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Coherence Regained

1. Methodological remarks

Coherence is regarded here as a property of dynamic systems such as the language production system or the language reception system. Only the linguistic entities produced or received by these systems can be directly observed. However, one cannot expect that these entities reflect all of the complicated processing going on under their production or reception. They certainly reflect some of the processing and it is assumed here that structural properties of the linguistic entities in some sense mirror their own processing. When dealing with dynamic systems it is generally agreed upon that one should also study the system in a state of disorder or under perturbation. With respect to these states one might be able to find out more about the system than in cases where the system is smoothly operating. In order to examine the nature of matter, physics normally examines systems at phase transitions, i.e. a gas becoming a liquid or a liquid becoming a solid body or the other way round. Analogously – in order to examine the nature of language – it is wise to concentrate upon linguistic data and phenomena which incorporate perturbations or incoherences as integral parts. Such data can be easily found in spoken language, among them are the so-called repairs.

2. Incoherence in linguistic entities

The primary data dealt with had been elicited in blocks-world experiments (see Forschergruppe Kohärenz, 1987). The design of these experiments was as follows: Two subjects had to interactively solve an instruction task. They could not see each other, but they could freely communicate. One of the subjects had to instruct the other to build a configuration of building blocks. The resulting spoken interaction was tape recorded and transcribed. These data contain interesting phenomena on both the syntactic and semantic level, i.e. data incorporating perturbations. On the syntactic level one finds different kinds of repairs such as covert repairs, as well as the prototypical member of the class, error repairs. The class of covert repairs contains pauses, hesitations and repetitions

as well as combinations of them as shown in (1). Error repairs are shown in (2) and (3). Syntactic incoherence is also found in connection with pivot constructions as e.g. (4). An interesting phenomenon on the semantic level are semantically wrong, but pragmatically successful descriptions as in (5) and (6). Although the subjects in the experiments had to manipulate three-dimensional blocks, they frequently refer to them with two-dimensional notions. Sometimes one subject corrects the other (cf. (7)), but most of the time the two-dimensional notion is simply accepted.

(1) der is also nich nich nich wie die . Wie die eh von denen mehrere da sind
    [it is I mean not not not as those . As those eh of which several are there]

(2) und den linken eh Quatsch den roten stellst du links hin
    [and the left one eh nonsense the red one put you to the left]

(3) die die Grund die Grundform sind is nich is nich eckig
    [the the base the base form are is not is not angular]

(4) und jetzt is eh oben auf dem . grünen . beziehungsweise blauen vier-
    eckigen eh Säulenteil? is oben noch ein gelbes Dach
    [and now is eh on top of the . green . respectively blue quadrangular eh
    pillar? is on top a yellow roof]

(5) auf dem roten Zylinder hab ich den grünen das grüne Quadrat
    [on top of the red cylinder have I the [masculine] green the [neuter] green
    square]

(6) und dann zwei . grüne Klötze die kleinen dicken . quadratischen Würfel
    [and then two . green blocks the small fat . quadratic cubes]

(7) P: so dann die nächst kürzeren Klötze das sind Quadrate
       [so and then the next shorter blocks they are squares]
    Q: n Würfel
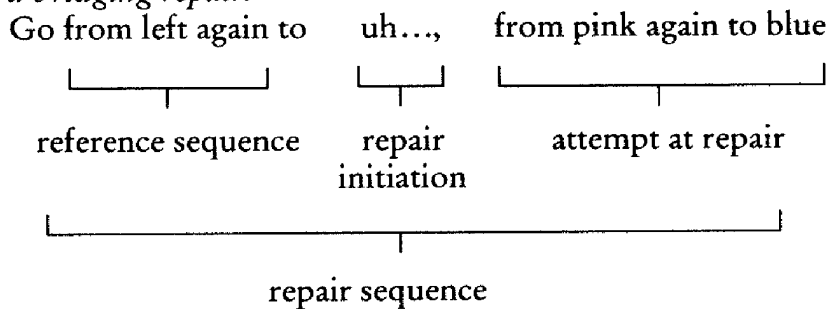   [n cubes]
    P: ja Würfel
       [yes cubes]

We selected sentence-internal self-repairs as our cases of interest. (2) and (3) belong to this class, (7) is from the syntactical point of view an other-repair, but also sentence-internal. According to Levelt (1983) the structure of a prototypical repair is the following:

(8a) Go from   left   again to   uh...,   from   pink   again to blue

           L⎯⏉⎯⏌   L⎯⏉⎯⏌   L⎯⏉⎯⏌

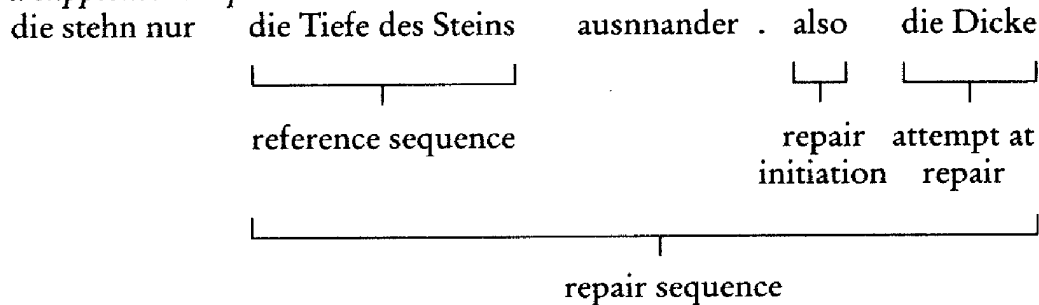   reparandum   editing phase   alteration

This structure had some impact on the parsing strategies for repairs touched upon in section 4.3. Apart from this structure Levelt (1983) proposes a classification of repairs into several subclasses some of which have already been mentioned. This classification, however, is both inhomogenous and incomplete. It is inhomogenous since it uses formal categories for the definition of some sub-

classes of repairs and semantic categories for others. The latter categories, more-over, heavily depend on interpretations of the production process. Since quite a few of the repairs we found in the blocks-world data could not be correctly classified, the Levelt classification is also incomplete. Thus, we propose here a classification subdividing repairs by operational criteria only. It contains two subclasses, namely bridging repairs and supplement repairs (cf. Kindt & Laubenstein, 1991). The two main subclasses of repairs directly correspond to the syntactic classification used in the formulation of the respective repair. Roughly speaking, bridging repairs are characterized by syntactic perturbations found in what we call the reference sequence or in the repair initiation (cf. (8b)) whereas supplement repairs show no syntactic perturbation at all (cf. (9)).

(8b)   *a bridging repair:*
       Go from left again to   uh...,   from pink again to blue

       |_____|_____| |_|_| |_____|_____|
            reference sequence   repair   attempt at repair
                                 initiation

       |_____|_____|
                          repair sequence

(9)   *a supplement repair:*
       die stehn nur   die Tiefe des Steins   ausnnander . also   die Dicke

                        |_____|_____| |_|_| |_____|____|
                          reference sequence   repair attempt at
                                                                        initiation repair

                        |_____|_____|
                                          repair sequence

3. A theoretical conception of coherence

The theoretical conception of coherence advocated here is based on properties of dynamic systems. The stability of such systems serves as the central explicans for coherence. We call the state of a system a stable state if minor perturbations do not affect the system's behaviour. A reception system, e.g., is in a stable state if it analyzes even moderately noisy inputs successfully. In general, a dynamic system assuming a stable state after some processing is said to be coherent, a system assuming an unstable state is said to be incoherent. The instability or incoherence of the system is caused by some problem which has arisen in the system. What sort of a problem this can be depends on the system looked at, especially whether it is a production or a reception system. Consequently, we will take a closer look

at several problems in section 4. If nothing were to happen, the system would perhaps stay in the incoherent state. We assume that besides the system talked about thus far – the object system – there is a second system – the meta-system – which interacts with the object system in the following way: Firstly, the meta-system detects the incoherent state of the object system and, secondly, both the meta-system and the object system try to transform the unstable, incoherent state into a new stable and coherent state (cf. figure 1).
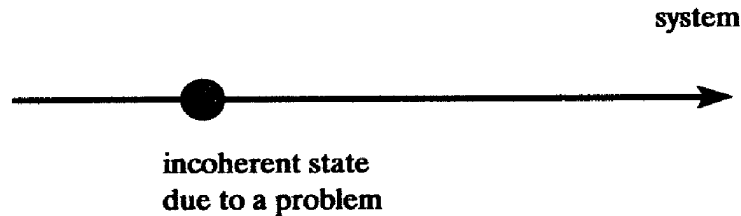
system

incoherent state
due to a problem

Figure 1: A system in an incoherent state.

