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TIME, MOTION, FORCE, AND THE SEMANTICS OF NATURAL LANGUAGES

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1. Introduction

The concepts of 'time', 'motion', and 'force' ('energy') refer to everyday experiences in locomotion, event perception, and action. It is obvious that this experience is also a topic in communication, be it phonic, gestural, or written. Time, motion, and force are at the same time basic categories in the physics of inanimate entities, i.e., stones or stars, in the biophysics of motion in animals, and in the cognitive analysis of processes such as motor perception and control, memory for motion, imagined motion, and finally the linguistic conceptualization of motion (time and force are also linked to motion). The question even arises if a proper explanation of language is not basically concerned with change (at the evolutionary, historical, and biographical levels) and whether *language* in itself is an entity in permanent motion.

If one considers language as an aspect of individual behavior, it is evident that there must be a mapping from the individual perception of time, motion, and force (and its enactment) to linguistic entities like lexemes, verbs, nouns, adjectives, adverbials, etc., as well as grammatical morphemes (suffixes and prefixes). If one compares different languages, it becomes apparent that time, motion, and force are mapped differently, i.e., linguistic categorization is not universal. This evidence was constitutive for the models proposed by cognitive semantics and is critically discussed in section 2. If in this tradition physics is at all taken into consideration, it is the *folk physics* that ethnologists have found to be relevant in corresponding ethnical groups.

Centuries before cognitive semantics was invented, the problem of a proper understanding of (and thus of a proper language for) time, motion, and force had been a question of science and philosophy[1].

The analysis of time, motion, and force in modern physics started with Galilei, Kepler, and Newton, went beyond Newton in Einstein's theory of relativity, and into quantum mechanics. As these generalizations concern the astronomical and the quantum level, the Newtonian concepts of time, motion, and force elaborated by Euler and Kant in the 18th century, and by Klein and Poincaré in the 19th century, are a valid platform for an interdisciplinary endeavor. Basic insights since Galilei include the following:

Motion can only be distinguished from non-motion (=state), if a proper space-time frame, i.e., an inertial system, is defined. Motion in itself does not consume energy or imply a force principle:

- Force is linked to the *law of energy conservation* and the transformation between types of energy (potential energy, kinetic energy, heat, etc.). This is the basic content of the first and the second law of thermodynamics.
- Time is not an absolute notion but needs a substratum, e.g., a space, a body[2].

The mathematics developed in the domain of differential calculus, differential topology, and dynamical system theory has driven progress in many natural sciences. The question is: Can it help us in modeling meaning and language? Two strategies have been followed in the last twenty years:

- A *deductive* (general) strategy applying findings in the theory of stability and catastrophe theory. The schemata proposed by René Thom (elaborated in Wildgen 1982, 1985) can be mapped onto the lexicon of verbs and the syntax of valence patterns.

[1] This was the case probably since Babylonian and Egyptian astronomy and geometry. Greek antiquity witnessed several basic but controversial models: the physics of Plato, Aristotle, and Democrit, a.o. Their aim was to go beyond naïve physics (which was never really "naïve", but reluctantly followed the progress of science and philosophy).

[2] In his *Critique of Pure Reason*, Kant says it is a subjective a-priori of our imagination (*Anschauung*), whereas space is an objective a-priori.

- An *inductive* (local) strategy based on neurophysiology and dynamic computation (neural nets) is able to model perceptual dynamics in the brain. A linguistic model may extrapolate these results and use the same algorithms (connectionist models of language).

In Petitot (1995) a possible synthesis of these strategies was proposed. In general, it is difficult to evaluate these proposals empirically, because in many cases the complexity of the phenomena in language (and in other fields of the humanities) lies beyond the modeling capacity of the mathematical models. Therefore, one must try to evaluate the conceptual gain of these proposals rather than their empirical adequacy.

The *fundamental* question is a semiotic one: Is there information about "real" motion in inanimates and animates, which is mapped onto language and, if so, what are the physical/physiological/psychological motion parameters which are chosen for this very selective mapping? A *correlated* question is: Are the structural relations between time, motion, and force in the realm of "real" motion mapped onto the architecture of thought and language?

A *second* question follows from the first: Insofar as the mathematics of natural, biological, and neural dynamics has to cope with the same problem as in modeling languages, can we learn something from a comparison between both types of symbolic form, mathematics and language?

A *third* question concerns the proper form of a theory of meaning (in language). Should it be a folk theory, which programmatically does not go beyond an ethnographic record of current categorizations (the Whorfian position), or should it be a scientific theory obeying the same standards of rigor and intersubjective control as the natural sciences (including biology, psychology, and sociology, if they aim at explicit models).

As I am not eager to enter into endless epistemological debates, I will now critically present three avenues in the search for an answer to the abovementioned questions.

2. *Motion and force in Cognitive Grammar/Semantics*[3]

In the framework of Cognitive Semantics two theoretical subtypes can be distinguished:

[3] Cf. chapter 2 of Wildgen (1994) for a more complete treatment of this topic.

- Langacker developed a very general theory first called “space grammar” and later Cognitive Grammar (see Langacker 1987, 1991). Within this framework he proposed imagistic representations for verbs and for the constituent structure of sentences containing dynamical verbs.
- Talmy introduced image-like representations for specific domains of grammar: local pronouns, spatial prepositions, and verbs of motion. In his FORCE-DYNAMIC model he treated causatives and connectives like *because* and *despite*.

