209 and 220–227) and coupling of dynamic systems cannot be explained in the context of this paper, I hope that the informal hypotheses which the model conveys are worth considering when we analyse phenomena of speech production.

The basis of the process of speech production is a coupled dynamic field consisting of:
a) the field of outer and inner perceptions in the time interval t: E (t),
b) the field of psychic excitations in the time interval t: $\varphi$(t).
The product of these two fields is canonically mapped into the field of



efferent processes in the time interval t': F(t'). This mapping can be called *verbal planning*.

But this mapping is not immediate: there exists an intermediate level, which is that of semantic archetypes (or fundamental semantic "gestalts"). Whereas the coupled dynamics of $E(t) \times \varphi(t)$ are high-dimensional (Zeeman speaks of 10 billions of individual activities), the intermediate structure has at most four dimensions (cf. postulate 3). Thom starts from an analyzer A, which by optimizing the resonance of the input dynamics with an inventory of low-dimensional archetypes, selects an archetypal representation G. The archetypal pattern G must now be read, exploited. Thom suggests a sort of circular reading process which after a short time collapses into the attracting origin of the circle (cf. for example the circular section C in fig. 2). The characteristic catastrophes encountered specify the verbal nucleus of the sentence and in a secondary wave the attractors contained in the archetypal map are exploited, such that a first classificatory pattern is derived from the topological archetype.

These semantic archetypes are projected along different dimensions, which roughly correspond to word-classes, into a serial pattern. The serial pattern can now be used as input for the efferent mechanism. Considering the context in which the utterance would be placed at this moment and the possibilities of turn-taking, the speaker decides to utter the sentence or to keep it in his short-time memory, combining the feedback of this possible utterance with new dynamics coming from perception and memory or imagination. The inner speech is continued until the realization of the product of verbal planning is judged to be appropriate.

In most cases the feedback of preliminary results in verbal planning leads to a secondary wave of elaboration introducing modifiers, adverbials of time and place, sentential modifiers, relative clauses etc.

## *4. Some remarks relating Thom's model of verbal planning to the phenomenon of hesitancy*

One of the merits of the reported model is certainly that it introduces a new formal language for the construction of theories of speech production. One could object however that its consequences for empirical work were trivial, that the model would do no more than translate our intuitive conjectures on the structure of verbal planning into the language of topology. It is true that the empirical consequences of Thom's model are not immediate. But good empirical descriptions must be explanatory and I will try to show that certain descriptions of hesitancy can gain explanatory force if their results are interpreted within the framework of Thom's model. The results of Goldman-Eisler can be taken as an example. She distinguishes between "old, well organized speech" and "new, organizing speech" and states: "The delays in the production of speech might accordingly be recognized as the "now" periods of speech organization" (Goldman-Eisler, 1958b: 67). The source of hesitation is located rather in a component of verbal planning called "mentation" than in the final stage called "action". Using Thom's model we can propose a finer classification of components of verbal planning, and derive more sophisticated hypotheses:

a) The input dynamics of speech production can be of different complexity or opacity. For example, on the very concrete level of the description of simple spatio-temporal processes it is rather easy to find those local accidents which can be mapped on a semantic archetype of the type mentioned above.

b) In the reading of a semantic archetype the speaker can choose different levels of complexity as the simpler catastrophes recur in the form of local structures in the higher catastrophes. This feature is very important if we want to describe reduced performance of learners and pidgin-speakers.

c) The realization of the semantic "gestalts", which are derived by "reading" the archetypal structure, is influenced by the availability of abstract lexical items.

Whereas the first two planning stages select the fundamental dynamics of the sentence (concentrated in the semantic base of the verbal constituent) and the role of nominal constituents, the third stage, at which the lexical fillers are chosen, presupposes a feedback loop comparing possible realizations with the input dynamics.

On the basis of this classification of levels of verbal planning some preliminary hypotheses can be stated:

a) The input dynamics become more complex in proportion to the increasing complexity of the task of perception, the internal structure of long term memory and psychic sensitivity.

b) The reading level seems to be rather stable. This explains the astonishing simplicity of our basic syntactic patterns. This level is only severely affected in situations of linguistic reduction (for example in child language, learner language, the language of aphasics).

c) The realization level increases in complexity with the growth of the lexicon; in this respect the amount of lexical alternatives for a specified situation is more decisive than the overall size of the lexicon. Many results of Goldman-Eisler can be attributed to this level.

It can be conjectured that level b) produces hesitancy only in the special situations mentioned above. Planning difficulties on level a) tend



rather to influence turn-taking and initial hesitancy, whereas planning problems on level c) will cause hesitancy inside the realization of an utterance.

## *Note*

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