With respect to the prototypical repair of Levelt (1983) things will roughly look as depicted in figure 2. Coherence is lost by the object system at 'Go from left again to', but – in cooperation with the meta-system – coherence is regained at 'from pink again to'. It has to be mentioned, however, that this picture is oversimplified. The location of the incoherent state in this example depends on whether one describes language production or language reception processes. A speaker, i.e. a production system, will detect the incoherent state earlier than the listener, i.e. the reception system. Moreover, the exact location of the incoherence cannot be determined in either case. The same holds for the regained coherent state as well.

meta system

object
system

incoherent state   coherent state
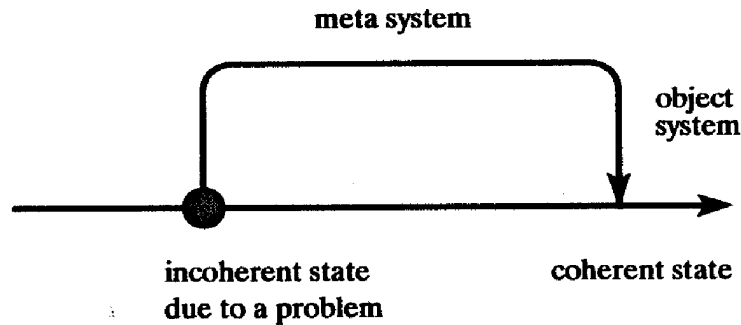due to a problem

Figure 2: Coherence is regained by cooperation of the object and the meta-system.

This dynamic view of incoherent states being transformed into coherent ones can be projected onto the linguistic entity involved. Consequently, we call the initial part of an utterance like the one above (including the reference sequence) incoherent. When the repair sequence is completed we call the corresponding part of the utterance coherent. Thus, coherence or incoherence of a linguistic entity – the so-called object coherence or incoherence – is derived from the

dynamic coherence or incoherence of the system the entity is embedded in. In other words, a dynamic notion of coherence is prior to a structural one. As a consequence, however, it is not possible to say that a linguistic entity E is coherent in general. One can only say that the entity E is coherent in a system S. Thus, there is no objective coherence of a linguistic entity per se.

4. Exemplifications

In the following sections several exemplifications of the theoretical conception of coherence developed above will be discussed. In all cases both the object and the meta-system will be briefly characterized. It will be described what exactly the incoherent state of the object system looks like and what the reason for assuming such a state is. In sections 4.1 and 4.2 the conception will be applied to the process of language production. With respect to section 4.1 the reason for the system changing into an incoherent state is a problem of search, with respect to section 4.2 it is a problem of correctness. In both cases it will be shown how the meta-system succeeds in restoring coherence by inducing different kinds of repairs. In section 4.3 the conception will be applied to the process of language perception. Parsing an utterance with a repair leads the system into an incoherent state, the problem being nonwords and/or corrupted syntactic constructions. Coherence is regained in this case by applying special parsing strategies. In the final section 4.4 it will be demonstrated, how sentence internal repairs can be modelled with grammatically regular constructions in a special kind of grammar.

4.1   The process of language production and problems of search

One type of problem which might occur during the production of an utterance is a search problem resulting in an incoherent state of the production system. A problem of search is at stake, if some subsystem of the production system requires another subsystem to deliver a result, and there is no such result available. A typical example for a problem of search is the "tip of the tongue-effect" (cf. Brown & McNeill, 1966; see also Brown, 1991, Burke et al., 1991, Jones, 1989, Jones & Langford, 1987, Meyer & Bock, 1992).

In order to overcome problems of search, the production system might be assumed to simply wait until the required result is available and not produce anything in the meantime. In a dialogical setting, however, a speaker who does not produce something runs the risk of losing his turn, i.e. of losing the right to speak. If the speaker wants to keep the floor, he has to use a "better" strategy. This is where the meta-system comes into play. The incoherent state of the object system in such situations is due to antagonistic requirements: (i) produce something in order to keep the floor and (ii) use all resources in order to solve the problem of search. The meta-system can overcome this problematic situation by initiating the production of a so-called covert repair. The production of

"something", i.e. a covert repair, is likely to be sufficient for keeping the floor. Additionally, the object system can use more of its resources for solving the problem of search.

Covert repairs include repetitions, hesitations, pauses, and combinations of these three (cf. (10), (11)). Among these three, repetitions are assumed to be most efficient in keeping the floor. Hesitations are less likely to do this job and pauses are still worse. They can be used only in combination with repetitions and hesitations or in situations where it is very unlikely at all that the speaker might lose his turn (for more details cf. Eikmeyer, 1987 and Schade & Eikmeyer, 1991).

(10)   wahrscheinlich sind meine Beispiele soo sprunghaft und und und eh ehm
       zu zu telegraph-
       [probably are my examples so erratic and and and eh ehm too too telegraf-]

(11)   und jetzt müßteste . nja gleichzeitig . eh . auf die linke Seite auf das lin
       linke Ende dieses blauen Steins
       [and now should you . Yeah simultaneously . eh . on the left side on
       the le left end of this blue block]

We have modelled this behaviour of the production system in two different ways: in a symbolic processing model using parallel communicating processes and in a connectionist model exploiting properties of network dynamics.

In the symbol processing model the object system consists of several subsystems:

- the turn-taking system which realizes the turn-taking rules of Sacks, Schegloff and Jefferson (1974),
- the syntactic-semantic planning system
- the phonological-coding system and
- the motor-programming system (cf. Bock, 1982, for these subsystems).

Each of these subsystems is supposed to operate sequentially, but they communicate via buffers with the other subsystems, all operating parallel. That means that one subsystem is required to write its result into a specified buffer where it can be picked up by another subsystem which will further process this result. Consequently, the syntactic-semantic planning component sends its result to a buffer which will be read by the phonological-coding system. This system, in turn, writes its results into a buffer where it will be read by the motor-programming subsystem (cf. figure 3).

Communication between the subsytems is supposed to be asynchronous, i.e. a process sending its result to a buffer does not wait until the receiver has read it and a receiver does not wait until the sender has sent its result. However, in a stable state a subsystem expecting an input should always find something in the buffer it reads. Thus, the problem giving rise to the instability is modelled as a synchronization problem between the subsystems involved. More specifically, the problem which finally leads to the production of covert repairs results
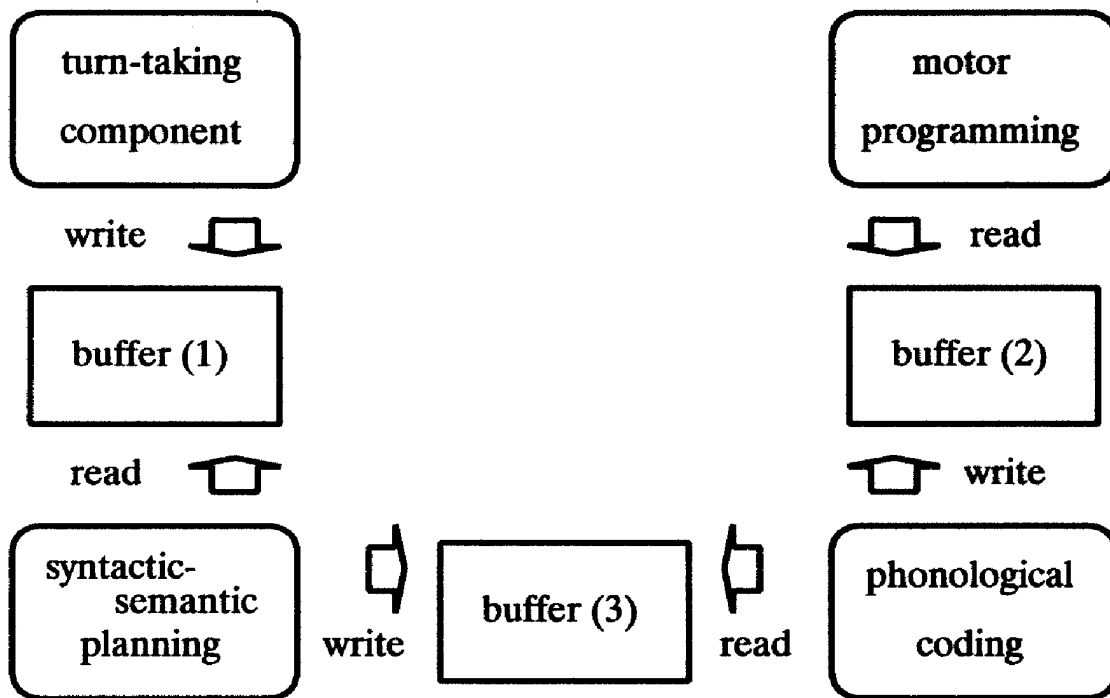
Figure 3: Communication of subsystems.