2.1. The representation of enter *and* find *by Langacker*

Langacker (1987, 1991) proposed imagistic representations for simple event and action sentences and tried to integrate traditional constituent analysis into his cognitive model. As an example I shall comment on his analysis of the lexical item *enter* and on the imagistic representation of the proposition ‘find-man-woman’ (*A man finds a woman*).

The representation of the verb *enter* in Fig. 1, taken from Langacker (1987), shows two stages in his analysis. In the upper part of the figure a number of snapshots of the basically continuous process are considered. In the lower part only three snapshots are considered; in fact, one could eliminate the intermediate picture and arrive at the traditional notion of a starting state and an end state. Langacker’s notation stops midway between a logical model (two states — one predicate of change of state) and a continuous model (an infinity of stages).

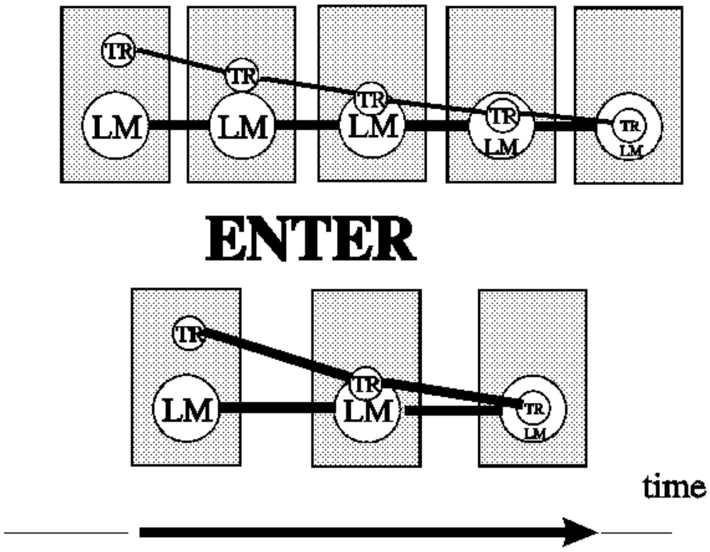

Figure 1. Langacker's analysis of the verb *enter*

Langacker's imagistic representation of sentences like *A man finds a woman* (or, in the logical language with predicate constants: 'find[man, woman]') shows an analogy with the monovalent picture for *enter*. As the entity 'woman' is located on the baseline, it is the patient of the process. The constituent 'man' makes a transition from 'seeking – not found' to 'found'.

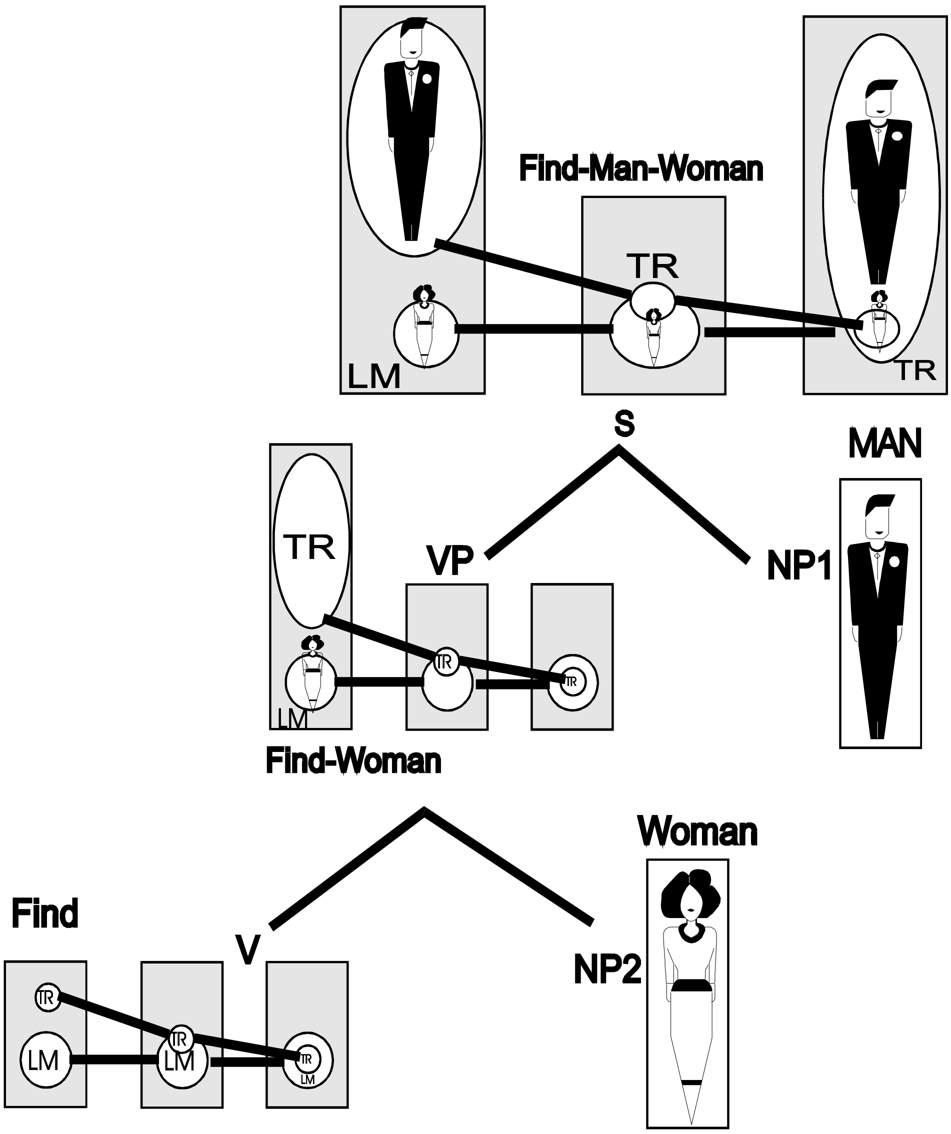

Figure 2. The constituent analysis of 'find-man-woman' in Langacker's analysis *(pictures have been added by the author)*

The only *cognitive* notion introduced is the very basic distinction between figure/trajector and ground/landmark, taken from gestalt psychology. It refers to a level of automatic discrimination in the visual system. This may be sufficient to describe primitive scenes like: something appears or disappears (against a background), or the interpretive shift in visually ambiguous pictures (cf. Wildgen 1995). It is insufficient, however, to describe the rather complex interactions of processes like catching or finding. In the example *The man found the woman* or in Langacker's example *The man found the cat*, two independently moving agents are present and a process of control or dominance is being predicated. The imagistic inconsistence of Langacker's solution can be easily seen if one compares the resultant image (on top) with one's intuition. For it is not the man who enters the sphere of the woman when he finds her, but the other way around. Langacker's description assigns the position of control or dominance to the lexical item in object position, i.e. to the constituent 'woman'. Semantically it is, however, the constituent in subject position which controls the process of finding, i.e. the 'man'. In the sentence *The woman found a man*, the woman would control the result. Our general impression is that the imagistic style of Langacker's Cognitive Grammar is redundant. Instead of proposing an imagistic analysis of sentence meaning based on the meanings of the constituents, he rather translates traditional constituent schemes into a pseudo-imagistic language. This language adds nothing to the already existing structural analysis of sentences, but replaces algebraically well-defined constituent structures with topologically (and geometrically) naïve pictograms[4].

My critique (for more details, see Wildgen 1994: 35–37) is that these "images" cannot help us understand meaning, and that they are neither cognitive nor imagistic. The mental dynamics of semantic compositionality is not explained, moreover[5].

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[4] In Wildgen (1994: 37; Fig. 2.3) I have corrected Langacker's analysis and made it more plausible. But Fig. 3 above correctly represents the analysis Langacker (1984: 13) proposed for the sentence *The man found the cat*, and it demonstrates the imagistic implausibility of his proposal.

[5] Langacker argues that his images are not representations but just discovery procedures, and this enables him to neglect any argument based on visual perception or visual memory, i.e. any serious consideration of cognitive and psychological aspects. He thus continues the classical strategy of structuralism in the 20th century responsible for the splendid isolation of generative linguistics from the interdisciplinary field of language studies.

2.2. Talmy's force dynamics

Talmy made use of imagistic representations in his analysis of verbs of motion and specifically in the analysis of prepositions that occur in sentences like the following (cf. Talmy 1975: 201–205):

(1) a. *The ball sailed* past *his head.*
b. *The ball rolled* across *the border.*
c. *The ball sailed* through *the window-pane.*
d. *The ball sailed* through *the hoop.*
e. *He walked* along *a row of houses.*
f. *He walked* along *the path.*
g. *He crawled* up inside *the chimney.*
h. *He walked* across *the field.*
i. *He ran* around *the house.*

Beginning with his article "How language structures space" (1983) in an interdisciplinary volume on *Spatial Orientation*, Talmy introduced the concept of IMAGING SYSTEMS. He first distinguished four systems:

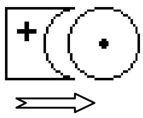
a. "abstract geometric characterizations of objects and their relationships to each other within different reference frames" (Talmy 1983: 253);
b. "perspective point — … the point within a scene at which one conceptually places one's "mental eyes" to look out over the rest of the scene" (ibid.: 255);
c. "the particular distribution of attention to be given to a referent scene from an indicated perspective point" (ibid.: 256);
d. "force dynamics, i.e. the ways that objects are conceived to interrelate with respect to the exertion of and the resistance to force, the overcoming of such resistance, barriers to the exertion of force and the removal of such barriers, etc." (ibid.: 257).

There is a major theoretical difference between Talmy's and Langacker's work, insofar as Talmy's semantics systematically considers parallels between spatial perception and basic linguistic schematizations. His descriptive analyses can be considered as the sampling of spatial and dynamical aspects of natural language, which show a plausible dependence on perceptual processes in our everyday experience. A theoretical (or formal) framework in which both semantic and perceptual facts could be integrated is not even programmatically postulated. In his article on "Force dynamics in language and cognition" (1988), Talmy introduces the following basic concepts:

- exertion of force,
- resistance to such exertion,
- overcoming of such resistance,
- blockage of a force, and
- removal of such blockage.