from a faulty communication between the planning- and the coding subsystem via buffer (1). The coding system expects a result of the planning process in this buffer, but in case there is no such result, i.e. in case buffer (2) is empty, the problem is there (cf. Eikmeyer, 1989). In other words, the system of parallel communicating subsystems is in an unstable and incoherent state. This incoherent state can be easily detected by the meta-system since it simply has to check whether a buffer is empty when a subsystem tries to read this buffer.

In a connectionist model there are no such things as symbols sent from one process to another, there are no buffers and the like. The process of language production is modelled by a flow of activation in a network of nodes or processors. These nodes represent linguistic entities relevant for the production process. Each node is characterized by its activation value which so to speak represents the strength of its being involved in a specific stage of the production process. The activation of the nodes changes in time according to the laws of an activation function which takes into account the current activation of the node in question and the activation of all nodes it is connected to. These connections can either be excitatory, i.e. one node stimulates another one, or they are inhibitory, i.e. one node impedes another one.

According to standard techniques in the field of connectionist modelling, the network of nodes is arranged in levels encompassing nodes which represent linguistic entities of the same "size" and type. Thus, the usual linguistic levels as e.g. the syntactic level, the semantic level, the level of syllables or syllable parts,

and the level of phonemes all appear in such networks. Let us concentrate on the level of phonemes here, because the result of a language production process is – under a certain perspective – a sequence of phonemes. All nodes of the network representing phonemes are collected in the phoneme level and we assume the network to operate in such a way that always at the end of a certain time interval one of the phoneme nodes is highly active whereas the others have a much lower activation value. The phoneme represented by the node with highest activation counts as being produced by the model. Thus, under this perspective the process of language production is a process of continued selections of the relevant phoneme node. What has been discussed with respect to the phoneme level analogously applies to all the other levels. Thus, we can talk about syllable selection, word selection and so on.

The networks we use are constructed in such a way that, with respect to all levels and under normal conditions, i.e. in a stable state, there will always be one node with a considerably higher activation than the other nodes of the level in question. Moreover, stability requires the activation value of this node to exceed a special value, the so-called selection threshold. Now, this concept ultimately allows for a formulation of a problem of search: there is no node in a level with an activation exceeding the selection threshold. In other words, the network has not yet decided upon a certain linguistic entity (cf. Schade & Eikmeyer, 1991). Such a state of the network is correspondingly unstable and it gives rise to the production of a covert repair.

Until now we discussed two possible models for incoherent states resulting from problems of search: in the symbolic model a buffer is empty and in the connectionist model there is no node exceeding the selection threshold. In either case the meta-system initiates the production of a covert repair in order to keep the floor (see below). At the same time, however, the object system keeps on working. If this finally leads to success, i.e. if the buffer in question has a value or if some node reaches the selection threshold, it is assumed, that the object system is in a coherent state again. The meta-system will then stop producing covert repairs.

The open question is, how the meta-system determines which variant of covert repairs, i.e. pauses, hesitations and repetitions, it should produce. We determine the variant produced by the relation of a parameter p_i with respect to two threshold values t_1 and t_2 ($0 \leq t_1 < t_2 \leq 1$). If a problem of search has occurred at time i and $0 \leq p_i \leq t_1$ holds, a pause will be produced; if $t_1 \leq p_i \leq t_2$ holds, a hesitation will be produced and if $t_2 < p_i \leq 1$ holds, a repetition will be produced. The parameter p_i is a function of (i) the speaker's judgement of the danger of losing his turn and of (ii) the number of covert repairs already produced in connection with a persisting problem. According to empirical evidence (cf. Brotherton, 1979) the speaker's judgement of the danger of losing his turn can be assumed to be constant for the production of a complete utterance. Since it is easy to imagine how these calculations can be integrated into a symbol-processing model we will discuss the connectionist realization here.

In the relevant part of the connectionist network (cf. figure 4) the node D represents the speaker's judgement of the danger of losing his turn. The higher this node is activated, the higher this danger will be judged. If a problem, an incoherent state of the production system is at stake, the node D will activate the node CR which controls the realisation of the covert repair. If the activation value of CR is below an activation threshold t_i then it cannot hand on any activation and nothing will be produced at all, i.e. a pause occurs. If the activation of CR exceeds t_1, the two nodes REP and HES will be activated. We assume the activation threshold of REP to be identical to the threshold t_2 mentioned above. If the activation of REP is below this threshold, i.e. if not enough activation arrives from CR, it does nothing. However, in this case the node HES will have received activation. Since its activation threshold is the lower value t_1, it will initiate the production of a hesitation, if the activation value of REP exceeds its threshold t_2, a repetition will be initiated. In this case REP will also inhibit HES, thus preventing the production of a hesitation.
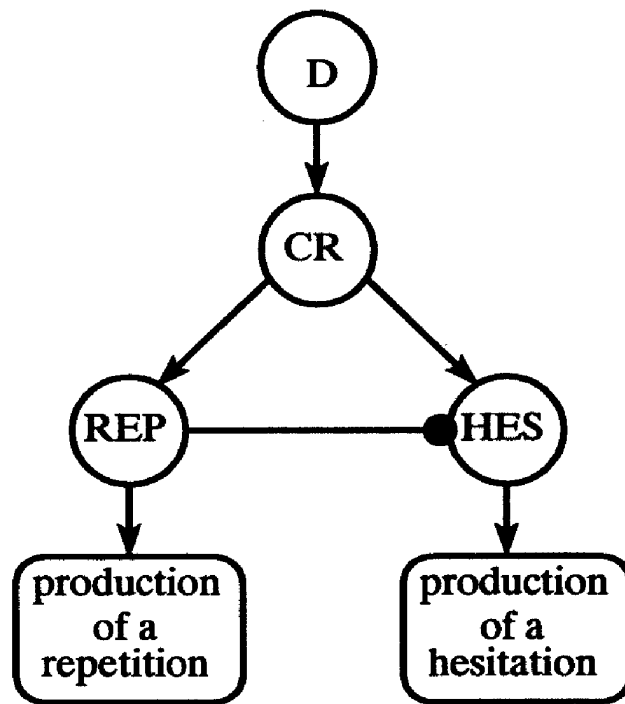

Figure 4: A connectionist network for the production of covert repairs.