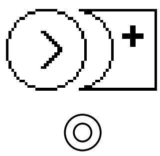
Talmy (1988: 5) considers the following sentences and proposes a schematization for them as shown below:

(1) *The ball kept rolling because of the wind blowing on it.*



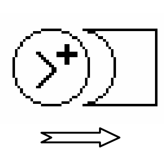
intrinsic force tendency: rest •
resultant of the force interaction: action →

(2) *The log kept lying on the incline because of the ridge there.*



intrinsic force tendency: action →
resultant of the force interaction: rest •

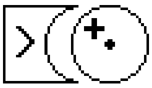
(3) *The ball kept rolling despite the stiff grass.*



intrinsic force tendency: action →

resultant of the force interaction: action →

(4) *The shed kept standing despite the gale wind blowing against it.*



◎	intrinsic force tendency:	rest	•
	resultant of the force interaction:	rest	•

The problem with an analysis like Talmy's is its integration into existing (partially) formalized theories of grammar. It is not consistent, if on one hand algebraic, generative formalisms (though not fully exploited) are taken for granted and, on the other, formal-topological devices are not accepted. Either the whole of grammar should be formulated in intuitive terms or every systematic piece of linguistic modeling should be further developed, with the aim of arriving at a formal account of at least the central parts of grammar.

2.3. A criticism of representations of time, motion, and force by Talmy and Langacker

A short overview of the types of representation proposed by Talmy and Langacker shows that:

- The schematizations used are neither systematic nor conclusive and rest only on an intuitive analysis. There is no theoretical account of how the images may be constructed; they are mere illustrations based on a set of vaguely defined conventions.
- The enormous possibilities of space-oriented modeling using geometry, topology, differential topology, and other mathematical models, which have dealt with similar conceptual problems (since antiquity), are systematically ignored.
- The epistemological claim that grammar must be independent of mathematical techniques is incompatible with the integration of standard techniques used in generative grammar, as these are based on algebraic concepts and not on "natural" categories.

One could reformulate the basic questions of cognitive linguistics and thus specify why it is different from structural linguistics in the European and the American tradition (from de Saussure to Chomsky):

- Can linguistic methodology cope with the natural dynamics of language (be it neural, developmental, historical, or evolutionary)?
- Can semantics cover the semiotic continuity between the spatiality and temporality of the world and our action in/on it, the mental models we use in perception and memory, and their mappings onto the patterns of communicative behavior?
- Can semantics (and a theory of language in general) achieve a serious level of generality and the scientific status linked to such an achievement, which would make it compatible with the scientific standards upheld in the natural sciences (including such disciplines concerned with language as neurobiology, evolutionary anthropology, neural computation, and others)?

I shall discuss answers to the first question and advocate a strategy which gives a positive answer to the last question in the next two sections.

3. *Motion and force in catastrophe-theoretic semantics*

A proper starting point for a model of motion is the PERCEIVING-ACTING CYCLE (see Turvey, Carello & Kim 1990). It is, on one hand, "enslaved" by the basic laws of biomechanics so that the laws of physics can be applied. On the other hand, higher cognitive activities such as semantic categorization are built on this cycle and its stable results (cognitive schemata and scenarios). Consequently, the general principles of dynamics are no longer considered sufficient. The bodily enacting of these principles must be taken into account. The results of dynamic semantics (see Wildgen 1982, 1985) are still relevant; they are just given more psychophysical reality[6].

[6] Following Thom's papers and books, different elaborations have been proposed by Jean Petitot-Cocorda, Wolfgang Wildgen, and Per Aage Brandt. Whereas Petitot first tried adapting Thom's theory to the semiotics of Greimas, and later to computational vision and neural networks, Wildgen followed a strategy of empirical validation, first in terms of a "frames-and-scenes" semantics in syntax, then in an application to nominal composition and narratology (cf. Wildgen 1994, 1999a). Brandt also started from Greimas, analyzed modality in terms of catastrophe theory (Brandt 1995), and finally combined his dynamic insights with techniques of mental-space modeling and theories of blending.

3.1. A cognitive behavioral framework for the analysis of verbs

I propose an initial, rather coarse, subdivision into three domains:

1. Verbs referring to bodily motions occurring in the immediate field of the body, i.e. in the motion of body parts and limbs relative to a body.
2. Verbs referring to motions or actions controlled by only *one agent*. The difference between motion and action *emerges* at this level, depending on the INTENTIONALITY of the process. I shall try to give an initial approximation of a naturalistic concept of intentionality.
3. Verbs referring to the INTERACTION between agents. This interaction can be a purely coordinated action (i.e. actions of type 2 in coordination), or it can presuppose very specific scenarios of social and communicative interaction, such as speaking/listening.

The strategy of the following analysis is threefold:

- A fundamental space-time system needs to be found, which underlies the types of motion/action considered. Simple mechanical models are good hypotheses for such basic schemata.
- The basic perceptual and motor schemata underlying a class of events and actions have to be found.
- The contents of a class of verbs using the schemata found must be described.

3.2. Process semantics of verbs of bodily motion

Movements of living bodies and body parts are subject to two types of control:

a. The nonlinear control of movements, which is largely independent of specific contextual factors and defines the goal of a movement. Nonlinear controls involve catastrophes, i.e. sudden changes in the evolution of a process.

b. The linear control adapts the movement in its metrical detail to specific contextual features, "tuning" the qualitative motion schema.

If we consider simple movements with one or two limbs and look for analogies in physical mechanics, we find the simple and the double pendulum.

Fig. 3 shows the analogy between a double pendulum and the movement of a human leg. The right-hand side of the figure shows phases in the movement of the human leg while a person is walking (experimental results from Johannson 1976: 386). The dynamical system of the human leg is comparable to that of a double pendulum (strongly damped and with restricted domains of freedom).

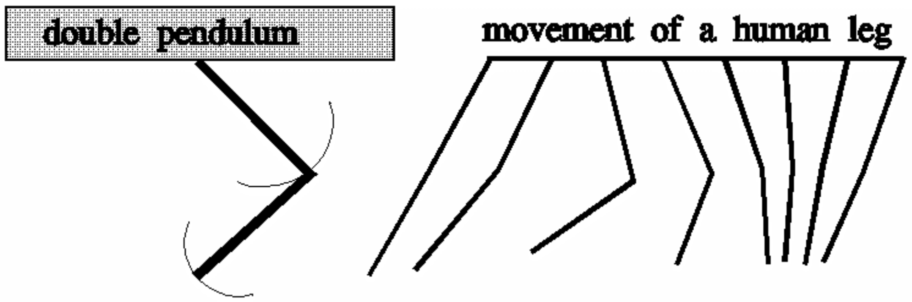


Figure 3. The motion of a double pendulum and of a human leg

If a person performs a locomotion which is composed of a number of separate limb motions, two levels can be distinguished:

a. The rhythm of the composed movements, which is a code for the categorical perception of moving agents.
b. The overall GESTALT of the movement. In the case of simple locomotion, there is an initial phase which starts the locomotion. It destabilizes the system in its position of rest and creates a steady evolution until the system is at rest again.

The coarse topology of locomotion has three phases:

A. loss of position of rest, beginning of motion;
B. steady motion;
C. gain of a new position of rest, end of locomotion.

Instabilities of a simple type can be added to the basic schema using different types of information:

a. *Intrinsic information* contained in the background schema: 'A speaks to B', where A = speaker and B = listener. This schema divides the space into fields of A and B, with a boundary between them. Forms of continuous locomotion can enter the field of A or leave it. Prototypical realizations of this schema are:

(6) ***C*** *comes.* (towards A = speaker)
(7) ***C*** *goes (away).* (away from A = speaker)

b. *Extrinsic information* given in the utterance or by the context of the utterance, as in:

(8) *John enters (the house).*
(9) *John leaves (the house).*

In both cases the underlying topological schema contains an instability of the type 'birth/death'. The basic dynamics is shown in Fig. 4. The specified domain (intrinsic: the domain of the speaker; extrinsic: any given domain) is a position of rest which is only reached if the boundary of the given zone is crossed. The existence of some larger domain of previous or later rest is given as a background of the process schema (cf. the lower plane in Fig. 4).

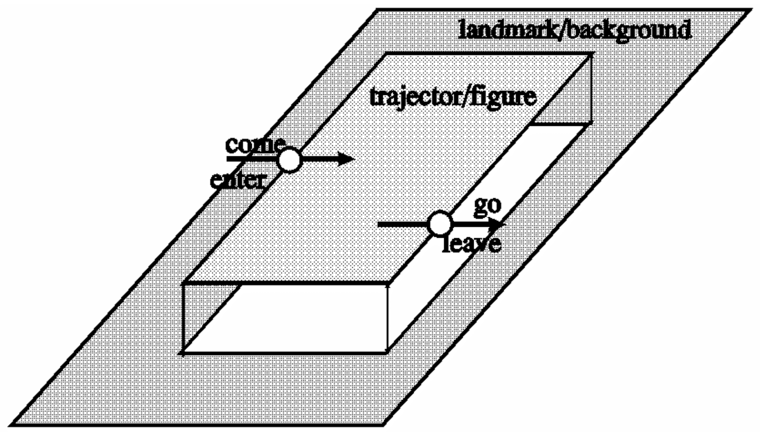


Figure 4. The topological schema of *enter* and *leave*

The process of locomotion of a body is either continuous (durative), or it involves an implicit or explicit boundary and an orientation of the process relative to this boundary. The introduction of an orientation defines an implicit goal and, in the context of human consciousness, it triggers the emergence of the phenomenon of intentionality.

The path from source to goal can be complicated by the introduction of intermediate forces. We find two fundamental types of intermediate force in linguistic scenarios:

1. INSTRUMENTAL MEDIATORS: They modify the mode and scope of locomotion. The overall schema remains qualitatively the same: e.g. a traveler going from Paris to Antwerp can travel by foot, bicycle, car, train, or plane, etc.
2. CAUSATION: Causation is mediation which includes the control of other agents or of natural processes. The attribution of causality (see Heider 1958) is linked to the perception of certain spatio-temporal correlations and presupposes more complicated mechanisms.

The cognitive schemata that have been classified here are not only relevant for the verb lexicon, they also form the cognitive basis of causative constructions (see Talmy 1976).

The coordination of interactive processes exploits basic kinematic and energetic sources and elaborates them. One specific process in this field will be more closely analyzed: the process of giving (receiving/exchanging).