The activation function for the node CR has been determined such that a sequence of covert repairs as in (1) will be produced as long as a problem of search is at stake. Since the activation of CR is additionally subjected to an activation decay, the usual activation pattern for CR is as depicted in figure 5. At time 2 the activation of CR is above t_2 and the system produces repetitions until at time 4 the activation is below t_2, but above t_1, when hesitations will be produced. Problems at time 7 again lead to a repetition.
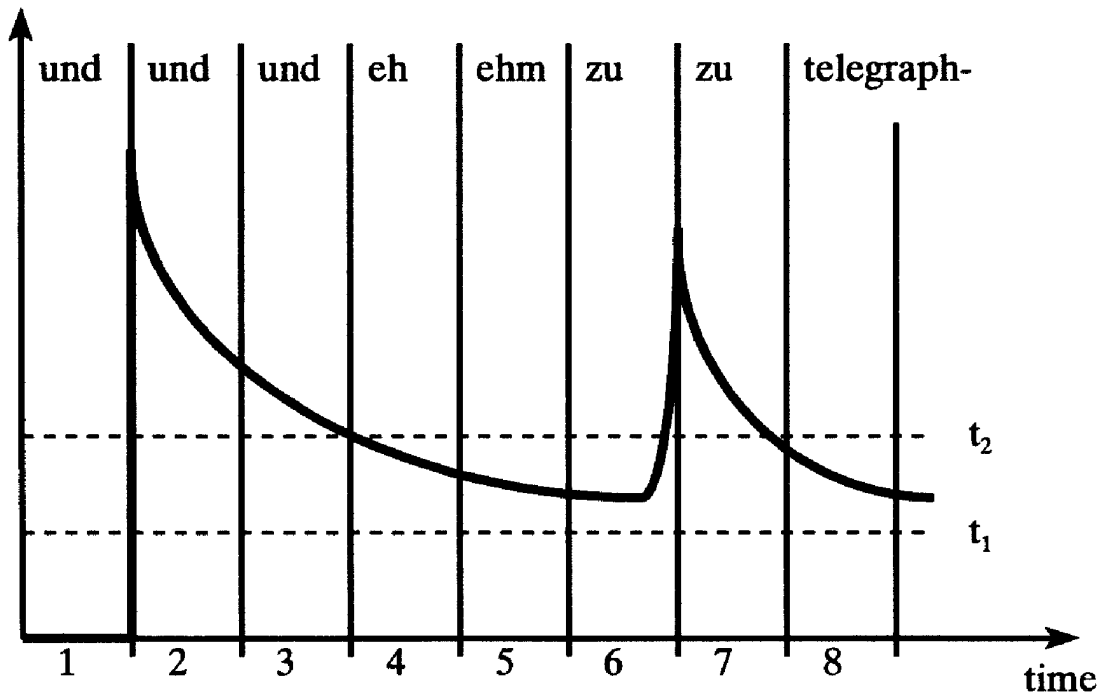
activation

Figure 5: The activation contour of the node CR.

## 4.2 The process of language production and problems of correctness

As demonstrated above, language production involves handling problems of search. Moreover, problems of correctness have to be dealt with as well. Problems of correctness coming up during the production prototypically result in the production of speech errors (cf. (2), (12), (13), (14)).

(12)　...und vorne drauf liegt ein grünes eh ein blaues Rechteck
[...and in front there lies a green eh a blue rectangle]
(Forschergruppe Kohärenz, 1987)

(13)　Rechtdoor rood, of sorry, rechtdoor zwart
[Straight on red, or sorry, straight on black]
(Levelt, 1983)

(14)　I'm two along, up one now: from the bottom... from the: left
(Garrod & Anderson, 1987)

A system which makes errors has to be able to correct itself in order to convey its message nevertheless. The ability to self-correct includes both the ability to detect errors and the ability to produce appropriate repairs. In connectionist language-production models (cf. Berg, 1986; Mackay, 1987, 1992; Schade, 1990, 1992) an incorrectness is detected or even anticipated by a so-called "monitor component". The monitor supervises language production by checking the dis-

tribution of activation at special points in time. If, e.g., the model has to produce the word "Bauklötzchen", three nodes are primarily involved, namely the nodes representing this word, its first syllable "bau", and the initial phoneme "/b/". When the initial consonant /b/ is to be selected, these nodes should all have an activation value which is much higher than the selection threshold. This is only a necessary condition, already touched upon in the previous section in connection with problems of search.
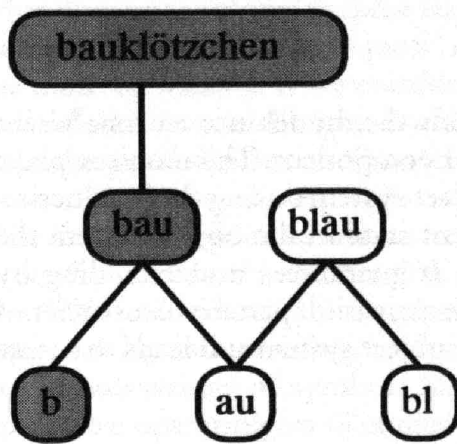
(a) coherent state   **(b) incoherent state**
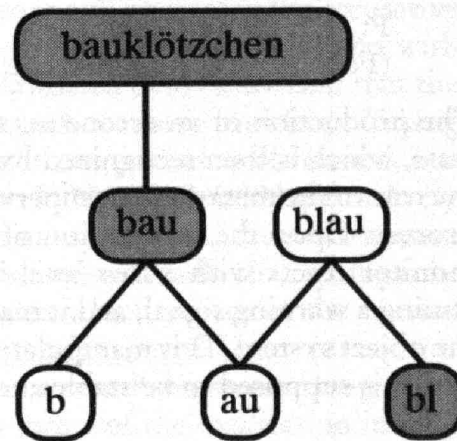
Figure 6: The distribution of activation in coherent and incoherent states.

Additionally, each of these nodes should have the highest activation value compared to all other nodes of its level (i.e. the word, syllable and phoneme-level, respectively). If the nodes with highest activation on adjacent levels are connected by excitatory links, the model is in a stable and coherent state. All other distributions are incoherent (cf. fig. 6). If the monitor detects an incoherent state it suspects that an error has occurred or is likely to occur. Then it does three things: Firstly, it interrupts the process of production. Secondly, it initiates the production of an editing term. These terms let the listener know that there is a problem, thus improving understanding. Thirdly, the monitor manipulates the activation pattern of a special subnet which keeps track of the linear order in which parts of the utterance, i.e. words, syllables, and phonemes, have to be produced.

The manipulation of this control subnet follows a simple algorithm (cf. Schade, 1990, 1992; Schade & Laubenstein, 1992) and, metaphorically speaking, "resets" the subnet. If, e.g., the intended utterance is "Take the red block!" and "Take the green" has been produced so far, the control subnet will be manipulated in such a way, that a whole noun phrase describing the concept of the red block has to be produced again. Thus, the resulting utterance would be "Take the green eh the red block!". As suggested by this example, the production process continues in its normal fashion after the subnet has been manipulated.

No attempt is made to analyze the error. This strategy may result in repair sequences, including examples such as (15) having multiple repairs ("repairs of repairs of repairs...").

(15) P: nein der steht ja nich hochkant' sondern er steht . eh längs aber auf
            der . auf der . Längs . seite auf der (Räuspern)
      R   auf der schmalen Seite
      P: auf der schmalen Seite
      [P: no it does not stand on the edge, however, it stands . eh along but
            on the . on the . longer . side on the (clearing the throat)
      R: on the small side
      P: on the small side]
      (Forschergruppe Kohärenz, 1987)

The production of an erroneous utterance leads the model into an incoherent state, which is then recognized by the monitor component. The monitor plays the role of the meta-system supervising the object system during the production process. Upon the recognition of an incoherent state in the object system the monitor reacts with a low-level interference. It guarantees understanding by issuing a warning signal, and it manipulates the activation pattern in a subnet of the object system. This manipulation resets the object system and leads to a state which is supposed to be stable and coherent.

4.3 Parsing repairs

Understanding natural language is, as a first approximation at least, frequently modelled by parsing systems. We follow a similar strategy here with respect to the understanding of repair constructions. The use of the term 'repair constructions' already indicates that we start with the hypothesis, gained from the empirical investigation of non-regimented discourse, that repairs have a regular, i.e. rule-bound set-up similar to 'non-deviant' natural language constructions. Actually, 'non-deviant' is a misnomer here, but we nevertheless use it in order to facilitate communication with people believing in the rough and ready competence-performance distinction.

The repair parser handles idealized versions of repairs, word fragments and hesitations found in non-regimented data. The idealizations maintained concern phonetic and phonological details, types of non-deviant syntactic constructions treated and types of lexical entries used. The whole approach is thus rather designed to enter upon a new area of empirical and formal research than to attain empirical breadth. Even the idealized versions of utterances were left unsegmented, in order to approximate the segmentation found in natural data which is clearly not word by word, whatever its metric grid ultimately may be.