3.3. The configuration of 'giving'

The basic schema or prototype of 'giving' can be configurationally described by a sequence of snapshots. Each snapshot represents an instantaneous, three-dimensional configuration in which the specific positions of sender, receiver, and object define a plane. The third dimension is a correlate of the subjective focus in the perception or the motor control of a specific region of the scene. At the beginning and end of the series, the focus has two attractors (maxima of attention or relevance), and in the middle of the series a third attractor appears, grows, and finally disappears (the participants focus on the exchanged entity). The intermediate, symmetric scene is the most unstable. Both agents concentrate their control on one target, and their control must be coordinated in order to secure a smooth exchange. Thus, if A releases his/her control before B grasps the object, or if A holds the object tight while B seizes it, the character of the process is dramatically changed and degenerates to ‘A loses, drops the object’ or ‘A and B compete for the object C’. The unstable state of exchange is the JUNCTION of the process, the point of coordination for the controls. It can be a meta-stable state, if the object gains some autonomy, for example if it lies on a table between A and B such that it is within the reach of both but not strictly controlled by either. This configuration corresponds to the topological schema of transfer (see Wildgen 1985: 185). The process of exchange, transfer, or change of possession is highly differentiated in the lexicon of German verbs.

In Fig. 5 we distinguish five major phases separated by the catastrophes called ‘emission’, ‘capture’, and ‘transfer’ (transition) between HAVE1 and HAVE2. The phases can be further subdivided by dominant perspective (M1 or M2). The line of ‘transfer’ separates *have* and *have not*.

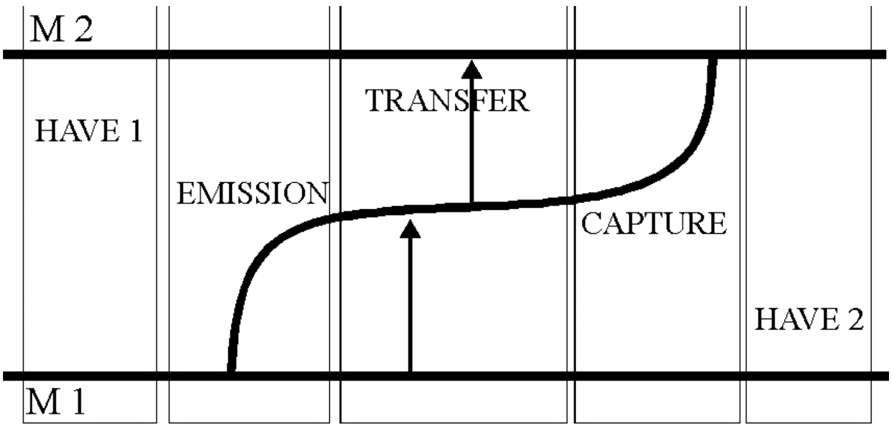


Figure 5. Phases of the ‘transfer’ schema

In relation to the basic intentions of the participants in the transfer scenario, the schema of giving is in disequilibrium as agent M1 finishes “poorer”, and agent M2 “richer”. A symmetric configuration is found in the schema of mutual exchange, which corresponds to a closed loop in the underlying control space of the catastrophe called ‘butterfly’. Fig. 6 shows this structure.

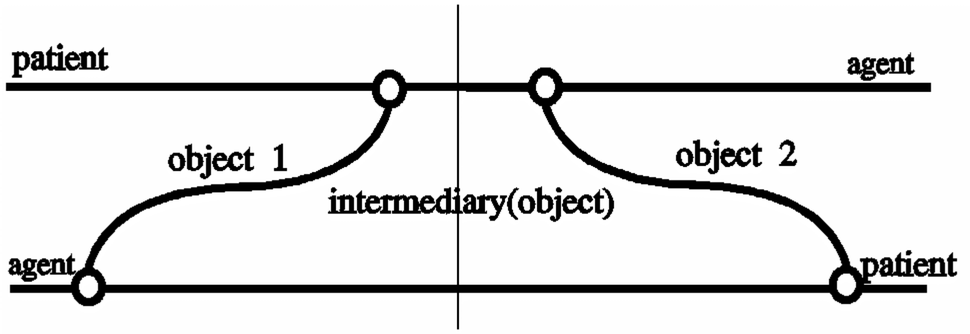


Figure 6. The energetic cycle of transfer

In the first phase, the patient gets object1 and "wins", thus creating an asymmetry of possession; in the second phase, the former agent gets object2 and "wins". In Fig. 5, the line of 'transfer' is defined by a shift of dominance ("→" from M1 to M2). The concept of a force's dominance allows us to define the notion of perspective; different dynamic perspectives are the basis for a semantic sub-classification of verbs. In English, we find the following subclasses for 'give':

receive, take, take off, rob, steal:	CAPTURE
give, donate, exchange:	TRANSFER (implying EMISSION and CAPTURE)
buy, buy from, purchase, shop:	TRANSFER + CAPTURE (foreground)
sell, lend/borrow, return:	TRANSFER + EMISSION (foreground)

The concept of dominance in a dynamical system can also be used for the modeling of topicalization and passive transformation (cf. Wildgen 1983).

3.4. *Limits*

The derivation of semantic archetypes first presupposes a classification of paths and, secondly, an interpretation of forces, e.g. the attractors are persons or objects, or the bifurcations are interactions in space-time or in some abstract space (of qualities, of possession, in a mental space). The classification of paths in elementary catastrophes must rely on results of global bifurcation analysis (cf. Guckenheimer & Holmes 1983). The second interpretive move has to fix an ontology which must be judged either empirically or on the basis of common sense (Wildgen 2001).