An example for a successfully analyzed utterance is the string

(16) *derkleineaehgrossemannschlaeft.*
      thelittleuhbigguysleeps.

This idealization is constructed roughly along the lines of e.g. the following example from the natural data:

(17) *und den linken – eh Quatsch den roten stellst du links hin*
      and the left [one] – uh shit the red [one] you put to the left.

(16) is still some way off (17), which should be imagined without spaces as well, but can't be handled by usual grammar or parsing systems. So, how do we solve the problem?

First of all we observe that large portions of (17) and a fortiori of (16) are well-formed according to the usual standards of German grammar. Taking (17), what does not conform to these standards are two noun phrases in the accusative case and the insertion of a 'queer' noun phrase *eh Quatsch* in combination with the finite verb *stellst*. If we consider all the constituents of (17), we find that the individual ones are all right, but their fitting together causes problems. Taking only the portion after *eh Quatsch*, we see that it can pass as well-formed, but this entails that we disregard the material before *eh*. Now it should be intuitively clear that the division of labour between the object system and the meta-system generally discussed in section 3 is particularly suited to handle the repair problem. The main idea is this: a grammar G is given which processes the normal input, i.e. input containing no deviant structures whatsoever. Upon encountering certain strings of symbols like hesitations or word fragments the parsing procedure operating on G comes to a halt. In terms of the explication in ch.3 this means that G is in an unstable or incoherent state. This situation indicates to the system that the normal grammar G cannot handle the input segment at hand. Thus, the halt functions as a switch device activating the meta-system MS. MS analyzes the current input segment according to its own well-formedness constraints. These embody the rules according to which deviant structures are built up/understood, from whence it follows that they realize the hypothesis mentioned at the beginning, viz. that structures count as deviant only with respect to systems like G above, but not with respect to a combination of G with a suitable meta-system MS grafted upon it. The whole set-up also nicely explains deviancy intuitions: These are usually made with respect to some supposedly well-understood system G.

The parser's object system is a conservative extension of a classical left-corner parser comprising the following components:

- a structured lexicon L suitable for detecting word fragments
- a context-free phrase structure grammar G (of which L is the subset of 'lexical' rules, following the pattern word-category → word-form)
- methods for handling non-determinism
- a structure controlling the parsing process and representing the final result in a 'forest' of interlinked standard syntax trees.

NB: Further on we will refer to this structure as 'parse forest'.

The implementation of L is an original development for the purposes of the

repair parser. It consists of a tree, the nodes of which represent initial segments of word forms. Smaller segments of length n dominate their possible extensions of length n + 1. The parser's word segmentation procedure matches graphemes from the input with sequences of nodes in L until a word form is encountered. It should be observed that since every input can usually be cut up in different ways due to identical initial segments of different words, we have non-determinism, i.e. alternative parses, already at the level of word segmentation.

In addition, G itself gives rise to non-determinism in familiar ways: If an input can be analyzed according to several rules in G, these different analyses are recognized, set up and carried out in parallel. It frequently happens, of course, that not all the analyses begun during a parse also terminate. However, the non-terminating ones are also kept in the 'parse forest', the reason being that they might be needed as a kind of socket to plug the repair analysis into. After an input has been 'used up' completely, the parsing result is represented in the 'forest'. (Since a real forest normally does not consist of trees of exactly the same length and of the same stage of development, the forest-metaphor is not entirely out of place here.)

If the object system runs into a word segmentation problem, i.e. if there is no match between the input segment considered and some word in the lexicon, the meta-system checks whether a hesitation or a word fragment was encountered. If this is the case, it adopts control and applies additional strategies, i.e. repair strategies or strategies for isolating word fragments. This device is quite powerful: It can manipulate parsing strategies and switch back and forth in the parse forest encoding the entire history of the parsing process.

Let us for purposes of illustration assume that the system were to parse (16). We supply G with the relevant rules and a few straightforward alternatives, yielding the following set of PSG rules:

[1]	s	→	np	vp	
[2]	np	→	det	adj_p	n
[3]	np	→	det	adj	n
[4]	adj_p	→	adj	conj	adj
[5]	vp	→	v		
[6]	vp	→	v	adv	
[7]	vp	→	v	adv_p	
[8]	adv_p	→	adv	conj	adv

[L1]	adj	→	kleine
[L2]	adj	→	tapfere
[L3]	adv	→	ruhig
[L4]	adv	→	tief
[L5]	conj	→	und
[L6]	det	→	der
[L7]	n	→	mann
[L8]	v	→	schläft

L is the subset of G that consists of [L1]–[L8]. The categories used in this context-free grammar have the following interpretation: s = sentence, np = noun-phrase, vp = verb-phrase, det = determiner, adj_p = complex adjective phrase, n = noun, adj = adjective, conj = conjunction, v = finite verb, adv = adverb, adv_p = complex adverb-phrase.

Using G we get two 'non-deviant' parses (i.e. parses without word-segmentation problems) of string (16) up to 'aeh', which can be analyzed according to the following two sequences of rules:

A: [1], [2], [L6], [4], [L1]
A': [1], [3], [L6], [L1]

We now give an outline of the strategy adopted by the parser to establish these two parsing alternatives. The first step is an unrestricted search for 'first words', i.e. words the forms of which match an initial segment of the input string. This task is performed by the segmentation procedure described above. In our example the only segmentation obtained in this way is that of the determiner "der".

This result is used to start upon a classical top-down strategy which requires a partial syntax-tree to derive from it a categorial hypothesis for the segmentation of following words. Thus we have to build such a partial syntax tree for every parsing alternative pursued, hence the notion of a 'parse forest'. In order to build these partial syntax trees we must find 'syntactical embeddings' of the segmented first words, i.e. sequences of rules that start with the given lexical rule for the first word, continue with rules that have the left-hand side of the preceding rule as their 'left corner' (first element on the right-hand side), up to a final "s"-rule. Different possible syntactical embeddings can act as another source of non-determinism. This is the case in our example, since the category "det" is the left corner in rules [2] and [3], the left-hand side of these both being "np", which in turn is the left corner in s-rule [1]. Consequently we arrive at a first 'parse forest' shown in figure 7.

The two alternatives A and A' have parsed the word "der" according to the sequences [1], [2] and [1], [3], respectively. They are represented in the implementation by pointers to the two "np"-nodes. Generally speaking, a parsing alternative is implemented as a pointer to that node under which the word last segmented has just been placed. The node pointed at by a parsing alternative is called an 'active node'. (Another item stored for each parsing alternative is the number of graphemes segmented by it from the input.)

What follows now is the 'normal procedure', the main part of the object system. First we have to compute a categorial hypothesis for the segmentation of the following word, which is equivalent to finding a place in the syntax tree to place the next segmented word under. The simplest way to achieve this is to look up the next category in the 'active rule', the rule represented by the currently active node. (We should remark here that the nodes in our 'syntax trees' are actually labelled with rules, not just with the categories normally used in a syntax tree and shown in the illustrations.) For alternative A' no more action needs to be taken.
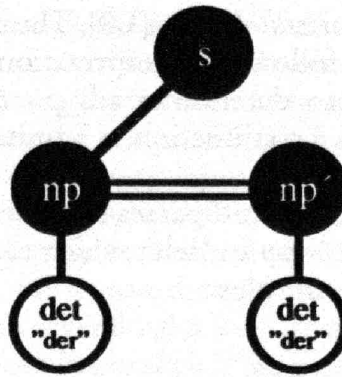
Figure 7: A parse forest. Note how we have attempted to organize the parse forest in an economic way, allowing both „np"-nodes dominated by the same „s"-rule [1] to share a single dominating „s"-node. The double line linking the two „np"-nodes indicates this and is best imagined as indicating a third dimension, since a standard syntax tree already occupies two dimensions. It should further be noted that we distinguish ‚syntactical' nodes, depicted by filled circles, from ‚lexical' ones (hollow circles).

But in the case of alternative A the next category is "adj_p", a non-lexical category, and actually one would expect to see an "adj_p"-node before agreeing that we are pointing at the correct node to place the next segmented word under. We must therefore find all "adj_p"-rules – another source of non-determinism – and, for each rule found, we must add an "adj_p"-node under the currently active "np"-node and finally establish a parsing alternative pointing at that node, multiplying, as one could say, the hitherto pursued alternative A. In the case of our example only one "adj_p"-rule is found, and we could simply say that alternative A 'relocates its activity' from the node "np" to a single new "adj_p"-node. After adding that node, both alternatives have the lexical category "adj" as their categorial hypothesis and we can proceed to the second step of the normal procedure, the segmentation procedure restricted by a categorial hypothesis. Matching the lexicon and the categorial hypothesis with the input string after "der", we find the word "kleine" for both A and A'. We add a lexical node just under the active nodes and arrive at the parse forest shown in figure 8.

Alternative A points at the node denoted as "adj_p", A' points at "np". The first step of the normal procedure is applied again and consists now, for both alternatives, of a simple switch to the next category in their respective active nodes, yielding the categorial hypotheses "conj" and "n" for A and A' respectively. But in both cases no successful segmentation is found. The meta-system starts to work and recognizes the hesitation "aeh" which activates the repair handling procedure. This procedure applies the following strategies:

(1) continue to use the currently active rule
(2) go back to previous constituents step by step up to the beginning of the active rule;
    further, go back (in one single step) to the beginning of the rules at all nodes dominating the currently active node
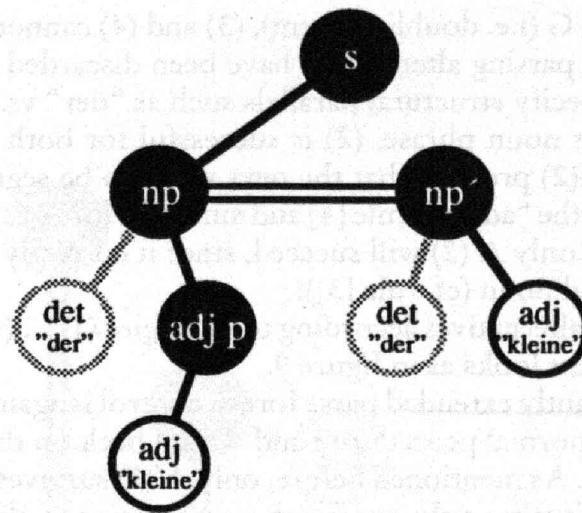
Figure 8: Another parse forest. We mark the ‚active‘ parts of the parse forest – i.e. active nodes, their
dominating nodes up to the top level and lexical nodes added since the last illustration – in
black and the remaining parts in grey.

(3) reactivate previously discarded parsing alternatives
(4) look for structurally similar starting points at all levels.

The idea is to generate a sufficiently large number of parsing alternatives accord-
ing to these strategies and then to let the normal parsing procedure select those
alternatives which are correct for the given input: The incorrect alternatives will,
at a point soon after the current position in the input, run into a second word
segmentation problem. Due to the lack of a second hesitation or fragment in the
input at that point, these alternatives will be discarded.

For alternatives A and A′, new alternatives with the following categorial hy-
potheses are computed according to grammar G and strategies (1) to (4):

strategies	A		A′	
(1)	[4]	conj	[3]	n
(2)	[4]	adj	[3]	adj
(2)′	[2]	det	[3]	det
(2)″	[1]	np	[1]	np
(3)	–		–	
(4)	–		–	

Strategies (1), (2), (2)′ and (2)″ create new parsing alternatives which are added
to the set of currently active parsing alternatives. In the case of (2)″ the computed
categorial hypothesis is non-lexical, but that problem is handled as described for
the normal parsing procedure, "multiplying" both A(2)″ and A′(2)″ by the num-

ber of "np"-rules in G (i.e. doubling them). (3) and (4) cannot be applied, however, (3) because no parsing alternatives have been discarded so far and (4) because G does not specify structural parallels such as "der" vs. "die kleine..." in the role of a subject noun phrase. (2) is successful for both A and A' for the following reason: A(2) predicts that the next word to be segmented will be an adjective because of the "adj_p"-rule [4] and similarly for A'(2) because of "np"-rule [3]. Ultimately, only A'(2) will succeed, since it correctly specifies the subsequent adjective and noun (cf. rule [3]).

After the parsing alternatives according to strategies (1) ... (4) have been computed, the parse forest looks as in figure 9.

With this significantly extended parse forest, control is again handed on to the object system (the 'normal procedure') and we are back on the familiar ground of the object system. As mentioned before, only A'(2) survives the next segmentation steps, indeed it takes only one word segmentation to eliminate all parsing alternatives but A(2) and A'(2), and one more segmentation to single out A'(2) as the only 'survivor'. A'(2) is the only alternative to complete a noun phrase analysis after parsing "mann", and in the subsequent process of 'switching to the next category' it 'goes up' to the dominating "s"-node, looks up the category "vp" there and expands it as already described. As there are three rules for "vp" in G we multiply the parsing alternative again by three, all of which continue to parse the verb "schlaeft". The alternative using the simple rule [5] reaches the end of its "s"-rule, checks that the input is used up as well, and reports a successful analysis. The other two try another segmentation according to the respective categorial hypotheses "adv" and "adv_p", but recognize their failure as there is no further input to segment. The state of the parse forest after the successful analysis is shown in figure 10 below. (We leave out the two unsuccessful "vp"-alternatives, which would be located on a double line next to the "vp"-node shown.)

It should be obvious that the usual parsing systems do not have strategies like (1) to (4) above. The development of the repair parser led to the following, perhaps surprising result: A classical parser with additional segmentation and lexical access facilities plus a suitable control component is all one needs to handle certain kinds of repairs.

The system can handle bridging repairs in the sense explicated in section 2, but not long distance repairs like

'The cat caught many mice uh the red cat oh sorry, shit, the tiger cat.'

Even if non-regimented data similar to this invented example are hard to get by (cf. Nooteboom, 1980 and Levelt, 1983), one would nevertheless like to have a system strong enough to handle such cases showing scope ambiguities and multiple recursion.