4. Time and memory as traces of transformations of ideal types

The elementary catastrophes classified by Thom and Mather in the sixties are ideal topologico-dynamic entities, which are comparable to regular polygons (e.g., the equilateral triangle, the square, …) and polyhedra (the pyramid, the cube, …). As such, they are invariants of transformations and have no history. Leyton (1992, 2001) proposed a theory of traces and memory, which considers traces as deformations: "Asymmetry is the memory that processes leave on objects […] Symmetry is the absence of process-memory" (Leyton 1992: 7). One could argue that elementary catastrophes are invariants of a process and thus cannot serve as an archetypal memory of processes. This could invalidate the claim that they are schemata used in our understanding and therefore memorizing of the world. This challenge can be met, however, if one considers two further features of catastrophe-theoretic semantics:

- The theory of elementary catastrophes tells us that certain dynamical systems are unstable *but* that their unfolding is stable. Thus, they go beyond static invariance and describe the unfolding as an ideal type of deformation. They are invariants of change, not of state or form.
- The paths considered in the construction of the archetypical schemata are not structurally stable and thus have a memory beyond the catastrophes. They allow the establishment of basic trace patterns[7].

[7] Mathematically these paths belong to global bifurcation analysis, and elementary catastrophes belong to local stability analysis (in the neighborhood of a singular point). Beside the positive effect that archetypical schemata are traces in Leyton's sense, there is the negative effect that their exhaustive classification is not only a question of mathematical proof — only very simple classifications have been made explicit. Moreover, a convention has to be adopted as to the dynamics: either the Maxwell convention of an immediate change to the strongest attractor, or a perfect-delay convention of a change in the last moment.

The semantic patterns of verbs in natural languages must have more memory content than archetypical traces, to allow for the richness of content in actual communication and thinking. Elaborations react to the specific conditions of individual speakers and of the language community. As such, they cannot be universal, i.e. the elaborated semantic structure in a given language is highly language-specific.

There are two basic types of memory in the semantics of a word:

- The memory of processes/things of a certain type, their similarities, contiguities, emotional/motivational values, etc.
- The memory of the history of the word itself. The history surfaces in analogies between words of a lexical family, in polysemy and in networks of frozen metaphors, and it can be uncovered by experts of diachronic linguistics.

I will now begin with the first type of memory.

4.1. Memory of process and action

A process, an event, or an action occur in space-time, and between the beginning and the end there is a lapse of time measurable in seconds, minutes, hours, etc., i.e. relative to *some* measure of time. The perception of a process, its enacting, is mapped onto the subjective time of perception, memory, rehearsal in imagination. If we call the first OBJECTIVE TIME (although it refers to a measure, which is itself a construction or choice), its fundamental time constants are very small, e.g. the Planck time at 10^{-44} sec or the Heisenberg time at 10^{-15} sec. The SUBJECTIVE TIME of humans has two comparable windows (cf. Pöppel 1994): the 30 msec (= $3 * 10^{-2}$ sec) window for attention and primary units of perception, and the 3 sec window for the analysis of structures, gestalts, wholes. This shows that time and motion mean very different things in physics and psychology, as they refer to different orders of magnitude. One could say that time and motion in psychology are *coarse* compared to time and motion in physics. The same is true for force. In physics, acceleration (the change of velocity) needs force and the minimal unit of energy in physics is the action quantum of Planck ($6{,}6252 \cdot 15^{-34}$ Js). In the human body, force receptors in the muscles have a set of thresholds (for fingers, arms, legs, the trunk, etc.) which can specify units of force. In observing external events, the internal concept of force is probably the ground for learning to understand causality. Therefore, causality has units of time sequence (cf. the 3 sec window) and of force perception as its building blocks. The first question then is: How are gestalts for processes, events, or actions perceived, memorized, and then used as prototypes for recognition and verbalization? The second question is: How do humans in different languages communicate about processes (time, motion, force)? Or, what are the aims and criteria of (optimal) communication about processes?

The first question may be answered in neurobiology and cognitive psychology, whereas the second should be assessed using methods of social psychology and of sociolinguistics. I can only try to answer the first question here. The visual features of a scene described by the sentence *Bill enters the restaurant* can be observed (measured) in real time, with the transition through the door normally falling within Pöppel's (1994) 3 sec window. As Petitot (1995: 264–274) demonstrated, a visual model of boundary detection is able to model the critical transition from outside to inside the restaurant (where Bill disappears for the observer who is outside the restaurant). This visually marked saddle (ibid.: 272) is the central piece of information; it is represented by the archetype of 'capture' (already implicit in Fig. 4) as elaborated in Fig. 7.