In principle this could be done at a technical level along the lines of the existing repair parser, but the repair strategies for constructions like these, especially the semantic and pragmatic aspects involved, are as yet not very well understood.
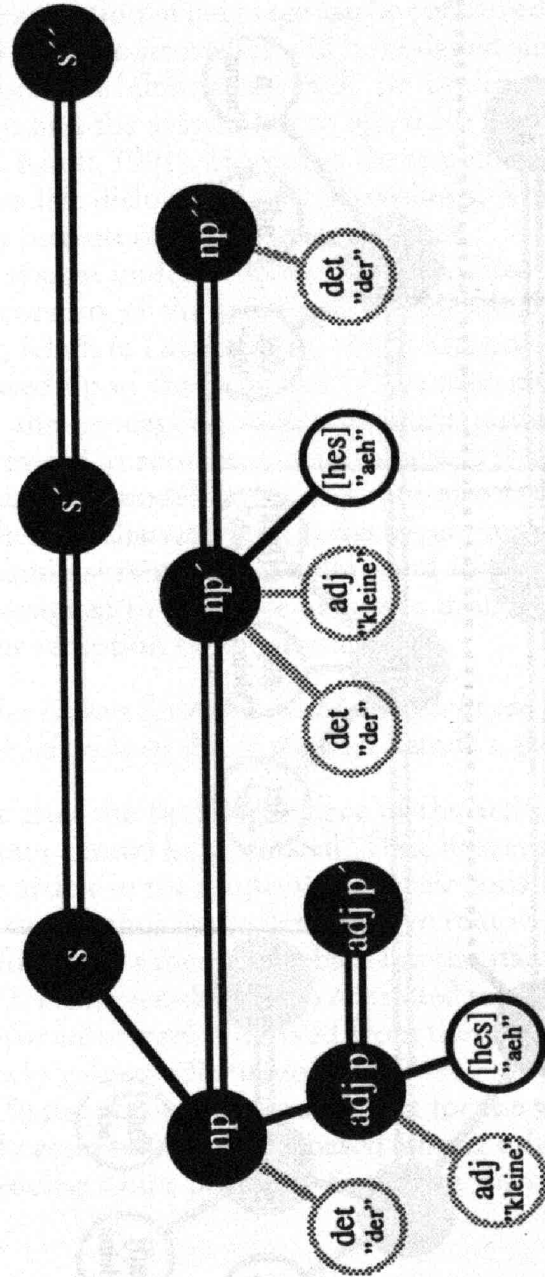
Figure 9: The third parse forest. The „np"-expansions of the nodes „s'", and „s'"", which are the active nodes of alternatives A(2)" and A'(2)", have been left out of the illustration. „adj_p" is the active node for A(1), „adj_p", for A(2), „np'" for A'(1) and „np'" for A'(2). Two „np"-nodes for A(2)' and A'(2)' – which dominate no further nodes – have been left out as well. These nodes are located to the left of „np'" .
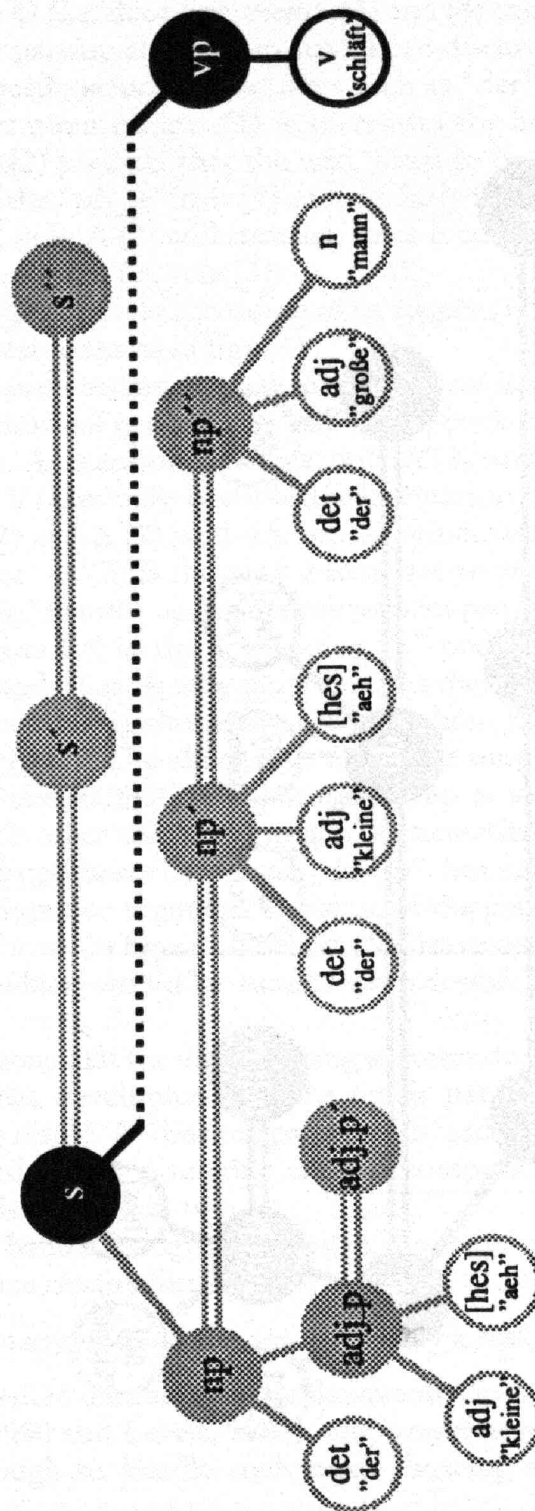
Figure 10: The final parse forest.

4.4 Dynamic grammar

The central idea of this approach is to present a model for sentence internal repairs with the help of grammatically regular constructions. It will be assumed that the assignment of grammatical structures to utterances during the production as well as the reception of language can be conceived of as a dynamic system. Normally not all possible structures will be assigned simultaneously, but rather only certain expectable alternatives will be preferred. Consequently, incoherence can occur and the system has to allow for a later revision of the structuring results (cf. Kindt, 1991). Moreover, the structuring uses grammatical constructions such as left dislocation and parenthesis, which have previously not been the primary interest of grammatical theories.

The dynamic system under proposal is constructed in such a way that each processing step consists of the execution of individual assignments (cf. Kindt, 1985, 1987, 1991; Kindt & Laubenstein, 1991). The possibility of incoherence in the system is based upon the principle of the non-monotony of information processing[1], i.e. the processing might produce unstable assignment results, which must be revised as soon as new information is added. Such revisions are not only necessary for modelling repairs, but also for garden-path sentences. Incoherence is thereby characterized as the trigger for processing revisions: in a state of the dynamic system two rivalling and inconsistent values have to be simultaneously assigned to the same linguistic unit. Thus, for example, during the production or reception of the utterance

(19)   *aber auf der linken Seite des des blauen steht ein grüner*
       'but on the left side of the of the blue stands a green one'

one expects that after the first occurrence of the article *des* ('of the') either an adjective or a noun should be produced. This, however, is contradicted by the repetition of the article in the scope of the repair construction.[2]

The dynamic system thus has to detect and to remove inconsistent assignment results. This is done by a subsystem which has the status of a metasystem in the sense of section 3. However, this task is restricted to the deletion of assumptions or expectations (or information derived from them) which turn out to be false according to newly gained information.

In example (19) the expected categorization for the word in the seventh position (the second occurrence of *des*) is based among others upon the assumption that the commencing noun phrase is free from distortions. This assumption

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[1] Information is conceptualized here as propositions, in which statements are made about the categorization of linguistic or material entities. To that extent the discussion of non-monotony can be connected to logic.

[2] Other than in repairs such a repetition of an article is only possible in constructions such as *Der Brief des des Mordes beschuldigten Mannes* ('the letter of the man accused of the murder') and therefore is rather unexpected.

turns out to be false, hence the accompanying assignment result has to be deleted. The revision triggered by distortions as in (19) is, however, not restricted to this deletion performed by the metasystem. It rather requires an extensive reorganization of the structuring of the utterance by the object system, which will be discussed in the following. The reorganization has to differentiate between bridging repairs and supplement repairs, since a syntactic reorganization is only necessary for the first type of repair. Example (19) constitutes a bridging repair and the revision task of the object system has to look for another 'normal' (but discontinuous) connection of the construction to the beginning of the utterance after the deletion by the meta-system. Some constructions for such backward connections will be discussed below.

Establishing coherence through repairs takes place in the dynamic grammar with the help of grammatically regular constructions. Already Levelt (1983) observed that repairs exhibit close similarities to coordination constructions (cf. also Günther et al., 1991). This observation can be made more precise as follows: Supplement repairs as (20a) in many instances make use of a construction corresponding to phrase coordinations as in (20b).

(20a) *dann muß das rote links stehen nein das blaue*
      'then the red one must stand at the left no the blue one'

(20b) *dann muß das rote links stehen oder das blaue*
      'then the red one must stand at the left or the blue one'

Bridging repairs as (21a), on the other hand, are performed with a construction corresponding to the *left-dislocated coordination* as in (21b). The necessary discontinuous backward connection must be established in an analogous way.

(21a) *dann muß das rote lin eh das blaue links stehen*
      'then the red one must stand at the le uh the blue one must stand at the left'

(21b) *dann muß das rote links oder das blaue links stehen*
      'then the red one must stand at the left or the blue one must stand at the left'

There are, however, certain important differences between repairs and conjunctional coordination. Thus the repair initiation *nein* ('no') in (20a) does not have the status of a conjunction. The same holds true of the hesitation signal *eh* in (21a). Moreover, when *eh* is replaced by *oder* in (21a), the well-formedness is lost, so that *lin* must additionally be extrapolated to *links*. What does the grammatical revision in the object system therefore look like?

Supplement repairs are always based upon a semantic inconsistency. A parenthetical construction for *nein* in (20a) will first be applied to a position which allows such a supplement. Consequently, the system has to wait for such a position before the repair can be carried out. Afterwards the attempt at repair will be introduced by a phrase coordination. This connection differs from the syn-

detic coordination by a paratactic conjunction in the fact that the semantic combination which is chosen according to the repair initiation remains syntactically implicit (asyndesis). In the case of (20a) the corresponding resulting construction can be paraphrased by

(20c) *dann muß nicht das rote links stehen sondern das blaue*
        'then not the red one must stand at the left but the blue one'

Bridging repairs, on the other hand, are always based upon a syntactic inconsistency[3]. An appropriate combination of parenthetic and left-dislocation constructions will be inserted in the syntactic organization. For short and formal distortions as in the following example such a complicated construction type is not necessary.

(21c) *dann muß das ro eh blaue links stehen*

Here the formal distortion *ro eh* functioning as the repair initiation can be joined as a parenthesis interrupting the noun phrase and the adjective *blaue* can be directly connected backwards to the article *das*.[4] The situation (21a) is more complicated and can only be explained procedurally. After the production of the repair initiation with the parenthetic construction the repair attempt will be connected to the undisturbed initial sequence *dann muß* in a way analogous to (21b) and according to the usual conditions of left-dislocation constructions. The location of the correct position for the connection in (21a) will be guaranteed by the functional equivalent (cf. Günther et al., 1992) of *das rote* and *das blaue*. The syntactic and semantic incoherence concerned with the reference sequence is not yet eliminated by this (cf. the unfulfilled expectation of the syntactic well-formed continuation for *das blaue*). For this reason the reference sequence will finally be detached from the beginning of the utterance by means of a syntactic reorganization. It is reinterpreted as parenthesis, thus conforming to other expected conditions of well-formedness.

The structure revisions necessary for bridging repairs can also be shown to be relevant for the reception of garden-path sentences (the producer, on the other hand, will generally only develop the correct structuring).

(22) *Bismarck schreibt der Historiker seinem Bruder war ein großer Politiker*
       'Bismarck wrote the historian to his brother was a famous politician'

In incremental word-by-word reception the first expectation to be revised in this example is that *Bismarck* is the subject of the verb schreibt. In an intermediate stage the listener may expect that *Bismarck* is a dative object. But even this

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[3] This holds true for production and reception more accurately when primarily the production of a disturbance-free utterance is assumed and hence when the execution is not planned or expected in advance at the respective position.

[4] Here it is assumed that the internal well-formedness conditions for parenthetic constructions differ from those for autonomous utterances/sentences.

assumption turns out to be incorrect. Finally, the only possible analysis remaining is to reinterpret *schreibt der Historiker seinem Bruder* as parenthetic and to connect *war* ('was') discontinuously back to *Bismarck*. Example (22) therefore demonstrates that the reorganization characteristic for repairs and the interaction of object and meta-system can also be at work in well-formed sentences without any distortions. Consequently, the tasks to be performed by both systems are not restricted to repairs.

The tasks to be performed by the syntactic adjustment in the organization of utterances will differ according to the type of repair. With respect to supplement repairs, the detection of a semantic inconsistency induces only the choice of the corresponding supplementing construction. With respect to bridging repairs, the detection of an instance of incoherence at first interrupts the processing of a word. It then leads already to a minimal syntactic reinterpretation of the beginning of the word as a component of the parenthetic repair initiation. The corresponding reinterpretations will be respectively arrived at by the deletion of the expectations leading to the inconsistency and the corresponding assignment results. After this operation the assumption that the reference sequence is to be connected to the beginning of the utterance will also be withdrawn. This will only occur after the attempt at repair is successfully connected back to the beginning of the utterance.

In spite of the principled identity of the grammatical method of constructing repairs in the production and in the reception of utterances, one must naturally take into account that the time at which incoherence is detected can be different from the time at which the possibly necessary syntactic reorganization is performed. An example of this is the following:

(23)   *ehm dann mußt du an der... rechten Seite müßte n Restaurant kommen*
       'uh then you must on the... there should be a restaurant on the right side'

Here the short pause between *an der* and *rechten* presumably indicates the beginning of the syntactic reorganization in the process of production. Contrary to this, in the case of reception the necessity of a reorganization will only be recognized when *müßte* is processed.

5. Conclusion

In this paper two main topics are developed. Firstly, a new definition of coherence is suggested. Coherence is regarded as a property of dynamic systems, i.e. the property of being in a stable state of normal, smoothly going-on activity. Dynamic systems in the sense relevant here are e.g. language production systems, language reception systems as well as subsystems thereof. Incoherence is conceived of as an unstable state of a system's subsystem. The subsystem involved is called "object system" here, since specially defined procedures (termed

"meta-system" hereafter) can operate on it and make use of it in various ways. Secondly, it is shown that incoherence in a system can be dealt with in the following way: The meta-system, constantly interacting with the object system, detects an impasse, acquires control and both systems try to solve the problem at hand. If this operation succeeds, the two systems continue to work, until some new instability is encountered. There is division of labour and cooperation among these two systems: neither can do without the other, the scope of each being restricted to specific tasks; normal business is carried out by the object system, local breakdowns are managed by the meta-system designed to cope with the unfamiliar and the unususal.

We have shown in this paper how this idea can be put into practice with respect to various problems, settings and model systems. All of the solutions proposed are intimately tied up with constructions encountered in spoken language, especially with so-called "repairs". We found out however, as an unexpected but welcome side effect that the object system *versus* meta-system technique can also be used to tackle some of the puzzles familiar from the literature on natural language semantics and pragmatics. Some of these are: the denotation of referentially used expressions, metaphors and indirect speech acts. We have shown examples of these cases in the natural language material already quoted above. Consider e.g. the reference of definite descriptions:

(5) auf dem roten Zylinder hab ich den grünen **das grüne Quadrat**
     [on top of the red cylinder have I the [masculine] green **the [neuter] green
     square]**

Since no squares are present in the original domain, *the [neuter] green square* will not designate an object. According to celebrated classical intuitions (Russell/Strawson), the embedding utterance will be false/meaningless. Well, this goes heavily against the conventions observed by discourse participants, who first try to provide an interpretation, come what may. The meta-system confronted with the problem could in this case set up a new local denotation of *square* comprising cubes, in order to provide a pragmatically successful reference to a green cube. The "rules of relaxation" used by the meta-system would have to be worked out of course. Still, the general direction for a feasible solution should be clear.

(4) below provides an example for the use of metaphor:

(4) und jetzt is eh oben auf dem . grünen . beziehungsweise blauen
     viereckigen eh Säulenteil? is oben noch **ein gelbes Dach**
     [and now is eh on top of the . green . respectively blue
     quadrangular eh pillar? is on top **a yellow roof**]

There are of course no roofs among the building blocks, only triangular blocks. When this metaphor was produced, similarity with respect to form and function was certainly involved. Hence, the meta-system's relaxation rule must also make use of it.

Example (5) also illustrates that an assertion can be used as a directive. Although the speaker of (5) describes his own assembly of blocks, in doing so he requests of his hearer to **put** the green block on the red cylinder. In order to solve this case, the existing meta-system would have to be enlarged a good deal. Still, its central ideas could be maintained. As a first attempt how (5), taken as a speech act, could be successfully analyzed, we suggest the following:

(a) The meta-system first resolves the repair contained in *hab ich den grünen das grüne Quadrat [have I the [masculine] green the [neuter] green square]*.

(b) The object system again gets control over the procedure, finds no referent for *das grüne Quadrat [the[neuter] green square]* and stops again.

(c) The meta-system takes over control, relaxes the extension of *square* and finds a referent.

(d) The object system again getting control over the whole interpretation process interprets the resulting assertion, namely, that, metaphysically speaking, the green cube is put on the red cylinder, it will also discover that the assertion is false, if taken for the addressee's side.

(e) The meta-system will now be asked whether it can nevertheless contribute some information in the context of the interpretation achieved, and it will suggest an interpretation as an indirect speech act, i.e. as a directive based on some principle of cooperation.

Clearly, charging by the mechanisms employed in this paper, getting (e) on the basis of (d) means a giant step still to take. However, directives like (5) abound in the empirical data, hence solutions have to be worked out in any case.

On the whole, the procedural explanation proposed here for the description of repairs, making use of the object system versus meta-system idea seems to yield an interesting generalization for semantic and pragmatic cases and is of interest beyond the special aims tied up with the description of natural discourse.

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