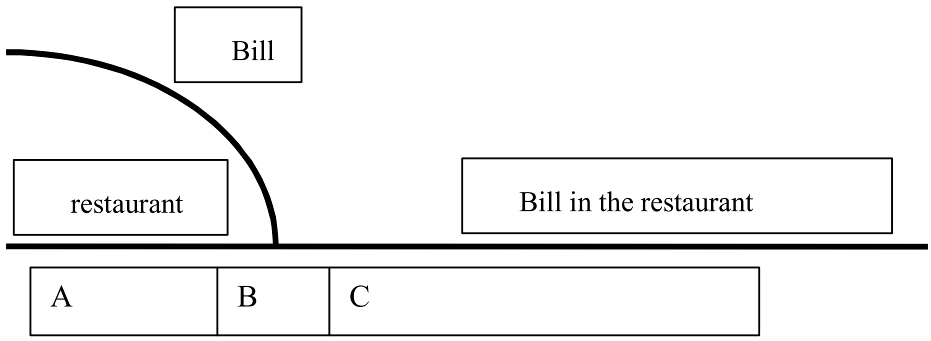


Figure 7. Elaboration of the archetype of 'capture'

The "best" information is contained in the point of (negative) bifurcation B. This recurrent feature forms the mnemonic prototype classifying all possible processes later on, and it is also the germ for the verbalization of this process. As this germ is a point, it does *not* have a temporal dimension of its own, but only a potential for temporal unfolding. In this sense, the process archetype can be unfolded on any time metric (larger than 3 sec), i.e. the process archetype is non-temporal (because it cannot be measured on a specific time scale).

Force is contained in a very abstract form within the archetype. The POTENTIAL[8] is given by the (negative) vector-gradient. It can be interpreted by different types of energy (physical, bodily, mental) in different models.

The advantage of the catastrophe-theoretical model lies in its neutrality in relation to models specifying time, space, force, etc., and in its abstract dynamics, which does not choose a specific time measure. The diffusion model chosen by Petitot (1995) is restricted to visual analysis, but it is clear that processes are not only experienced visually. If enacted, there is a motor or even a muscular memory of a process. Forces are experienced by the body under the impact of gravitation, through experiences of shock, wounds, or even mortal danger[9]. Beyond the process archetype, memory must react to deformations of this schema (in the sense of Leyton). One has to consider at least the following steps:

- changes in velocity (due to energy changes);
- changes in manner, either due to the context (e.g. *swim, climb, crawl*), the rhythm, or to the regularity/irregularity of motion (*hasten, rush* or *tumble, march*);
- a change in instrumentality: *bicycle, bus, car, horse, airplane, rocket*, …

As the examples show, the diversity of specifications concerns rather simple locomotion (*go, walk*). As soon as a steady motion is replaced by a bifurcating motion, as in *enter* or *give,* these specifications tend to be reduced or are expressed at the phrase level, and not in the verb stem (as with *enter*):

(10) *rush/tumble* into *the restaurant*

[8] Lagrange introduced the notion of potential in 1773. The potential in a narrow sense is the energy due to the position of a mass-point. Thus, the potential (energy) of a ball is higher on top of a hill than down the hill.

[9] Being eaten up by a carnivore is a possible experience of 'capture', which was a real danger for australopithecines and is still prominent in modern human imagination (Wildgen, submitted).

In the case of *give*, other specifications related to property, social goals, and obligations appear. Therefore, we can say that Leyton's view that memory is based on asymmetries and deformations relative to some ideal configuration is only valid for the memory of simple shapes, and possibly of simple motion patterns (straight, continuous motion). As soon as bifurcations occur, they constitute the basic level for memory traces and control all further specifications. Thus, the categorization of bifurcation patterns lies at the heart of the semantics of verbs and basic (action) sentences.

4.2. Memory of word histories

The access of speaker/hearers to word histories is indirect and partial. In Leyton's sense, the basis of transformations, i.e. the ETYMON, is rather opaque. Word families stemming from the same etymon may be understood easily and thus mapped onto a common source, as the following examples from the lexical field *hand* show:

- *Hand* has many readings: 'grasping organ' / 'hind foot of an ape' / 'pointer on a dial' / 'personal possession'. These readings refer to a (historical) process of meaning diffusion (by metaphor/metonymy) and are accessible to an attentive language user[10].
- Derivations like *handle, handling, handful* or compounds like *hand ax, hand cheese, handicap* may be less easy to map on some base meaning of *hand*.
- Words similar in meanings, like *manual, manuscript, manipulate, maneuver, manicure,* or *mandate*, may be associated with *hand* and tell the speaker that a second etymon (from Lat. *manus* = 'hand') has been introduced into English. Words similar in sound and spelling, like *hunt*, may on the contrary seem disconnected, as the etymological relation to *hand* is obscured by meaning shifts.

As de Saussure observed, diachronic information is rather irrelevant for the majority of speakers. Nevertheless, it may be relevant for people with higher levels of linguistic consciousness, e.g. people who write (as opposed to analphabets). Specific contexts may extract covert diachronic information

[10] For further elaboration of this topic, cf. Wildgen (1999b) and (2004: ch. 8).

for current usage. Leyton's view that understanding a form means recovering its history is plausible in visual understanding, but insufficient in the case of language. It is only plausible, if one can reconstruct the proper ideal form from which deformations and specifications can be derived. In the case of language, the chain of historical (or even evolutionary) forces which have formed words (sentences) and their meanings is so long that neither the speaker nor the linguist is able to recover their histories and, thus, to "explain" language in the sense of Leyton, i.e. completely and with high reliability. It may be a major goal of linguistics to contribute to the recovery of lost meanings, as well as to the uncovering of the transformations which have unfolded and elaborated linguistic meaning. But linguistics still has a long way to go before reaching this goal.

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